Problem Soils

(Left) Large cracks in soil indicate extensive drying and shrinking of expansive clay. This type of crack appears during dry seasons. *(Photo by Raymond C. Harris)*

(Right) Repeated shrinking and swelling of clay produces a characteristic "popcorn" texture. *(Photo by Larry D. Fellows)*

How Can Soil Cause Problems?

Damage to structures in Arizona is commonly related to soil characteristics, with expansive (shrink/swell) soils and collapsing soils causing the most problems. Cracking of foundations, walls, driveways, swimming pools, and roads costs millions of dollars each year in repairs. Severe or recurring damage can lower the value of a house or property. According to the American Society of Civil Engineers, about half of the houses built in the United States each year are situated on unstable soil, and about half of these will eventually suffer some soil-related damage.

The causes of soil expansion or collapse are related to the type and amount of clay minerals in the soil, conditions under which the clay originated, and original density of the soil. Clay minerals can form in-place by weathering of rocks, or they can be transported and deposited by water or wind. A change in the moisture content of a soil can cause clay minerals to swell like a sponge or to lose cohesion and collapse.

Expansive (Shrink/Swell) Soils

Many soils have a high content of clay minerals, some of which can act like sponges and absorb large quantities of water, causing the clay mineral to increase substantially in volume. When the clay mineral dries out, it shrinks. Clays that are high in sodium can expand as much as a thousand percent when water is added. Because soils are usually not composed entirely of clay minerals, expansion is typically much less than in pure clay. However, structures may be damaged when a soil expands by as little as five percent.

Expansion of clay minerals can cause walls and foundations to crack and roads and sidewalks to warp, in a manner similar to frost heaving. The first sign of expanding soil beneath a building may be misalignment of doors and windows. Another indication of soil expansion is when patio or driveway slabs buckle or move away from the house. Non-load-bearing walls, which do not have enough weight to resist the pressure produced by expansion, typically crack before load-bearing walls do.

Upon drying, expansive soil shrinks, forming large, deep cracks or "popcorn" texture in surface exposures.

Large cracks in soil indicate extensive drying and shrinking of expansive clay. This type of crack appears during dry seasons. *(Photo by Raymond C. Harris)*

Popcorn texture is the result of repeated shrink/swell cycles, producing marble-sized pellets. In extreme cases, cracks formed by drying clay can be large enough to mimic earth fissures (discussed in the **Subsidence** chapter). However, desiccation cracks are not as long or deep as earth fissures. Expansive clays in Arizona commonly originate from volcanic ash deposits or sediment and alluvium that contain volcanic debris.

Location Of Expansive Soils In Arizona

Phoenix area

Expansive soils are scattered throughout the Phoenix area. Shrink/swell potential is moderate to high in soils in terraces along the Gila and Salt Rivers, old alluvial fan surfaces, and scattered areas in the valley plains. These areas have been delineated on soil survey maps produced by the U.S. Natural Resources Conservation Service (formerly the Soil Conservation Service, part of the U.S. Department of Agriculture). (See map, p. 12)

Tucson area

Expansive soils are found in numerous places in and around Tucson. Many of these areas are associated with exposures of clay-rich beds in the Pantano Formation, mostly in the foothills of the Santa Catalina and Rincon Mountains around the northern and eastern margins of the valley. Tilted strata of the Pantano Formation are exposed prominently along Sunrise Drive and Snyder Road. (See map, p. 13)

Colorado Plateau

Expansive soils are widespread on the Colorado Plateau in northern Arizona. Commonly associated with the Triassic Chinle Formation (famous for the abundant logs in Petrified Forest National Park), clays on the Plateau are composed largely of montmorillinite, which has a high shrink/swell potential. In the Colorado Plateau, exposures of expansive clays are notable for their popcorn textures.

Other areas

Areas where soils have moderate to high shrink/swell potential include parts of the Safford and Duncan valleys, Willcox area, upper San Pedro Valley, upper Santa Cruz River Valley to Nogales, and Yuma. In each of these areas, problem soils are scattered; evaluation of shrink/swell potential must be done on a site-by-site basis.

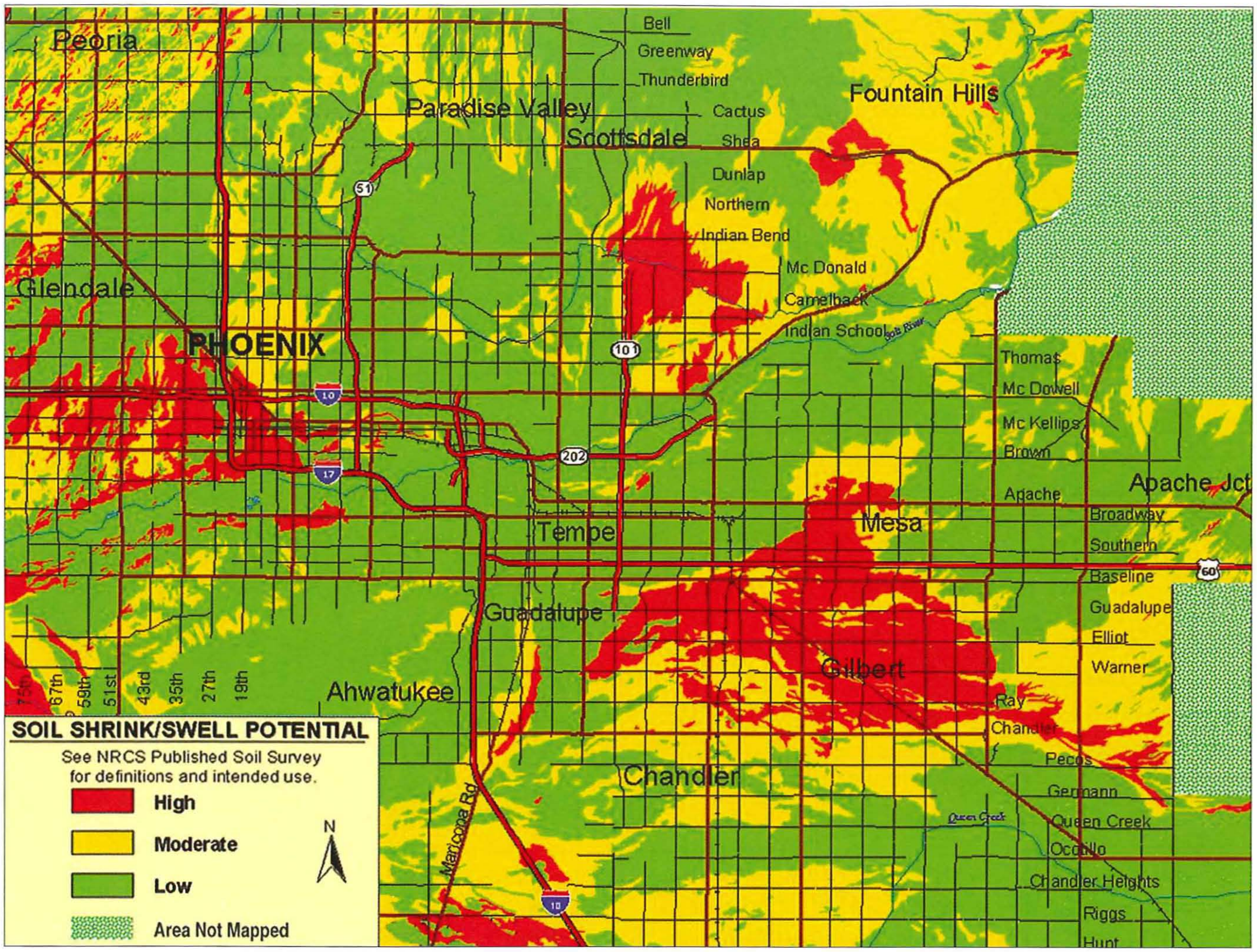
Dealing With Expansive Soil

Identification

The presence of expansive clays can be detected by direct observation: polygonal soil cracking (mudcracks) or popcorn texture in exposures is indicative of shrink/swell clay. Soil survey maps delineate areas of clay-rich soils that are known to have shrink/swell potential. For other areas, laboratory testing of the soil may be the only way to determine if a specific area has shrink/swell soil. Soil engineering laboratories routinely perform tests that evaluate amount of shrink/swell, expansion pressure, and behavior of soil as the water content changes. Although these tests range from \$50 to \$150 per sample, the up-front cost is considerably less than the cost of repairing cracks in foundations and walls, and the potential decrease in property value.

Mitigation

Mitigation of expanding clay soil can be accomplished in several ways. Application of hydrated lime to swelling soils is a common treatment that is usually effective in preventing or reducing expansion. In this method the sodium in the clay is replaced with calcium, thereby reducing the ability to swell. Another effective method is to remove the expansive soil and replace it with non-expansive fill. This method is practical if the expansive soil is relatively thin and near the surface. Pre-wetting to increase the moisture content before building may help limit future swelling, as long as the moisture content can be held fairly constant. Application or use of protection barriers (coatings, geomembranes) that surround the house foundation



Soil scientists of the Natural Resources Conservation Service (NRCS) have mapped the occurrence of expansive soils. This is a portion of a soils map of the Phoenix region available from NRCS. *(Map courtesy of NRCS)*

help keep soil moisture levels constant and prevent infiltration of surface water. For construction of larger structures, deep piers or footings and specially reinforced or post-tensioned foundation slabs are increasingly common in areas that have expansive soils.

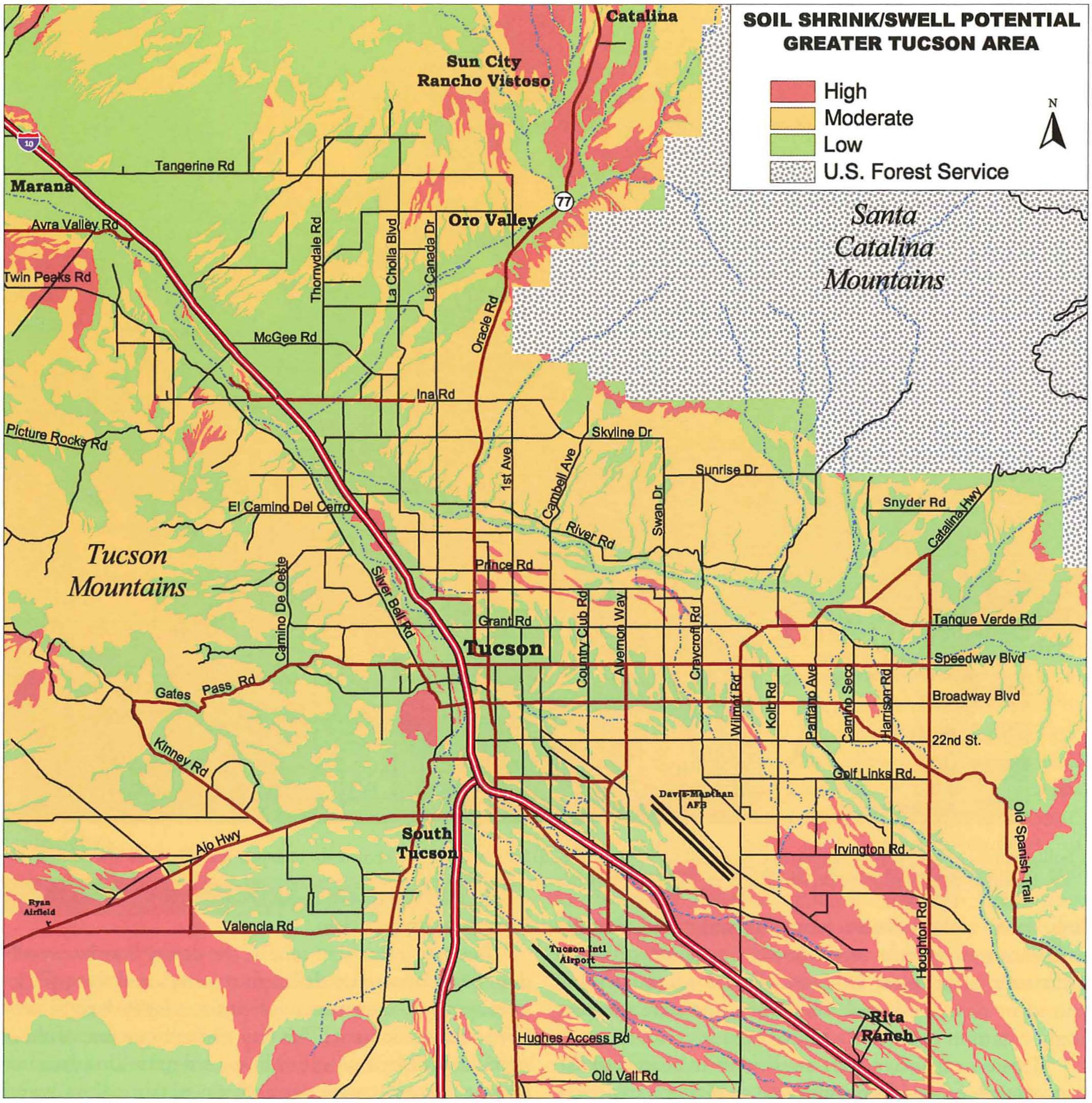
Because expansive soils swell with increased moisture, drainage should be controlled to divert water away from the structure. Poor drainage can result in ponding of water, which allows clays to absorb water, expand, and cause problems. Rain gutter downspouts should direct water away from buildings to prevent infiltration near the foundation. Use of moisture protection barriers surrounding the house help keep soil moisture levels constant and prevent infiltration of surface water. Watering of landscaping plants and lawns, especially deep watering by drip irrigation systems, also can trigger soil expansion. Planting adjacent to foundations should be avoided. Desert-adapted plants are recommended over non-native plants that require more watering, especially near buildings.

Hydrocompaction

Because infrequent rain in the desert Southwest seldom penetrates more than a foot or two and then quickly evaporates, near-surface deposits usually have a very low moisture content. The clay and silt in some of these deposits act like a glue, holding sand grains in place but leaving space between them. Upon wetting, the silt and clay lose their cohesion, and the sand grains move closer together and take up less space. This process, referred to as hydrocompaction, is especially troublesome in soils that have large amounts of silt.

Common events that can trigger compaction include deep watering of plants, ponding of rain runoff, water leaking from pipes, and leaking evaporative coolers. Potential for compaction is increased when a load, such as a house, adds weight to the soil. Hydrocompaction can occur years or even decades after a structure is built.

The problem of hydrocompaction is not to be confused with the common occurrence of settling of fill



Soil scientists of the Natural Resources Conservation Service (NRCS) have mapped the occurence of expansive soils. This is portion of a soils map of the Tucson region available from the NRCS. *(Map courtesy of NRCS)*

material. Any type of fill may later settle if it was not properly compacted during placement. Damage from this type of settling may be prevented by compaction during placement or by waiting a few months before building to allow the fill to compact on its own.

Hydrocompaction can mimic earth fissures (which are caused by subsidence due to groundwater pumping). Damage from hydrocompaction tends to be restricted to a small area, usually smaller than a backyard, and is commonly circular in area; earth fissures are narrow and long, typically extending over several hundred yards. Earth fissures should be suspected only if cracks in structures or in the ground are aligned for a greater distance, such as across a neighborhood.

Distribution Of Hydrocompaction Hazards

Tucson

In Tucson, hydrocompaction has occurred on the floodplains of the Santa Cruz and Rillito Rivers and

Pantano Wash. Soils prone to compaction are also present in a large area of north-central and east-central Tucson known as the Cemetery Terrace. Soils having the potential for hydrocompaction also are present in the Marana area northwest of Tucson.

Benson area

Collapsing soils present a major problem in the Benson area in the upper San Pedro Valley. There, some silty clays and soil formed on alluvium derived from granitic rocks may be subject to significant settling upon wetting or application of loads.

Phoenix area

Floodplain deposits susceptible to compaction are present along the Gila and Salt Rivers in the Phoenix region. Soils formed on the fine-grained lower parts of alluvial fans emanating from mountains and piedmonts also have potential for hydrocompaction.

Preventing Damage From Compacting Soils

Before building, it would be wise to examine published soil surveys or to have a survey or test made of the engineering properties of the soil on the site. It is much easier to take required remedial measures before construction than it is to retrofit. Soil tests can determine the likelihood of compaction based on how much water the soil is capable of holding compared to how much water is needed to lower the strength. Soil may be treated by application of large amounts of water, followed by several weeks or months to allow settling to occur before construction on the site. A large weight, called a preload, can also be applied to fully compact the soil before building. Compaction can be achieved using a vibratory roller or tamper on wetted soil. If the compaction-prone soil is not very deep, removal and replacement with stable soil may be an effective treatment.

Preventative measures for areas that have compacting soils are similar to those that have swelling soils. Rain runoff should be directed away from structures to avoid infiltration. Deep watering of plants may trigger collapse. When landscaping near structures, choose desert-adapted native plants over non-native plants that require extensive watering. Provide for drainage away from structures; ponded water may infiltrate several feet and trigger hydrocompaction. Finally, ensure that walls, footings, and foundations are properly reinforced to withstand minor soil compaction.

Where To Go For More Information

The Natural Resources Conservation Service (NRCS) publishes maps and reports showing distribution and properties of soils, and provides information to the public. The NRCS is listed in the blue Government section of the telephone directory under U.S. Department of Agriculture. Soil maps from the NRCS are available for inspection in the AZGS library. AZGS surficial geologic maps contain some soil information.

Consultants specializing in soil properties are listed in the phone book under *Engineers*, subcategories including *civil*, *geotechnical*, and *soils*. Developers commonly perform engineering studies of properties, and their consultants' reports may be available for inspection.

Selected References

Facing Geologic and Hydrologic Hazards - Earth-Science Considerations, W.W. Hays, editor, 1981: U.S. Geological Survey Professional Paper 1240-B, 108 p.

A Guide to Swelling Soils For Colorado Homebuyers and Homeowners, by D.C. Noe, C.L. Jochim, and W.P. Rogers, 1997: Colorado Geological Survey Special Publication 43, 76 p.

So Your Home is Built on Expansive Soils - A Discussion of How Expansive Soils Affect Buildings, Warrren Wray, editor, 1995: New York, American Society of Civil Engineers, 59 p.

Collapsing Soil - a Geologic Hazard, B.J. Murphy, 1975: Arizona Bureau of Mines [now Arizona Geological Survey] Fieldnotes, v. 5, no. 4, pp. 8-10.