

## TOPOGRAPHY, GEOLOGY, AND SOILS

This section provides an overview of the geologic setting in the Study Area and preliminary information concerning geotechnical and geologic conditions in the Study Area. The evaluation presented in this section is based on available information on regional and local geology, mining activity, regional and local seismicity, and regional and local land subsidence and earth fissuring.

Numerous geotechnical studies have been conducted in the Study Area. Two previous studies, *Preliminary Geotechnical Investigation Report, Southwest Loop Highway – SR 218, I-10 & 59th Avenue to I-10 & Pecos Road* (Sergent, Hauskins, & Beckwith 1987a) and *Geotechnical Investigation Report, Southwest Loop Highway – SR 218, I-10 & 59th Avenue to I-10 & Pecos Road* (Sergent, Hauskins, & Beckwith 1987b), were performed for ADOT. Reynolds (1985) performed a detailed study of geology at the South Mountains, and Demsey (1989), Reynolds and Skotnicki (1993), and Waters and Ravesloot (2000) published studies regarding the Quaternary geology in the Study Area. Studies regarding soils in the Study Area were performed by Adams (1974), Hartman (1977), and Johnson et al. (1986). Groundwater and well data are available from the Arizona Well Registry Distribution Database (ADWR 2002) and from the Groundwater Sites Inventory (ADWR 2008). Regional land subsidence and earth fissuring maps were created by Laney et al. (1978), Schumann (1974, 1992), Shipman (2007), and the ADWR Hydrology Division (ADWR 2008). The regional seismicity was detailed by Euge et al. (1992) and USGS (2006).

### AFFECTED ENVIRONMENT

#### Overview of Geologic Conditions

The Study Area lies within the desert region of the Basin and Range Physiographic Province. The dominant physiographic feature in the Study Area is the South Mountains, which are isolated, northeast-trending ridges surrounded by a broad expanse of alluvial deposits. The northern side of the South Mountains is drained by the Salt River, and the southern and southwestern sides of the South Mountains are drained by the Gila River.

Study Area topography is dominated by the presence of the Salt and Gila rivers and the South Mountains. The elevation generally ranges from 2,400 feet above mean sea level at the crest of the South Mountains to 950 feet above mean sea level at the confluence of the Salt and Gila rivers, which is at the western edge of the Study Area, in the Western Section. In the Western Section of the Study Area, the topography north of the Salt River is relatively flat, gently sloping to the southwest. The topography south of the Salt River also is relatively flat, gently sloping either to the northwest toward the Salt River or to the southwest toward the Gila River. The topography in the Eastern Section of the Study Area is variable in elevation, traversing the low foothills of the South Mountains.

The dominant geologic features are the bedrock of the southern flanks and foothills of the South Mountains, adjacent alluvial fans and piedmonts, and the basin sediments of the Salt and Gila rivers, including their associated floodplains and terraces. The bedrock geology of the southern flanks of the South Mountains and their associated foothills in the Study Area consists of granitic and related rock and metamorphic gneissic rock. The alluvial fan deposits and piedmonts of the South Mountains are predominantly granular deposits that can include abundant cobble- and boulder-sized material. These deposits vary in thickness and often exist as only a thin veneer of colluvium or alluvium overlying bedrock. The geology of the Salt and Gila rivers and of their associated floodplains and terrace deposits generally consists of highly stratified, predominantly fine-grained, alluvial deposits and active channel deposits consisting of varying mixtures of clay, silt, sand, gravel, and cobbles. Typically, the Gila River channel deposits contain less gravel and cobbles and more sand than do the Salt River deposits.

#### Groundwater

The Study Area lies within the West Salt River Valley Subbasin of the Phoenix AMA. Groundwater distribution in the Study Area is highly variable. In the alluvial environments dominated by the Salt and Gila rivers, groundwater is abundant and may be found near

the surface. In the bedrock, piedmont, and alluvial fan environments associated with the South Mountains, little-to-no groundwater is likely to be found. Groundwater use differs substantially in the Study Area. South of Estrella Drive, generally in the Eastern Section of the Study Area, there is relatively little groundwater use. North of Estrella Drive, generally in the Western Section of the Study Area, groundwater is used extensively for agricultural and municipal purposes. In Ahwatukee Foothills Village, in the Eastern Section of the Study Area, groundwater is used to fill private lakes for golf courses and residential neighborhoods.

Depth to groundwater varies throughout the Study Area. Along the Eastern Section of the Study Area, depth to groundwater is greater than 50 feet. USGS groundwater level data were obtained in the Ahwatukee Foothills Village area for several different wells, and the depth to groundwater ranged between 97 and 117 feet below ground surface (USGS 2006). Areas south of Lower Buckeye Road may have depths to groundwater of less than 50 feet (ADWR 2002). Also in the Eastern Section, ADWR Groundwater Site Inventory data from 2007 to 2008 indicate depths to groundwater of about 65 to 75 feet below ground surface in the Laveen Village area just west of the western flanks of the South Mountains (based on data from two wells), and about 120 feet below ground surface in the Ahwatukee Foothills Village area near Chandler Boulevard and I-10 (based on data from one well). USGS data for multiple wells in the Western Section of the Study Area (including Laveen Village and the Salt River areas) indicate that depths to groundwater range from 9 to 134 feet below ground surface. Also in the Western Section, ADWR Groundwater Site Inventory data from 2007 to 2008 indicate depths to groundwater of about 40 to 120 feet below ground surface north of the Salt River (based on data from seven wells), and about 30 to 40 feet below ground surface south of the Salt River (based on data from four wells). Shallow, perched groundwater could be present in the southern portion of the Eastern Section and the northern portion of the Western Section in areas under irrigation

or previously under cultivation. In most instances, this groundwater would be the result of seepage from tailwater ditches or unlined irrigation laterals. In both the Eastern and Western Sections, progressing toward the South Mountains and their foothills, the unconsolidated deposits thin and groundwater may be isolated in perched zones.

### Land Subsidence and Earth Fissuring

Land subsidence attributable to groundwater withdrawal in alluvial basins in the Basin and Range Physiographic Province is a process of compression and subsequent consolidation of the alluvial sediments. Through geologic time, groundwater levels in the alluvial basin materials were at or near the ground surface or at elevations controlled by the rivers and drainage systems traversing the basins. Human activities have affected and are continuing to affect groundwater levels in many of these basins. Groundwater pumping, primarily for agricultural, industrial, and municipal uses, has depleted stored groundwater in many areas. In addition, damming of rivers in mountainous portions of the surrounding watersheds has reduced the available recharge potential.

Based on regional mapping (Laney et al. 1978; Schumann 1974, 1992) and available National Geodetic Survey data, land subsidence in the Study Area has been limited to less than 1 foot. Historic groundwater declines have been between 50 and 100 feet in areas located away from the South Mountains and their associated foothills (Laney et al. 1978; Laney and Hahn 1986; ADWR 2002). Declines of this magnitude have resulted in only minor land subsidence. In the early 1990s, scientists began to use Synthetic Aperture Radar and interferometric processing (Interferometric Synthetic Aperture Radar) to detect land surface elevation changes. Interferometric processing has developed into a highly reliable land subsidence monitoring tool used by ADWR since 2002 to identify and map subsidence features in Arizona. The most current ADWR subsidence maps were reviewed at the ADWR Web site (ADWR 2009). Based on the ADWR mapping, no land subsidence zones exist within or adjacent to the Study Area.

Earth fissuring poses an erosional hazard because normal surface drainage captured by fissures can result

in the formation of substantial fissure gullies. Earth fissures in areas of large groundwater decline in alluvial aquifers are likely associated with a process termed “generalized differential compaction.” Because of this process, fissures commonly develop along the perimeter of subsiding basins, often in apparent association with buried or protruding bedrock highs, suspected mountain-front faults, or distinct facies changes in the alluvial section. The Arizona Geological Survey conducts comprehensive mapping of earth fissures and delivers earth fissure map data to ASLD. Earth fissure planning maps covering Maricopa County (Shipman 2007) were reviewed to identify known or reported earth fissures within or near the Study Area. Based on these maps, no earth fissures are known to exist within or adjacent to the Study Area.

### Regional and Local Seismicity

Minimal historical seismic activity has been recorded in Maricopa County and the Study Area. No recognized active faults are located within the proposed alignments of any of the action alternatives (USGS 2006). Euge et al. (1992) prepared a report for ADOT that included evaluation of seismic criteria for the state of Arizona. This report presents maps of expected horizontal acceleration in bedrock, with a 10 percent probability of exceedance in both 50 and 250 years. For the Study Area region, the approximate values of acceleration are 0.03 of unit gravity (g) for an exposure time of 50 years and 0.07g for 250 years.

While the Euge et al. (1992) report included a regional evaluation of seismic criteria, USGS data were used to evaluate a specific site within the Study Area. Probabilistic earthquake ground motion values were obtained from the USGS National Seismic Hazard Mapping Project, Earthquake Hazards Program (USGS 2002) for the intersection of 51st Avenue and Pecos Road (specifically, for 36.28 degrees North latitude, -112.16 degrees West longitude). Interpolated, probabilistic ground motion values of peak ground acceleration in rock for 2 and 10 percent probabilities of exceedance in 50 years were obtained for this site in the Study Area:

- 10 percent probability of exceedance in 50 years, with a return period of 475 years: 0.037g

- 2 percent probability of exceedance in 50 years, with a return period of 2,475 years: 0.072g

These peak ground acceleration values are for firm rock (rock with shear-wave velocity of 2,500 to 5,000 feet per second in the upper 100 feet of profile), categorized as Site Class B in accordance with the International Building Code, Chapter 16, Section 1613.2, Table 1613.5.2 (International Code Council, Inc. 2006). These values would need to be evaluated and adjusted as appropriate based on the subsurface profile encountered during final geotechnical investigations. Seismic ground motion values for design of the roadway, bridges, and other structures would need to be adjusted using appropriate attenuation factors for actual in-place materials as presented in Chapter 16 of the International Building Code (2006).

### Mineral Resources

Mineral resources in the Study Area include sand and gravel and precious metals. Sand and gravel are the most important mineral resources in the Study Area. These resources are primarily found adjacent to or within the Salt and Gila rivers. The South Mountains and their associated foothills contain potential precious metal resources. Historical mining of precious metals has been limited in scope, however, and it is unlikely that mining in the Study Area would occur in the foreseeable future.

A search of the Arizona Mineral Industry Location System database (Arizona Department of Mines and Mineral Resources 2001), examination of aerial photographs, and field investigations indicated that seven sand and/or gravel operations or companies are within the R/W of the various Western Section action alternatives.

One gold mining claim and six unknown mining claims are included in the database but are not located within the proposed alignments of the action alternatives. From topographic maps, several mining features are located south of the South Mountains, but none of these are located within the proposed alignment of the E1 Alternative.

## ENVIRONMENTAL CONSEQUENCES

This section outlines the construction impacts on geologic and geotechnical conditions in the Study Area. No impacts on geologic and geotechnical conditions would occur as a result of operation of the proposed action.

### Action Alternatives, Western and Eastern Sections

Within the context of this preliminary analysis, substantive variations in the geotechnical conditions do not appear to exist among the action alternatives. Alternative and design option divergences would occur in terrain underlain by the alluvial, unconsolidated sediments of the Salt River near its confluence with the Gila River, which is located at the western edge of the Western Section. All of the Western Section action alternatives would cross the Salt River, with no notable distinction between the various locations when considering the anticipated ground conditions that would be encountered. In addition, the alluvial deposits both north and south of the Salt River channel would be similar throughout the Study Area to a degree that no distinction should be made based on this preliminary analysis.

In the Western Section of the Study Area, shallow groundwater exists throughout the area where the action alternatives and design options would diverge across the floodplain and terraces of the Salt River. Coarse-grained alluvial deposits, some cemented soils, and the potential for encountering both expansive and compressible/collapsible soils in the shallow profile would provide constraints in the Western Section. These groundwater and soil conditions may influence both the design and method of construction of roadway sections and/or bridge foundations; such conditions are commonly encountered, however, and construction technologies to overcome these conditions are readily available.

The W59 (Preferred) Alternative would adversely affect three different sand and gravel companies, at least one of which appears to be an active operation. The W71 Alternative would adversely affect two different sand and gravel companies; the operations of each appear to be inactive. The W101 Alternatives and Options

would adversely affect two sand and gravel companies; the operations of only one appear to be active.

In the Eastern Section, geotechnical constraints would likely include excavation of competent bedrock and evaluation of stability of slopes completed in the bedrock. The E1 (Preferred) Alternative would traverse the foothills along the southern flank and western tip of the South Mountains, where competent bedrock generally consisting of granite and gneiss is either exposed or likely underlies a thin surface veneer of colluvial and alluvial deposits. During construction of the proposed freeway, these bedrock units would likely be encountered, resulting in difficult excavation conditions in cut sections and possibly requiring blasting to facilitate removal. The rock material resulting from the excavation of bedrock would be highly variable in particle size, with the likely production of some materials not directly suitable for use as roadway embankment fill because of the preponderance of oversized particles. If produced, these materials would need to be rejected or subjected to additional processing.

Construction through several rock slopes would likely occur along portions of the Eastern Section of the Study Area and along the aforementioned mountain flank. Design of stable slope angles and configurations would need detailed geomechanical characterization to define the orientation and condition of the rock discontinuities. These slopes would probably not be influenced by groundwater seepage nor by freeze-thaw mechanisms, thus providing a relatively stable environment for safe slopes over the long term. The major design issue would be evaluation and mitigation of the potential for detachment of portions of the constructed slope face along natural fractures in the rock mass.

In addition to the likelihood of production of some oversized particles during the excavation of rock, both the channel deposits of the Salt River and the upland portions of the alluvial fan and piedmont deposits likely contain a relatively coarse fraction. Selection or treatment may be required to use these materials as structural fill. These upland, unconsolidated alluvial

### Mitigation for Vibration-related Impacts

Near the South Mountains, bedrock may be encountered during project construction. Cuts through ridgelines of the South Mountains would be anticipated. As a result, blasting may be needed to fragment the bedrock material for removal.

Members of the public expressed concerns about potential damage to structures caused by blasting. According to one individual, blasting for construction of homes near the Study Area caused damage to other homes.

Three main adverse effects occur from blasting: flyrock, airblast, and ground motion. Flyrock is rock that is propelled through the air from a blast. Flyrock is controlled by blasting methods that reduce the likelihood of flyrock's occurrence. Access is controlled at blast sites to reduce the potential for bodily injury. Airblast is the airborne shock wave that results from the blast. In some cases, the airblast is audible, but normally the predominant frequencies are below the range of human hearing; therefore, airblast is usually felt rather than heard. The primary cause of blast damage is ground motion. Ground motion also may be caused by heavy equipment operation such as ripping. Ground motion is measured in terms of peak particle velocity, usually expressed in inches per second. As vibrations from a blast arrive at a particular location, a particle of soil or rock will vibrate randomly in all directions (longitudinal, transverse, and vertical) for a short period of time. Peak particle velocity refers to the highest velocity that the particle achieves in any of the three directions following an event.

According to the *ADOT Standard Specifications for Road and Bridge Construction* (2008), Section 107.10, the contractor is responsible for all damage resulting from the use of explosives. Special provisions for a recent project (Grand Avenue Underpass

Project, constructed in 2004) required that the contractor perform preblast surveys of two existing structures. Preblast surveys are required routinely for mining operations. According to 30 C.F.R. § 816.62, preblast surveys within ½ mile of blasting are required for mining operations.

Preblast surveys assess the condition of the dwellings or structures and document any existing defects and other physical factors that could reasonably be affected by blasting. Minor defects in structures, such as cracks in plaster, masonry, and other structural materials, normally result from the relative movement of the different materials of construction with changes in temperature and humidity. Preblast surveys document existing damage by photographing and recording the location, length, and width of any cracks or other visible defects in the building's foundation, interior, or exterior.

Postblast surveys may be performed following a blasting episode, but normally occur only if a blast-related damage claim is made by the homeowner to the contractor. If damages were documented in the postblast survey, according to *ADOT's Standard Specifications for Road and Bridge Construction* (2008), the contractor would be responsible for the damages.

According to the *ADOT Standard Specifications for Road and Bridge Construction* (2008), responsibility for all damage resulting from the use of explosives is assigned to the contractor that uses the explosives. In the special provisions of the construction contract for the proposed action, ADOT would include a requirement for the contractor to perform in-depth pre- and postconstruction surveys for all structures located within ½ mile in the event any blasting and/or heavy ripping were to be planned for construction purposes. This documentation should include photographic and video documentation.

units may also be cemented to a degree such that excavation would be moderately difficult.

Although their lateral distribution is not defined in the available data reviewed for this report, the geologic setting related to the valley floor and the mountain flank is conducive to the deposition of soils that may

possess potential for either expansion or compression/collapse. Moisture-sensitive, low-density alluvial deposits susceptible to compression or collapse often occur along the fringes of alluvial fans. Expansive soils may occur in the overbank deposits of the master streams, low in the valley floor. Geotechnical conditions would be further defined during the design phase. However, based on available data, no geotechnical constraints are anticipated.

Some soils in irrigated portions of the Study Area near tailwater ditches and canals may have a high moisture content. If present, these soils would require drying before use as roadway embankment fill or to provide sufficient bearing capacity under roadways or other structures. Because of more recent rises in the groundwater table elevation in portions of the Study Area and a slowing of the rate of decline in other parts of the Study Area, future land subsidence would be expected to have only minimal, if any, effects on the design or performance of project elements (see *Alternatives Studied in Detail*, on page 3-40, for descriptions of the action alternatives). If future groundwater withdrawal were to result in considerable groundwater-level decline, however, subsidence of sufficient magnitude to affect performance of project elements would be possible. If land subsidence were to occur within or adjacent to the Study Area, earth fissures could develop along the foothills of the South Mountains.

#### **No-Action Alternative**

Under the No-Action Alternative, only ongoing development and construction activities would affect the geologic and geotechnical conditions in the Study Area.

#### **MITIGATION**

Appropriate design of the facilities would mitigate geotechnical-related construction effects. Appropriate design would include excavations and slopes in soil and rock with an accepted degree of safety, placement of fills with an accepted degree of safety, protection of excavation and fill slopes against erosion, and design of roadway subgrade and foundations in accordance with accepted practices (see text box on page 4-115 for additional mitigation).

Implementation of the Western Section action alternatives would mean acquisition of sand and gravel operations within the Salt River riverbed. These properties would be included in the project's acquisition and relocation assistance program. The program is conducted in accordance with the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (49 C.F.R. § 24), which identifies the process, procedures, and time frame for R/W acquisition and relocation of affected businesses. Relocation resources would be available to all business relocatees, without discrimination. All acquisitions and relocations resulting from the proposed freeway would comply with Title VI of the Civil Rights Act of 1964 and with 49 C.F.R. § 24. Private property owners would be compensated at fair market value for land and may be eligible for additional benefits. In the final determination of potential relocation impacts during the acquisition process, ADOT would provide, where possible, alternative access to properties losing access to the local road network. In the event that alternative access could not be provided, ADOT would compensate affected property owners in accordance with 49 C.F.R. § 24.

Prior to issuance of the ROD, ADOT would consider protective and hardship acquisition on a case-by-case basis in accordance with criteria outlined in the ADOT *Right-of-Way Procedures Manual* (2009a). After the ROD, ADOT would consider protective and hardship acquisition of properties in those freeway sections not planned for immediate construction. Protective acquisition would aid in reducing the number of required acquisitions closer to the time of construction.

#### **CONCLUSIONS**

Geologic conditions within the Study Area would influence how the proposed action would be designed and ultimately constructed. Although preliminary investigations did not reveal any unique conditions that would substantially constrain the majority of construction activities, two geologic conditions were identified that would control design aspects and construction techniques for the proposed action. In the Western Section, shallow groundwater may influence the design of elements of the proposed freeway. In the Eastern Section, construction through mountain ridgelines would entail rock excavation in some form and need additional coordination with surrounding residents. Under the No-Action Alternative, continuing urban development would alter the landscape of the area.

No substantial differences were identified when comparing impacts among the Western Section action alternatives. Appropriate design—as commonly applied to projects of the size and features of the proposed action and to the mitigation measures outlined in this section—would mitigate any geotechnical-related construction effects.