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4.14 Soils and Geology

This section summarizes existing soils and geologic conditions in the project area and describes consequences of the system alternatives, which include System Alternatives 1, 2, 3, and the Preferred Alternative. Information regarding soils and geology in the project area was collected from available NRCS, USGS and Colorado Geological Survey (CGS) publications, and previous environmental and geotechnical investigations.

4.14.1 Current Conditions

The project corridor is located in an area of broadly rolling topography, with local steepening of the terrain where resistant bedrock units crop out. The area's most significant topographic feature is the broad valley of the South Platte River, which lies 10 to 50 feet below the surrounding surface. Elevations range from 5200 feet along the river near US 6 to 5290 feet along I-25 at Logan Street.

I-25 lies largely in the South Platte River valley, generally close to the east bank of the river except near the southern end of the project area. In the project area, the river valley slopes toward the river at gradients on the order of 1 percent, as well as more gently downstream (generally northward). Approximately 2000 to 2500 feet west of the river the terrain abruptly rises 80 feet or more at gradients from 5 to more than 10 percent. To the east the margin of the river valley, is less clearly defined, as the ground rises irregularly over distances of 2000 feet to more than 4000 feet from the South Platte River.

The project area has been developed over an extended period. Construction of roads and railroads, as well as of industrial, commercial, and residential buildings, has modified the native earth materials with cuts and, locally, several generations of fills. In addition, a segment of the river has been re-aligned. Industrial, commercial, and residential development has resulted in numerous local modifications to the topography including cuts, fills, and installation of retaining walls.

4.14.1.1 Geologic Setting

The project area, which lies within the Denver Basin geologic province, consists largely of a sequence of sedimentary rock formations deposited and preserved in the Denver Basin, a structural depression in north-central Colorado. Underlying the area is the west-central portion of the Denver Basin, a major north-south trending structural depression containing sediments ranging in age from late Pennsylvanian through Quaternary.

In the project area, sedimentary rocks dip eastward at low angles (less than 10 degrees, typically) and are overlain by a variety of surficial deposits including alluvial (stream-laid) sediments deposited by the South Platte River and other streams, eolian (wind-blown) materials, and colluvial (slope-wash) deposits.

Much of I-25 in the project area, particularly at the interchanges, is constructed on artificial fill. This artificial fill is composed of varying amounts of clay, silt, sand, gravel, and other debris including concrete, brick, wood, vegetation, and trash (Lindvall, 1978; Shroba, 1980), ranging in thickness from 5 to 40 feet. There have been many quarry operations adjacent to the river (CGS, 1974a). Because many of the abandoned quarries were later used as landfills, artificial fill may include debris, trash, and other landfill material. The extent of known fill material is described in **Section 4.13** *Hazardous Waste*.

4.14.1.2 SOILS

The NRCS of the U.S. Department of Agriculture has not conducted a formal soil survey for the City and County of Denver. Urbanization has altered the natural soils due to fill, excavation, and other construction activities. Generalized soils studies for the Denver metropolitan area have focused on the mapping of soil characteristics as these affect construction activities. Three major soil problems have been identified including swelling of clay-rich soils after extensive watering, settling or consolidation of loess/river clay soils, and the potential for landslides along steep slopes.

Soils with "low-swelling potential" have been mapped within the South Platte River alluvium corridor and extend approximately one-quarter of a mile on either side of the river in the project corridor (CGS, 1974b). West of the river, "high-swelling potential" soils band a broad area of "medium-swelling potential" soils farther west. An area of windblown sand or silt is mapped to the east of the alluvium in the project area. Although this material generally has low-swelling potential, windblown material may be subject to settlement or hydrocompaction problems when water is allowed to saturate the deposits. River clays within the alluvium may also have the potential for settling problems.

4.14.1.3 UNCONSOLIDATED DEPOSITS

Figure 4.8-1, in **Section 4.8** *Paleontology,* illustrates the generalized surficial geology in the project area. Natural alluvial deposits consist of sand, gravel, silt, and clay. Surficial deposits just outside the floodplain generally consist of Quaternary-aged (Pleistocene) loess, consisting of non-striated, clayey sandy silt.

The bedrock is incised by the South Platte River and associated alluvial deposits are present. These range from relatively recent (Post-Piney Creek) materials near the active channel to older deposits (e.g., Piney Creek Alluvium and Broadway Alluvium) at depth and preserved on terraces overlooking the river. The alluvial deposits consist largely of coarse sands and gravels, with local cobbles as well as lenses of clays and silty sands. The thickness of the alluvium overlying bedrock ranges from about 4 feet to more than 50 feet. Although the alluvial deposits are irregularly interbedded, and lateral and vertical changes in material type commonly are abrupt, cobbles and coarse gravels generally will be more common in the deposits immediately overlying the bedrock.

The Quaternary Alluvium is made up of several identified geologic units (see **Figure 4.8-1** in **Section 4.8** *Paleontology*). The Broadway Alluvium (Qb) is composed of light brown, non-calcareous, clean to slightly silty pebbly sand interbedded with sandy silt to silty sand along the South Platte River in central Denver where it forms terraces which are approximately 18 to 30 feet thick. The Piney Creek Alluvium (Qp) consists of light gray to dark grayish-brown, humic, slightly calcareous, sandy silt and clay overlying non-calcareous, clean to silty pebbly sand interbedded with sandy silt with a thickness of approximately 18 to 25 feet along the South Platte River in central Denver. The Post-Piney Creek Alluvium (Qpp) consists of light gray to light brown, non-calcareous, clean to slightly silty pebbly sand interbedded with sandy silt and with a thickness of approximately 3 to 10 feet (Shroba, 1980).

Boreholes drilled west of Broadway during investigations for the I-25/Broadway Viaduct Replacement Project generally encountered clay fill with gravel and dark-colored fill (Ballofet-Entranco, 2001a). A layer of sand and gravel was present in most boreholes with thickness ranging from 5 to 30 feet. Boreholes in the area of I-25/Broadway Avenue encountered sand and gravel with large rounded cobbles. Areas of fill included clayey soil containing gravel, brick, concrete, and asphalt fragments.

4.14.1.4 BEDROCK

The Denver Formation, of late Cretaceous and early Paleocene age, is present beneath alluvial materials and/or fill materials at depths from 10 to 60 feet. The bedrock consists of yellowish-brown to grayish-olive tuffaceous claystones, mudstones, and sandstones interbedded with scattered lenticular conglomerates (Shroba, 1980).

In the Denver metropolitan area, the Denver Formation consists largely of claystones and sandstones interbedded on various scales. The claystones typically are moderately to highly expansive. Siltstones and well-cemented, resistant sandstones are encountered locally, as well as over-consolidated, but uncemented and friable sandstones.

Claystones have comprised the bulk of the Denver Formation materials encountered in test holes drilled for various studies along the alignment (Ground Engineering, 1999). They were moderately to highly plastic and expansive. Sandstones were encountered locally, typically in thin, isolated beds and lenses. Typically the uppermost several feet of bedrock materials were severely weathered.

The deepest top of bedrock encountered during I-25/Broadway viaduct investigations was approximately 28 to 32 feet below ground surface (Ballofet-Entranco, 2001a). Claystone, siltstone, and sandstone bedrock samples corresponded to descriptions of the Denver Formation. Weathered, highly-oxidized claystone/siltstone was generally present at thicknesses ranging from 5 to 10 feet, overlying the more competent Denver Formation claystone/siltstone/sandstone. Denver Formation bedrock in the vicinity has been described in numerous investigations as having various colors and textures such as brown hard sandy silty claystone, tan sandstone, tight gray-blue silty sandstone (the "Denver Blue"), strongly cemented olive-brown clayey sandstone, and gray-olive claystone with iron staining.

4.14.1.5 GROUNDWATER

Within the project area, groundwater is typically encountered at depths ranging from 10 to 30 feet below ground surface, with the shallower depths to groundwater near the South Platte River. The shallow alluvial aquifer varies in character within the project area. The areas of highest transmissivity and thus highest groundwater flow are likely to be in the sand and gravel deposit along the South Platte River. In other locations, the magnitude of groundwater flow within the alluvial aquifer will vary, primarily due to variations in grain size. The general direction of groundwater flow in the alluvial aquifer is expected to be toward or parallel to the South Platte River; however, this is likely to vary locally due to the influence of topography, paleochannels, and other influences. Groundwater movement through the bedrock is dominated by flow through sandstone layers and through fractures. Due to the variability in fracture density and connectivity, groundwater flow through the bedrock is highly variable. However, flow through bedrock is generally substantially less than through the overlying alluvium.

4.14.1.6 ENGINEERING SEISMICITY

Neither site reconnaissance nor review of available geologic maps indicates the presence of active or potentially active faults traversing or immediately adjacent to the project area. Therefore, the likelihood of surface fault rupture at the site is considered to be low.

The closest documented active fault to the site is the Rocky Mountain Arsenal Fault, which is located approximately 11 miles to the northeast (Kirkham and Rogers, 1981). This fault is approximately 15 miles in length, trends generally northwest/southeast and is considered to be a right-lateral, strike-slip fault. The most recent significant seismic movements associated with the fault occurred in the 1960s, generating earthquakes up to magnitude 5.5. Research performed by the USGS concluded that a strong correlation existed between the seismic activity of this fault and pressure injection of liquid waste into a disposal well located at the nearby Rocky Mountain Arsenal (Kirkham and Rogers, 1981). Pressure injection in the disposal well was discontinued in 1966 and only minor seismic activity along the fault has been recorded since. The risk of this fault giving rise to damaging, earthquake-induced ground motions at the alignment is considered to be relatively low given the low previously recorded seismic magnitudes.

The Golden Fault passes about 12 miles to the west of the site. That fault is considered to be potentially active (Kirkham and Rogers, 1981). No measurable displacement across the fault has been detected during the last 100 years. Significant movement across that fault is generally considered to have ended in the Eocene Epoch. Sporadic micro-seismicity near the Golden Fault was recorded in the course of studies performed in the 1980s and early 1990s. The risk of the Golden Fault giving rise to a damaging earthquake during the design life of the proposed structures also is considered low.

4.14.1.7 SLOPE STABILITY

The project area topography is comparatively flat-lying except where modified by construction. The native slopes appear to be generally stable. Neither field observations nor a review of published maps indicate landslide deposits on or adjacent to the project area. No features have been identified that are related to mass-wasting processes associated with steep slopes, such as landslides, slumps, or unusual soil creep. Therefore, the likelihood of project improvements being affected by large scale, unanticipated slope instabilities is considered low.

4.14.2 Consequences of the Alternatives

Based on the information presented above, the primary geologic hazards that could affect the system alternatives, including the Preferred Alternative, are swelling of expansive soils and settling or other effects from artificial fill material due to historic landfills. The consequences of these conditions on the alternatives are summarized below.

4.14.2.1 NO ACTION ALTERNATIVE

The No Action Alternative will not involve new construction. Therefore, this alternative would not be affected by geologic conditions in the project area.

4.14.2.2 SYSTEM ALTERNATIVE 1

Structures and roadways that would be constructed under System Alternative 1 could be impacted by expansive soil and artificial fill material. This alternative has the least amount of excavation and has fewer structures than the other system alternatives. However, roadways and structures will still be substantial and are likely to encounter these hazards.

The largest excavation associated with System Alternative 1 would be the grade separation (underpass) at the crossing of Santa Fe/Kalamath and the Consolidated Main Line railroad. Excavation would also be required to widen the current underpass, which takes I-25 under Alameda Avenue.

4.14.2.3 SYSTEM ALTERNATIVE 2

Structures and roadways that would be constructed under System Alternative 2 could also be impacted by expansive soil and artificial fill material. In addition to the excavation areas required for System Alternative 1, System Alternative 2 would require excavation for a grade separation structure (tunnel) to carry traffic from southbound Broadway to southbound I-25. This system alternative would also require excavation to widen the underpass carrying Alameda Avenue under the Consolidated Main Line and LRT.

4.14.2.4 SYSTEM ALTERNATIVE 3

Structures and roadways that would be constructed under System Alternative 3 could also be impacted by expansive soil and artificial fill material. In addition to the excavation areas required for System Alternative 1, System Alternative 3 would require excavation for a grade separation structure (underpass) to carry traffic on Santa Fe/Kalamath under Alameda Avenue. The base of this structure would be lower than the South Platte River, such that drainage would represent a design challenge. This system alternative would also require excavation to widen the underpass carrying Alameda Avenue under the Consolidated Main Line and LRT.

4.14.2.5 PREFERRED ALTERNATIVE

Structures and roadways that would be constructed under the Preferred Alternative could also be impacted by expansive soil and artificial fill material. The Preferred Alternative has less excavation and has fewer structures than System Alternatives 2, and 3. The Preferred Alternative is similar to System Alternative 1 in terms of excavation but has additional structure construction on US 6 (braided ramp from Federal Blvd. to eastbound US 6).

The largest excavation associated with the Preferred Alternative would be the grade separation (underpass) at the crossing of Santa Fe/Kalamath and the Consolidated Main Line railroad. Excavation would also be required to widen the current underpass, which takes I-25 under Alameda Avenue.

4.14.3 Mitigation Measures

Avoidance of all subsurface hazards is not possible due to the distribution of these conditions throughout the project area and project needs. However, impacts of these subsurface conditions will be minimized through appropriate geotechnical investigation, design, and construction measures. These measures will be considered and specified in detail during final design.

As in all roadway construction projects, a detailed geotechnical analysis of the surrounding subsurface will be required during the preliminary/final design process to determine the structural stability and load-bearing capacity of the geological formation within the limits of the proposed structures. The extent of these analyses is determined by federal, state, and local requirements. The results of the geotechnical analysis will be used to establish the design of the roadway and structures such as bridge piers, retaining walls, and grade separation structures.