4.15 Mineral Resources, Geology, and Soils

Summary

This section discusses the geologic setting along the United States Highway 36 (US 36) corridor and impacts to minerals, geology, and soils. Information was gathered on geologic conditions, geologic hazards, and geologic factors that could potentially affect the design of any of the build packages. Although several geologic constraints have been identified, no significant impacts to geology, soils, or mineral resources are expected due to the implementation of any of the proposed packages. Conditions that have been identified along the US 36 corridor that may require mitigation during construction include expansive soils and bedrock, steeply dipping bedrock, collapsible soils, soil erosion, and mine subsidence (collapse of an underground mine causing movement to the surface above). The results of this analysis indicate that coal beds located under the Superior/Louisville and Boulder segments would not impact construction on US 36.

Several geologic constraints have been identified along the US 36 corridor; however, no significant impacts to the geology, soils, or mineral resources are expected due to the implementation of any of the proposed packages.

Affected Environment

All Segments

Geologic Hazards

A geologic hazard, as defined by Colorado House Bill 1041 (1974), is "a geologic phenomenon which is so adverse to past, current, or foreseeable construction or land use as to constitute a significant hazard to public health and safety or to property." Physical and/or chemical properties associated with natural deposits, both bedrock and surficial, may impose risk or constraints to the use of the corridor and the proposed improvements. In addition, past human activities (such as mining) can also create risks and hazards. Geologic hazards and engineering constraints along the corridor include expansive soils and bedrock, steeply dipping bedrock, corrosive soils, collapsing soils, and mine subsidence, as described below.

Expansive Soils and Bedrock

Expansive soils and bedrock are widespread throughout the project area. The altered volcanic ash layers that are common in most bedrock units underlying the project area are composed primarily of swelling clay minerals. Soils that develop from and on them tend to have elevated swell potential as well. Expansive soils and bedrock can repeatedly swell when wet and contract when dry; potentially damaging man-made structures.

Expansive soils and bedrock can repeatedly swell when wet and contract when dry; potentially damaging man-made structures.

Steeply Dipping Bedrock

Steeply dipping bedrock units that contain layers with varying swell potential occur along the US 36 corridor. This geologic hazard is distinguished from relatively flat-lying expansive bedrock hazards due to the differential movement that can occur with steeply dipping bedrock. Heaving bedrock and surficial deposits that have significant swell potential, but are relatively flat-lying, generally expand in fairly uniform directions. However, steeply dipping bedrock that contains layers with different swell potential can cause extreme structural damage by either heaving or rebounding along individual bedrock layers and/or by asymmetrical thrust-like heaving along bedding planes or fractures (Noe 1997).

Corrosive Soils

Corrosive soils underlay portions of the US 36 corridor. Most of the soils in the Denver Basin area can produce high concentrations of sulfate salts and, therefore, can corrode metals and concrete in moist conditions.

Collapsing Soils

Collapsing soils occur along the US 36 corridor in several surficial deposits. Upon inundation with water, these deposits undergo sudden changes in structural configuration with an accompanying decrease in volume that is expressed as settlement at the surface. Eolian sands, loess, and loose sands and silts are deposits near the surface that are prone to collapse.

Mine Subsidence

Mine subsidence occurs when a void at depth collapses and causes vertical displacement (settlement) to the surface. Mine subsidence occurs at depth, rather than near the surface, as with collapsing soils. Coal was mined along the corridor starting in the 1860s and continued locally into the 1970s, using a room-and-pillar technique in which a coal seam was mined into “chambers.” Unmined coal pillars were left at the corners of rooms to help support the mine roof. Over time, the mine roof and coal pillars collapsed, and the empty void space left by mining is destroyed. Because the rock units in and surrounding the coal seams do not resist stress well, subsidence typically occurs relatively soon after mining ceases. In addition, in many of the mines, the pillars were removed when mining was completed to encourage collapse of the void space.

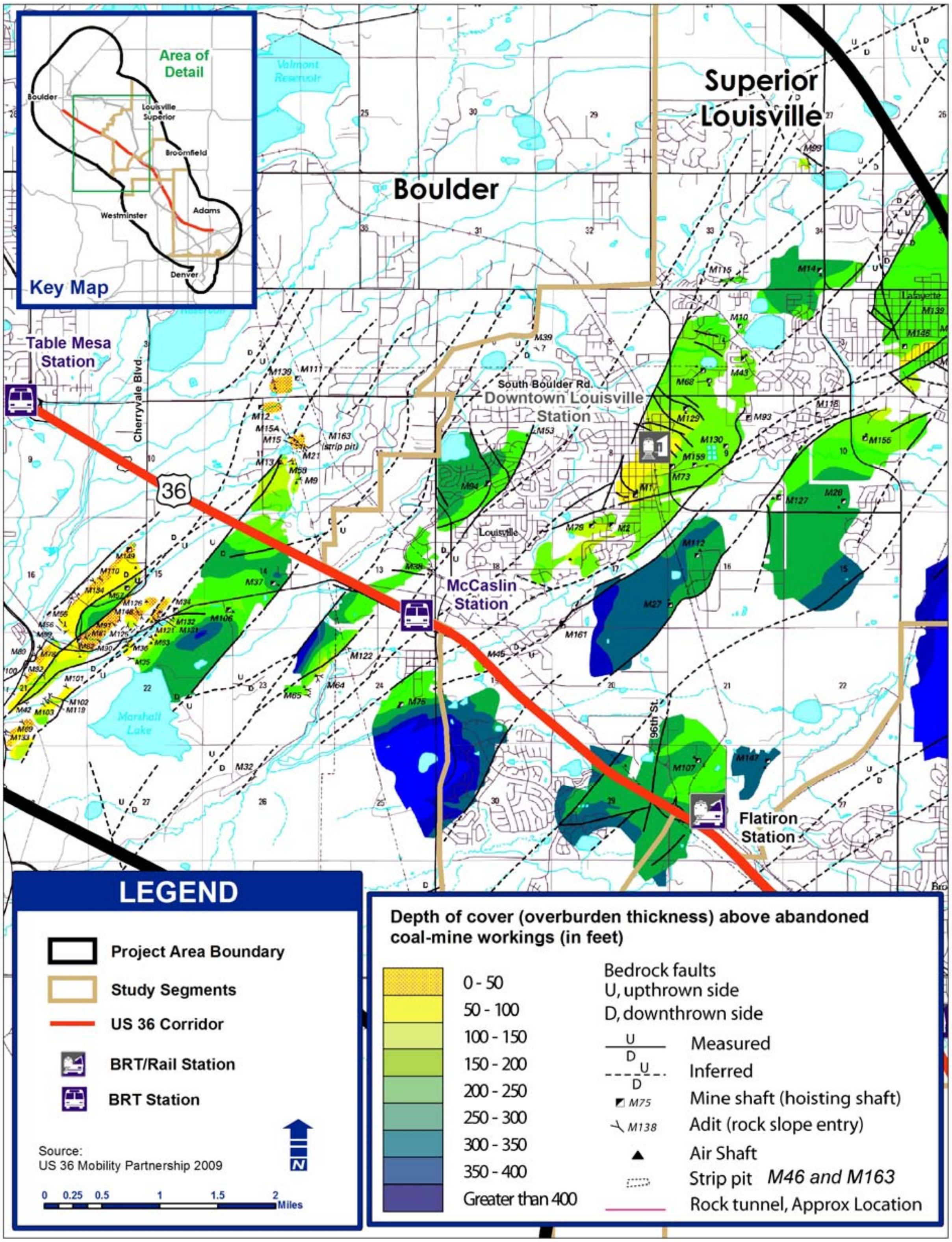
The US 36 corridor would cross portions of four abandoned coal mines in the Broomfield, Superior/Louisville, and Boulder segments.

Some mine void space probably remains today. Therefore, the potential for subsidence and possible damage to structures at the surface also exists. Overburden depths of 100 to 150 feet or less appear to increase the likelihood of subsidence expressed at the surface, whereas overburden depths of at least 200 feet appear to reduce the likelihood of subsidence expressed at the surface. Additionally, increased time since cessation of mining increases the likelihood that subsidence is complete.

The US 36 corridor would cross portions of four abandoned coal mines (Roberts et al. 2001) in the Broomfield Segment, the Superior/Louisville Segment, and the Boulder Segment. The Superior/Louisville Segment contains the Monarch No. 2/ Lucas mine (M107), the Enterprise mine (M45), and the new Crown mine (M38). M107 operated between 1908 and 1947 and is between 200 to 350 feet deep. M45 conducted operations between 1895 and 1898 and is between 150 to 200 feet deep. M38 operated between 1938 and 1955 and is between 200 to 300 feet deep. The Boulder Segment contains the old Crown mine (M37), which operated between 1919 and 1937 and is 200 to 300 feet deep.

Figure 4.15-1, Abandoned Coal Mines, illustrates the areas of abandoned coal mines with associated depths of overburden that underlay the US 36 corridor. No known areas of underground abandoned coal mine fire areas have been identified within the US 36 corridor.

Figure 4.15-1: Abandoned Coal Mines



Faulting and Seismicity

There are no known active faults either on or adjacent to the US 36 corridor, so the potential for surface fault rupture is low.

The project area is considered to be in a seismically-inactive area. There are no known active faults either on or adjacent to the US 36 corridor, so the potential for surface fault rupture is low. Faults within the US 36 corridor are believed to have been inactive for at least the last 45 million years. Therefore, seismic hazards at this site are a consequence of ground shaking caused by events on distant, active faults. Based on a review of seismic data available from the U.S. Geological Survey (USGS) (2003) for the US 36 corridor, the peak ground acceleration with a 10 percent probability of exceedance in 50 years, is approximately 0.02 percent gravity.

Soils

Generalized soil associations, taken from U.S. Department of Agriculture and Natural Resources Conservation Service (NRCS) (formerly known as the Soil Conservation Service) maps, show soil distributions across the US 36 corridor. The NRCS rates the erosion susceptibility of the soils. Using this information and known conditions in the US 36 corridor, the generalized descriptions are rated to have slight, moderate, or severe susceptibility to erosion.

Mineral Resources

Mineral resources along the US 36 corridor include coal, coalbed methane, oil and gas, and aggregate resources.

Deposits of coal and lignite beds appear in the Late Cretaceous and Early Tertiary sedimentary units. The Laramie Formation and the Denver Formation both contain fairly extensive, low rank coal deposits. The Laramie Formation was developed in a coal mining area known as the Boulder-Weld coalfield. Mining began here in the 1860s with production continuing up until the 1960s. The coal was extracted from a seam that was up to 15 feet thick. This stratigraphic sequence is located 150 to 350 feet below the ground surface in the vicinity of the US 36 corridor. Coal mining has ceased in this region, but the resource has not been depleted. Coal reserves remain in both mined and unmined areas along the US 36 corridor. Recovery percentages in mined areas typically vary from 30 to 50 percent (Amuedo and Ivey et al. 1975), meaning that considerable resource remains even in extensively mined areas. However, mines located along the US 36 corridor have been abandoned for at least 60 years. Widespread residential and business development over and adjacent to unmined areas makes reopening of mines highly unlikely.

Coalbed methane is a potential, but untapped, resource across the project area. Development of this resource is hypothetically feasible, but would be socially and economically complicated in an urban area. In addition, adequate means to protect the quantity and the quality of groundwater in aquifers within, above, and below the coalbed methane-bearing strata would need to be defined and implemented. Whether these means would be sufficient or economical has not been determined. Even if extraction of the resource were to occur, the narrow project corridor, coupled with its route along existing highways, decreases the likelihood that conflict would occur between future resource development and the transportation system.

Active oil and gas production near and in the US 36 corridor is present from the Wattenberg, Superior, and Boulder fields. The US 36 corridor is within the mapped boundaries of the Wattenberg Field from approximately where Independence Road parallels US 36 to the FlatIron Mall. Active production in the Wattenberg Field occurs one-half to more than a mile north of the US 36 corridor. From Superior near Rock Creek to where Marshall Road parallels US 36, the corridor is within the Superior Field. No active production occurs within the Superior Field near the US 36 corridor. The Boulder Field is crossed by the US 36 corridor from approximately Independence Road to 63rd Street. Active production occurs in the Boulder Field within 0.25 mile of the US 36 corridor. Production in each of these fields is from Cretaceous rocks, typically at depths of 3,000 to 7,000 feet (Weimer 1996; Colorado Oil and Gas

Conservation Commission 2004). Oil and gas fields in the area are established and are unlikely to expand into the US 36 corridor.

Aggregate resources exist throughout the US 36 corridor and are currently being mined at numerous locations. This includes aggregate recovery of clay and shale from the Pierre Shale Formation, sand and gravel from the Fox Hills Sandstone and the Denver Formation, and clay from the Laramie Formation. In addition to the aggregate resources from the sedimentary units, sands and gravels have been produced from the current stream channels and older alluvial deposits. Within the project area, the South Platte River, Clear Creek, Coal Creek, and South Boulder Creek have significant deposits of floodplain sand and gravel, and quarries are or have been operated on each drainage (Schwochow 1972). The floodplain of Clear Creek has been most extensively quarried in the project area. Pediment gravels intersect the alignment on both banks of Clear Creek and north of Rock Creek. Many areas have been mined out, but considerable reserves remain across the region along major drainages. However, the wide distribution of these resources makes the importance of the reserves at a specific locale less formidable in terms of development potential.

Aggregate resources are currently being mined at numerous locations throughout the US 36 corridor.

Denver/Adams Segment

The Adams Segment is underlain by bedrock of the Denver Formation. This formation is overlain in places by alluvium deposited from former, higher river levels, and wind-deposited loess. Geologic hazards and constraints associated with these geologic deposits include expansive soils and bedrock, corrosive soils, and collapsing soils.

Mineral resources for the Adams Segment include potential aggregate sources. Sands and gravels have been produced from the current stream channels, older alluvial deposits, and from the Denver Formation bedrock unit. Some alluvial and bedrock deposits may be sufficiently extensive to be mineable resources.

Westminster Segment

The geology of the Westminster Segment consists of bedrock of the Denver and Arapahoe formations. These formations are overlain in places by alluvium and loess. The alluvium is deposits from former, higher river levels and the loess is wind-deposited material. Several hazards and constraints are associated with these geologic deposits, which include expansive soils and bedrock, corrosive soils, and collapsing soils. These geologic hazards are similar to those previously described in the Adams Segment.

Mineral resources for the Westminster Segment include potential aggregate sources. Sands and gravels have been mined from the current stream channels and older alluvial deposits. Some alluvial deposits are sufficiently extensive to be a mineable resource within the Westminster Segment. The Denver Formation has been mined for sand and gravel and remains a potential source for this material.

Broomfield Segment

The Broomfield Segment is underlain by bedrock of the Arapahoe and Laramie formations. These formations are overlain in places by alluvium, which was deposited from former, higher river levels. Several hazards and constraints are associated with these geologic deposits, including expansive soils and bedrock, and corrosive soils.

Mineral resources include aggregate, coal, and oil and gas. The Laramie Formation remains a potential source for clay. Mineable coal seams likely exist in the western portion of the Broomfield Segment in the areas underlain by the Laramie Formation. The Broomfield Segment intersects active oil and gas fields.

Superior/Louisville Segment

The Superior/Louisville Segment is underlain by bedrock of the Laramie Formation. This formation is overlain in places by alluvium. The alluvium consists of deposits from former, higher river levels. Several hazards and constraints are associated with these geologic deposits, including expansive soils and bedrock, corrosive soils, and mine subsidence. Excluding mine subsidence, these hazards are similar to those described in the previous sections above. The depth to the coal mines is several hundred feet below the ground surface.

Mineral resources include aggregate, coal, and oil and gas. The Laramie Formation remains a potential source for clay, similar to the Broomfield Segment. Also, coal seams likely exist within the Superior/Louisville Segment in the areas underlain by the Laramie Formation. The Superior/Louisville Segment intersects active oil and gas fields.

Boulder Segment

The Boulder Segment is underlain by bedrock of the Laramie Formation, Fox Hills Sandstone, and Pierre Shale. These formations are overlain in places by alluvium. The alluvium consists of deposits from present-day and former, higher river levels. Several hazards and constraints are associated with these geologic deposits, including mine subsidence, expansive bedrock and soil, steeply dipping bedrock, corrosive soils, and an unstable slope. Mine subsidence in this segment is similar to that described in the Superior/Louisville Segment. An induced slope failure can be observed along the north-facing cut slope of Davidson Mesa. A small rotational landslide occurred here; possibly due to grading operations.

Mineral resources within the Boulder Segment include aggregate, coal, and oil and gas fields. Aggregate has been mined within the Boulder Segment and ongoing resources include clay and shale in the Pierre Shale Formation, sand and gravel in the Fox Hills Sandstone, and clay from the Laramie Formation. Coal seams likely exist within the Boulder Segment in the areas underlain by the Laramie Formation. The Boulder Segment intersects active oil and gas fields.

Impact Evaluation

There is no clear distinction between direct impacts to geology, geologic hazards, soils, or mineral resources associated with the US 36 corridor under any of the proposed build packages.

There is no clear distinction between direct impacts to geology, geologic hazards, soils, or mineral resources associated with the US 36 corridor under any of the proposed build packages. All of the build packages would cross surficial and bedrock geology units that may require standard mitigation during construction. Additionally, soil erosion may create increased sedimentation in local streams. No additional indirect impacts to geology, geologic hazards, and soil or mineral resources identified within the US 36 corridor would occur over what is described in Package 1 below.

Methodology

Geologic conditions present along the corridor were identified using information from geologic maps, topographic maps, USGS reports, Colorado Geological Survey publications, NRCS soil survey reports, and geotechnical consulting reports. This information was supplemented with field reconnaissance, communications with local engineering and planning personnel, and communications with experts in abandoned coal mine subsidence and reclamation. Evaluation of existing geologic conditions was based on proximity to the project corridor, history of occurrence, and impact of occurrence on transportation and mobility.

Package 1: No Action

Direct Impacts

All Segments

Package 1 would not have any direct impacts associated with the geology, geologic hazards, and soil or mineral resources identified within the US 36 corridor.

Indirect Impacts

All Segments

Under Package 1, the planned population increase in the project area of 28 percent in 2035 would result in more construction and development. These activities would place a greater demand for sand and gravel for concrete and subject more land to disturbance and subsequent erosion. Soil loss from development may be minimized by implementing best management practices (BMPs), but aggregate resources would be permanently committed. No additional coal mining is anticipated in 2035.

Package 2: Managed Lanes/Bus Rapid Transit

Direct Impacts

All Segments

Geologic conditions that have been identified along the US 36 corridor that may be directly impacted by Package 2 include expansive soils and bedrock, corrosive soils, steeply dipping bedrock, soil erosion, collapsible soils, and mine subsidence. None of these geologic conditions constitute an impact that should alter the location of Package 2.

Expansive soils and bedrock and corrosive soils may cause damage to transportation system components over a period of years. Steeply dipping bedrock has locally demonstrated severe damage to pavement and transportation structures from differential movement. Collapsible soils can damage the system infrastructure by either large settlement areas or differential settlement. Mine subsidence may also cause settlement at the surface. However, due to their depth, it is likely that any former mining voids are deeper than the zone of influence of the proposed improvements associated with Package 2 and would not pose a hazard from mine subsidence.

> *It is likely, due to their depth, that any former mining voids are deeper than the zone of influence of the proposed improvements associated with Package 2 and would not pose a hazard from mine subsidence.*

Indirect Impacts

All Segments

No additional indirect impacts over Package 1 would result from Package 2.

Package 4: General-Purpose Lanes, High-Occupancy Vehicle, and Bus Rapid Transit

Direct Impacts

All Segments

Geologic conditions associated with Package 4 that may be directly impacted include expansive soils and bedrock, corrosive soils, steeply dipping bedrock, soil erosion, collapsible soils, and mine subsidence. The direct impacts previously described for Package 2 are the same for Package 4.

Indirect Impacts

All Segments

No additional indirect impacts over Package 1 would result from Package 4.

Combined Alternative Package (Preferred Alternative): Managed Lanes, Auxiliary Lanes, and Bus Rapid Transit

Direct Impacts

All Segments

Geologic conditions associated with the Combined Alternative Package (Preferred Alternative) that may be directly impacted include expansive soils and bedrock, corrosive soils, steeply dipping bedrock, soil erosion, collapsible soils, and mine subsidence. The direct impacts previously described for Packages 2 and 4 are the same for the Combined Alternative Package (Preferred Alternative).

Indirect Impacts

All Segments

No additional indirect impacts over Package 1 would result from the Combined Alternative Package (Preferred Alternative).

Mitigation

Conditions that have been identified along the US 36 corridor that may require standard mitigation during construction include expansive soils and bedrock, corrosive soils, steeply dipping bedrock, collapsible soils, and soil erosion. The direct impacts could be mitigated through several standard techniques and should conform to CDOT's *Standard Specifications for Road and Bridge Construction* (1999).

Expansive soils and bedrock and collapsible soils could be mitigated at structure locations by designing deep foundation systems.

Expansive soils and bedrock and collapsible soils could be mitigated at structure locations by designing deep foundation systems, such as driven H-piles or drilled piers, rather than on shallow foundations. Foundation pads could also be designed to form a raft across any swelling or collapsing materials. Additionally, floating floor slabs could be designed instead of slab-on-grade construction. Structural retaining walls, such as soil nail walls, ground anchors, mechanically stabilized earth walls, cantilever walls, or reinforced soil slopes may be built to stabilize slopes, steep gradients (e.g., 3 horizontal to 1 vertical), or where potential slope failures may occur due to the presence of water and loose material.

Expansive subgrade soils under pavement sections could be stabilized with chemicals (e.g., lime), removed and recompacted, or removed and replaced with imported structural fill of better quality.

Collapsible subgrade materials under pavement sections could be mitigated by flooding, deep dynamic compaction, over-excavation prior to embankment placement, or additional loading with a thicker section of embankment material.

Steeply dipping bedrock areas would require alternative practices, such as over-excavation with refill and compaction to remove the conditions that perpetuate heaving. A barrier between the subgrade material and the pavement section could be constructed from imported structural fill materials that range in thickness from 3 to 5 feet. Under structures, this depth of sub-excavation and replacement could be as much as 10 feet under the base of the shallow foundation footer.

The collection and diversion of surface drainage away from paved areas is critical to the satisfactory performance of pavement. Proper design of drainage should include prevention of ponding water on or immediately adjacent to pavement areas. All landscape sprinkler heads and lines adjacent to pavement areas should be frequently inspected for leaks and maintained in good working order. Surface and subsurface water conditions must be addressed in the design of any retaining wall systems. For example, design should consider diverting and controlling surface water around or away from the wall areas and the wall designs should incorporate an internal drainage system. Horizontal drains may increase slope stability by reducing the seepage and freezing pressure acting within fractures in rock and within zones of weakness in the soil. Slopes and other stripped areas should be protected against erosion by revegetation or other methods.

The collection and diversion of surface drainage away from paved areas is critical to the satisfactory performance of pavement.

A Stormwater Management Plan that contains BMPs used to minimize soil erosion and methods for monitoring conditions before, during, and after construction will be prepared and implemented. Measures that will be required are typical of erosion control procedures used in highway construction projects such as those described in *Standard Specifications for Road and Bridge Construction,* Section 208, Erosion Control (CDOT 1999), and the *Urban Storm Drainage Criteria Manual* Volume 3 (UDFCD 1999).

The proposed mitigation measures are summarized in Table 4.15-1, Mitigation Measures — Mineral Resources, Geology, and Soils.

Table 4.15-1: Mitigation Measures — Mineral Resources, Geology, and Soils

Impact	Impact Type	Mitigation Measures
Expansive soils	Construction	• Engineering measures, such as installation of deep foundation systems, raft foundations, and floating floor slabs will be considered during preliminary and final design.
Unstable slopes	Construction	• Engineering measures, such as cantilevered retaining walls, soil nail walls, ground anchors, and MSE walls will be considered during preliminary and final design.
Expansive subgrade soils	Construction	• Engineering measures, such as soil stabilization with lime treatment, removal and recompaction, or removal and replacement with imported fill material will all be considered during preliminary and final design.
Collapsible subgrade soils	Construction	• Engineering measures, such as stabilization by flooding, deep dynamic compaction, over-excavation, and pre-loading prior to construction will be considered during preliminary and final design.
Steeply dipping bedrock	Construction	• Engineering measures, such as stabilization by over-excavation and replacement with imported fill materials will be considered during preliminary and final design.
Soil erosion	Construction/ Operations	• Refer to Section 4.20, Water Resources: Water Quality and Floodplains, and the Construction Management Plan discussion in Section 4.22, Construction-Related Impacts.

Source: US 36 Mobility Partnership, 2004.
Note:
MSE = mechanically stabilized earth