Northwest Corridor
A TRANSPORTATION ENVIRONMENTAL STUDY

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4.19 GEOLOGY, SOILS, AND MINERAL RESOURCES

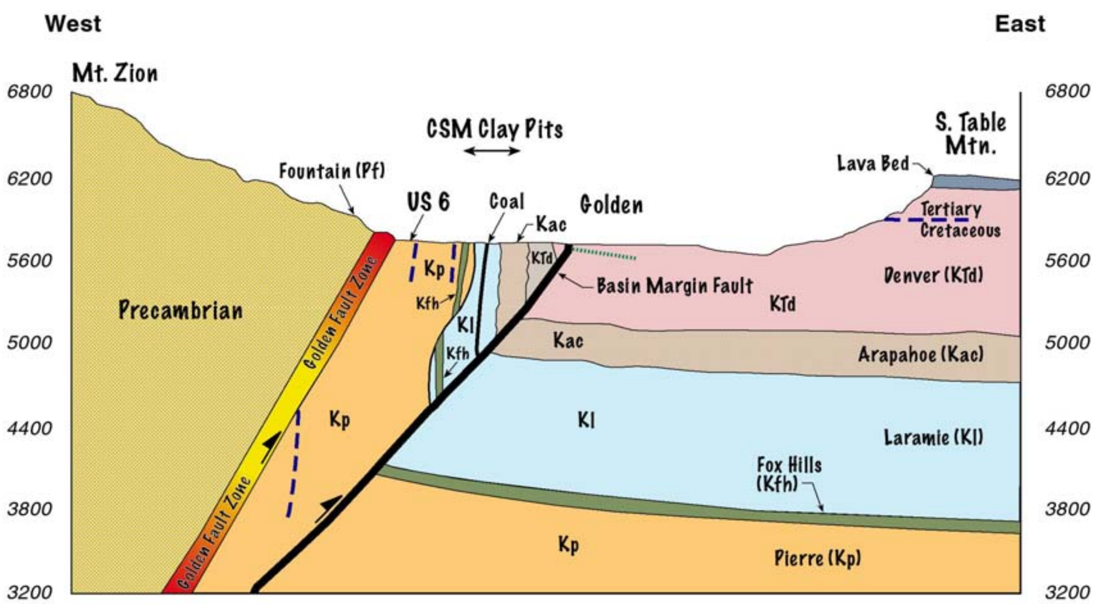
INTRODUCTION

This geologic overview provides information on existing geologic and soils conditions in the study area. The geologic and soils conditions present can affect the structural foundation for potential future roadway development and, therefore, construction and maintenance cost. Additionally, the development of roadways can complicate the extraction of valuable mineral resources; occupy areas having high-quality agricultural soils; or can be complicated by local geologic conditions (see **Northwest Corridor Supporting Technical Document-Geology and Soils**). No public concerns were expressed through the public involvement process regarding geology, soils, and mineral resources.

4.19.1 AFFECTED ENVIRONMENT

The study area lies along the eastern edge of the Rocky Mountain Front Range and the adjacent western edge of the Denver Basin. A representative diagram of geology in the study area shows a fault zone along the mountain front with eastward steeply dipping sedimentary rock layers into the Denver Basin (see **Figure 4.19-1**). A few miles to the east, the sedimentary rock layers are nearly horizontal. The configuration of the fault system varies along the mountain front. Nonetheless, steeply dipping sedimentary rocks near the mountain front, interrupted by faulting, and tilted, much less steeply sloping sedimentary rocks within a short distance to the east of the mountain front, are typical in the study area.

Figure 4.19-1 Cross-Section of Front Range near Golden



Source: Weimer, 1996.

4.19.1.1 GEOLOGY

Over most of the study area, the sedimentary rock units closest to the ground surface are 72- to 64-million-year-old Cretaceous sandstone, siltstone, mudstone, shale, and/or claystone, locally with conglomerate, coal, and/or limestone. Some of the better cemented sandstones and conglomerates are moderately resistant to weathering, but many other units weather deeply and rapidly. Expansive clay in many of the units tends to increase rock weathering rates. Thin beds of alternating lithology are common in Cretaceous bedrock. This arrangement tends to direct and compartmentalize fluid flow, which can lead to seeps, springs, slumps, and landslides, particularly where the rock layers are steeply dipping. Regionally, a high proportion of mineral resources are concentrated in the Cretaceous bedrock units, including oil, gas, coal, lightweight aggregate, limestone aggregate, brick clay, fire clay, and minor uranium ore. In addition, coalbed methane is a potential, but as of yet, undeveloped resource from these formations.

Over about the last two million years, gravity and stream action have deposited eroded rock material along the mountain front. Both unconsolidated and cemented deposits of clay, silt, sand, gravel, and/or boulders have accumulated, particularly at the foot of steep slopes (colluvium) and along major drainages (alluvium). Sand and gravel are quarried from many of the alluvial deposits. The terrace surfaces dip very gently but overlie eroded, steeply dipping bedrock near the mountain front. Young, windblown loess deposits of sandy and clayey silt up to ten feet thick are scattered over the study area, particularly away from the mountain front. Areas with broad deposits of loess include:

- Much of the area northeast of US 36.
- Areas adjacent to Rock Creek near Louisville.
- The region northeast, east, and southeast from Standley Lake.
- The area downstream from Leyden Lake; and around Crown Hill Lake in Lakewood.

The visually dominant topographic features within the study area are North Table Mountain and South Table Mountain. These features are atypical for the area east of the foothills because they are composed of both igneous and sedimentary rock units.

The older, lower rock units consist of 250 to 500 feet of interbedded sandstone and claystone, with a thick but laterally discontinuous conglomerate at the base. They are exposed in a narrow band around the western sides of both North Table Mountain and South Table Mountain.

The younger, overlying rock units include the Cretaceous/Tertiary boundary that marks the end of the "dinosaur age." They consist of at least 700 feet of sandstone, claystone, and conglomerate, each with volcanic material. At least three distinct lava flows are recorded in the upper third of the unit by layers of basalt-like latite on North Table Mountain; the younger two flows extend farther south to South Table Mountain. The cliffs of both mountains are composed of the second and third lava flows, and the top of the third lava flow forms the flat caps of the mountains. The source of the lava appears to have been in the area of Ralston Dike, about two miles north of North Table Mountain.

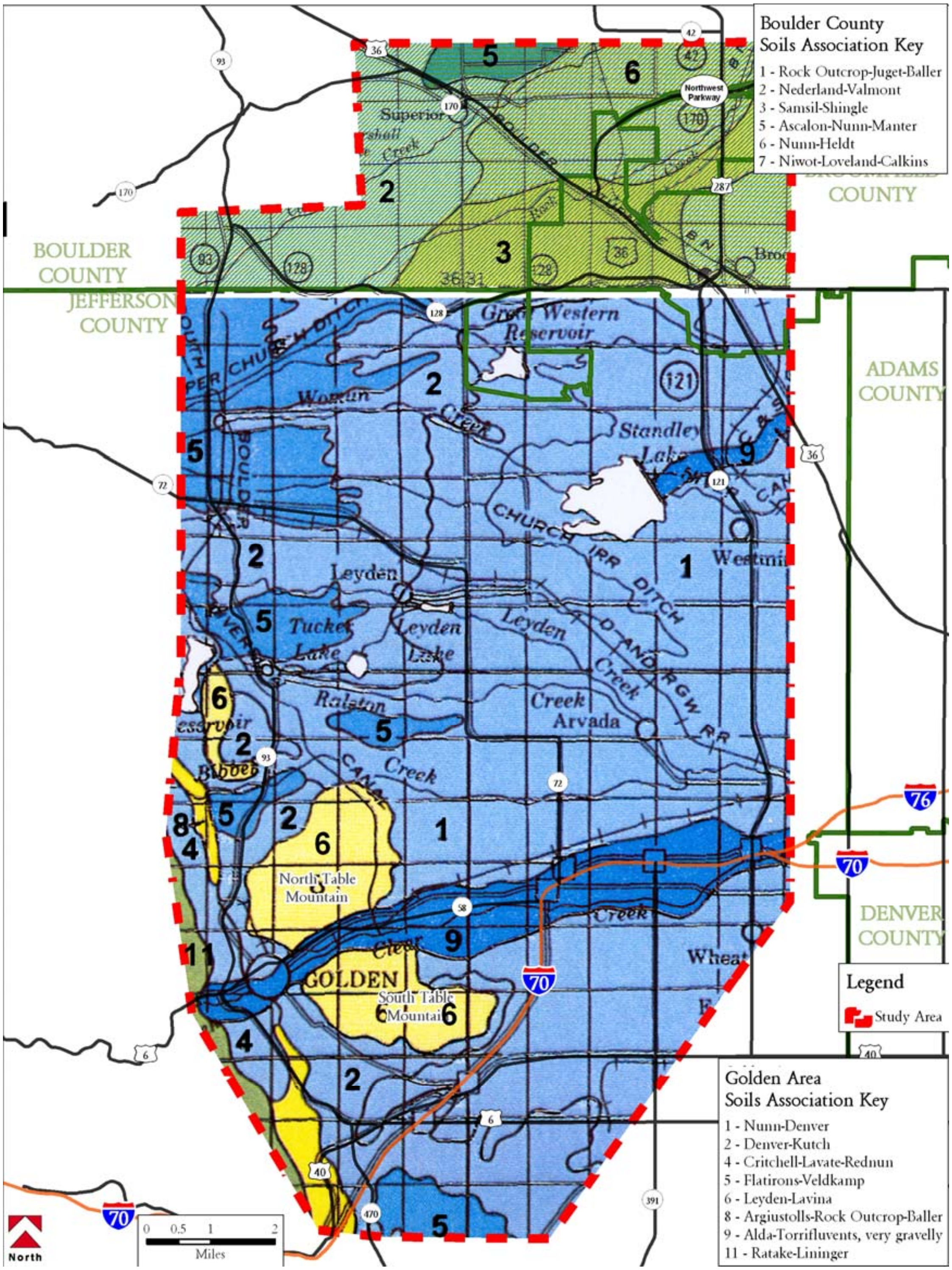
Claystones found in these units have high swell potential, and the rocks as a whole have low stability on steep slopes, especially where they are steeply dipping or steeply cut. Sandstone in the lower unit is moderately resistant to very resistant to weathering; sandstone in the upper unit weathers to a depth of three to four feet and becomes weaker and more friable when weathered.

The igneous rocks at Ralston Dike weather slowly and provide excellent slope stability except near the edges of excavations. Sedimentary shale layers around the igneous dike are baked and fractured, and several cross-cutting joint sets cut the dike. Some of the igneous rocks exhibit vertical cooling joints that separate it into columns up to four feet in diameter. The unit has low slope stability at its margins; rockfall risk is high to moderate.

4.19.1.2 Soils

Twelve soil associations are representative of soils in the study area (see **Figure 4.19-2** and **Table 4.19-1**). Physical and chemical characteristics for the major soils are compiled (see **Table 4.19-1**). Many area soils have high shrink-swell potential, a consideration for all construction. All of these soils are moderately to highly corrosive to uncoated steel, and some are moderately corrosive to concrete. Some have seasonally high water tables, and some are highly susceptible to erosion. Higher quality agriculturally suitable soils are found along the bottoms of many valleys where irrigation is possible. Soils on drier surfaces and on most slopes are generally shallow and of little agricultural value.

Figure 4.19-2 Soil Associations



Sources: Boulder County: Moreland and Moreland, 1975.
Remainder of the study area: Price and Amen, 1980

Table 4.19-1 Soil Associations

Associations	Location/Description
Boulder County[1] Soil	
Nederland-Valmont	West and south of Superior; north and south of Coal Creek. Nearly level to moderately steep, deep. Very cobbly to cobbly. On old high terraces, alluvial fans, benches. Moderately to highly corrosive to steel. High shrink-swell potential in Valmont subsoils. High erosion susceptibility where less permeable.
Samsil-Shingle	Along and south of Rock Creek in the eastern two-thirds of the study area. Gently sloping to moderately steep, shallow. On shale or sandstone hills and ridges. Highly corrosive to steel. Some moderately corrosive to concrete. Some with high shrink-swell potential. Highly susceptible to erosion where less permeable.
Ascalon-Nunn-Manter	North and east of Superior, north of Coal Creek. Nearly level to moderately steep, deep. On terraces, valley sides, and uplands. Moderately corrosive to steel. Some with high shrink-swell potential. Some highly susceptible to erosion.
Nunn-Heldt	East of a north-south line through Superior in the area along and between Coal Creek on the north and Rock Creek on the south. Nearly level to moderately sloping, deep. On terraces and uplands. Highly corrosive to steel. Moderate to high shrink-swell potential. Susceptible to erosion and waterlogging.
Golden Area[2] Soil	
Nunn-Denver	Dominantly well-drained clayey and loamy soils on high terraces, hill slopes, and fans. Derived from mudstone and shale. Highly corrosive to steel. Moderate to high shrink-swell potential. Some with seasonally high water table at 2 to 6 feet deep. (The Nunn-Denver and Denver-Kutch soil associations dominate the study area east of the foothills in areas away from mesas, terraces, and drainages. The margin between the two is irregular, with the Nunn-Denver association dominating the eastern half to two-thirds of the study area, and the Denver-Kutch association more prevalent to the west, as well as at the southern margin of the study area surrounding Green Mountain.)
Denver-Kutch	Moderately sloping to steep, deep and moderately deep, well-drained, clayey. Derived from mudstone and shale. Highly corrosive to steel; some moderately corrosive to concrete. Moderate to high shrink-swell potential. Some susceptible to wind and/or water erosion. Some underlain by soft bedrock at 20 to 40 inches deep. (The Nunn-Denver and Denver-Kutch soil associations dominate the study area east of the foothills in areas away from mesas, terraces, and drainages. The margin between the two is irregular, with the Nunn-Denver association dominating the eastern half to two-thirds of the study area, and the Denver-Kutch association more prevalent to the west, as well as at the southern margin of the study area surrounding Green Mountain.)
Critchell-Lavate-Rednun	In a northwest-southeast band along or near the western margin of the study area from south of Van Bibber Creek to south of Clear Creek. Nearly level to moderately steep, deep, well-drained, loamy and clayey. Formed in reddish material derived from sedimentary rocks. Moderately to highly corrosive to steel. Some with moderate to high shrink-swell potential. Some susceptible to water erosion and/or highly susceptible to wind erosion. Dominantly well-drained, cobbly and gravelly soils on fans, terraces, hill slopes, and stable summits.

Associations	Location/Description
Flat Irons-Veldkamp	In the western one-third of the study area from SH 72 north; along or near the western margin of the study area in small discontinuous areas south of Leyden Creek, south of Ralston Creek, south of Van Bibber Creek; and on Green Mountain at the southern margin of the study area. Nearly level to steep, deep, well-drained, cobbly and gravelly. Formed in mixed alluvium. Some moderately corrosive to concrete. Some with low permeability.
Leyden-Lavina	Narrow north-south band east and southeast of Ralston Reservoir, turning east just north of Van Bibber Creek, all west of SH 93; in the western one-third to one-half of the study area east of Golden, from south of Van Bibber Creek to north of US 6 and I-70. Nearly level to very steep, moderately deep to shallow, well-drained, stony and clayey. Derived from volcanic rock and shale. Moderate to high shrink-swell potential. Some with soft bedrock at 20 to 40 inches deep; some with hard bedrock at 10 to 20 inches deep. Dominantly well-drained, stony and loamy soils on hogbacks and hill slopes:
Argiustolls-Rock outcrop-Baller	Narrow northwest-southeast band at the western margin of the study area, both north and south of Van Bibber Creek; northwest-southeast band near the western margin south of Clear Creek. Moderately steep to very steep, shallow to deep, well-drained, stony and loamy. Formed in colluvium derived from sedimentary rocks. Physical and chemical characteristics highly variable. Some with hard bedrock at 10 to 20 inches deep. Dominantly somewhat excessively drained and somewhat poorly drained, loamy, very gravelly, and sandy soils on flood plains and low terraces:
Alda-Torrifluvents, very gravelly	In the Clear Creek floodplain; in the drainage running generally northeastward from Standley Lake. Nearly level, deep, somewhat excessively drained and somewhat poorly drained, loamy, very gravelly, and sandy. Formed in mixed alluvium. Highly susceptible to frost action. Moderately corrosive to steel. Seasonally high water table in Alda soils, at 2 to 3 feet deep. Torrifluvents, very gravelly, have highly variable physical and chemical characteristics. Dominantly well-drained, stony, gravelly, loamy, and sandy soils on mountain side slopes and stable summits and drainageways:
Ratake-Lininger	Narrow north-south band in extreme southwest corner of study area north and south of Clear Creek. Moderately sloping to very steep, shallow to moderately deep, well-drained, stony, gravelly, and loamy soils. Derived from igneous and metamorphic rocks. Moderately susceptible to frost action. Moderately to highly corrosive to uncoated steel. Some with up to 45% rock fragments greater than 3 inches diameter in surface layer. Some with weathered bedrock at 10 to 20 inches depth, others with weathered bedrock at 20 to 40 inches deep.

Notes: [1]Includes part of current Broomfield County.
[2]Includes Jefferson County and part of current Broomfield County.

Sources: Moreland and Moreland, 1975.

Price and Amen, 1980.

4.19.1.3 MINERAL RESOURCES

The study area contains a rich supply of mineral resources that have been utilized throughout history. The area has produced abundant quantities of coal, clay, and other industrial minerals. Some production of natural gas and non-coal industrial minerals continues today. The industrial mineral resources in the study area include cobbles (for landscaping and for crushing), gravel, sand, crushed rock aggregate, lightweight aggregate, brick clay, and refractory clay (see **Northwest Corridor Supporting Technical Document-Geology and Soils**).

4.19.1.4 GEOLOGIC HAZARDS

Geologic hazards are areas where dynamic geologic conditions can create special construction conditions or hazards to the public. The areas to be considered are those where surface subsidence is possible; areas where severe swelling of soils and heaving of bedrock are possible; fault zones; landslide areas; and areas where rockfalls are possible.

SUBSIDENCE OVER ABANDONED MINES

A band of steeply dipping Laramie Formation containing abandoned coal mines and clay pits lies close to SH 93 north of SH 58 and close to US 6 south of SH 58. The mine trend crosses beneath the roadways at three locations: near Leyden Gulch, just north of SH 58, and where US 6 turns eastward south of Golden. Part of the interchange area where I-70 and C-470 meet is underlain by the Laramie Formation, but no abandoned coal mines have been identified there (see **Northwest Corridor Supporting Technical Document-Geology and Soils**).

SWELLING BEDROCK AND SWELLING SOIL

Clay minerals that expand when wet and contract when dry are present as discrete layers or as matrix in coarser-grained bedrock across most of the study area. Soil derived from expansive bedrock typically is also expansive. These soils can create problems for the foundation of roadbeds and can increase road maintenance.

Bedrock with high swell generally expands in a relatively uniform way if it is in flat-lying layers, but steeply dipping bedrock can cause extreme structural damage by heaving differentially along individual bedrock layers with different swell potentials. Areas within a few miles east of the Front Range and areas along faults are most likely to have steeply dipping rock layers containing expansive clays. This condition occurs along SH 93.

FAULTS

Colorado is in a moderate seismic risk area and could experience damaging earthquakes, but a risk assessment across the entire study area indicates less than a 5 percent probability of ground motion values reaching threshold levels for damage to older (pre-1965) dwellings within a 50 year time period.

Three groups of faults are important to the study area: the potentially active Rocky Mountain Arsenal/Derby seismic source (RMA); faults listed in the Colorado Geological Survey's Late Cenozoic Fault and Fold Database (Golden Fault, Golden Graben, Walnut Creek Fault, Rock Creek Fault, Valmont Fault); and the numerous faults in the Boulder County/Broomfield County coal field.

US 6 crosses the Golden Fault south of Clear Creek and SH 93 crosses the Golden Fault north of Clear Creek. North of Clear Creek, SH 93 lies within 1,000 feet of the fault up to Golden Gate Canyon Road, then runs along and/or on the fault trace for approximately one mile north. A parallel fault, locally known as the Basin Margin Fault, lies a maximum of about 1,500 feet east of SH 93 at SH 58 and crosses to the west side of SH 93 within a few hundred feet north of Golden Gate Canyon Road.

LANDSLIDES

Areas of Jefferson County are susceptible to landsliding. Within the region, areas have been identified as having active, known, probable, and possible landslide potential. The margins of steep-sided alluvial surfaces are susceptible to landsliding, especially where seeps and springs saturate shale and claystone bedrock underlying gravel-rich caps. Areas from Leyden Gulch to Rocky Flats and northeast to US 36 experience landslides like these. The area adjacent to US 6 and SH 93 from north of Golden to I-70 is identified as a landslide area in the 2000 review of the *1988 Colorado Landslide Hazard Mitigation Plan*. Jefferson County recognizes that the US 6 and SH 93 corridor passing to the west of Golden has high landslide susceptibility, but widening and realigning of the roadway has done much to mitigate what was previously a persistent problem. Slumps and slides also occur on lesser slopes, as is true on the west side of US 36 between Boulder and Superior on Davidson Mesa.

One landslide area of interest within the study area, located west of SH 93 and north of SH 58, is associated with the Golden Fault and is called the Golden Bypass Slide. In 1991, during construction of the Golden Bypass on SH 93, a landslide began to develop west of the highway where excavation had removed material at the bottom of the slope. The landslide was mitigated with a retaining wall with bedrock anchors and groundwater drains.

ROCKFALL

Rockfall is associated with canyons, cliffs, overhangs, and natural or manmade steepened slopes. It commonly occurs where rock is highly jointed, fractured, weathered, unconsolidated, or water saturated, especially where rock layers are steeply inclined and/or where a potential surface of sliding intersects a void. These conditions are found in the western and southern margins of the study area. Rockfall has occurred at the following locations:

- Along Clear Creek Canyon west of Golden and along the steep mountain front to the north and south.
- Around North Table Mountain and South Table mountain.
- Along the ridge north and south of Van Bibber Creek at the west margin of the study area where clay has been quarried in deeply dipping strata.
- Around Upper Long Lake, especially where quarrying has produced steep slopes or cliffs.
- Along the ridge that is just east of SH 93 and north of Leyden Gulch.

4.19.2 ENVIRONMENTAL CONSEQUENCES

Considering geologic and soils impacts resulting from development of an alternative roadway is somewhat different than many resources because a roadway does not only impact important geological resources, local geology and soils can also impact the design of a planned roadway. The following sections summarize those important considerations for geologic conditions and soils of the study area. Identification of impacts relies on information and maps (see **Northwest Corridor Supporting Technical Document-Geology and Soils**).

4.19.2.1 DEVELOPMENT IMPACTS

Both the impacts from roadway development and the impacts to a potential future roadway from geologic conditions or soils should be considered before any alignment decision is made regarding future roadways. There are several impacts from potential roadway alternatives that can be identified. These impacts occur for three specific reasons which include:

- Roadway alternatives overlying (requiring right-of-way containing) potentially valuable mineral resources and agricultural soils precluding their development for societal use.
- Roadway alternatives precluding access to parcels having important geologic resources that eliminate or complicate their development for societal use.

- Geologic or soil conditions that require special design, special materials, or a special construction approach to address the difficulties of a particular location.
    - A geotechnical analysis was performed to examine the risk factors associated with constructing an underpass at the intersection of SH 93 and Iowa Street. Soil stability concerns would arise and the drainage system within this area would be further complicated with the construction of this underpass. (see **Northwest Corridor Supporting Technical Document-Preliminary Geotechnical Investigation Report for SH 93/Iowa Street Intersection SH 93 Underpass Assessment**).

The resources identified as having potential unique value within the study area include aggregate, clay, coal, coalbed methane, oil and gas, and high quality agricultural soils. The conditions within the study area that could require special accommodation in the roadway design include mine subsidence, mine gases, swelling surface materials, and areas of faults, landslides, and rockfalls. Not all of the alternatives affect or are affected by geologic conditions and soils in the same manner because of the locational nature of the geologic setting. The anticipated impacts from roadway development on these natural resources and how the local geologic setting will likely impact the roadway alternatives being considered in this document is discussed below (see **Table 4.19-2** and **Table 4.19-3**).

While there are many similarities between the alternatives under consideration in this document regarding geology and soils, each of the alternatives is somewhat different in the environmental consequences they manifest. After consideration of all the various ways geologic resources and soils can affect the alternative roadways and how the potential roadway alternatives can affect the development of natural resources, there is little discernable difference between the alternatives because they all have geologic challenges and they all affect, to a limited extent, the natural resources of the study area. For a more detailed explanation, (see **Northwest Corridor Supporting Technical Document-Geology and Soils**).

4.19.2.2 No Action Alternative

Several limited transportation projects are included in the No Action Alternative, none as expansive as the alternatives considered for the Northwest Corridor. Additionally, no projects included in the No Action Alternative are located along SH 93 where geologic conditions are complex due to upturned sediments, steep slopes, and regionally important faulting. Each of the No Action Alternative projects requiring excavation and foundation engineering will still have to consider the affects of localized swelling soils, slope conditions, and the potential for abandoned underground mining areas in their individual project plans. However, some of the planned projects have limited surface area disturbance and will be little affected by geologic conditions. Because all of the planned projects are relatively small and located in urbanized areas, the No Action Alternative is not expected to have any affect on the future development of the area's mineral resources.

4.19.2.3 Freeway Alternative

The Freeway Alternative alignment crosses the Leyden Mine, New Mine, and Loveland Mine areas of north Golden, areas of expansive soils (approximately 16,000 feet), fault areas (approximately 49,000 feet), the Golden Bypass Land Slide, the aggregate production area north of Arvada-Blunn Reservoir and Leyden Gulch, and will occupy soils considered important to agriculture (352 acres).

4.19.2.4 Tollway Alternative

The Tollway Alternative alignment crosses the Leyden Mine, New Mine, and Loveland Mine areas of north Golden, areas of expansive soils (approximately 16,000 feet), fault areas (approximately 49,000 feet), the Golden Bypass Land Slide, the aggregate production area north of Arvada-Blunn Reservoir and Leyden Gulch, and will occupy soils considered important to agriculture (355 acres).

4.19.2.5 Regional Alternative

The Regional Alternative alignment crosses the New Mine and Loveland Mine areas of north Golden, areas of expansive soils (approximately 23,000 feet), fault areas (approximately 55,000 feet), the Golden Bypass Land Slide, and will occupy soils considered important to agriculture (203 acres). This alternative is the only alternative that encroaches on the steeply dipping beds of the Leyden Hogback, a formation that could pose rockfall hazard potential.

4.19.2.6 Combined Alternative (Recommended Alternative)

The Combined Alternative (Recommended Alternative) alignment crosses the Leyden Mine, New Mine and Loveland Mine areas of north Golden, areas of expansive soils (approximately 17,000 feet), fault areas (approximately 49,000 feet), the Golden Bypass Land Slide, the aggregate production area north of Arvada-Blunn Reservoir and Leyden Gulch, and will occupy soils considered important to agriculture (339 acres).

Table 4.19-2 Potential Geologic Resource Impacts from Roadway Development

Resource	Resource Impact	Commercial Resource in ROW	Alternative Affected	Mitigation
Aggregate	Yes	Yes	Freeway Alternative Tollway Alternative Combined Alternative (Recommended Alternative)	Pre-mine in ROW, provide access to non-ROW parcels
Clay	No	Unlikely	All Build Alternatives	Provide access to non-ROW parcels
Coal	No	Unlikely	All Build Alternatives	Provide access to non-ROW parcels
Coalbed Methane	No	Unlikely	All Build Alternatives	Provide access to non-ROW parcels
Oil and Gas	No	Unlikely	All Build Alternatives	Provide access to non-ROW parcels
Agricultural Soils*	Yes	Yes	All Build Alternatives with Combined Alternative (Recommended Alternative) Being Most Affected	Pre-strip topsoils for ROW reclamation

Note: *See **Section 4.18** for more detailed discussion of farmlands.

Source: Northwest Corridor Supporting Technical Document-Geology and Soils.

Table 4.19-3 Potential Roadway Impacts from Geologic Conditions

Potential Geologic Condition	Condition In ROW	Alternative Affected	Potential Affect on Roadway	Mitigation
Coal or Clay Mine Subsidence	Yes	All Build Alternatives	Bridge support and/or roadway settlement	Deep drilling ROW to identify near-surface voids, increased road maintenance budget
Coal Mine Gases	Yes	Freeway Alternative Tollway Alternative Combined Alternative (Recommended Alternative)	Gas accumulation in subsurface excavations	Continuous gas monitoring in excavations, ventilation of excavations
Swelling Beds and Soils	Yes	All Build Alternatives	Differential roadway settlement	Subgrade removal and/or soil stabilization with lime or cement
Faults	Yes	All Build Alternatives	Low earthquake potential	No mitigation except where swelling beds or soils are exposed in faulted areas
Landslides	Yes	All Build Alternatives	Roadway loss, safety hazard	Identification of susceptible areas, engineering for increased stability
Rockfalls	Yes	Regional Arterial Alternative	Safety hazard	Screen installation, monitoring, and scaling program

Source: Northwest Corridor Supporting Technical Document-Geology and Soils.

4.19.3 Suggested Mitigation

All of the impacts from roadway development can be mitigated (see **Table 4.19-2**). The potential loss of construction aggregates and agricultural soils can be mitigated by resource removal prior to roadway development (pre-mining). These materials can be ultimately utilized in the selected roadway project for various purposes or moved offsite for final use. Because the other potentially affected natural resources are located at depth or cover large areas, they can be accessed from properties adjacent to the potential roadway and would be little affected by construction of any alternative roadway being considered.

The potential impacts from adverse geologic or surface soil conditions posed to roadway development can also be mitigated (see **Table 4.19-3**).

The existence of subsurface mines or rock openings (subsidence voids) and the potential for surface subsidence can be predicted through deep drilling in those areas of past mining prior to roadway development. If voids are identified they can be either filled or collapsed to create a stable foundation for roadway development. Gases from either coal mining or gas storage at the Leyden Mine needs to be addressed during construction to assure a safe working environment. Continuous gas monitoring for explosive atmospheres and oxygen concentration in subsurface excavations can eliminate much of these risks. Proper ventilation is another approach to eliminating the hazards posed by gas accumulation.

Swelling soils are problematic foundation materials and can be mitigated through removal and replacement with suitable material. Another approach to swelling soils is to use soil stabilized through mixing with competent material, lime, or concrete.

The potential for landslides is found throughout the study area and will have to be addressed through proper engineering practices to maintain slope stability. The unique slope stability problem posed by the Golden Bypass Fault may be improved by roadway development because all of the alternatives being considered for this project require the addition of fill at the toe of the slide area, thereby increasing its slope stability.

The potential for rockfalls to affect a roadway can be mitigated through screening the problematic area, monitoring problematic slopes, and scaling loose rock during the periods of frequent freezing and thawing.

4.19.4 SUMMARY

After consideration of all the various ways geologic resources and soils can affect the alternative roadways and how the potential roadway alternatives can affect the development of natural resources, there is little discernable difference between the alternatives because they all have geologic challenges and affect, to a limited extent, the natural resources of the study area. The Regional Arterial Alternative would have the greatest potential for residual impacts. This alternative would cross the greatest length of areas containing expansive soils and fault areas. This alternative is also the only alternative that encroaches on the steeply dipping beds of the Leyden Hogback. All other alternatives present very similar impacts to relatively the same amount of area.

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