APPENDIX H

PRELIMINARY GEOTECHNICAL INVESTIGATION

PRELIMINARY GEOTECHNICAL EVALUATION
DESERTXPRESS RAIL LINE
VICTORVILLE, CALIFORNIA
TO LAS VEGAS, NEVADA

PREPARED FOR:

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May 1, 2007
Project No. 206725001

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Mr. Scott Steinwert
CIRCLEPOINT
135 Main Street, Suite 1600
San Francisco, California 94105

Subject: Preliminary Geotechnical Evaluation
DesertXpress Rail Line
Victorville, California to Las Vegas, Nevada

Dear Mr. Steinwert:

Transmitted herein are the results of our preliminary geotechnical evaluation for the proposed DesertXpress rail line from Victorville, California, to Las Vegas, Nevada. This study included evaluation of the geologic and geotechnical conditions along potential rail alignments within the project study area. We understand that the results of this study will be utilized in project planning and project feasibility evaluations.

We appreciate the opportunity to be of service.

Respectfully submitted,
NINYO & MOORE

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1. INTRODUCTION

In accordance with your request, Ninyo & Moore has performed a preliminary geologic evaluation for the proposed DesertXpress rail line from Victorville, California, to Las Vegas, Nevada. The purpose of the study was to evaluate geologic and geotechnical conditions for proposed new rail line alignments within the project study area. The study area was limited to the vicinity of the planned new alignment, consisting of an approximately 200-mile-long route from a planned new station in Victorville, California, that generally follows the corridor of Interstate 15 (I-15) to a planned new station in Las Vegas, Nevada (Figure 1). The conceptual alignment consists of seven segments. This report presents our preliminary findings and conclusions pertaining to the geotechnical aspects of the proposed alignments for the DesertXpress.

Ninyo & Moore's scope of services has included the following items:

- Review of pertinent, readily available geotechnical literature including geologic maps, regional fault maps, seismic data, stereoscopic aerial photographs, and geotechnical and geologic reports by others. Documents reviewed for our evaluation are listed in the Selected References.
- Review of as-built highway plans and geotechnical support documents for the construction of I-15 obtained from the California Department of Transportation (CalTrans).
- Review of preliminary conceptual alignment drawings for the proposed DesertXpress by Korve Engineering.
- Compilation and analysis of the data obtained, with particular emphasis on potential geologic and geotechnical hazards, such as faulting and seismicity.
- Preparation of this report to present our findings and conclusions, particularly regarding possible geotechnical constraints and possible mitigative measures.

2. REGULATORY ENVIRONMENT AND METHODS OF EVALUATION

2.1. Regulatory Requirements

Various building codes, municipal laws and legislative regulations present guidelines for design parameters and construction activities related to geotechnical aspects of the proposed DesertXpress rail system. Various public agencies would have regulatory authority over both construction and operational activities related to geotechnical aspects of the proposed rail system. During the construction period of the proposed rail system, certain agencies would have authority over the design review, permitting and inspection of various construction-related activities. Some of these agencies would have a long-term role in the regulation of geotechnical conditions of the rail line during the operational period.

During the design and permitting of the proposed rail system, regulatory agencies would have authority to review design plans and consultant reports for conformance with geotechnical-related issues of applicable guidelines, codes and legislative acts. Some regulatory agencies may seek third party review of project plans/reports, and design interaction with these parties and the agencies may be anticipated.

During the construction of the proposed rail system, public agencies would have authority to inspect various geotechnical aspects and safety aspects of the construction such as excavations for both shallow and deep foundations of the rail system and associated structures, excavations for areas to receive fill, tunneling excavations and subsurface drainage improvements.

These agencies would include, but are not limited to the following:

- Incorporated cities whose limits include the proposed rail alternatives including Victorville and Barstow, California, and Las Vegas, Nevada.
- Counties of San Bernardino, California and Clark, Nevada.
- The California Geological Survey (CGS).
- Cal-OSHA.
- California Department of Transportation (CalTrans).
- Nevada Department of Transportation (NDOT).
- Nevada Bureau of Mines and Geology (NBMG).
- U.S. Department of Interior, Bureau of Land Management (BLM).

During the operational period of the proposed rail system, some of these regulatory agencies may have authority over operational activities related to geotechnical issues. For example, if a potential geotechnical hazard affected the operation of the rail system, certain agencies may have authority over the inspection/testing of the system, or maintenance/repair of the system.

2.2. Methods of Evaluation of Impacts

2.2.1. Study Methods

To evaluate potential geologic and seismic hazards considered for the proposed new rail alignments within the project study area, review of readily available geologic and seismic literature, maps and information, and conceptual plans of the proposed project was performed. The study area was limited to the vicinity of the proposed new alignment alternatives described below. Field reconnaissance, subsurface exploration, and laboratory testing of materials were not included in the scope of this evaluation.

Geotechnical considerations associated with potential geologic and seismic hazards have been evaluated from a review of available published geotechnical literature pertinent to the proposed project. These include, but are not limited to: aerial photographs; geologic, seismic and topographic maps, data, and other publications by the California Division of Mines and Geology (CDMG), CGS, United States Geological Survey (USGS), NBMG; the safety elements of the general plan for the County of San Bernardino; and available geotechnical reports and as-built highway plans from CalTrans pertinent to the project.

2.2.2. Proposed Improvement Alternatives

The proposed rail line improvements consist of an intra-regional rail transportation system, which will connect the populous Southern California region with tourism and business activities in Las Vegas. We understand that for the majority of its length, the rail line will be constructed at grade and that elevated structures will be needed at various roadways, drainage channels, and other crossings. A planned crossing of the Mojave

River west of Barstow will entail construction of a bridge. We further understand that some tunneling structures may be utilized in the Mountain Pass segment of the Alignment.

The Alignment has been divided into seven segments as shown on Figure 1: Segment 1 – Victorville to Lenwood, California; Segment 2 – Lenwood to Yermo, California; Segment 3 – Yermo to Mountain Pass, California; Segment 4 – Mountain Pass to the California state line; Segment 5 – the Nevada state line to Sloan, Nevada; Segment 6 – Sloan to Las Vegas, Nevada; and Segment 7 – City of Las Vegas. There are two alternative routes within Segments 1 through 5 of the Alignment that are being considered for the rail line; Segment 6 has four alternative routes; and Segment 7 has three alternative routes. The routes generally follow existing transportation routes, primarily highways and railways, with the exception of proposed alignments in the Hodge/Lenwood area southwest of Barstow (Segment 1, Alternative B), the proposed Mojave River crossing in the Lenwood/Barstow area, and the proposed Mountain Pass/Clark Range tunneling alignment (Segment 4, Alternative B). The alternative routes that are being considered are described below.

Due to the close proximity on the median and northwest sides of I-15, respectively, Alternatives A and B of Segment 3 have been evaluated as one Alignment. Similarly, Alternatives A and B of Segment 5 have been evaluated as one; Alternatives A and B of Segment 6 have been evaluated as one; Alternatives C and D of Segment 6, which closely parallel each other, have been evaluated as one; and Alternatives A and B of Segment 7 have been evaluated as one.

2.2.2.1. Segment 1, Alternatives A and B: Victorville to Lenwood, California (Figure 2)

- Segment 1 begins in Victorville and ends in Lenwood on the west side of the city of Barstow. Separate alternatives A and B diverge in different directions from the planned Victorville station.

- Alternative A is currently planned along the existing Burlington Northern Santa Fe (BNSF) rail line that roughly follows the National Trails Highway (Route 66) north from Victorville. This alternative turns northeasterly at Helendale and ends in Lenwood on the west side of Barstow.

- Alternative B follows the west side of I-15 northeast from the Victorville station. Near the crossing with Hodge Road, this alternative turns north across a sparsely developed desert area to Lenwood.

- Alternatives A and B of Segment 1 meet at a common point in Lenwood, wherein Segment 2 begins.

2.2.2.2. Segment 2, Alternatives A and B: Lenwood to Yermo, California (Figure 3)

- Segment 2 begins in Lenwood and travels northeast across largely undeveloped land on the south bank of the Mojave River to a planned bridge crossing of the river. On the north side of the river, the Alignment turns eastward utilizing an abandoned BNSF right-of-way into the central Barstow area. East of the BNSF right-of-way, Segment 2 continues east across partially developed land and then converges to the north side of I-15 east of Barstow. East of Barstow, near Fort Irwin Road, the Segment separates into Alternatives A and B.

- Alternative A diverges approximately ½ to ¾ mile north from I-15 and travels parallel to the highway, crossing several roads, until re-converging with I-15 east of Yermo.

- Alternative B is planned to parallel the north side of I-15.

- Alternatives A and B of Segment 2 meet at a common point east of Yermo, wherein Segment 3 begins.

2.2.2.3. Segment 3, Alternatives A and B: Yermo to Mountain Pass, California (Figure 4)

- Segment 3, the longest segment of the route at about 90 miles, is planned to parallel I-15. The segment begins east of Yermo and travels northeast through the Mojave River Valley, Cronese Valley, Soda Mountains, Soda Dry Lake, Baker, Halloran Springs, Halloran Summit, and Shadow Valley and ends at Mountain Pass in the Clark Mountain/Mescal Range.

- Alternative A is planned to align along the median of I-15.

- Alternative B is planned to align along the northwest side of I-15.

2.2.2.4. Segment 4, Alternatives A and B: Mountain Pass to near the State Line (Figure 5)

- Segment 4 begins roughly at the summit of the Mountain Pass area and ends about ½ mile southwest of the California/Nevada state line.

- Alternative A continues along the median of I-15 from the endpoint of Segment 3 and descends east from Mountain Pass. A wide, curving turn toward the northeast is planned to diverge from the I-15 median on the descent in the Wheaton Wash area. The Alignment re-converges with the median of I-15 and travels north/northeast into the Ivanpah Valley to near the state line.

- Alternative B diverges north from I-15 near the summit of Mountain Pass and is planned to descend northward through the Clark Mountain Range utilizing two proposed tunnels. This alternative then descends into the Ivanpah Valley and meets with Alternative B at the endpoint of Segment 4.

2.2.2.5. Segment 5, Alternatives A and B: State Line to Sloan, Nevada (Figure 6)

- Segment 5 is planned to parallel I-15 and begins southwest of the California/Nevada state line. The Alignment travels north/northeast in the Ivanpah Valley through Primm, Nevada, the Roach Dry Lake area, and Jean and ends near Sloan at the south end of the Las Vegas Valley.

- Alternative A is planned to align along the median of I-15.

- Alternative B is planned to align along the northwest or southeast side of I-15.

2.2.2.6. Segment 6, Alternatives A, B, C, and D: Sloan to Las Vegas, Nevada (Figure 7)

- Segment 6 begins in Sloan and travels north into the Las Vegas Valley and the city of Las Vegas. Four alternative routes, A, B, C, and D, are proposed as various alignments for this segment of the project.

- Alternative A follows the median of I-15 from Sloan approximately to the intersection with Tropicana Avenue in Las Vegas.

- Alternative B parallels the west side of I-15 from Sloan approximately to the intersection with Tropicana Avenue in Las Vegas.

- Alternative C diverges from I-15 at Sloan Road near the south end of Segment 6 and travels northwest. This alternative roughly follows an existing Union Pacific Railroad (UPRR) rail line and approximately 3 miles to the west of I-15, meets with and parallels this existing line. At a point to the south of Blue Diamond Boulevard, the alternative converges back toward I-15 utilizing the existing UPRR alignment and ends just south of the intersection with Flamingo Avenue. A maintenance facility is proposed on this alternative north of Blue Diamond Boulevard.

- Alternative D is a branch of Alternative C that utilizes a different portion of the UPRR right-of-way.

2.2.2.7. Segment 7, Alternatives A, B and C: Las Vegas, Nevada (Figure 7)

- Segment 7 begins in the City of Las Vegas and travels north into across the Las Vegas Valley to the proposed Las Vegas Station. Three alternative routes, A, B and C are proposed as various alignments for this last segment of the project.

- Alternative A follows the median of I-15 approximately from the intersection with Tropicana Avenue to the station in Las Vegas.

- Alternative B parallels the west side of I-15 approximately from the intersection with Tropicana Avenue to the station in Las Vegas.

- Alternative C follows an existing Union Pacific Railroad (UPRR) rail line located to the west of I-15 approximately from the intersection with Tropicana Avenue to the station in Las Vegas.

3. AFFECTED ENVIRONMENT

3.1. Regional Environment Description

The study area consists of an approximately 200-mile-long alignment (hereinafter referred to as the "Alignment") extending from the southern edge of the Mojave Desert in Victorville, California, northeast across the desert to Las Vegas, Nevada (Figure 1). The Alignment generally follows the I-15 transportation corridor. The Alignment begins at the northern edge of the urbanized Victorville area and passes through the cities of Barstow and Baker in San Bernardino County, California, and through the cities of Primm and Las Vegas in Clark County, Nevada. Outside of these cities, the Alignment generally crosses sparsely developed rural desert areas.

The proposed Alignment alternatives generally utilize the I-15 highway corridor except for: 1) proposed alternatives northwest of I-15 between Victorville and Barstow, 2) a proposed tunneling alternative in the Clark Mountain Range north and west of I-15 in the Mountain Pass Area, and 3) proposed alternatives west of I-15 in the City of Las Vegas.

The physical geography within the Alignment study area varies from low-lying valleys to higher elevation mountainous areas. Much of the Alignment region lies between elevations of about 2,000 and 4,000 feet above mean sea level (MSL). The lowest elevation point on the Alignment is at approximate elevation 920 feet MSL in Baker, California. The highest point on the Alignment is at the summit of the Mountain Pass area at an approximate elevation of 4,600 feet MSL.

The Alignment begins at about elevation 3,000 feet MSL in Victorville and descends to Barstow to an elevation of about 2,100 feet MSL. From Barstow to Baker, the Alignment descends along the Mojave River Valley, Cronese Valley, Soda Mountains, and Soda Dry Lake to Baker at an elevation of about 920 feet MSL. From Baker, the Alignment ascends the Halloran Springs Valley and Halloran Summit at an elevation of about 4,100 feet MSL. Between Halloran Summit and Mountain Pass, the Alignment descends into Shadow Valley to an elevation of approximately 3,750 feet MSL. At Mountain Pass, the highest point on the Alignment, elevations close to 4,600 feet above MSL are attained. From Mountain Pass, the Alignment descends to the Ivanpah Valley to an approximate elevation of 2,600 feet MSL. The Alignment reaches elevations of approximately 2,600 to 2,800 feet MSL along the Ivanpah Valley between Primm and Sloan, Nevada, and then descends into the Las Vegas Valley to an approximate elevation of 2,000 feet MSL at the proposed Las Vegas station locations.

The Mojave River, which is the major drainage crossing the region, originates in the San Bernardino Mountains and flows for about 100 miles northeast and through the southwest region of the Alignment study area. The Mojave River ends in Soda Lake near Baker, California. Much of the time flow in the Mojave River is underground, except where shallow bedrock causes the water to surface or during periods of high rainfall (County of San

Bernardino, 2005d). In general, the groundwater table in the region is generally deep, typically on the order of a few hundred feet, although some exceptions do occur (County of San Bernardino, 2005d). A crossing of the Mojave River west of Barstow is planned for the Alignment.

Surface conditions over much of the Alignment consist of open desert terrain comprising extensive soil and rock exposures. Numerous ephemeral (seasonal) streams and relatively shallow drainages traverse the Alignment. Many of these streams and drainages are dry and typically have relatively limited duration water flow during the rainy season in response to precipitation. The ground surface along the Alignment generally contains sparse desert vegetation, which typically consists of cactus, shrubs, and native grasses. Annual precipitation amounts vary across the Alignment region. Based on rainfall data for selected locations along the Alignment obtained from San Bernardino and Clark Counties, annual precipitation varies in the following ranges at the locations indicated on the following Table 1:

Table 1 – Range of Annual Rainfall Totals at Selected Alignment Locations

Alignment Segment & Lternative	Rainfall Station Location	Rainfall Record Years	Range Of Annual Rainfall Totals (Inches)
1a And B	Victorville	1939 To 2006	1.23 To 15.98
2a	Barstow	1960 To 2006	1.11 To 11.27
2a, 2b, 3a, And 3b	Yermo	1961 To 2006	0.36 To 8.03
3a And 3b	Baker	1956 To 2006	0.40 To 7.52
4a And 4b	Mountain Pass	1954 To 2006	2.29 To 14.32
5a And 5b	Jean	1990 To 2006	0.16 To 8.38
6a, 6b, 6c, And 6d	Las Vegas (South)	1989 To 2006	0.44 To 9.10
6a, 6b, 6c, And 6d	Las Vegas (North)	1989 To 2006	0.64 To 7.09
7a, 7b, And 7c	Las Vegas (North)	1989 To 2006	0.64 To 7.09

3.2. Regional Geology

The Alignment is located within two geomorphic regions characterized by the morphology of the landforms, the general type and age of the geologic materials, and by the tectonic-structural features of the geology in the region. The California portion of the Alignment is within the Mojave Desert Geomorphic Province, and the Nevada portion of the Alignment is within the Basin and Range Geomorphic Province. These provinces have a transitional physiographic change, although generally the state line is a commonly used boundary.

Both regions are characterized by mountain ranges and hills of moderate relief that are partially buried and separated by broad alluviated basins. The Basin and Range province includes a large part of the southwestern United States in which elongate mountain ranges are separated by broad, nearly flat valleys (Norris and Webb, 1990). In contrast, valleys in the Mojave Desert province are proportionally broader and mountains are more widely spaced and the mountains generally do not stand as high above their surroundings. Mountain ranges in the Mojave Desert province show less consistency in orientation than those of the Basin and Range province (Norris and Webb, 1990).

The mountain ranges and hills of the Alignment region are comprised primarily of Mesozoic era (65 to 245 million years old) granitic and volcanic rocks and Paleozoic era (245 to 570 million years old) metamorphic rocks. These rocks generally include Mesozoic era granite, quartz monzonite, and porphyritic volcanic rocks and Paleozoic era gneiss and limestone. Some Tertiary age (2 to 65 million years old) surface exposures of non-marine volcanic and sedimentary rocks are mapped along the Alignment in Segment 2 east of Barstow, in Segment 3 in the Soda Mountains, and in Segment 5 in the Jean Hills area.

Valleys, drainage areas, and alluvial fans along the flanks of mountains and valleys within the Alignment are underlain at depth by the basement rocks described above but have been filled by Quaternary age (last 2 million years) alluvium and other sediments. The Quaternary deposits are generally subdivided into two stratigraphic units according to relative age: younger Holocene deposits (last 11,000 years) and older Pleistocene (11,000 to 2 million years ago) age deposits. Holocene deposits typically consisting of relatively young, poorly consolidated or unconsolidated silt, sand, and gravel are anticipated to be present in washes, valley bottoms, lake beds, and include river sands and Aeolian (wind-blown) sands. Pleistocene age alluvial deposits generally consist of gravel, sand, silt, and clay that is moderately to well consolidated and often slightly cemented. These materials include older alluvial fan deposits, continental terrace deposits, and older lacustrine (lake) or playa deposits.

The majority of the Alignment extends across alluviated areas in the Mojave River Valley, Cronese Valley, the Baker/Halloran Springs Valley, Shadow Valley, Ivanpah Valley, and the Las Vegas Valley. Within these areas, much of the Alignment is underlain by Quaternary alluvial sediments, with the exception of local outcrops and exposures of rock units. Geologic maps reviewed indicate that some segments of the Alignment are underlain by shallow rock formations that may be encountered at the ground surface. Regional geologic maps showing the geology and the Alignment routes are shown on Figures 8, 9, 10, and 11. The surficial geology of each segment of the Alignment is described in more detail in the following sections.

3.3. Resources by Segment

The following sections describe the geology along the Alignment within each proposed alternative segment of the route. Each section contains a table listing the geologic unit type and the age and description of geologic units mapped within that segment of the Alignment. The various symbols listed for the geologic units and descriptions of the units are inclusive of the various geologic maps and references reviewed. Geologic information was obtained from published geologic maps and references and is supplemented by information from Caltrans geotechnical borings for investigations for crossing structures along I-15 reported on Log of Test Borings (LOTB) sheets from CalTrans As-Built plans for I-15. The Caltrans boring locations are limited to crossing structures located along I-15. A discussion of the surficial geologic setting of each segment interpreted from the published maps and Caltrans LOTB sheets is included in the section along with the table.

The presence of artificial fill soils is anticipated at various locations along the Alignment. Fill associated with mining activities, private properties, roadway construction, utility trench backfill, retaining wall backfill, and general grading of right-of-way areas for I-15 should be anticipated. The presence of these fill soils is anticipated but was not specifically evaluated as part of the scope of this study. Fill soils are included in our description of the surficial geology of the Alignment where indicated on published geologic maps.

3.3.1. Segment 1, Alternative A (Victorville to Lenwood, California)

Alternative A begins below the southeast flank of Quartzite Mountain at the proposed Victorville station on the southeast side of Bell Mountain Wash. This route travels west across Bell Mountain Wash and across the southern flank of Quartzite Mountain to the east bank of the Mojave River. The segment then travels north and northeast along the east/southeast bank of the river meeting the beginning of Segment 2 about 2½ miles southwest of Lenwood. The segment crosses the inferred, concealed trace of a potentially active portion of the Helendale-South Lockhart fault northeast of the community of Helendale.

Geologic maps indicate that this segment is underlain primarily by alluvial deposits that are present along the banks of the Mojave River. The alluvial deposits include younger Holocene river sediments (Qrs, Qw) and valley sediments (Q, Qa) and older Pleistocene valley and fan sediments (Qo, Qoa, Qod), marl (Qoc) and alluvial fanglomerate deposits (Qof). Some areas of Holocene Aeolian (wind-blown) sands (Qs) are mapped near the north end of Segment 1.

The geologic maps indicate that Alternative A is underlain at depth by older Mesozoic age igneous quartz monzonite (granitic) rocks (KJqm, qm), metamorphic rocks comprised of gneiss (gg), and metavolcanic porphyritic rock (Mzv, lp; a rock comprising large mineral crystals in a fine-grained groundmass). These rocks underlie the alluvial deposits along this segment and are mapped at the surface along a portion of the southern end of this alternative segment and in outcrops along the east side of the Mojave

River. A table listing the geologic unit, geologic age, and description of the unit is presented below. A geologic map of Segment 1, Alternative A, showing the geology and the Alignment route is shown on Figure 8.

Table 2 – Geologic Units Segment 1, Alternative A

Geologic Unit (Symbol[s])	Geologic Age	Description
Aeolian Deposits (Qs)	Holocene	Wind-Blown Sand
Younger Alluvial Valley Sediments (Q, Qa)	Holocene	Unconsolidated, Poorly Sorted Alluvial Silt, Sand And Gravel Sediments.
Younger Alluvial River/ Wash Deposits (Qw, Qrs)	Holocene	Alluvial Wash Deposits; Mojave River Sand.
Older Alluvial Valley And Fan Sediments (Qo, Qoa, Qod)	Pleistocene	Weakly Consolidated Dissected Alluvial Gravel, Sand, And Silt Derived Mainly From Granitic And Metamorphic Rocks Of San Gabriel And San Bernardino Mountains.
Older Alluvial Fanglomerate (Qof)	Pleistocene	Cobble Fanglomerate And Gravel Derived From Metavolcanic Rocks.
Older Alluvial Valley Sediments (Qoc)	Pleistocene	Marl (Clay).
Quartz Monzonite (Kjqm, Qm)	Cretaceous - Late Jurassic	Intrusive Igneous (Granitic) Rock.
Metavolcanic Rocks (Mzv, Lp)	Mesozoic	Porphyritic Volcanic And Metavolcanic Rocks. Includes Sidewinder Volcanic Series Of Bowen, 1954, And Oro Grande Of Hershey, 1902.
Granite Gneiss (Gg)	Paleozoic	Metamorphosed Granitic Rock Or Similar Composition Volcanic Rock.

3.3.2. Segment 1, Alternative B (Victorville to Lenwood, California)

Alternative B begins below the southeast flank of Quartzite Mountain at the proposed Victorville station on the southeast side of Bell Mountain Wash. This route travels northeast across Bell Mountain Wash and along the eastern flank of Quartzite Mountain into Sidewinder Valley. North of Sidewinder Valley, this alternative crosses the trace of the active Helendale-South Lockhart fault, indicated by an abrupt change in the mapped alluvial units. The segment then travels north and meets with Alternative A on the south-east bank of the Mojave River at the end of Segment 1.

The geologic maps indicate that Alternative B is underlain by both alluvial sediments and older Mesozoic age granitic, volcanic, and metavolcanic rocks. The alluvial deposits include younger Holocene wash sediments (Qw) and valley sediments (Q, Qa); and older Pleistocene valley and fan sediments (Qo, Qoa, Qod), and alluvial fanglomerate deposits (Qof). Exposed within portions of this segment and underlying the alluvial sediments at a relatively shallow depth are granitic quartz monzonite, hornblende diorite-gabbro and granite (KJqm, qm, gqm, hd), and porphyritic metavolcanic rock (Mzv, lp, pf).

Caltrans LOTB sheets from investigations for I-15 crossing structures indicate that borings located along this segment at Stoddard Wells Road, Cement Company Undercrossing, Bell Mountain Wash, Wild Wash, and Hodge Road encountered alluvial sands and gravel of varying density. Weathered granitic rock was encountered in borings at Wild Wash Bridge at depths ranging from 10 to 19 feet below ground surface (bgs) and at a depth of 28 feet bgs in a boring located at Bell Mountain Wash Bridge.

A table listing the geologic unit, geologic age, and description of the unit is presented below. A geologic map of Segment 1, Alternative B, showing the geology and the Alignment route is shown on Figure 8.

Table 3 – Geologic Units Segment 1, Alternative B

Geologic Unit (Symbol[s])	Geologic Age	Description
Younger Alluvial Valley Sediments (Q, Qa)	Holocene	Unconsolidated, Poorly Sorted Alluvial Silt, Sand, And Gravel Sediments.
Younger Alluvial Wash Deposits (Qw)	Holocene	Alluvial Wash Deposits.

Older Alluvial Valley And Fan Sediments (Qo, Qoa, Qod)	Pleistocene	Weakly Consolidated Dissected Alluvial Gravel, Sand, And Silt Derived Mainly From Granitic And Metamorphic Rocks Of San Gabriel And San Bernardino Mountains.
Older Alluvial Fanglomerate (Qof)	Pleistocene	Cobble Fanglomerate And Gravel Derived From Metavolcanic Rocks.
Quartz Monzonite (Kjqm, Qm, Gqm, Hd)	Cretaceous - Late Jurassic	Intrusive Igneous (Granitic) Rock, Quartz Monzonite, Hornblende Diorite-Gabbro, And Granite.
Metavolcanic Rocks (Mzv, Lp, Pf)	Mesozoic	Porphyritic Volcanic And Metavolcanic Rocks. Includes Sidewinder Volcanic Series Of Bowen, 1954, And Oro Grande Of Hershey, 1902.

3.3.3. Segment 2, Alternative A (Lenwood to Yermo, California)

Alternative A begins on the southeast bank of the Mojave River about 2½ miles southwest of the community of Lenwood southwest of Barstow. This segment travels northeast across the broad southeast river bank toward the Mojave River and crosses the river north of Lenwood on a planned new bridge. The segment crosses the active zone of the Lenwood-Lockhart-Old Woman Springs fault north of Lenwood. Fault maps indicate that this fault has experienced creep near the community of Lenwood in historic time. On the north side of the Mojave River, this segment turns east and travels along the north river bank and wash areas of the Mojave River through the City of Barstow. On the north side of the river, the segment crosses the concealed trace of the active Mt. General fault and crosses the concealed trace of a potentially active portion of the Gravel Hills-Harper Lake fault. On the east side of Barstow, the segment continues eastward along the north side of the Mojave River valley as the river bends toward the south/southeast. The segment crosses a small drainage valley between Barstow and Yermo and ends on the southeast flank of the Calico Mountains east of Yermo.

The geologic units that underlie this segment of the Alignment can be divided into three areas: 1) Mojave River sediments along the southeast and north banks of the river, 2) an exposure of sedimentary and volcanic rocks east of Barstow, and 3) valley alluvium sediments in the small drainage valley west of Yermo.

The geologic maps indicate that the southeast bank of the Mojave River at the beginning of Alternative A and a small area of the north river bank at the planned bridge crossing is underlain by deposits of Aeolian sands (Qs). On the north side of the Mojave River, this segment is underlain by both river sands (Qrs, Qw) and alluvial valley deposits (Q, Qa) and is underlain at depth by older Mesozoic age granitic rocks (Jhd, qm, hd) and Paleozoic age metamorphic gneiss (wg) that are exposed within portions of this segment and underlying the alluvial sediments at a relatively shallow depth. East of the Mojave River, the segment crosses an area of older alluvial valley sediments (Qof, Qoc, QT) that are present in the small drainage valley.

The exposure of Tertiary age rock (Mc, Mi, Tt, Tat, Tls, Td, Ts, Tsl) that this segment crosses east of Barstow is mapped as a formation of volcanic and sedimentary rocks and is described in Table 4. In the small drainage valley east of this rock exposure, the segment crosses alluvial deposits consisting of young fan and valley sediments (Q, Qa), and a mapped clay unit deposited from a playa or small lake bed (Qc, Ql). Northeast of Yermo, the end of this segment is underlain by older alluvium (Qo, Qoa) and fan gravel (Qf) on the southeast flank of the Calico Mountains. This older alluvium and fan gravel mantles the formational Tertiary volcanic and sedimentary rock that comprises the Calico Mountains.

Caltrans LOTB sheets from investigations for I-15 crossing structures indicate that two borings located along this segment at Hiker Ditch Bridge, located at the interchange of I-15 and Old Highway 58, encountered sandy to clayey gravel, gravelly sand, and silt to depths ranging from 27 to 34 feet bgs. Sandy claystone to clayey siltstone was encountered in these borings between 27 and 58 feet bgs, and highly weathered rhyodacite rock (intrusive volcanic rock) was encountered at depths below 53 feet.

A table listing the geologic unit, geologic age, and description of the unit is presented below. A geologic map of Segment 2, Alternative A, showing the geology and the Alignment route is shown on Figure 8.

Table 4 – Geologic Units Segment 2, Alternative A

Geologic Unit (Symbol[s])	Geologic Age	Description
Aeolian Deposits (Qs)	Holocene	Wind-Blown Sand.
Younger Alluvial River/ Wash Sediments (Qrs, Qw)	Holocene	Alluvial Wash Sediments And River Sand; Mojave River Sand.
Younger Alluvial Valley/ Fan Sediments (Q, Qa)	Holocene	Unconsolidated, Poorly Sorted Alluvial Silt, Sand, And Gravel Sediments.
Younger Alluvial Valley Sediments (Ql, Qc)	Holocene	Lake Deposits, Clay Of Small Playas.
Younger Alluvial Fan Sediments (Qf)	Holocene	Fan Gravel.
Older Alluvial Sediments (Qo, Qoa)	Pleistocene	Dissected Alluvial Fan Material Com-posed Of Gravel, Sand, And Some Boulders.
Older Alluvial Valley Sediments (Qof, Qoc, Qt)	Pleistocene	Fanglomerate And Gravel (Qof); Clay And Marl (Qoc); Continental Deposits Of Gravel, Sand, Silt And Clay (Qt).
Volcanic And Sedimentary Rocks (Mc, Mi, Tt, Tat, Tls, Td, Ts, Tsl)	Tertiary	Miocene Continental Deposits And Intrusive Rocks; Tuff Breccia; Dacite Breccia; Limestone, Shale And Tuff; Dacite; Interbedded Shale And Sandstone.
Granitic Rocks (Jhd, Qm, Hd)	Cretaceous - Late Jurassic	Intrusive Igneous (Granitic) Hornblende Diorite-Gabbro Rock; Quartz Monzonite.
Metavolcanic Rocks (Mzv, Ql, Ap)	Mesozoic	Porphyritic Volcanic And Metavolcanic Rocks, Andesite To Latite Porphyry.
Granitic Gneiss (Wg)	Paleozoic	Waterman Gneiss Of Bowen, 1954: Metamorphosed Quartz Diorite Gneiss.

3.3.4. Segment 2, Alternative B (Barstow to Yermo, California)

Alternative B is a branch of Alternative A that begins on the west side of the small drainage valley east of Barstow. This alternative segment travels parallel to Alternative A and approximately ¾ mile to the south, crossing a small drainage valley area before re-connecting with Alternative A at the end of Segment 2 east of Yermo.

The geologic maps indicate that the beginning of this segment is underlain by a formation of volcanic and sedimentary rocks (Mc, Mi, Tt, Tat, Tls, Td, Ts, Tsl) described below in Table 5. East of the rock formation area in the small drainage valley, this segment is underlain by young valley sediments (Q, Qa). The segment crosses the east finger of the mapped clay unit (Ql, Qc) that also underlies Alternative A. Northeast of Yermo, Alternative B is underlain by older fan gravel (Qf) on the southeast flank of the Calico Mountains. The older fan gravel unit mantles the formational Tertiary volcanic and sedimentary rock that comprises the Calico Mountains.

Caltrans LOTB sheets from investigations for I-15 crossing structures indicate that borings located along this segment at Calico Road Undercrossing (Ghost Town Road), Calico Road, First Street, Yermo Ditch Bridge, and East Yermo Overcrossing encountered alluvial sands and gravel of varying density, and some interbedded clay. Bedrock was not encountered in borings along this segment to depths explored ranging from 34 to 60 feet.

A table listing the geologic unit, geologic age, and description of the unit is presented below. A geologic map of Segment 2, Alternative B, showing the geology and the Alignment route is shown on Figure 8.

Table 5 – Geologic Units Segment 2, Alternative B

Geologic Unit (Symbol[s])	Geologic Age	Description
Younger Alluvial Valley/ Fan Sediments (Q, Qa)	Holocene	Unconsolidated, Poorly Sorted Alluvial Silt, Sand And Gravel Sediments.
Younger Alluvial Valley Sediments (Ql, Qc)	Holocene	Lake Deposits, Clay of Small Playas.
Younger Alluvial Fan Sediments (Qf)	Holocene	Fan Gravel.
Volcanic And Sedimentary Rocks (Mc, Mi, Tt, Tat, Tab, Tls)	Tertiary	Miocene Continental Deposits And Intrusive Rocks; Tuff Breccia; Andesite Breccia; Dacite Breccia; Limestone, Shale And Tuff.

3.3.5. Segment 3, Alternatives A and B (Yermo to Mountain Pass, California)

Alternatives A and B of Segment 3 are in close proximity to each other, on the median and northwest sides of I-15, respectively, and they have been evaluated as one alignment for purposes of describing general geologic conditions along that segment. Segment 3 begins on the southeast flank of the Calico Mountains, east of Yermo, and travels northeast through the alluviated Mojave River Valley, Manix lake beds, older alluviated areas between the Mojave River Valley and Cronese Valley, the alluviated Cronese Valley, Soda Mountains, alluviated Soda Dry Lake and Halloran Springs area, Halloran Summit, Shadow Valley, and Mountain Pass area. Segment 3 crosses the concealed trace of the active Calico-Hidalgo fault near the beginning east of Yermo. Between Yermo and Manix, the segment crosses the west/southwestern end of the active Manix fault.

The geologic maps indicate that the beginning part Segment 3 in the Mojave River Valley southwest of Manix is underlain primarily by younger alluvial valley and fan sediments (Q, Qa, Qal, Qf), and partially by older fanglomerate and gravel alluvium in local outcrops (Qof, QT). Northeast of Manix, the Alignment is underlain by Manix Lake Beds sand and silt sediments (Qms, Qol), by younger river sand (Qrs, Qw) from tributary channels of the Mojave River, and by an area of older alluvium. Further northeast, the Alignment continues through the Mojave River Valley and is underlain by younger valley alluvial sediments (Qal) and lacustrine (lake) deposits (Ql).

At the northeast end of the Mojave River Valley, the Alignment crosses areas shown on the geologic maps to be underlain by older Pliocene-Pleistocene sediments of varying composition (Qc, QP). The Alignment turns east traveling along the south side of the Cronese Mountains. In this portion of Segment 3, the geologic maps show that the Alignment is primarily underlain by younger alluvial sediments (Qal) and partially by exposures of Tertiary-Mesozoic age granitic rocks (gr, gr-m, TKq). These granitic rocks are also mapped on the south side of the Cronese Valley and underlie the segment at depth in this area beneath alluviated areas. The predominant unit mapped along this segment in the Cronese Valley is younger alluvium (Qal). The geologic maps indicate that a concealed, potentially active, unnamed fault is located skew to the Alignment in the Cronese Valley.

In the Soda Mountains area between the Cronese Valley and Baker, geologic maps indicate that the Alignment is underlain by younger valley and alluvial fan deposits (Qal), older Pliocene-Pleistocene sediments of varying composition (Qc, QP), and by Tertiary age volcanic and sedimentary rocks (Tv, Tc). Along this portion of Segment 3, exposures of Tertiary-Mesozoic age granitic rocks (gr, TKq) are mapped on the southeast side of the Alignment. The geologic maps indicate that the Alignment crosses the potentially active Baker fault on the east side of the Soda Mountains approximately 6 miles southwest of Baker. In Baker, the geologic maps indicate the Alignment is underlain by younger lacustrine Soda Lake Bed sediments (Ql).

Caltrans LOTB sheets from investigations for I-15 crossing structures indicate that borings located along Segment 3 between Yermo and Baker generally encountered alluvial and other soil deposits predominantly consisting of sands and gravel of varying density, and some interbedded clay and silt; some dune sands were also encountered. Dense sandstone and hard, calcareous mudstone was encountered in a boring at Afton Road Overcrossing at a depth of 7 feet bgs. Granitic rock was encountered in two borings at Basin Road Overcrossing at depths of 11 feet and 25 feet bgs.

Northeast of Baker, the Alignment travels adjacent to Halloran Wash and ascends a broad, sloping alluvial fan that flanks the southwest side of the Halloran Summit. Between Baker and Halloran Springs, the Alignment is underlain by younger valley and alluvial fan deposits (Qal). The Halloran Summit area is shown on the geologic maps to be comprised of a large body of Tertiary-Mesozoic age granitic rock (gr, TKq) that is overlain by younger Pleistocene age volcanic basalt flows (Qpv, Qeb). The granitic rock body is intruded into an older, Precambrian metamorphic rock unit comprised of gneiss (epЄ, pЄg) that is mapped on the west side of the Halloran Summit. The geologic maps indicate that the Alignment is underlain by the gneissic rock and younger alluvium

(Qal) on the west side of the summit. Younger alluvium is mapped within the I-15/Alignment corridor pass through the Halloran Summit but is underlain at a relatively shallow depth by the granitic and/or volcanic rock. The inactive Halloran fault is mapped in this corridor pass parallel to I-15.

Caltrans LOTB sheets from investigations for I-15 crossing structures indicate that borings located along Segment 3 between Baker and Halloran Summit generally encountered alluvial and other soil deposits predominantly consisting of sands and gravel of varying density, and some interbedded clay and silt. Basalt and volcanic breccia was encountered in borings at Dale Ditch at depths ranging from 5 to 20 feet bgs. Granitic rock was encountered in several borings at Kali Ditch Bridge at depths ranging from 5 to 23 feet bgs.

In Shadow Valley between Halloran Summit and Mountain Pass, younger valley and fan alluvium (Qal) underlies much of the Alignment. A small exposure of Paleozoic age dolomite (IP/ls, DЄg, DЄgb1) is mapped on the southwest side of Shadow Valley, and younger lacustrine deposits (Ql) from the Valley Wells lake bed are mapped on the valley bottom. Ascending from Shadow Valley up to Mountain Pass, the Alignment crosses Pliocene-Pleistocene non-marine sediments (Qc, Qoa) that are mapped along the base of the Mescal Range and Clark Mountain Range that comprise the Mountain Pass area.

Caltrans LOTB sheets from investigations for I-15 crossing structures indicate that borings located along Segment 3 in the Shadow Valley area generally encountered alluvial and other soil deposits predominantly consisting of sands and gravel of varying density, and some interbedded clay and silt. Underlying the alluvium in Shadow Valley in the vicinity of Valley Wells, Caltrans borings encountered a sedimentary rock formation comprised of interbedded sandstone, conglomerate, siltstone, and claystone. This formation was encountered at Hot Wash Bridge at approximate depths ranging from 42 to 61 feet bgs, at West Valley Wells Ditch Bridge at approximate depths ranging from 78 to 83 feet bgs, at Valley Wells Ditch Bridge at approximate depths ranging from 10 to 53 feet bgs, at Windmill Station Ditch Bridge at approximate depths ranging from 15 to

22 feet bgs, and at Wells Ditch Bridge at approximate depths ranging from 4 to 12 feet bgs. A Caltrans boring at Cima Road Overcrossing in the Valley Wells area encountered travertine (limestone) at a depth of approximately 7 feet bgs.

The Mountain Pass area in Segment 3 is comprised of a block of Precambrian age metamorphic rocks (epЄ, pЄg, pЄgr, pЄga, pЄgc, pЄgb) comprised chiefly of injection gneiss, granite gneiss, and granite augen gneiss (Olson, 1951). This rock is bounded on the east by alluvium of the Ivanpah Valley and is separated from Mesozoic and Paleozoic age metasedimentary and metavolcanic rocks (IP/ls, CM, DЄg, DЄgu, Ds, Dsi) to the west by the inactive Clark Mountain fault. Inactive faults crossed by the Alignment in the Mountain Pass area, as shown on the geologic maps, include the Mesquite Thrust fault, Clark Mountain fault, Middle fault, and North fault.

The geologic maps indicate that in the Mountain Pass area, the Alignment is mostly underlain by younger alluvium (Qal) and older alluvial fan deposits (Qc, Qoa) that are present in the I-15 corridor through the pass. The maps indicate that rock units also underlie the Alignment at the surface in some areas. These rock units underlie the Alignment at a relatively shallow depth through the pass. West of the Clark Mountain fault, the Alignment is underlain at depth by Paleozoic age dolomite and limestone with thin interbedded shale and sandstone (IP/ls, CM, DЄg, DЄgu, Ds, Dsi). East of the Clark Mountain fault at the end of Segment 3, the maps indicate that the Alignment is underlain by the metamorphic gneiss unit (epЄ, pЄg, pЄgr, pЄga, pЄgc, pЄgb).

Caltrans LOTB sheets from investigations for I-15 crossing structures indicate that borings located along Segment 3 in the Mountain Pass area generally encountered alluvial and other soil deposits predominantly consisting of sands and gravel of varying density. Metamorphosed volcanic rock (meta-dacite and meta-basalt), gneiss, and schist were encountered in borings at Bailey Road Overcrossing at depths ranging from 7 to 8 feet bgs. Metamorphic igneous rock (gneiss) was encountered in two borings at Cenda Ditch Bridge at depths ranging from 3 to 8 feet bgs.

A table listing the geologic unit, geologic age, and description of the unit is presented below. Geologic maps of Segment 3, Alternatives A and B, showing the geology and the Alignment routes are shown on Figures 8, 9 and 10.

Table 6 – Geologic Units Segment 3, Alternatives A and B

Geologic Unit (Symbol[s])	Geologic Age	Description
Younger Alluvial Valley and Fan Sediments (Q, Qa, Qal)	Holocene	Unconsolidated Valley Alluvial Deposits of Silt, Sand, and Gravel; Alluvial Fan Deposits.
Younger Alluvial River/ Wash Sediments (Qw, Qrs)	Holocene	Alluvial Wash Sediments and River Sand.
Younger Alluvial Fan Sediments (Qf)	Holocene	Fan Gravel.
Younger Lacustrine Deposits (Ql)	Holocene	Lake And Playa Sediments Including Clay, Silt, and Fine Sand; Soda Lake Bed Sediments.
Older Alluvial Valley Sediments (Qof, Qt)	Pleistocene	Fanglomerate And Gravel (Qof); Continental Deposits of Gravel, Sand, Silt, and Clay (Qt).
Older Lacustrine Deposits (Qms, Qol)	Pleistocene	Manix Lake Bed Sediments, Including Silt and Fine Sand.
Volcanic Rocks (Qpv, Qeb)	Pleistocene	Undifferentiated Volcanic Basalt Flows.
Older Alluvial Deposits (Qc, Qp, Qo, Qoa, Qt)	Pleistocene And Plio-Pleistocene	Dissected Alluvial Gravel, Sand, And Silt; Continental Terrace Deposits of Gravel, Sand, Silt, and Clay.
Volcanic And Sedimentary Rocks (Tv, Tc)	Tertiary	Undivided Continental Sedimentary Rocks and Volcanic Rhyolite Flows.
Granitic Rocks (Gr, Tkq)	Tertiary/ Mesozoic	Intrusive Igneous Rock; Includes Teutonia Quartz Monzonite of Hewett, 1956.
Granitic and Metamorphic Rock (Gr-M)	Mesozoic	Granitic And Metamorphic Rock.
Marine Sedimentary and Metasedimentary Rocks (Cm)	Paleozoic - Mississippian	Limestone And Dolomite; Includes Monte Cristo Limestone of Hewett, 1956.

Table 6 – Geologic Units Segment 3, Alternatives A and B

Geologic Unit (Symbol[s])	Geologic Age	Description
Marine Sedimentary and Metasedimentary Rocks (Ds, Dsv, Dsi)	Paleozoic - Devonian	Sultan Limestone of Hewett, 1956, Including Valentine Limestone And Ironside Dolomite Members.
Marine Sedimentary and Metasedimentary Rocks (Ip/Ls, Dєg, Dєgu, Dєgb1)	Paleozoic – Cambrian And Devonian	Dolomite and Limestone With Thin Interbedded Shale and Sandstone; Goodsprings Dolomite and Carbonate Rocks Including Breccia of Hewett, 1956.
Metamorphic Rocks (Epє, Pєg, Pєga, Pєgc, Pєgb)	Precambrian	Undifferentiated Injection Gneiss, Schist, Granitic Gneiss, Granite Augen Gneiss Complex.
Granitic Rocks (Pєgr)	Precambrian	Undivided Syenite, Shonkite, Granite Stocks, And Dikes, Including Carbonate Veins and Irregular Bodies In Mountain Pass Area.

3.3.6. Segment 4, Alternative A (Mountain Pass to State Line)

Alternative A begins in the Mountain Pass area at the end of Segment 3 and descends east along the I-15 corridor adjacent to Wheaton Wash, and then northeast into the Ivanpah Valley. The segment crosses Ivanpah Dry Lake and ends just west of the Nevada state line in Ivanpah Valley.

The geologic maps indicate that the beginning part of Alternative A in the Mountain Pass area is underlain by Precambrian age metamorphic rocks (epЄ, pЄg) comprised chiefly of injection gneisses and granitic gneisses and is also underlain by valley alluvium (Qal) and shallow wash alluvium from Wheaton Wash (Qal). In the Ivanpah Valley, the Alignment is underlain by younger valley alluvium (Qal) and lake deposits from Ivanpah Dry Lake (Ql).

Caltrans LOTB sheets from investigations for I-15 crossing structures indicate that borings located along Alternative A between the Mountain Pass area and the Nevada state line generally encountered alluvial and other soil deposits predominantly consisting of sands and gravel of varying density. Metamorphic gneiss and schist were encountered in borings at Wheaton Springs Wash Bridge at depths ranging from 6 to 29 feet bgs.

A table listing the geologic unit, geologic age, and description of the unit is presented below. A geologic map of Segment 4, Alternative A, showing the geology and the Alignment route is shown on Figure 10.

Table 7 – Geologic Units Segment 4, Alternative A

Geologic Unit (Symbol[s])	Geologic Age	Description
Younger Alluvial Deposits (Qal)	Holocene	Unconsolidated Valley Alluvial Deposits of Silt, Sand And Gravel; Alluvial Stream/Wash Deposits.
Younger Lacustrine Deposits (Ql)	Holocene	Lake And Playa Sediments Including Clay, Silt and Fine Sand; Ivanpah Lake Bed Sediments.
Metamorphic Rocks (Epє, Pєg)	Precambrian	Undifferentiated Injection Gneiss, Schist, Granitic Gneiss, Granite Augen Gneiss Complex.

3.3.7. Segment 4, Alternative B (Mountain Pass to State Line)

Alternative B begins in the Mountain Pass area at the end of Segment 3 along I-15 and diverges north from the I-15 corridor across the east side of the Clark Mountain Range. Two tunnels in the mountain range are currently proposed for this segment. North of the proposed tunnels, approximately 2 miles north of I-15, this segment turns east/northeast and descends along the northeast flank alluvial fan of the Clark Mountains and into the Ivanpah Valley, re-connecting with the I-15 corridor at the end of the Segment 4 just west of the Nevada state line.

The geologic maps indicate that the beginning part of this segment in the Mountain Pass area is underlain by Precambrian age metamorphic rocks comprised chiefly of injection gneisses and granitic gneisses (epЄ, pЄg). The maps show that this area consists of former mining prospects, but no mines are located on the maps in this area. Significant mining activities in the Mountain Pass District are located west and southwest of this segment. The maps indicate that tunneling through this area along the planned alignment will pass through the metamorphic gneiss unit and will cross the inactive North fault in the Clark Mountains.

On the northeast flank of the Clark Mountains, this segment descends over younger alluvial fan deposits (Qal) which are underlain at a relatively shallow depth by the metamorphic rocks. In the Ivanpah Valley, the segment is underlain by younger valley alluvium (Qal), lake deposits from Ivanpah Dry Lake (Ql), and a rocky outcrop of metamorphic gneiss (epЄ, pЄg) protruding through the valley alluvium. A table listing the geologic unit, geologic age, and description of the unit is presented below. A geologic map of Segment 4, Alternative B, showing the geology and the Alignment route is shown on Figure 10.

Table 8 – Geologic Units Segment 4, Alternative B

Geologic Unit (Symbol[s])	Geologic Age	Description
Younger Alluvial Deposits (Qal)	Holocene	Unconsolidated Valley Alluvial Deposits of Silt, Sand, and Gravel; Alluvial Fan Deposits.
Younger Lacustrine Deposits (Ql)	Holocene	Lake and Playa Sediments, Including Clay, Silt, and Fine Sand; Ivanpah Lake Bed Sediments.
Metamorphic Rocks (Epє, Pєg)	Precambrian	Undifferentiated Injection Gneiss, Schist, Granitic Gneiss, Granite Augen Gneiss Complex.

3.3.8. Segment 5, Alternatives A and B (State Line to Sloan, Nevada)

Alternatives A and B of Segment 5 are in close proximity to each other, on the median and east or west sides of I-15, respectively, and they have been evaluated as one alignment for purposes of describing general geologic conditions along that segment. Segment 5 begins just south of the California/Nevada state line in the Ivanpah Valley and travels north/northeast along the I-15 corridor through the Ivanpah Valley. The segment crosses the trace of the potentially active Stateline fault, mapped on the California side, and parallel to the state line. North of Primm, Nevada, this segment passes along the west side of Roach Dry Lake. At the north end of the Ivanpah Valley north of Jean, the Alignment passes through the Jean Hills between the Bird Spring and McCullough Ranges and enters the south end of the Las Vegas Valley at the end of Segment 5 near the community of Sloan, Nevada.

Geologic maps indicate that the portion of Segment 5 in the Ivanpah Valley between the state line and Jean Hills is underlain by younger alluvial deposits that are present in the valley. The alluvial deposits include younger Holocene wash sediments and alluvial fan deposits (Qa, Qal, Qay, Qay_2, Qay_3) and older early-Holocene to late-Pleistocene alluvial fan deposits (Qay_1). Playa fringe deposits (Qpf) are mapped along the west side of Roach Lake in close proximity to the Alignment. Some areas of fill soil and other disturbed areas (Qx) are mapped along this segment of the Alignment, specifically at the highway onramp/off-ramp areas. An outcrop of Paleozoic-age dolomite (DЄg, MzPzs) is mapped on the west side of the Alignment between Primm and Jean.

In the Jean Hills and northeast of the Jean Hills along Segment 5, the geologic maps show that the Alignment is underlain by younger alluvium, older alluvium and rock formations. Younger Holocene alluvial sediments comprised of wash and alluvial fan deposits underlie portions of this area (Qa, Qal, Qay, Qay_2, Qay_3), and some areas are underlain by older, Pleistocene age alluvial fan deposits (Qay_1, Qai). These older sediments are described on the geologic maps as moderately to strongly consolidated. Ancient Pleistocene to late-Miocene age alluvium (Qao, QTa) comprised primarily of gravel is also mapped in portions of this area. Rock formations that underlie this portion of Segment 5 include Tertiary age sedimentary rocks (Tao) comprised of fluvial gravel with minor sandstone and mudstone, Tertiary age volcanic rocks ranging in composition from basalt to rhyolite (Tv, Tsf), and a Paleozoic to Mesozoic era formation (Pbs, PPMb, MzPzs) of limestone and dolomite with interbedded shale, sandstone, and conglomerate.

A table listing the geologic unit, geologic age, and description of the unit is presented below. A geologic map of Segment 5, Alternatives A and B, showing the geology and the Alignment routes is shown on Figure 11.

Table 9 – Geologic Units Segment 5, Alternatives A and B

Geologic Unit (Symbol[s])	Geologic Age	Description
Disturbed And Modified Areas (Qx)	Holocene	Areas of Anthropogenic Disturbance, Artificial Fill, Commercial Development Areas, and the I-15 Corridor.
Undivided Young Alluvial Deposits (Qa, Qal, Qay)	Holocene	Undivided Alluvial Fan and Wash Deposits of Gravel, Sand, and Minor Silt.
Playa Fringe Deposits (Qpf)	Holocene	Deposits Of Silt, Sand, and Gravel Along The Perimeter Of Playa Surfaces.
Youngest Active Alluvium (Qay3)	Late-Holocene	Active Wash and Alluvial Fan Deposits of Gravel, Sand, and Minor Silt.
Young Active Alluvium (Qay2)	Holocene	Alluvial Fan and Wash Deposits of Gravel, Sand, and Minor Silt of Intermittently Active Alluvial Surfaces.
Oldest Young Alluvium (Qay1)	Early-Holocene	Alluvial Fan and Wash Deposits of Gravel, Sand, and Minor Silt of Inactive Alluvial Surfaces.
Intermediate Alluvium (Qai)	Pleistocene	Deposits Of Relict, Inactive Alluvial Fans, Moderately To Strongly Consolidated.
Older Alluvial Deposits (Qao, Qta)	Pleistocene To Late-Miocene	Dissected Alluvial Fan Deposits, Primarily Gravel With Some Sand and Silt.
Sedimentary Rocks (Tao)	Tertiary	Fluvial Gravel Beds With Minor Sandstone and Mudstone.
Volcanic Rocks (Tv, Tsf)	Tertiary	Volcanic Rocks Ranging In Composition From Basalt To Rhyolite.
Marine Sedimentary And Metasedimentary Rocks (Pbs, Ppmb, Mzpzs)	Mesozoic To Paleozoic (Carboniferous)	Dolomite and Limestone with Interbedded Shale, Sandstone, and Conglomerate; Bird Spring Formation.
Marine Sedimentary And Metasedimentary Rocks (Dєg, Mzpzs)	Paleozoic – Cambrian And Devonian	Dolomite and Limestone with Interbedded Shale, Sandstone, and Conglomerate; Goodsprings Dolomite and Carbonate Rocks Of Hewett, 1956.

3.3.9. Segment 6, Alternatives A and B (Sloan to Las Vegas, Nevada)

Alternatives A and B of Segment 6 are in close proximity to each other, on the median and west side of I-15, respectively, and they have been evaluated as one alignment for purposes of describing general geologic conditions along this segment. Alternatives A and B of Segment 6 begin near the community of Sloan, Nevada, at the south end of the Las Vegas Valley and travel north along the I-15 corridor across the valley into the City of Las Vegas.

Geologic maps indicate that a limestone formation (Mmc, Mm) mantled by younger alluvium underlies the southern end of Segment 6 at the south end of the Las Vegas Valley. The majority of Segment 6 in the Las Vegas Valley is underlain by alluvial deposits that are present in the valley. The alluvial deposits include younger Holocene wash sediments and alluvial fan deposits (Qa, Qal, Qs), older Holocene/Pleistocene alluvial fan deposits (Qai, Qoa) that are typically moderately to well consolidated to cemented in places, and older Pliocene consolidated sediments (QTs) that are typically moderately to well consolidated to strongly cemented.

A common characteristic of alluvial soils in the Las Vegas Valley and surrounding region is the post-depositional development of calcium carbonate cemented layers. These petrocalcic layers are commonly referred to as caliche and consist of alluvial sediments that have been cemented by calcium carbonate and can have varying degrees of cementation. The development of caliche is a function of time and older soils tend to have more caliche development. The geologic maps indicate that younger Holocene alluvial wash and fan deposits (Qa) in this segment may be cemented in places by petrocalcic carbonate. Older Pleistocene alluvium (Qoa) may contain a petrocalcic carbonate horizon approximately 6 feet thick near the surface. And older Plio-Pleistocene consolidated sediments in this segment are described as having moderately to well consolidated to strongly cemented layers of petrocalcic carbonate, and surface exposures are capped in places by a resistant petrocalcic crust.

A table listing the type of geologic unit, geologic age, and description of the unit is presented below. A geologic map of Segment 6, Alternatives A and B, showing the geology and the Alignment routes is shown on Figure 11.

Table 10 – Geologic Units Segment 6, Alternatives A and B

Geologic Unit (Symbol[s])	Geologic Age	Description
Younger Alluvial Deposits (Qa, Qal, Qs)	Holocene	Active Wash, Alluvial Fan and Sheet Wash Deposits of Gravel, Sand, and Minor Silt; Unconsolidated to Locally Calcic-Cemented.
Intermediate Alluvial Deposits (Qai)	Holocene- Pleistocene	Deposits of Sand and Gravel on Relict, Inactive Alluvial Fans; Slightly to Moderately Consolidated.
Older Alluvial Deposits (Qoa)	Pleistocene	Pebble and Small Cobble Gravel with Pebbly Sand; Moderately to Well Consolidated to Locally Cemented; Caliche Horizon Approximately 6 Feet Thick Occurs at or Near Surface.
Consolidated Sediments (Qts)	Pliocene To Pleistocene	Fine Sand Interbedded With Silt, Pebbly Sand, and Gravel; Moderately to Well Consolidated to Strongly Cemented. Common Caliche Layers and Resistant Caliche Surface Crust.
Marine Sedimentary And Meta-Sedimentary Rocks (Mmc, Mm)	Mesozoic To Paleozoic (Carboniferous)	Monte Cristo Limestone (Mm).

3.3.10. Segment 6, Alternatives C and D (Sloan to Las Vegas, Nevada)

Alternatives C and D of Segment 6 are in close proximity to each other following the alignment of a UPRR rail line, and they have been evaluated as one alignment for purposes of describing general geologic conditions along this segment. Alternatives C and D of Segment 6 begin along I-15 near the community of Sloan, Nevada, at the south end of the Las Vegas Valley and diverge northwest from the I-15 corridor utilizing an existing UPRR rail line alignment for travel across the Las Vegas Valley and into the city of Las Vegas.

At the beginning of Alternatives C and D, at the southern end of the Las Vegas Valley, geologic maps indicate that formations of limestone with interbedded shale, sandstone, and conglomerate (Ds, Pbs, PPMb) underlie the Alignment in a hilly area west of I-15.

This rock formation is mantled by younger alluvium (Qal). After passing though this hilly area, the Alignment turns toward the northeast and descends into the Las Vegas Valley. The majority of Alternatives C and D in the Las Vegas Valley are underlain by alluvial deposits.

The alluvial deposits include younger Holocene wash sediments and alluvial fan deposits (Qa, Qal, Qs), older Holocene/Pleistocene alluvial fan deposits (Qai, Qoa) that are typically moderately to well consolidated to cemented in places, older Pleistocene gravel deposits (Qog) that are consolidated to strongly cemented, and older Pliocene consolidated sediments (QTs) that are typically moderately to well consolidated to strongly cemented.

The geologic maps indicate that younger alluvial wash and fan deposits (Qa) in this segment may be cemented in places by petrocalcic carbonate. Older alluvium (Qoa) may contain a petrocalcic carbonate horizon approximately 6 feet thick near the surface. Older gravel deposits (Qog) are described as being capped by a petrocalcic horizon greater than approximately 10 feet thick. Older Plio-Pleistocene consolidated sediments (QTs) in this segment are described as having moderately to well consolidated to strongly cemented layers of petrocalcic carbonate, and surface exposures are capped in places by a resistant petrocalcic crust.

A table listing the type of geologic unit, geologic age, and description of the unit is presented below. A geologic map of Segment 6, Alternatives C and D showing the geology and the Alignment routes is shown on Figure 11.

Table 11 – Geologic Units Segment 6, Alternatives C and D

Geologic Unit (Symbol[s])	Geologic Age	Description
Younger Alluvial Deposits (Qa, Qal, Qs)	Late-Holocene	Active Wash, Alluvial Fan and Sheet Wash Deposits Of Gravel, Sand, and Minor Silt; Unconsolidated to Locally Calcic-Cemented.
Intermediate Alluvial Deposits	Pleistocene	Deposits Of Sand and Gravel on Relict, Inactive Alluvial Fans; Slightly to

Table 11 – Geologic Units Segment 6, Alternatives C and D

Geologic Unit (Symbol[s])	Geologic Age	Description
(Qai)		Moderately Consolidated.
Older Alluvial Deposits (Qoa)	Pleistocene	Pebble and Small Cobble Gravel with Pebbly Sand; Moderately to Well Consolidated to Locally Cemented; Caliche Horizon Approximately 6 Feet Thick Occurs at or Near Surface.
Older Alluvial (Gravel) Deposits (Qog)	Pleistocene	Alluvial Fan Clast-Supported Gravel Deposits; Consolidated to Strongly Cemented; Capped by a Matrix-Supported Caliche Horizon Greater than Approximately 10 Feet Thick.
Consolidated Sediments (Qts)	Pliocene To Pleistocene	Fine Sand Interbedded with Silt, Pebbly Sand, and Gravel; Moderately to Well Consolidated to Strongly Cemented. Common Caliche Layers and Resistant Caliche Surface Crust.
Marine Sedimentary And Metasedimentary Rocks (Pbs, Ppmb)	Mesozoic To Paleozoic (Carboniferous)	Dolomite and Limestone with Interbedded Shale, Sandstone and Conglomerate; Bird Spring Formation.
Marine Sedimentary And Metasedimentary Rocks (Ds)	Paleozoic - Devonian	Sultan Limestone (Hewett, 1956).

3.3.11. Segment 7, Alternatives A and B (City of Las Vegas, Nevada)

Alternatives A and B of Segment 7 are in close proximity to each other, on the median and west side of I-15, respectively, and they have been evaluated as one alignment for purposes of describing general geologic conditions along this segment. Alternatives A and B of Segment 7 begin in the City of Las Vegas and travel north along the I-15 corridor across the Las Vegas Valley. This last segment of the Alignment ends at a planned new station in Las Vegas.

Geologic maps indicate that Segment 7 in the Las Vegas Valley is underlain by alluvial deposits. The alluvial deposits include younger Holocene wash sediments and alluvial fan deposits (Qa, Qal, Qs), older Holocene/Pleistocene alluvial fan deposits (Qai, Qoa) that are typically moderately to well consolidated to cemented in places, and older Pliocene consolidated sediments (QTs) that are typically moderately to well consolidated to strongly cemented.

A common characteristic of alluvial soils in the Las Vegas Valley and surrounding region is the post-depositional development of calcium carbonate cemented layers. These petrocalcic layers are commonly referred to as caliche and consist of alluvial sediments that have been cemented by calcium carbonate and can have varying degrees of cementation. The development of caliche is a function of time and older soils tend to have more caliche development. The geologic maps indicate that younger Holocene alluvial wash and fan deposits (Qa) in this segment may be cemented in places by petrocalcic carbonate. Older Pleistocene alluvium (Qoa) may contain a petrocalcic carbonate horizon approximately 6 feet thick near the surface. And older Plio-Pleistocene consolidated sediments in this segment are described as having moderately to well consolidated to strongly cemented layers of petrocalcic carbonate, and surface exposures are capped in places by a resistant petrocalcic crust.

A table listing the type of geologic unit, geologic age, and description of the unit is presented below. A geologic map of Segment 7, Alternatives A and B, showing the geology and the Alignment routes is shown on Figure 11.

Table 12 – Geologic Units Segment 7, Alternatives A and B

Geologic unit (symbol[s])	Geologic age	Description
Younger Alluvial Deposits (Qa, Qal, Qs)	Holocene	Active Wash, Alluvial Fan and Sheet Wash Deposits of Gravel, Sand, And Minor Silt; Unconsolidated to Locally Calcic-Cemented.
Intermediate Alluvial Deposits (Qai)	Holocene-Pleistocene	Deposits of Sand and Gravel on Relict, Inactive Alluvial Fans; Slightly to Moderately Consolidated.

Table 12 – Geologic Units Segment 7, Alternatives A and B

Geologic unit (symbol[s])	Geologic age	Description
Older Alluvial Deposits (Qoa)	Pleistocene	Pebble and Small Cobble Gravel with Pebbly Sand; Moderately to Well Consolidated to Locally Cemented; Caliche Horizon Approximately 6 Feet Thick Occurs at or Near Surface.
Consolidated Sediments (Qts)	Pliocene To Pleistocene	Fine Sand Interbedded with Silt, Pebbly Sand, and Gravel; Moderately to Well Consolidated to Strongly Cemented. Common Caliche Layers And Resistant Caliche Surface Crust.

3.3.12. Segment 7, Alternative C (City of Las Vegas, Nevada)

Alternative C of Segment 7 follows the alignment of an existing UPRR rail line, beginning at about the intersection of Tropicana Avenue, and travels across the Las Vegas Valley. This last segment of the Alignment ends at a planned new station in the City of Las Vegas.

Geologic maps indicate that Segment 7 in the Las Vegas Valley is underlain by alluvial deposits. The alluvial deposits include younger Holocene wash sediments and alluvial fan deposits (Qa, Qal, Qs), older Holocene/Pleistocene alluvial fan deposits (Qai, Qoa) that are typically moderately to well consolidated to cemented in places, older Pleistocene gravel deposits (Qog) that are consolidated to strongly cemented, and older Pliocene consolidated sediments (QTs) that are typically moderately to well consolidated to strongly cemented.

The geologic maps indicate that younger alluvial wash and fan deposits (Qa) in this segment may be cemented in places by petrocalcic carbonate. Older alluvium (Qoa) may contain a petrocalcic carbonate horizon approximately 6 feet thick near the surface. Older gravel deposits (Qog) are described as being capped by a petrocalcic horizon greater than approximately 10 feet thick. Older Plio-Pleistocene consolidated sediments (QTs) in this segment are described as having moderately to well consolidated to strongly cemented layers of petrocalcic carbonate, and surface exposures are capped in places by a resistant petrocalcic crust.

A table listing the type of geologic unit, geologic age, and description of the unit is presented below. A geologic map of Segment 7, Alternative C showing the geology and the Alignment route is shown on Figure 11.

Table 13 – Geologic Units Segment 7, Alternative C

Geologic Unit (Symbol[s])	Geologic Age	Description
Younger Alluvial Deposits (Qa, Qal, Qs)	Late-Holocene	Active Wash, Alluvial Fan and Sheet Wash Deposits of Gravel, Sand, And Minor Silt; Unconsolidated to Locally Calcic-Cemented.
Intermediate Alluvial Deposits (Qai)	Pleistocene	Deposits of Sand and Gravel on Relict, Inactive Alluvial Fans; Slightly to Moderately Consolidated.
Older Alluvial Deposits (Qoa)	Pleistocene	Pebble and Small Cobble Gravel with Pebbly Sand; Moderately to Well Consolidated to Locally Cemented; Caliche Horizon Approximately 6 Feet Thick Occurs at or Near Surface.
Older Alluvial (Gravel) Deposits (Qog)	Pleistocene	Alluvial Fan Clast-Supported Gravel Deposits; Consolidated to Strongly Cemented; Capped by a Matrix-Supported Caliche Horizon Greater than Approximately 10 Feet Thick.
Consolidated Sediments (Qts)	Pliocene To Pleistocene	Fine Sand Interbedded with Silt, Pebbly Sand, and Gravel; Moderately to Well Consolidated to Strongly Cemented. Common Caliche Layers and Resistant Caliche Surface Crust.

3.3.13. Groundwater and Surface Water

Groundwater information along the Alignment is limited, and preliminary information regarding the depth to groundwater at selected locations was obtained from published geologic maps, the County of San Bernardino and Caltrans LOTB sheets. Based on varied topographic and geologic conditions along the Alignment, groundwater depths are anticipated to be variable along different segments of the Alignment. Shallow groundwater conditions may be anticipated beneath the Mojave River and beneath active washes and streams along the Alignment. The depths to groundwater may be influenced by seasonal variations, precipitation, irrigation, soil/rock types, groundwater pumping, and other factors and are subject to fluctuations. Shallow perched conditions may be present in places. Further study, including site exploration, should be performed to evaluate the presence of groundwater, seepage, and/or perched groundwater, and the potential impacts on design and construction of project improvements.

The County of San Bernardino has indicated some areas within the Alignment study area with potential for shallow groundwater. These areas include:

- Areas along the Mojave River (Segments 1A, 2A, 2B, 3A and 3B);
- Areas adjacent to some faults that form groundwater barriers (which can cause groundwater to rise), such as areas southwest of the Calico fault near Barstow (Segments 2A and 2B) and southwest of the Lockhart fault west of Barstow;
- The Mojave River Wash area south of the intersection of I-15 and Basin Road (Segments 3A and 3B); and
- The area between Baker and north toward Silver Lake (north of Segments 3A and 3B).

Groundwater contour maps of the Las Vegas Valley from 1979 groundwater data were reviewed as part of our study; the map coverage begins in the southern part of the valley and includes the north portions of Segment 6 and Segment 7. The maps indicate that groundwater in the southern part of the valley underlying Segment 6 is deeper than 100 feet below the surface. The maps indicate that groundwater becomes shallower toward the northeast. Along Alternatives A and B of Segment 6 (along I-15), the groundwater reaches a depth of 100 feet below the surface near the intersection with Russell Road. Along Alternatives C and D of Segment 6 (following the UPRR alignment), the groundwater reaches a depth of 100 feet below the surface near the intersection with Tropicana Avenue. North of these locations, the maps show that groundwater becomes shallower toward the northeast and is approximately 20 bgs along Segment 7 and at the planned station locations at the north end of the Alignment.

Caltrans LOTB sheets from investigations for I-15 crossing structures contain information on groundwater encountered in borings along the Alignment. A table listing the crossing structure location, ground surface elevation, and depth to groundwater in selected borings at that location is presented below.

Table 14 – Depth To Groundwater In Caltrans Borings For I-15 Construction

Alignment Segment and Alternative (Geographic Location)	Caltrans Crossing Structure Location	Boring Number (Date)	Ground Surface Elevation (Feet)	Depth To Ground-water (Feet)
2a (Barstow)	Hiker Ditch Bridge	B-1 (October 12, 1994)	1,996	50
3a And B (Soda Mountains)	Marl Ditch Bridge	B-2 (February 2, 1957)	1,451	11
3a And B (Soda Mountains)	Turtle Ditch Bridge	B-1 (February 1, 1957)	1,328	21
3a And B (Soda Mountains)	Banner Ditch Bridge	B-1 (January 31, 1957)	1,111	10
3a And B (Soda Lake)	Sheep Ditch Bridge	B-1 (January 31, 1957)	1,067	3
3a And B (Soda Lake)	Mobi Ditch Bridge	B-1 (October 22, 1956)	920	6
3a And B (Soda Lake)	West Baker Overcrossing	Various (March 25, 1959)	921 (Average)	26
3a And B (Baker)	Mojave River (Baker) Bridge	Various (March 1959)	921 (Average)	23 To 24
3a And B (Baker)	Baker Inn Ditch	B-1 (August 20, 1959)	944	30
3a And B (Halloran Springs)	Halloran Wash Bridge	B-5 (October 27, 1956)	2,506	19
3a And B (Valley Wells)	Hot Wash Bridge	B-1 (October 26, 1956)	3,711	13
3a And B (Valley Wells)	West Valley Wells Ditch Bridge	Various (January/February 1999)	3,700 (Average)	55 To 74
3a And B (Valley Wells)	Valley Wells Ditch Bridge	Various (February/March	3,682 (Average)	31 To 75

Table 14 – Depth To Groundwater In Caltrans Borings For I-15 Construction

Alignment Segment and Alternative (Geographic Location)	Caltrans Crossing Structure Location	Boring Number (Date)	Ground Surface Elevation (Feet)	Depth To Ground-water (Feet)
		1999)		
3a And B (Valley Wells)	Windmill Station Ditch Bridge	Various (January 1999)	3,697 (Average)	63 To 72
3a And B (Valley Wells)	Wells Ditch Bridge	Various (February/March 1999)	3,697 (Average)	26 To 34

Surface flow within streams and washes along the Alignment is ephemeral and typically limited to during or shortly after intense periods of rain. Some of the dry stream beds are susceptible to flash flooding. During periods of heavy rain, water may pool in dry lake beds and in scattered areas in the alluvial flood plains and washes.

3.4. Regional Active and Potentially Active Faults

The Alignment is situated within a seismically active region of southern California and Nevada, and numerous active and potentially active faults have been mapped within or adjacent to the study area. As defined by the California Geological Survey (CGS), an active fault is one that has had surface displacement within Holocene time (roughly the last 11,000 years). Potentially active faults are those which show evidence of surface displacement during Quaternary time (roughly the last 1.6 million years) but for which evidence of Holocene movement has not been established.

An inactive fault is one that has not shown evidence of surface displacement during Quaternary time (roughly the last 1.6 million years.) Faults generally develop due to tectonic forces resulting in stresses and strains to earth materials. Over geologic time, the seismic environment of a geomorphic region can change due to regional tectonic changes, consequently changing the dynamics of tectonic forces on the rocks. Inactive faults are remnants of former tectonic activity in the rock formation and are present in formations within the Alignment in areas that are not considered to be seismically active. There are numerous inactive fault traces that have been mapped crossing the alternative routes within the Alignment. Since these types of faults are not considered to have potential for rupture, they are not discussed in the seismic section of this report, but are discussed in the site geology sections of this report as appropriate.

The approximate locations of the principal faults in the region and their geographic relationship to the Alignment are shown on the Regional California Fault Map, Figure 12. Information regarding faults in Nevada is more limited than California. Figure 13 shows faults and earth fissures that have been mapped in the Las Vegas Valley. Table 15 lists nearby principal faults, the maximum moment magnitude (M_{max}), the fault type, the slip rate, the fault source type, and significant historic earthquakes that have occurred on the faults. The following subsections discuss the principal fault zones within the Alignment region that have had a dominant role in forming the present seismic environment.

Table 15 – Principal Regional Active and Potentially Active Faults

Fault	Maximum Moment Magnitude (M_{max})[1]	Fault Type[1]	Slip Rate (mm/yr)[1]	Source Type[1]	Historic Earthquakes[2]
Blackwater	7.1	SS	0.6	B	-
Burnt Mountain	6.5	SS	0.6	B	M7.3 Landers, 6/28/92
Calico-Hidalgo	7.3	SS	0.6	B	M5.3 Calico, 4/18/97
Camp Rock	7.5	SS	1.0	-	M7.3 Landers, 6/28/92
Clamshell – Sawpit	6.5	R	0.5	B	M5.8 Sierra Madre, 6/28/91
Cleghorn	6.5	SS	3.0	B	-
Cucamonga	6.9	R	5.0	B	-
Death Valley (South)	7.1	SS	4.0	-	-
Elsinore (Chino-Central Avenue)	6.7	SS	1.0	B	-
Elsinore (Glen Ivy)	6.8	SS	5.0	A	M6, 5/15/1910
Eureka Peak	6.4	SS	0.6	B	M7.3 Landers, 6/28/92
Garlock (East)	7.5	SS	7.0	B	-
Garlock (West)	7.3	SS	6.0	B	-
Gravel Hills–Harper Lake	7.1	SS	0.6	B	-
Helendale-South Lockhart	7.3	SS	0.6	B	-
Homestead Valley	7.0	SS	0.5	-	M7.3 Landers, 6/28/92
Johnson Valley (Northern)	6.7	SS	0.6	B	M7.3 Landers, 6/28/92

Table 15 – Principal Regional Active and Potentially Active Faults

Fault	Maximum Moment Magnitude (M_{max}) [1]	Fault Type[1]	Slip Rate (mm/yr) [1]	Source Type[1]	Historic Earthquakes[2]
Kickapoo (Landers)	7.3	SS	0.6	B	-
Lavic Lake	6.8	SS	0.8	-	M7.1 Hector Mine, 10/16/99
Lenwood-Lockhart-Old Woman Springs	7.5	SS	0.6	B	-
Little Lake	6.9	SS	0.7	B	-
Lockhart	7.5	SS	0.8	-	-
Manix	7.0	SS	0.1	-	M6.5 Manix, 4/10/47
Mt. General	N/A	SS	N/A	-	-
North Frontal Fault Zone (West)	7.2	R	1.0	B	-
North Frontal Fault Zone (East)	6.7	R	0.5	B	-
Owl Lake	6.5	SS	2.0	B	-
Panamint Valley	7.4	N	2.5	B	-
Pinto Mountain	7.2	SS	2.5	B	-
Pisgah-Bullion Mt.-Mesquite Lake	7.3	SS	0.6	B	-
Puente Hills Blind Thrust	7.1	R	0.7		-
Raymond	6.5	RO	1.5	B	-
San Andreas (Mojave)	7.4	SS	30	A	M8 Fort Tejon, 1/9/1857
San Andreas (San Bernardino)	7.5	SS	24	A	-
San Andreas (Coachella)	7.2	SS	25	A	-
San Andreas (Cholame)	7.3	SS	34	A	-
San Gabriel	7.2	SS	1.0	B	-
San Jacinto (San Bernardino)	6.7	SS	12	A	M6.3 Loma Linda, 7/22/1923
San Jacinto (San Jacinto Valley)	6.9	SS	12	A	M6.8 San Jacinto, 4/21/1918
San Jacinto (Anza)	7.2	SS	12	A	-
San Jose	6.4	RO	0.5	B	M4.7 Upland, 6/28/88 M5.4 Upland, 2/28/90
Sierra Madre	7.2	R	2.0	B	-
South Emerson-Copper Mountain	7.0	SS	0.6	B	M7.3 Landers, 6/28/92
Tank Canyon	6.4	N	1.0	B	-
Upper Elysian Park Blind Thrust	6.4	R	1.3	B	-
Verdugo	6.9	R	0.5	B	-
Whittier (Elsinore Fault Zone)	6.8	RO	2.5	A	M5, 5/15/1910

Notes:
DS – Dip Slip
N-T – Normal-Thrust
R – Reverse
RO – Reverse-Oblique
SS – Strike Slip

References: [1]Blake, T.F., 2001b.
[2]SCEC, 2007; Co. of San Bernardino, 2005d

3.4.1. San Andreas Fault Zone

The San Andreas fault zone has long been recognized as the dominant seismotectonic feature in California. Two of California's three largest historic earthquakes, the 1906 San Francisco earthquake and the 1857 Forth Tejon earthquake, occurred along the San Andreas fault. The fault is a right lateral strike-slip fault which is capable of producing earthquakes in excess of M_{max} 7.5. It is inferred that the segment of the San Andreas Fault zone closest to the site is currently locked and accumulating substantial amounts of strain in response to the stresses generated by the relative movement between the Pacific and North American plates. The available geologic and seismicity data indicate that this strain is released during infrequent major earthquakes (M_{max} 7 to 8+ events) rather than by more frequent smaller magnitude earthquakes. The San Andreas Fault is located approximately 21.3 miles southwest of the southwest end of the Alignment.

3.4.2. Garlock Fault

The Garlock fault is a prominent fault in southern California and crosses the northern part of the Mojave Desert province. The east end of the fault is approximately 20 miles north-northwest of Segment 3. Although this fault has not produced large earthquakes historically, geomorphic and stratigraphic evidence indicates that it has done so in the past. A total of about 30 to 40 miles of left-lateral strike slip has been documented across this fault. The Garlock fault is considered capable of generating about a M_{max} 7.5 earthquake.

3.4.3. Eastern California/Mojave Shear Zone

The Eastern California/Mojave Shear Zone (ECMSZ) is an approximate 50-mile-wide zone of tectonic deformation that crosses the central Mojave Desert and is characterized by northwest trending, right lateral, strike-slip faults roughly centered around Barstow. The ECMSZ is estimated to accommodate between 9 and 23 percent of the relative motion between the Pacific and North American tectonic plates (Southern California Earthquake Data Center [SCEC], 2007). The ECMSZ crosses the Alignment between about Helendale and Manix, California. The ECMSZ is comprised of several northwest trending, right lateral, strike-slip faults that include the Blackwater, Bullion, Calico, Emerson, Helendale, Landers, Lockhart, Lenwood, Camp Rock, Harper, Harper Lake, Homestead Valley, Johnson Valley, Kickapoo (Landers), Lavic Lake, Mesquite Lake, and West Calico faults.

Several moderate to large earthquakes have ruptured faults within this region, including the M_{max} 7.3 Landers earthquake of June 28, 1992, and the M_{max} 7.1 Hector Mine earthquake of October 16, 1999. The Landers earthquake produced an approximate 53-mile-long surface rupture that averaged approximately 10 to 13 feet of slip and occurred along portions of the Johnson Valley, Landers, Homestead Valley, Emerson, and Camp Rock faults (County of San Bernardino, 2005d). These surface rupture areas occurred south of the Alignment study area.

On March 18, 1997, a M_{max} 5.3 earthquake occurred along the Calico fault approximately 12 miles east-northeast of Barstow. This earthquake was the last aftershock of the Landers earthquake of 1992 to reach M_{max} 5. Although there was no surface rupture attributed to this earthquake, the Calico fault had exhibited some triggered slip during the 1992 Landers event (County of San Bernardino, 2005d).

3.5. Active and Potentially Active Faults Crossing Segments of the Alignment

Five active faults are mapped crossing the alternative routes of the Alignment. With the exception of the northeast trending Manix fault, these active faults are associated with the ECMSZ and comprise northwest trending strike-slip faults that cross alternative segments of the Alignment. Five potentially active faults are mapped crossing the alternative routes of the Alignment. Two of these potentially active faults are associated with the ECMSZ, while the other three faults are located northeast of, and are not associated with the ECMSZ. The approximate locations of these faults and their geographic relationship to the Alignment are shown on the Figure 12.

Three active faults that cross the Alignment, the Helendale-South Lockhart fault, the Mt. General fault, and the Calico-Hidalgo fault, have been designated by the State of California as Earthquake Fault Zones under the Alquist-Priolo Special Studies Zone Act of 1972 (Hart, E.W., and Bryant, W.A., 1997). Development within Earthquake Fault Zones will need further evaluation to address the potential for fault rupture. The location of the boundaries of the Earthquake Fault Zone is based on the presence of well-defined, active fault traces. Zone boundaries are typically 500 to 660 feet away from the fault traces and are positioned to accommodate imprecise locations of the faults and the possible existence of active branches. Table 16 lists information about the active and potentially active faults crossing the Alignment including: the recency of activity; the Alignment segment(s) affected by the faults; the M_{max}; the fault type; the slip rate; the degree of exposure of the fault; the proximity to a State Earthquake Fault Zone; and significant historic earthquakes that have occurred on these faults.

Table 16 – Active and Potentially Active Faults Crossing Segments of the Alignment

Fault	Activity (Recency) [1]	Affected Segment Crossing the Fault	Maximum Moment Magnitude (M_{max}) [2]	Fault Type[2]	Slip Rate (mm/yr) [2]	Mapped Fault Exposure	Segment Crosses Earthquake Fault Zone	Historic Earthquakes*
Helendale-South Lockhart	Potentially Active (late-Quaternary)	1A	7.3	SS	0.6	Concealed by alluvium	No**	ND
Helendale-South Lockhart	Active (Holocene)	1B	7.3	SS	0.6	Surface	Yes	ND
Lenwood-Lockhart-Old Woman Springs	Active (Historic)	2A	7.5	SS	0.6	Surface/ concealed	No**	ND
Mt. General	Active (Holocene)	2A	ND	SS	ND	Surface	Yes	ND
Gravel Hills–Harper Lake	Potentially Active (late-Quaternary)	2A	7.1	SS	0.6	Concealed by alluvium	No**	ND
Calico-Hidalgo	Active (Holocene)	3A & B	7.3	SS	0.6	Concealed by alluvium	Yes	M 5.3 Calico, 4/18/97
Manix	Active (Holocene)	3A & B	7.0	SS	0.1	Surface/ concealed	No**	M 6.5 Manix, 4/10/47
Unnamed (Cronese Valley)	Potentially Active (early-Quaternary)	3A & B	ND	SS	ND	Concealed by alluvium	No	ND
Baker	Potentially Active (early-Quaternary)	3A & B	ND	SS[3]	ND	Surface/ concealed	No	ND
Stateline	Potentially Active (early-Quaternary)	5A & B	ND	SS	ND	Concealed by alluvium	No	ND

mm/yr – millimeters per year
SS – Strike Slip
ND – No data available
*County of San Bernardino General Plan, 2005
**Other portions of fault not underlying segment mapped as State of California Earthquake Fault Zone
[1]Jennings, C.W., 1994.
[2]Blake, T.F., 2001b.
[3] probable interpretation (SCEC, 2007).

3.5.1. Helendale-South Lockhart Fault (active and potentially active portions)

The active Helendale fault is a right-lateral, strike-slip fault about 56 miles in length and may form a roughly continuous fault system with the active South Lockhart fault located northwest of the study area (County of San Bernardino, 2005d). These faults could rupture together during an earthquake and are considered capable of producing a M_{max} 7.3 earthquake. Alternative segments of the Alignment cross a portion of the Helendale-South Lockhart fault that is mapped as active, and cross a portion of the fault mapped as potentially active (Figure 12).

3.5.2. Lenwood-Lockhart-Old Woman Springs Fault

The active Lenwood and Lockhart faults are prominent right-lateral, strike-slip faults that may form a continuous system crossing the Alignment study area in the community of Lenwood southwest of Barstow (County of San Bernardino, 2005d). The Lenwood fault extends for a length of about 47 miles and is reported to have experienced some triggered slip, or creep, in the community of Lenwood in 1992 due to the Landers earthquake (County of San Bernardino, 2005d). The Lockhart fault extends for a length of about 44 miles northwest of the communities of Lenwood and Barstow. These faults are considered capable of producing a M_{max} 7.5 earthquake.

3.5.3. Mt. General Fault

The active Mt. General fault is a right-lateral, strike-slip fault approximately 13 miles in length and is considered to have ruptured in the Holocene period along the middle section of the fault (SCEC, 2007). This fault is designated by the state as an Earthquake Fault Zone.

3.5.4. Gravel Hills-Harper Lake Fault

The potentially active Gravel Hills-Harper Lake fault is a fragmented fault with a total length of approximately 43 miles. The slip rate of this right-lateral, strike-slip fault is estimated to be approximately 0.6 mm/yr, and the fault is considered capable of producing a M_{max} 7.1 earthquake. Active portions of the Gravel Hills-Harper Lake fault are located to the northwest of the Alignment study area.

3.5.5. Calico-Hidalgo Fault

The active Calico-Hidalgo fault zone, source of the 1997 Calico Earthquake (M_{max} 5.3), is a right-lateral, strike-slip fault approximately 34 miles in length. The slip rate along this fault is estimated to be approximately 0.6 millimeters per year (mm/yr) and the fault is estimated to be capable of producing a M_{max} 7.3 earthquake. The Calico – Hidalgo fault exhibited triggered slip during the 1992 Landers earthquake. This fault zone could rupture simultaneously with the West Calico and Hidalgo faults to the south (County of San Bernardino, 2005d).

3.5.6. Manix Fault

The active Manix fault is a left-lateral, strike slip fault that is located on the southeast side of and is sub-parallel to I-15 in the community of Manix between Barstow and Baker, California. The fault is roughly broken into thirds, with a total length of about 22 miles. Fault maps (Jennings, 1994) indicate that the west/southwest end of the Manix fault that crosses the Alignment is active. The State of California Earthquake Fault Zone for this fault is approximately 4½ miles long and is located on a segment of the fault located approximately 1.3 miles southwest of the Alignment in Manix. On April 10, 1947, a M_{max} 6.5 earthquake occurred on the Manix fault. The length of the surface rupture was about 3 miles, and the maximum slip was about 5 centimeters (County of San Bernardino, 2005d). The rupture was located on the zoned segment of the fault. The Manix fault is considered capable of producing a M_{max} 7.0 earthquake.

3.5.7. Unnamed (Cronese Valley) Fault

A concealed, potentially active fault is mapped in the Cronese Valley (Jennings, 1994), as shown on Figure 12. This fault is unnamed, and information about this fault is not provided on the available State references reviewed.

3.5.8. Baker Fault

Information regarding the potentially active Baker fault is limited. The information about the Baker fault was obtained from the SCEC. According to the SCEC, the fault type is uncertain but is probably a right-lateral, strike-slip fault of approximately 28 miles length. It may have ruptured in late-Quaternary time at its southern end.

3.5.9. Stateline Fault

The Stateline fault is mapped as a concealed, potentially active fault (Jennings, 1994). Information about this fault is limited on the available State references reviewed.

3.5.10. Faults in Las Vegas Valley

Faults in the Las Vegas Valley are indicated as active on the geologic maps reviewed, but the activity is attributed to subsidence, not tectonic activity.

There is some controversy among Nevada geologists as to the origin of these faults, which are sometimes referred to as "compaction faults," in the Las Vegas Valley. Differing proposed origins for these faults include:

- Differential consolidation or compaction over time of the thick alluvial and lakebed sediments in the Las Vegas Valley.
- Tectonic factors associated with faults that may extend into the basement bedrock beneath the valley's sediment.
- A combination of differential consolidation and tectonic factors.

A fault map of Segments 6 and 7 showing faults and earth fissures and the Alternative routes of these Segments is shown on Figure 13.

4. ENVIRONMENTAL CONSEQUENCES

4.1. Regional Effects – Operational Period

Environmental consequences of the affected environment that pertain to geotechnical issues during the operational period of the rail system include potential seismic and geologic hazards. Seismic and geologic hazards that might potentially affect improvements within the Alignment during long-term operations include surface rupture due to faulting, ground shaking, liquefaction, and dam inundation. These potential geologic and seismic hazards associated with the operational period of the project are further discussed in the following sections. Mitigation measures for these potential seismic and geologic hazards are presented in Section 6.

4.1.1. Surface Fault Rupture

Surface fault rupture is the offset or rupturing of the ground surface by relative displacement across a fault during an earthquake. Evaluation of the potential hazard of surface fault rupture is based on the concepts of recency and recurrence of faulting along existing faults. In general, the more recent the faulting the greater the probability for future faulting (Allen, 1975). Stated another way, faults of known historic activity during the last 200 years, as a class, have a greater probability for future activity than faults classified as Holocene age (last 11,000 years) and a much greater probability of future activity than faults classified as Quaternary age (last 1.6 million years). However, it should be kept in mind that certain faults have recurrent activity measured in tens or hundreds of years whereas other faults may be inactive for thousands of years before being reactivated. The magnitude, sense, and nature of fault rupture also vary for different faults or even along different strands of the same fault. Even so, future faulting generally is expected to recur along pre-existing faults (Bonilla, 1970). The development of a new fault or reactivation of a long-inactive fault is relatively uncommon and generally need not be a design consideration in project development.

The greatest probability for surface fault rupture within the Alignment is along active faults (Holocene-age), particularly along active faults designated as Earthquake Fault (Alquist-Priolo) Zones. Active faults crossing the Alignment include the Helendale-South Lockhart, Lenwood-Lockhart-Old Woman Springs, Mt. General, Calico-Hidalgo, and the Manix faults. The approximate location of these faults and their geographic relationship to the Alignment are shown on Figure 12. Faults in the Las Vegas Valley are indicated as active on the geologic maps reviewed, but the activity is attributed to subsidence, and not tectonic activity, and the potential for surface rupture due to an earthquake is considered low.

During an earthquake on one of the active faults crossing the Alignment, potential surface rupture of the fault would manifest in relative displacement of ground across the fault surface. Typically, since the active faults crossing the Alignment are strike-slip faults, the displacement would be anticipated in a horizontal direction, but some vertical component of offset may occur.

Damage could occur to the proposed rail alignments and associated structures due to fault rupture if those elements are constructed across the fault rupture surface. Damages may include offset/damage to at-grade rail alignments at portions of the Alignment crossing the fault rupture; damage to structural elements of the rail line such as aerial guideways or bridges that are placed across the fault rupture; or damage to facilities built across the fault rupture.

4.1.2. Ground Shaking

Ground shaking is the response of the surface to the passing of earthquake wave fronts radiating from the focus of the earthquake. The period of shaking corresponds with the passage of the seismic wave through the site. Earthquake events, which could significantly affect the Alignment, would be strong ground shaking following an earthquake along one of the regional active or potentially active faults within or near the Alignment. Disregarding local variations in ground conditions, the intensity of shaking at different locations within the Alignment can generally be expected to decrease with distance away from an earthquake source.

Ground shaking could cause detrimental damage to project improvements if the appropriate design for the anticipated level of shaking is not considered. Damages due to ground shaking could include misaligned rail lines and other structural elements, and cracks in concrete foundations, walls and structures such as bridges and guideways.

In order to evaluate the level of ground shaking that might be anticipated within the Alignment, the Caltrans method of estimating peak horizontal ground accelerations from the region's principal seismic sources was reviewed. Figure 14 shows the estimated peak horizontal ground accelerations within the limits of the Alignment, based on Caltrans California Seismic Hazard Map (Mualchin, L., 1996b). The map indicates that the Alignment is located in an area where peak horizontal accelerations ranging from 0.1g to 0.6g would be considered during design. Peak horizontal ground accelerations estimated on Figure 14 are summarized by segment in Table 17 below.

Table 17 – Estimated Peak Horizontal Ground Accelerations Anticipated Along Segments of the Alignment

Segment Portion	Estimated Peak Horizontal Ground Accelerations (%G) [1]
Segment 1	0.4 To 0.6 G
Segment 2	0.5 To 0.6 G
Segment 3 (Beginning Of Segment Southwest Of Manix)	0.5 To 0.6 G
Segment 3 (Approximately Between Manix And Baker)	0.3 To 0.5 G
Segment 3 (Approximately Northeast Of Baker)	0.2 To 0.3 G
Segment 4 (In Mountain Pass Area Southwest Of Ivanpah Valley)	0.3 To 0.4 G
Segment 4 (Ivanpah Valley)	0.4 To 0.6 G
Segment 5 (Ivanpah Valley)	0.2 To 0.6 G
Segment 5 (Approximately North Of Ivanpah Valley)	0.1 To 0.2 G
Segment 6 (Las Vegas Valley)	0.1 To 0.2 G [2]
Segment 7 (City Of Las Vegas)	0.1 To 0.2 G [2]

Notes:
[1] (Mualchin, 1996a)
[2] (United States Geological Survey [Usgs], 2002rev)

4.1.3. Liquefaction

Liquefaction is a phenomenon in which soil loses its shear strength for short periods of time during an earthquake. Ground shaking of sufficient duration can result in the loss of grain-to-grain contact, due to a rapid increase in pore water pressure, causing the soil to behave as a fluid for short periods of time. To be susceptible to liquefaction, a soil is typically cohesionless, with a grain size distribution of a specified range (generally sand and silt), loose to medium dense, below the groundwater table, and subjected to a sufficient magnitude and duration of ground shaking.

The State of California Seismic Hazards Mapping Program produces maps identifying areas of the state susceptible to liquefaction but has not yet produced maps in the relatively less populated desert areas within the study area. The county of San Bernardino has identified some areas within the Alignment study area with potential for liquefaction based on where alluvial soils exist with shallow groundwater. These areas include:

- Areas along the Mojave River;
- Areas adjacent to certain faults that form groundwater barriers (which can cause groundwater to rise), such as areas southwest of the Calico fault near Barstow and southwest of the Lockhart fault west of Barstow;
- The Mojave River Wash area south of the intersection of I-15 and Basin Road; and
- The area between Baker and north toward Silver Lake.

In the Nevada portion of the Alignment, our evaluation has indicated that the majority of the proposed segments are underlain by a relatively deep groundwater table. Areas of relatively shallow groundwater may exist along the Alignment, particularly in the Roach Lake area and the Las Vegas Valley near the north end of the Alignment, and these areas may have potential for liquefaction. A groundwater contour map of the Las Vegas Valley studied for our evaluation indicates that Segment 6 of the Alignment is underlain by a groundwater table that becomes shallower toward the northeast. This map indicates that the groundwater may be as deep as 400 feet below the surface near the south end of

Segment 6, and may be as shallow as 20 feet near the north end of Segment 6 and along Segment 7.

Liquefaction could cause damage to the proposed rail improvements without appropriate consideration during design. The potential damaging effects of liquefaction include differential settlement, loss of ground support for foundations and other rail improvements, ground cracking, heaving and cracking of structure slabs due to sand boiling, buckling of deep foundations due to liquefaction-induced ground settlement, and lateral spreading along embankments and natural slopes along drainages.

4.1.4. Dam Inundation

The county of San Bernardino has identified some areas within the Alignment study area with potential for inundation due to dam failure. County mapping data indicate the inundation would potentially occur from Lake Arrowhead and Silverado Lake in the San Bernardino Mountains south of the Alignment project area. The data indicate that inundation from these lakes would occur along the Mojave River in the Alignment project area between Victorville and Baker, which is the drainage course of the river. Since the potential inundation would occur along the Mojave River, portions of the following segments would be affected according to the map:

- Segment 1, Alternative A.
- Segment 2, Alternative A.
- Portions of Segment 3, Alternatives A and B, located near the Cronese Valley and Soda Lake.

California dams are monitored by various governmental agencies (such as the State of California Division of Safety of Dams and the U.S. Army Corps of Engineers) to guard against the threat of dam failure. Current design and construction practices, and ongoing programs of review, modification, seismic retrofitting or total reconstruction of existing dams are intended to see that dams are capable of withstanding the maximum credible earthquake (MCE) for the site. In addition, it is anticipated that the County of San Bernardino has made provisions for flood control measures in areas of the Mojave River upstream of the Alignment to accommodate the anticipated inundation.

Due to regulatory monitoring of dams and the probable flood control measures that are in place, the impact of inundation due to dam failure is not considered a significant constraint to the project. The effect of inundation would be temporary, and may necessitate minor maintenance in the affected segments to make the rail system operational.

4.2. Regional Effects – Construction Period

Environmental consequences of the affected environment that pertain to potential geologic hazards during the construction period of the rail system include settlement, corrosive soils, expansive soils, landslides, caliche/hard rock excavation, ground fissures, and shallow groundwater. Although the potential seismic hazards discussed in Section 4.1 are considered long-term consequences to the operational period of the rail system, those seismic hazards may affect the rail system during the construction period. These potential geologic hazards associated with the construction period of the project are further discussed in the following sections. Mitigation measures for these potential environmental consequences are presented in Section 6.

4.2.1. Settlement (Natural Soils and Undocumented Fill)

Much of the study area is mantled by young alluvial soils, which are generally poorly consolidated, reflecting a history without substantial loading. The older alluvial deposits present in the Alignment are generally relatively dense or weakly cemented and less compressible than the young alluvial soils. However, older alluvial deposits may include potentially collapsible layers above the groundwater table. Collapsible soils are distinguished by their potential to undergo a significant decrease in volume upon an increase in moisture content, even without an increase in external loads.

Portions of the Alignment study area contain existing fill soils associated with roadway construction, railway construction, property and structure development, utilities, and other factors. The degree of compaction, material types, and underlying ground conditions of existing fill soils in the study area is unknown. Undocumented or poorly compacted fill may be present in these areas. In addition, the Alignment transitions between highly variable materials ranging from loose soils to hard rock, and the potential for differential ground movement can exist at these transitions.

Compressible natural soils and undocumented fills pose the risk of adverse settlement under static loads imposed by new embankment fills, shallow foundations for proposed rail system and associated structures. Differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements.

Since the project will involve construction of new railway embankments, stations and maintenance facilities and other at-grade structures that will be loaded upon the existing soils, potential settlement and/or collapsible soils should be a consideration in design and construction of project improvements. Potential settlement of these surficial soils is generally not a constraint for construction of deep foundations, tunnels and other deep structures.

4.2.2. Corrosive Soils

Potentially corrosive soils may be present along the alternative segments proposed for the Alignment. Corrosive soils, especially in areas of shallow groundwater that may be present in portions of the study area, can present a corrosion hazard to concrete and metal foundations, utilities, and other buried improvements. Areas of corrosive groundwater or soil could cause of premature deterioration of underground structures.

4.2.3. Expansive Soils

Potentially expansive soils may be present along the alternative segments proposed for the Alignment. Expansive soils are characterized by their ability to undergo significant volume change (shrink or swell) due to variations in moisture content. Earth materials susceptible to these volumetric changes include soils and rock formations containing clays. Changes in soil moisture content can result from rainfall, irrigation, utility leakage, surface drainage, perched groundwater, drought, or other factors.

Volumetric change of expansive soil may cause excessive cracking and heaving of structures with shallow foundations, tunnel walls, concrete slabs-on-grade, or pavements supported on these materials. The relative potential impact of expansive soils is low for deep foundations such as for bridges and aerial guideways, since volumetric changes of expansive soils diminish with overburden depth.

4.2.4. Landslides

Landslides typically occur in areas of steep slopes where underlying earth materials are relatively weak and particularly where high rainfall occurs and/or high groundwater levels are present. Ground shaking due to earthquakes can also cause landslides to develop or trigger landslides that are incipient. Landslides can consist of rock falls, shallow slumps, flows and erosional failures, or deeper-seated rotational and block failures. Shallow failures are typically caused by high incident rainfall or concentrated surface runoff conditions that weaken surficial materials. Rotational and block-type slides form deeper within the ground, typically within rock formations, and are generally related to discontinuities in the rock that manifest into a sliding surface. Rainfall and other water infiltration into the ground can exacerbate and trigger these deeper sliding conditions.

Our review of referenced geologic reports does not indicate the presence of previous landslide deposits along the proposed Alignment alternatives. Due to the relatively flat-lying nature of the majority of the Alignment, landslide hazards should not be a significant constraint to the project in those areas of gentle slopes. Due to low average annual precipitation levels in the Alignment study area, the hazard of shallow type slope failures described above is considered low and not anticipated to significantly impact the project, with the exception of areas of moderately steep to steep terrain. Portions of the Alignment located in areas of moderate to steep terrain (especially the Mountain Pass

Segment 4, Alternative B) may have potential landslide hazards, and the stability of slopes in these areas should be further evaluated prior to design of project improvements.

Review of geologic maps and other references indicate that surface soils along the Alignment are primarily comprised of sands with variable amounts of gravel, and some fine-grained silt and clay soils. Sandy soils typically have low cohesion, and have a relatively high potential for erosion from surface runoff when exposed in cut slopes or utilized near the face of fill embankments. These materials are also more susceptible to shallow slumps and other surficial slope failures when saturated by rain or heavy irrigation.

Slope areas within the project study area, including constructed cut slopes, fill slopes, natural slopes and rail embankments could potentially be affected by landsliding or surficial slope failures. Slopes may have potential for surficial slope failures during rainfall. Slopes cut in bedrock may be subject to rock fall, rock slides, or other rock slope failures where discontinuities, such as joints and fractures, or weathered rock are encountered. Landslides and surficial slope failures, if not mitigated, can cause damage to slopes, embankments, the rail alignment, foundations and other structures that are upon or impacted by the landslide. A landslide could potentially bury the rail Alignment, rendering it non-operational until the landslide debris is removed.

4.2.5. Caliche/Hard Rock Excavation

Based on our evaluation of geologic references and previous professional experience, we anticipate that the Quaternary alluvium in the desert of southern Nevada contains scattered layers of cemented soils (caliche) along portions of the Alignment. Caliche layers contain calcareous cementation which can be moderately hard, hard, and very hard and may range in thickness from a few inches to several feet. These soils may be resistant to excavation, and may pose an impact on construction techniques for both shallow and deep improvements for the rail system in the Las Vegas Valley.

Based on our review of geologic maps of the Alignment study area, portions of the Alignment are underlain by crystalline bedrock, and other rock types that may be hard. Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered.

4.2.6. Ground Fissures

Geologic maps of the Las Vegas Valley showing the locations of mapped ground fissures were reviewed, and the maps do not indicate known ground fissures fields within the Alignment study area. However, ground fissures may be present in areas not previously identified. Ground fissures, caused by differential stress resulting from regional and local subsidence associated with withdrawal of groundwater may occur near faults in the Las Vegas Valley. Differential movement associated with ground fissures could cause detrimental damage to surface project improvements such as rail alignment, shallow foundations, pavements, as well as the proposed Las Vegas maintenance facility and station.

4.2.7. Shallow Groundwater

Shallow groundwater has been identified in some segments of the Alignment. Due to the potentially shallow groundwater levels reported along segments of the Alignment, wet or saturated soil conditions may be encountered in excavations during construction. Groundwater in excavations can cause instability of the excavations, and present a constraint to the construction of foundations. Excavations extending below the groundwater table for deep foundations in areas with anticipated shallow groundwater, such as the Mojave River bridge and aerial guideways in Las Vegas, may need to be cased/shored and/or dewatered below the groundwater to maintain stability of the excavations and provide access for construction. Areas of shallow excavation and construction would be less affected by shallow groundwater.

Shallow groundwater can also impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. If not adequately monitored by the contractor, dewatering of excavations could induce consolidation of the underlying soils, which could cause differential settlement of existing structures and improvements located near the excavation. The amount of consolidation due to dewatering would depend on many factors, including the areal extent and depth of dewatering, soil type, soil density, and the methods used by the dewatering contractor. Excavations for the underground structures will need to be performed with care to reduce the potential for lateral deflection of excavation sidewalls and/or shoring, which could also cause differential movement of structures located near the excavation.

4.3. Regional Effects by Segment

The potential seismic and geologic hazards described in the previous sections that might affect improvements during the operational period and the construction period for each of the alternative alignment segments is presented below. The relative impact of the potential seismic and geologic hazards are summarized in Table 18 in Section 5. Mitigation measures for these potential seismic and geologic hazards are presented in Section 6.

4.3.1. Segment 1 (Victorville to Lenwood, California)

4.3.1.1. Operational Period Segment 1, Alternative A

Surface Fault Rupture

Segment 1, Alternative A, crosses the inferred, concealed trace of a potentially active portion of the Helendale-South Lockhart fault, and the relative potential impact of surface fault rupture in this segment, presented in Table 18, is considered moderate. Since surface fault rupture could cause detrimental damage to project improvements as described in Section 4.1.1., a detailed evaluation, as described in Section 6.1.1., could be performed to further evaluate the fault-rupture hazard. Mitigation measures to reduce the potential for fault-rupture hazard are presented in Section 6.1.1.

Ground Shaking

Due to the proximity to nearby active faults, the potential for strong ground motions to occur along Segment 1, Alternative A, is significant, and the relative potential impact of ground shaking in this segment, presented in Table 18, is considered high. Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.4g to 0.6g could be anticipated along this segment. Since this level of ground shaking can cause detrimental damage to project improvements as described in Section 4.1.2., the potential for relatively high seismic accelerations will need to be evaluated in the design of the proposed improvements, as described in Section 6.1.2. Mitigation measures to reduce the potential ground shaking hazard are presented in Section 6.1.2.

Liquefaction

Segment 1, Alternative A, travels along the bank of the Mojave River in an area of reported shallow groundwater, and by soils that have a potential for liquefaction. Due to these factors, the relative potential impact of liquefaction in this segment, presented in Table 18, is considered high. Liquefaction could cause significant damage to the proposed rail improvements, as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

The potential for dam inundation to affect Segment 1, Alternative A has been identified by the County of San Bernardino. Since this segment is adjacent to the projected inundation course, the relative potential impact of dam inundation in this segment, presented in Table 18, is considered moderate. Due to the regulatory monitoring of dams and typical flood control measures that may exist, it is anticipated that the inundation effect would not be significant. The effects of dam inundation on the rail line, and the Victorville station and maintenance facility would be expected to be temporary, and may necessitate minor maintenance to make the rail system operational.

4.3.1.2. Operational Period Segment 1, Alternative B

Surface Rupture

Segment 1, Alternative B, crosses the trace of the active Helendale-South Lockhart fault, zoned by the State of California as an Earthquake Fault Zone, and the relative potential impact of surface fault rupture in this segment, presented in Table 18, is considered high. Since surface fault rupture could cause detrimental damage to project improvements as described in Section 4.1.1., a more detailed evaluation, as described in Section 6.1.1., could be performed to further evaluate the fault-rupture hazard. Mitigation of the potential fault-rupture hazard can be achieved through measures described in Section 6.1.1.

Ground Shaking

Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.4g to 0.6g could be anticipated along this segment. The ground shaking hazard for this alternative is the same as for Segment 1, Alternative A. Mitigation measures to reduce the potential ground shaking hazard are presented in Section 6.1.2.

Liquefaction

Portions of Segment 1, Alternative B, may be underlain by soils that have a potential for liquefaction. Although shallow groundwater was not indicated in this segment in the information reviewed, areas of potentially shallow groundwater may exist. Due to these factors, Segment 1, Alternative B is considered to have a moderate liquefaction potential. Liquefaction could cause significant damage to the proposed rail improvements as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

The southwest end of this segment near the location of the proposed Victorville station and maintenance facility is adjacent to the projected inundation course. The relative potential impact of dam inundation in this segment, presented in Table 18, is considered low, and is only anticipated to affect this end of the segment. Due to the regulatory monitoring of dams and typical flood control measures that may exist, it is anticipated that the inundation effect would not be significant. The effect would be temporary, and may necessitate minor maintenance to make the rail system operational.

4.3.1.3. Construction Period Segment 1, Alternative A

Settlement (Natural Soils and Undocumented Fills)

As indicated on geologic maps reviewed, the surficial geology of Segment 1, Alternative A, is highly variable and includes Mesozoic and older crystalline basement rock and metavolcanic rock interfingered with younger and older alluvial deposits. The alluvium may contain compressible layers. Areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate.

As discussed is Section 4.2.1., differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1., to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Corrosive Soils

Potentially corrosive soils may be present along Segment 1, Alternative A. Corrosive soils, especially in areas of shallow groundwater that are reported in portions of Segment 1, Alternative A, can present a corrosion hazard to concrete and metal foundations, utilities, and other buried improvements. A more detailed evaluation, as described in Section 6.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

Potentially expansive soils may be present along Segment 1, Alternative A. The relative potential impact of expansive soils in this segment, presented in Table 18, is considered high due to clay units mapped in this segment. Expansive soils can undergo volumetric changes in response to moisture changes and could cause detrimental damage to improvements. Accordingly, a more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Landslides

Much of Segment 1, Alternative A travels across areas of relatively gentle topography and the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered low. Stability analysis of slope areas within the segment, including constructed cut and fill slopes, rail embankments, and natural slopes should be evaluated during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Caliche/Hard Rock Excavation

Caliche layers have not been identified in Segment 1, Alternative A on the geologic references reviewed for the study area. Accordingly, the potential for excavation difficulties due to caliche is not anticipated to have a significant impact on Segment 1, Alternative A.

Portions of Segment 1, Alternative A are underlain by crystalline bedrock, and other rock types that may be hard. Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered. The relative potential impact of excavation difficulties in this segment, presented in Table 18, is considered moderate. A more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

Ground Fissures

Ground fissures have not been identified in Segment 1, Alternative A on the geologic references reviewed for the study area. Accordingly, the potential ground fissure hazard, as discussed in Section 4.2.6., is not anticipated to have a significant impact on this segment.

Shallow Groundwater

Shallow groundwater may be anticipated along portions of Segment 1, Alternative A, since this segment travels along the bank of the Mojave River in an area with reported shallow groundwater. Due to this potential for shallow groundwater, the relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered high. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations, below ground structures, and can impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation, as described in Section 6.2.7., should be undertaken to assess the groundwater conditions along the Alignment so that earthwork and foundation systems can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.7.

4.3.1.4. Construction Period Segment 1, Alternative B

Settlement (Natural Soils and Undocumented Fills)

The surficial geology of Segment 1, Alternative B, is highly variable and includes Mesozoic and older crystalline basement rock and metavolcanic rock interfingered with younger and older alluvial deposits. The alluvium may contain compressible layers. Areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1., to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Corrosive Soils

The corrosive soils hazard for this segment is the same as for Segment 1, Alternative A. A more detailed evaluation, as described in Section 6.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

Potentially expansive soils may be present along Segment 1, Alternative B. The relative potential impact of expansive soils in this segment, presented in Table 18, is considered moderate. Accordingly, a more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Landslides

Much of Segment 1, Alternative B travels across areas of relatively gentle to moderate topography, and across previously undeveloped areas, and the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered moderate. In areas of moderate to steep topography, a higher potential for landslides and surficial slope failures exists. Landslides can cause damage to the rail alignment, deep foundations and other structures that are upon or impacted by a landslide, as discussed in Section 4.2.4. Stability analysis of slope areas within the segment, including constructed cut and fill slopes, rail embankments, and natural slopes should be evaluated during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Caliche/Hard Rock Excavation

The relative potential impact of excavation difficulties in this segment is the same as for Segment 1, Alternative A, and, as presented in Table 18, is considered moderate. Accordingly, a more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

Ground Fissures

Ground fissures have not been identified in Segment 1, Alternative B on the geologic references reviewed for the study area. Accordingly, the potential ground fissure hazard, as discussed in Section 4.2.6., is not anticipated to have a significant impact on this segment.

Shallow Groundwater

Although shallow groundwater was not indicated in Segment 1, Alternative B in information reviewed, areas of potentially shallow groundwater may exist. The relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered low. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations and below ground structures, such as for the proposed aerial guideways in this segment, and can impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation as described in Section 6.2.7., should be undertaken to assess the groundwater conditions along the Alignment so that earthwork and foundation systems can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.7.

4.3.2. Segment 2 (Lenwood to Yermo, California)

4.3.2.1. Operational Period Segment 2, Alternative A

Surface Fault Rupture

Segment 2, Alternative A, crosses the active zone of the Lockhart-Lenwood fault north of Lenwood. The Lenwood fault to the southeast of this segment is zoned by the State of California as an Earthquake Fault Zone. Segment 2, Alternative A, crosses the concealed trace of the active Mt. General fault, zoned by the State of California as an Earthquake Fault Zone. Segment 2, Alternative A, crosses the concealed trace of a potentially active portion of the Gravel Hills-Harper Lake fault. Due to the proximity of these active faults crossing the proposed Alignment, the relative potential impact of surface fault rupture in this segment, presented in Table 18, is considered high. Since surface fault rupture could cause detrimental damage to project improvements, as described in Section 4.1.1, a more detailed evaluation, as described in Section 6.1.1, should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential fault-rupture hazard. Mitigation measures to reduce the potential fault-rupture hazard are presented in Section 6.1.1.

Ground Shaking

Due to the proximity to nearby active faults, the potential for strong ground motions to occur along Segment 2, Alternative A, is significant, and the relative potential impact of ground shaking in this segment, presented in Table 18, is considered high. Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.5g to 0.6g could be anticipated along this segment. Since this level of ground shaking can cause detrimental damage to project improvements, as described in Section 4.1.2, the potential for relatively high seismic accelerations will need to be evaluated in the design of the proposed improvements, as described in Section 6.1.2. Mitigation of the potential ground shaking hazard can be achieved through measures described in Section 6.1.2.

Liquefaction

Segment 2, Alternative A, is located in the Mojave River Valley, crosses the Mojave River, and travels along the banks of the river in an area with reported shallow groundwater and by soils that have a potential for liquefaction. Due to these factors, the relative potential impact of liquefaction in this segment, presented in Table 18, is considered high. Liquefaction could cause significant damage to the proposed rail improvements, as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

Segment 2, Alternative A travels adjacent to the Mojave River, which is the projected course of inundation flow due to dam failure. Since this segment is adjacent to the projected inundation course, the relative potential impact of dam inundation in this segment, presented in Table 18, is considered moderate. Due to the regulatory monitoring of dams and typical flood control measures that may exist, it is anticipated that the inundation effect would not be significant. If inundation were to occur, the effect would be temporary, and may necessitate minor maintenance to make the rail system operational.

4.3.2.2. Operational Period Segment 2, Alternative B

Surface Fault Rupture

Based on geologic and seismic maps reviewed, no active faults cross the Alignment in Segment 2, Alternative B. Accordingly, the potential surface fault rupture hazard discussed in section 4.1.1. is not anticipated to have a significant impact on Segment 2, Alternative B.

Ground Shaking

Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.5g to 0.6g could be anticipated along this segment. The ground shaking hazard for this alternative is the same as for Segment 2, Alternative A. Mitigation measures to reduce the potential ground shaking hazard are presented in Section 6.1.2.

Liquefaction

Segment 2, Alternative B, is located in the Mojave River Valley in an area with reported shallow groundwater and by soils that have a potential for liquefaction. Due to these factors, the relative potential impact of liquefaction in this segment, presented in Table 18, is considered high. Liquefaction could cause significant damage to the proposed rail improvements, as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

The potential for dam inundation for this segment is the same as for Segment 2, Alternative A. Due to the regulatory monitoring of dams and typical flood control measures that may exist, it is anticipated that the inundation effect would not be significant. The effect would be temporary, and may necessitate minor maintenance to make the rail system operational.

4.3.2.3. Construction Period Segment 2, Alternative A

Settlement (Natural Soils and Undocumented Fills)

As indicated on geologic maps reviewed, the surficial geology of Segment 2, Alternative A, is highly variable and includes Mesozoic and older crystalline basement rocks, metavolcanic rocks and Tertiary lithified volcanic and sedimentary rocks interfingered with younger and older alluvial deposits, including potentially compressible clays. The alluvium may contain compressible layers. Areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate.

Compressible natural soils and undocumented fills pose the risk of adverse settlement under static loads imposed by new embankment fills, shallow foundations for proposed rail system and associated structures. As discussed is Section 4.1.8, differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1, to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Corrosive Soils

Corrosive soils, especially in areas of shallow groundwater that are reported in portions of Segment 2, Alternative A, can present a corrosion hazard to concrete and metal foundations, utilities, and other buried improvements. A more detailed evaluation, as described in Section 6.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

Potentially expansive soils may be present along Segment 2, Alternative A. The relative potential impact of expansive soils in this segment, presented in Table 18, is considered high due to clay units mapped in this segment. Expansive soils can undergo volumetric changes in response to moisture changes and could cause detrimental damage to improvements. Accordingly, a more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Landslides

Much of Segment 2, Alternative A travels across areas of relatively gentle to moderate topography, and the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered moderate. In areas of moderate to steep topography, a higher potential for landslides exists. Landslides can cause damage to the rail alignment, foundations and other structures that are upon or impacted by a landslide, as discussed in Section 4.2.4. Stability analysis of slope areas within the project study area, including proposed cut slopes, fill slopes and rail embankments should be evaluated during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Caliche/Hard Rock Excavation

Caliche layers have not been identified in Segment 2, Alternative A on the geologic references reviewed for the study area. Accordingly, the potential for excavation difficulties due to caliche is not anticipated to affect Segment 2, Alternative A.

Based on our review of geologic maps of the Alignment study area, portions of Segment 2, Alternative A are underlain by crystalline bedrock, and other rock types that may be hard. Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered. The relative potential impact of excavation difficulties in this segment, presented in Table 18, is considered moderate. A more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

Ground Fissures

Ground fissures have not been identified in Segment 2, Alternative A on the geologic references reviewed for the study area. Accordingly, the potential ground fissure hazard discussed in section 4.2.6., is not anticipated to affect Segment 2, Alternative A.

Shallow Groundwater

Shallow groundwater may be anticipated along portions of Segment 2, Alternative A, since this segment travels along the banks of the Mojave River in an area with reported shallow groundwater. Due to this potential for shallow groundwater, the relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered high. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations and below ground structures, such as for the proposed bridge across the Mojave River; and can impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation as described in Section 6.2.7., should be undertaken to assess the groundwater conditions along the Alignment so that earthwork and foundation systems can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.7.

4.3.2.4. Construction Period Segment 2, Alternative B

Settlement (Natural Soils and Undocumented Fills)

As indicated on geologic maps reviewed, the surficial geology of Segment 2, Alternative B, is highly variable and includes Mesozoic and older crystalline basement rocks, metavolcanic rocks and Tertiary lithified volcanic and sedimentary rocks interfingered with younger and older alluvial deposits. The alluvium may contain compressible layers, including potentially compressible clays. Areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate.

Compressible natural soils and undocumented fills pose the risk of adverse settlement under static loads imposed by new embankment fills, shallow foundations for proposed rail system and associated structures. As discussed is Section 4.2.1., differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1, to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Corrosive Soils

The corrosive soils hazard for this segment is the same as for Segment 2, Alternative A. A more detailed evaluation, as described in Section 6.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

The expansive soils hazard for this segment is the same as for Segment 2, Alternative A. A more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Landslides

Much of Segment 2, Alternative B travels across areas of relatively gentle topography with the exception of a hilly area of moderate topography at the west end of the segment. Since the topography is gentle across much of this segment, the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered low. In areas of moderate to steep topography, a higher potential for landslides exists. Landslides can cause damage to the rail alignment, foundations and other structures that are upon or impacted by a landslide, as discussed in Section 4.2.4. Stability analysis of slope areas within the project study area, including proposed cut slopes, fill slopes, rail embankments, and natural slopes should be evaluated during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Caliche/Hard Rock Excavation

Caliche layers have not been identified in Segment 2, Alternative B on the geologic references reviewed for the study area. Accordingly, the potential for excavation difficulties due to caliche is not anticipated to affect Segment 2, Alternative B.

Based on our review of geologic maps of the Alignment study area, portions of Segment 2, Alternative B are underlain by volcanic bedrock, and other rock types that may be hard. Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered. The relative potential impact of excavation difficulties in this segment, presented in Table 18, is considered moderate. A more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

Ground Fissures

Ground fissures have not been identified in Segment 2, Alternative B on the geologic references reviewed for the study area. Accordingly, the potential ground fissure hazard discussed in Section 4.2.6., is not anticipated to affect Segment 2, Alternative B.

Shallow Groundwater

Shallow groundwater may be anticipated along portions of Segment 2, Alternative B, since this segment travels in the Mojave River valley in an area with reported shallow groundwater. Due to this potential for shallow groundwater, the relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered high. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations and below ground structures, such as for the proposed aerial guideways in this segment; and can impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation as described in Section 6.2.7., should be undertaken to assess the groundwater conditions along the Alignment so that earthwork and foundation systems can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.7.

4.3.3. Segment 3 (Yermo to Mountain Pass, California)

4.3.3.1. Operational Period Segment 3, Alternatives A and B

Surface Fault Rupture

Segment 3, Alternatives A and B, cross the concealed trace of the active Calico-Hidalgo fault, zoned by the State of California as an Earthquake Fault Zone. Segment 3, Alternatives A and B, cross an active portion of the Manix fault. Segment 3, Alternatives A and B, cross an unnamed (Cronese Valley), concealed fault, and cross the potentially active Baker fault. Due to the proximity of these active and potentially active faults crossing the proposed Alignment, the relative potential impact of surface fault rupture in this segment, presented in Table 18, is considered high. Since surface fault rupture could cause detrimental damage to project improvements, as described in Section 4.1.1, a more detailed evaluation, as described in Section 6.1.1., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential fault-rupture hazard. Mitigation of the potential fault-rupture hazard such as locating improvements away from the fault trace and designing the improvements for rupture can be achieved through measures described in Section 6.1.1.

Ground Shaking

Due to the proximity to nearby active faults, the potential for strong ground motions to occur along Segment 3, Alternatives A and B, is significant, and the relative potential impact of ground shaking in this segment, presented in Table 18, is considered moderate to high. Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.5g to 0.6g could be anticipated along this segment southwest of Manix. Between Manix and Baker along Segment 3, peak horizontal ground accelerations on the order of 0.3g to 0.5g could be anticipated. Northeast of Baker, peak horizontal ground accelerations on the order of 0.2g to 0.3g could be anticipated along this segment. Since this level of ground shaking can cause detrimental damage to project improvements, as described in Section 4.1.2, the potential for relatively high seismic accelerations will need to be evaluated in the design of the proposed improvements, as described in Section 6.1.2. Mitigation of the potential ground shaking hazard can be achieved through measures described in Section 6.1.2.

Liquefaction

Segment 3, Alternatives A and B, crosses the Mojave River Valley, Soda Lake, Valley Wells, and other areas with reported shallow groundwater and by soils that have a potential for liquefaction. Due to these factors, the relative potential impact of liquefaction in this segment, presented in Table 18, is considered moderate to high. Liquefaction could cause significant damage to the proposed rail improvements, as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

The potential for dam inundation to affect portions of Segment 3, Alternatives A and B has been identified by the County of San Bernardino, since this segment travels near the Mojave River and across Soda Lake, the projected course of inundation flow due to dam failure. Since this segment is adjacent to the projected inundation course, the relative potential impact of dam inundation in this segment, presented in Table 18, is considered moderate. Due to the regulatory monitoring of dams and typical flood control measures that may exist, it is anticipated that the inundation effect would not be significant. The effect would be temporary, and may necessitate minor maintenance to make the rail system operational.

4.3.3.2. Construction Period Segment 3, Alternatives A and B

Settlement (Natural Soils and Undocumented Fills)

As indicated on geologic maps reviewed, the surficial geology of Segment 3, Alternatives A and B, is highly variable and includes Mesozoic and older crystalline basement rocks, metavolcanic rocks and Tertiary lithified volcanic and sedimentary rocks interfingered with younger and older alluvial deposits. The alluvium may contain compressible layers, including potentially compressible clays. Areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate.

Compressible natural soils and undocumented fills pose the risk of adverse settlement under static loads imposed by new embankment fills, shallow foundations for proposed rail system and associated structures. As discussed is Section 4.2.1., differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1, to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Corrosive Soils

Potentially corrosive soils may be present along Segment 3, Alternatives A and B. Corrosive soils, especially in areas of shallow groundwater that are reported in portions of Segment 3, Alternatives A and B, can present a corrosion hazard to concrete and metal foundations, utilities, and other buried improvements. A more detailed evaluation, as described in Section 6.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

Potentially expansive soils may be present along Segment 3, Alternatives A and B. The relative potential impact of expansive soils in this segment, presented in Table 18, is considered moderate. Expansive soils can undergo volumetric changes in response to moisture changes and could cause detrimental damage to improvements, as described in Section 4.2.3. Accordingly, a more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Landslides

Much of Segment 3, Alternatives A and B travels across areas of relatively gentle to moderate topography, and the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered moderate. In areas of moderate to steep topography, a higher potential for landslides exists. Landslides can cause damage to the rail alignment, foundations and other structures that are upon or impacted by a landslide, as discussed in Section 4.2.4. Slope areas within the project study area, including constructed cut slopes, fill slopes and rail embankments could potentially be affected by surficial slope failures, as discussed in section 4.2.4. Accordingly, the potential for landslides and surficial slope failures to affect this segment of the project should be evaluated during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Caliche/Hard Rock Excavation

Caliche layers have not been identified in Segment 3, Alternatives A and B on the geologic references reviewed for the study area. Accordingly, the potential for excavation difficulties due to caliche is not anticipated to affect Segment 3, Alternatives A and B.

Based on our review of geologic maps of the Alignment study area, portions of Segment 3, Alternatives A and B are underlain by crystalline and volcanic bedrock, and other rock types that may be hard. Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered. The relative potential impact of excavation difficulties in this segment, presented in Table 18, is considered moderate. A more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

Ground Fissures

Ground fissures have not been identified in Segment 3, Alternatives A and B on the geologic references reviewed for the study area. Accordingly, the potential ground fissure hazard discussed in section 4.2.6., is not anticipated to affect Segment 3, Alternatives A and B.

Shallow Groundwater

Shallow groundwater may be anticipated along portions of Segment 3, Alternatives A and B, since this segment crosses the Mojave River Valley, Soda Lake, Valley Wells, and other areas with reported shallow groundwater. Due to this potential for shallow groundwater, the relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered high. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations and below ground structures; and can impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation as described in Section 6.2.7., should be undertaken to assess the groundwater conditions along the Alignment so that earthwork and foundation systems can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.7.

4.3.4. Segment 4 (Mountain Pass to State Line)

4.3.4.1. Operational Period Segment 4, Alternative A

Surface Fault Rupture

Based on geologic and seismic maps reviewed, no active faults cross the Alignment in Segment 4, Alternative A. Accordingly, the potential surface fault rupture hazard discussed in section 4.1.1 is not anticipated to affect Segment 4, Alternative A.

Ground Shaking

Due to the proximity to nearby active faults, the potential for strong ground motions to occur along Segment 4, Alternative A, is significant, and the relative potential impact of ground shaking in this segment, presented in Table 18, is considered moderate to high. Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.3g to 0.4g could be anticipated along this segment in the Mountain Pass area, while peak horizontal ground accelerations on the order of 0.4g to 0.6g could be anticipated in the Ivanpah Valley area of this segment. Since this level of ground shaking can cause detrimental damage to project improvements, as described in Section 4.1.2, the potential for relatively high seismic accelerations will need to be evaluated in the design of the proposed improvements, as described in Section 6.1.2. Mitigation of the potential ground shaking hazard can be achieved through measures described in Section 6.1.2.

Liquefaction

Segment 4, Alternative A, travels along the Wheaton Wash area and across the Ivanpah Valley, and, although shallow groundwater was not indicated in these areas in information reviewed, potentially shallow groundwater may exist. Soils with a potential for liquefaction may exist in this segment, and the relative potential impact of liquefaction in this segment, presented in Table 18, is considered low. Liquefaction could cause significant damage to the proposed rail improvements, as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

Based on information reviewed, the potential for dam inundation to affect Segment 4, Alternative A is remote since the potential inundation area associated with the Mojave River ends in Soda Lake in Segment 3. Accordingly, the potential dam inundation hazard discussed in Section 4.1.4. is not anticipated to affect Segment 4, Alternative A.

4.3.4.2. Operational Period Segment 4, Alternative B

Surface Fault Rupture

Based on geologic and seismic maps reviewed, no active faults cross the Alignment in Segment 4, Alternative B. Accordingly, the potential surface fault rupture hazard discussed in section 4.1.1. is not anticipated to affect Segment 4, Alternative A.

Ground Shaking

Due to the proximity to nearby active faults, the potential for strong ground motions to occur along Segment 4, Alternative B, is significant, and the relative potential impact of ground shaking in this segment, presented in Table 18, is considered moderate to high. Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.3g to 0.4g could be anticipated along this segment in the Mountain Pass area, while peak horizontal ground accelerations on the order of 0.4g to 0.6g could be anticipated in the Ivanpah Valley area of this segment. Since this level of ground shaking can cause detrimental damage to project improvements, as described in Section 4.1.2, the potential for relatively high seismic accelerations will need to be evaluated in the design of the proposed improvements, as described in Section 6.1.2. Mitigation of the potential ground shaking hazard can be achieved through measures described in Section 6.1.2.

Liquefaction

Segment 4, Alternative B, crosses the Ivanpah Valley, and, although shallow groundwater was not indicated in this area in information reviewed, potentially shallow groundwater may exist. Soils with a potential for liquefaction may exist in this segment, and the relative potential impact of liquefaction in this segment, presented in Table 16, is considered low. Liquefaction could cause significant damage to the proposed rail improvements, as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

Based on information reviewed, these is no potential for dam inundation to affect Segment 4, Alternative B since the potential inundation area associated with the Mojave River ends in Soda Lake in Segment 3. Accordingly, the potential dam inundation hazard discussed in section 4.1.4., is not anticipated to affect Segment , Alternative .

4.3.4.3. Construction Period Segment 4, Alternative A

Settlement (Natural Soils and Undocumented Fills)

As indicated on the geologic maps reviewed, the surficial geology of Segment Alternative A, is variable and includes Precambrian metamorphic basement rocks mantled with younger and older alluvial deposits. The alluvium may contain compressible layers. Areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate.

Compressible natural soils and undocumented fills pose the risk of adverse settlement under static loads imposed by new embankment fills, shallow foundations for proposed rail system and associated structures. As discussed is Section 4.2.1., differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1., to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Corrosive Soils

Potentially corrosive soils may be present along Segment 4, Alternative A. Corrosive soils, especially in areas of shallow groundwater that may exist in portions of Segment 4, Alternative A, can present a corrosion hazard to concrete and metal foundations, utilities, and other buried improvements. A more detailed evaluation, as described in Section 6.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

Potentially expansive soils may be present along Segment 4, Alternative A. The relative potential impact of expansive soils in this segment, presented in Table 18, is considered moderate. Expansive soils can undergo volumetric changes in response to moisture changes and could cause detrimental damage to improvements, as described in Section 4.2.3. Accordingly, a more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Landslides

Portions of Segment 4, Alternative A travels across areas of relatively gentle to moderate topography, and the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered moderate. In areas of moderate to steep topography, a higher potential for landslides exists. Landslides can cause damage to the rail alignment, foundations and other structures that are upon or impacted by a landslide, as discussed in Section 4.2.4. Stability analysis of slope areas within the project study area, including natural slopes, and proposed cut slopes, fill slopes and rail embankments should be performed during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Caliche/Hard Rock Excavation

Caliche layers have not been identified in Segment 4, Alternative A on the geologic references reviewed for the study area. Accordingly, the potential for excavation difficulties due to caliche is not anticipated to affect Segment 4, Alternative A.

Based on our review of geologic maps of the Alignment study area, portions of Segment 4, Alternative A are underlain by crystalline bedrock. Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered. The relative potential impact of excavation difficulties in this segment, presented in Table 18, is considered moderate. A more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

Ground Fissures

Ground fissures have not been identified in Segment 4, Alternative A on the geologic references reviewed for the study area. Accordingly, the potential ground fissure hazard discussed in Section 4.2.6., is not anticipated to affect Segment 4, Alternative A.

Shallow Groundwater

Although not reported in information reviewed, shallow groundwater may be anticipated along portions of Segment 4, Alternative A, and the relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered low. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations and below ground structures, and can impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation as described in Section 6.2.7., should be undertaken to assess the groundwater conditions along the Alignment so that earthwork and foundation systems can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.7.

4.3.4.4. Construction Period Segment 4, Alternative B

Settlement (Natural Soils and Undocumented Fills)

As indicated on the geologic maps reviewed, the surficial geology of Segment 4, Alternative B, is variable and includes Precambrian metamorphic basement rocks mantled with younger and older alluvial deposits. The alluvium may contain compressible layers. Some areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate.

Compressible natural soils and undocumented fills pose the risk of adverse settlement under static loads imposed by new embankment fills, shallow foundations for proposed rail system and associated structures. As discussed is Section 4.2.1., differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1., to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Corrosive Soils

Potentially corrosive soils may be present along Segment 4, Alternative B. Corrosive soils, especially in areas of shallow groundwater that may exist in portions of

Segment 4, Alternative B, can present a corrosion hazard to concrete and metal foundations, utilities, and other buried improvements, including the tunnel structures. A more detailed evaluation, as described in Section 6.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

Potentially expansive soils may be present along Segment 4, Alternative B. The relative potential impact of expansive soils in this segment, presented in Table 18, is considered moderate. Expansive soils can undergo volumetric changes in response to moisture changes and could cause detrimental damage to improvements, including tunnel structures. Accordingly, a more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Landslides

Portions of Segment 4, Alternative B in the Clark Range cross areas of relatively steep topography, and the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered high. Landslides can cause damage to the rail alignment, foundations, tunnels and other structures that are upon or impacted by a landslide, as discussed in Section 4.2.4. The stability of natural slopes adjacent to the Alignment and proposed cut slopes, fill slopes and rail embankments should be evaluated during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Caliche/Hard Rock Excavation/Tunneling

Caliche layers have not been identified in Segment 4, Alternative B on the geologic references reviewed for the study area. Accordingly, the potential for excavation difficulties due to caliche is not anticipated to affect Segment 4, Alternative B.

Based on our review of geologic maps of the Alignment study area, portions of Segment 4, Alternative B are underlain by metamorphic gneiss bedrock. Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered. Tunneling through the east side of the Clark Mountain Range, through this metamorphic gneiss rock unit, is planned for Segment 4, Alternative B.

The maps indicated that the planned tunneling will pass through faulted rock. Information regarding conditions of this rock at the locations of the proposed tunneling was not available; some information from Caltrans borings nearby this area is available. The conditions of this area with regard to aspects of tunneling should be evaluated prior to design of the tunnels.

The relative potential impact of excavation difficulties in this segment, presented in Table 18, is considered high, due to proposed tunneling. A more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

Ground Fissures

Ground fissures have not been identified in Segment 4, Alternative B on the geologic references reviewed for the study area. Accordingly, the potential ground fissure hazard discussed in Section 4.2.6., is not anticipated to affect Segment 4, Alternative B.

Shallow Groundwater

Although not reported in information reviewed, shallow groundwater may be anticipated along portions of Segment 4, Alternative B, and the relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered high due to the proposed tunnels. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations and below ground structures, tunnel excavation, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation as described in Section 6.2.5., should be undertaken to assess the groundwater conditions along the Alignment so that tunneling excavation, foundation systems and earthwork can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.5.

4.3.5. Segment 5 (State Line to Sloan, Nevada)

4.3.5.1. Operational Period Segment 5, Alternatives A and B

Surface Fault Rupture

Based on geologic and seismic maps reviewed, no active faults cross the Alignment in Segment 5, Alternatives A and B. Accordingly, the potential surface rupture hazard discussed in Section 4.1.1. is not anticipated to affect Segment 5, Alternatives A and B.

Ground Shaking

Due to the proximity to nearby active faults, the potential for strong ground motions to occur along Segment 5, Alternatives A and B, is significant, and the relative potential impact of ground shaking in this segment, presented in Table 18, is considered low to high, depending on location; the farther north in this segment reduces the relative impact of ground shaking. Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.2g to 0.6g could be anticipated along this segment in the Ivanpah Valley area, while peak horizontal ground accelerations on the order of 0.1g to 0.2g could be anticipated along this segment north of the Ivanpah Valley area of this segment. Since this level of ground shaking can cause detrimental damage to project improvements, as described in Section 4.1.2, the potential for relatively high seismic accelerations will need to be evaluated in the design of the proposed improvements, as described in Section 6.1.2. Mitigation of the potential ground shaking hazard can be achieved through measures described in Section 6.1.2.

Liquefaction

Segment 5, Alternatives A and B, cross the Ivanpah Valley, and, although shallow groundwater was not indicated in this area in information reviewed, potentially shallow groundwater may exist. Soils with a potential for liquefaction may exist in this segment, and the relative potential impact of liquefaction in this segment, presented in Table 18, is considered low. Liquefaction could cause significant damage to the proposed rail improvements, as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

Based on information reviewed, the potential for dam inundation to affect Segment 5, Alternatives A and B is remote. Accordingly, the potential dam inundation hazard discussed in Section 4.1.4., is not anticipated to affect Segment 5, Alternatives A and B.

4.3.5.2. Construction Period Segment 5, Alternatives A and B

Settlement (Natural Soils and Undocumented Fills)

As indicated on geologic maps reviewed, the surficial geology of Segment 5, Alternatives A and B, is variable and predominantly includes younger and older alluvial deposits overlying Tertiary volcanic and sedimentary rocks and Paleozoic limestone/carbonate rocks. The alluvium may contain compressible layers. Areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate.

Compressible natural soils and undocumented fills pose the risk of adverse settlement under static loads imposed by new embankment fills, shallow foundations for proposed rail system and associated structures. As discussed is Section 4.2.1., differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1., to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Landslides

Much of Segment 5, Alternatives A and B cross areas of relatively gentle to moderate topography, and the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered moderate. In areas of moderate to steep topography, a higher potential for landslides exists. Landslides can cause damage to the rail alignment, foundations and other structures that are upon or impacted by a landslide, as discussed in Section 4.2.4. Slope areas within the project study area, including proposed cut slopes, fill slopes and rail embankments could potentially be affected by surficial slope failures. Accordingly, the potential for landslides and surficial slope failures to affect this segment of the project should be evaluated during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Corrosive Soils

Potentially corrosive soils may be present along Segment 5, Alternatives A and B. Corrosive soils, especially in areas of shallow groundwater that may exist in portions of Segment 5, Alternatives A and B, can present a corrosion hazard to concrete and metal foundations, utilities, and other buried improvements. A more detailed evaluation, as described in Section 6.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

Potentially expansive soils may be present along Segment 5, Alternatives A and B. The relative potential impact of expansive soils in this segment, presented in Table 18, is considered moderate. Expansive soils can undergo volumetric changes in response to moisture changes and could cause detrimental damage to improvements. Accordingly, a more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Ground Fissures

Ground fissures have not been identified in Segment 5, Alternatives A and B on the geologic references reviewed for the study area. However, according to information reviewed, ground fissures may be present in this part of Nevada. The relative impact of potential ground fissure hazard in this segment, presented in Table 18, is considered moderate. Accordingly, a more detailed evaluation, as described in Section 6.2.6., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential ground fissure hazard. Mitigation of the potential expansive ground fissure hazard can be achieved through measures described in Section 6.2.6.

Shallow Groundwater

Although not reported in information reviewed, shallow groundwater may be anticipated along portions of Segment 5, Alternatives A and B, and the relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered low. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations and below ground structures; and can impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation as described in Section 6.2.7 should be undertaken to assess the groundwater conditions along the Alignment so that earthwork and foundation systems can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.7.

Caliche/Hard Rock Excavation

Caliche layers may be present in Segment 5, Alternatives A and B based on the geologic references reviewed for the study area, and the relative potential impact for excavation difficulties due to caliche in Segment 5, Alternatives A and B, presented in Table 18, is considered moderate. Caliche layers contain calcareous cementation which can be moderately hard, hard, and very hard and may range in thickness from a few inches to several feet. These soils may be resistant to excavation, and may pose an impact on construction techniques for both shallow and deep improvements for the rail system in the Las Vegas Valley and surrounding region.

Based on our review of geologic maps of the Alignment study area, portions of Segment 5, Alternatives A and B are underlain by limestone and volcanic bedrock, and other rock types that may be hard. Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered. The relative potential impact of excavation difficulties in this segment, presented in Table 18, is considered moderate. A more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

4.3.6. Segment 6 (Sloan to Las Vegas, Nevada)

4.3.6.1. Operational Period Segment 6, Alternatives A and B

Surface Rupture

Based on geologic and seismic maps reviewed, no active faults cross the Alignment in Segment 6, Alternatives A and B. Accordingly, the potential surface rupture hazard discussed in Section 4.1.1., is not anticipated to affect Segment 6, Alternatives A and B.

Ground Shaking

There is a potential for moderately strong ground motions to occur along Segment 6, Alternatives A and B, and the relative potential impact of ground shaking in this segment, presented in Table 18, is considered low. Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.1g to 0.2g could be anticipated along this segment. The potential for relatively moderate seismic accelerations will need to be evaluated in the design of the proposed improvements, as described in Section 6.1.2. Mitigation of the potential ground shaking hazard can be achieved through measures described in Section 6.1.2.

Liquefaction

Since Segment 6, Alternatives A and B, travels across the Las Vegas Valley where the potential for shallow groundwater (at the north end of the segment) and soils with a potential for liquefaction exist, the relative potential impact of liquefaction in this segment, presented in Table 18, is considered moderate. Liquefaction could cause significant damage to the proposed rail improvements, as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

Based on information reviewed, the potential for dam inundation to affect Segment 6, Alternatives A and B is remote. Accordingly, the potential dam inundation hazard discussed in Section 4.1.4. is not anticipated to affect Segment 6, Alternatives A and B.

4.3.6.2. Construction Period Segment 6, Alternatives A and B

Settlement (Natural Soils and Undocumented Fills)

As indicated on geologic maps reviewed, the surficial geology of Segment 6, Alternatives A and B, is variable and predominantly includes younger and older alluvial deposits. Some Paleozoic limestone/carbonate rocks are present at the south end of this segment. The alluvium may contain compressible layers. Areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate.

Compressible natural soils and undocumented fills pose the risk of adverse settlement under static loads imposed by new embankment fills, shallow foundations for proposed rail system and associated structures. As discussed is Section 4.2.1., differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1, to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Corrosive Soils

Potentially corrosive soils may be present along Segment 6, Alternatives A and B. Corrosive soils, especially in areas of shallow groundwater that are reported in portions of Segment 6, Alternatives A and B, can present a corrosion hazard to concrete and metal foundations, utilities, and other buried improvements. A more detailed evaluation, as described in Section 6.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

Potentially expansive soils may be present along Segment 6, Alternatives A and B. The relative potential impact of expansive soils in this segment, presented in Table 18, is considered moderate. Expansive soils can undergo volumetric changes in response to moisture changes and could cause detrimental damage to improvements. Accordingly, a more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Landslides

Much of Segment 6, Alternatives A and B travels across areas of relatively gentle topography in the Las Vegas Valley, and the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered moderate. In areas of moderate to steep topography, a higher potential for landslides exists. Landslides can cause damage to the rail alignment, foundations and other structures that are upon or impacted by a landslide, as discussed in Section 4.2.4. Slope areas within the project study area, including constructed cut slopes, fill slopes and rail embankments could potentially be affected by surficial slope failures. Accordingly, the potential for landslides and surficial slope failures to affect this segment of the project should be evaluated during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Caliche/Hard Rock Excavation

Caliche layers may be present in Segment 6, Alternatives A and B in the Las Vegas Valley based on the geologic references reviewed for the study area, and the relative potential impact for excavation difficulties due to caliche in Segment 6, Alternatives A and B, presented in Table 18, is considered high. Caliche layers contain calcareous cementation which can be moderately hard, hard, and very hard and may range in thickness from a few inches to several feet. These soils may be resistant to excavation, and may pose an impact on construction techniques for both shallow and deep improvements for the rail system in the Las Vegas Valley.

Additionally, the southern portions of Segment 6, Alternatives A and B are underlain by limestone bedrock that may be hard, based on our review of geologic maps of the Alignment study area. Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered. A more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

Ground Fissures

Ground fissures have been mapped in portions of the Las Vegas Valley in the vicinity of Segment 6, Alternatives A and B on the geologic references reviewed for the study area. Accordingly, the relative impact of potential ground fissure hazard in this segment, presented in Table 18, is considered high. A more detailed evaluation, as described in Section 6.2.6., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential ground fissure hazard. Mitigation of the potential ground fissure hazard can be achieved through measures described in Section 6.2.6.

Shallow Groundwater

Shallow groundwater may be anticipated along northern portions of Segment 6, Alternatives A and B, and the relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered moderate. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations such as for aerial guideways; and can impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation as described in Section 6.2.7., should be undertaken to assess the groundwater conditions along the Alignment so that earthwork and foundation systems can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.7.

4.3.6.3. Operational Period Segment 6, Alternatives C and D

Surface Fault Rupture

Based on geologic and seismic maps reviewed, no active faults cross the Alignment in Segment 6, Alternatives C and D. Accordingly, the potential surface rupture hazard discussed in section 4.1.1. is not anticipated to affect Segment 6, Alternatives C and D.

Ground Shaking

There is a potential for moderately strong ground motions to occur along Segment 6, Alternatives C and D, and the relative potential impact of ground shaking in this segment, presented in Table 18, is considered low. Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.1g to 0.2g could be anticipated along this segment. Since this level of ground shaking can cause detrimental damage to project improvements, as described in Section 4.1.2., the potential for relatively moderate seismic accelerations will need to be evaluated in the design of the proposed improvements, as described in Section 6.1.2. Mitigation of the potential ground shaking hazard can be achieved through measures described in Section 6.1.2.

Liquefaction

Since Segment 6, Alternatives C and D, travels across the Las Vegas Valley where the potential for shallow groundwater (at the north end of the segment) and soils with a potential for liquefaction exist, the relative potential impact of liquefaction in this segment, presented in Table 18, is considered moderate. Liquefaction could cause significant damage to the proposed rail improvements, as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

Based on information reviewed, the potential for dam inundation to affect Segment 6, Alternatives C and D is remote. Accordingly, the potential dam inundation hazard discussed in Section 4.1.4. is not anticipated to affect Segment 6, Alternatives A and B.

4.3.6.4. Construction Period Segment 6, Alternatives C and D

Settlement (Natural Soils and Undocumented Fills)

As indicated on geologic maps reviewed, the surficial geology of Segment 6, Alternatives C and D, is variable and predominantly includes younger and older alluvial deposits. Some Paleozoic limestone/carbonate rocks are present at the south end of this segment. The alluvium may contain compressible layers. Areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate.

Compressible natural soils and undocumented fills pose the risk of adverse settlement under static loads imposed by new embankment fills, shallow foundations for proposed rail system and associated structures. As discussed is Section 4.2.1., differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1, to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Corrosive Soils

Potentially corrosive soils may be present along Segment 6, Alternatives C and D. Corrosive soils, especially in areas of shallow groundwater that are reported in portions of Segment 6, Alternatives C and D, can present a corrosion hazard to concrete and metal foundations, utilities, and other buried improvements. A more detailed evaluation, as described in Section 6.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

Potentially expansive soils may be present along Segment 6, Alternatives C and D. The relative potential impact of expansive soils in this segment, presented in Table 18, is considered moderate. Expansive soils can undergo volumetric changes in response to moisture changes and could cause detrimental damage to improvements. Accordingly, a more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Landslides and Surficial Slope Failures

Much of Segment 6, Alternatives C and D travels across areas of relatively gentle topography in the Las Vegas Valley, except for a hilly area at the south end of the segment, and the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered moderate. In areas of moderate to steep topography, a higher potential for landslides exists. Landslides can cause damage to the rail alignment, foundations and other structures that are upon or impacted by a landslide, as discussed in Section 4.2.4. Slope areas within the project study area, including proposed cut slopes, fill slopes and rail embankments should be evaluated during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Caliche/Hard Rock Excavation

Caliche layers may be present in Segment 6, Alternatives C and D in the Las Vegas Valley based on the geologic references reviewed for the study area, and the relative potential impact for excavation difficulties due to caliche in Segment 6, Alternatives C and D, presented in Table 18, is considered high. Caliche layers contain calcareous cementation which can be moderately hard, hard, and very hard and may range in thickness from a few inches to several feet. These soils may be resistant to excavation, and may pose an impact on construction techniques for both shallow and deep improvements for the rail system in the Las Vegas Valley.

Additionally, the southern portions of Segment 6, Alternatives C and D are underlain by limestone bedrock that may be hard, based on our review of geologic maps of the Alignment study area. Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered. A more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

Ground Fissures

Ground fissures have been mapped in portions of the Las Vegas Valley in the vicinity of Segment 6, Alternatives C and D on the geologic references reviewed for the study area. Accordingly, the relative impact of potential ground fissure hazard in this segment, presented in Table 18, is considered high. A more detailed evaluation, as described in Section 6.2.6., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential ground fissure hazard. Mitigation of the potential ground fissure hazard can be achieved through measures described in Section 6.2.6.

Shallow Groundwater

Shallow groundwater may be anticipated along northern portions of Segment 6, Alternatives C and D, and the relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered moderate. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations, and other deep structures; and can impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation as described in Section 6.2.7., should be undertaken to assess the groundwater conditions along the Alignment so that earthwork and foundation systems can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.7.

4.3.7. Segment 7 (City of Las Vegas, Nevada)

4.3.7.1. Operational Period Segment 7, Alternatives A and B

Surface Fault Rupture

Based on geologic and seismic maps reviewed, no active faults cross the Alignment in Segment 7, Alternatives A and B. Accordingly, the potential surface fault rupture hazard discussed in Section 4.1.1 is not anticipated to affect Segment 7, Alternatives A and B.

Ground Shaking

There is a potential for moderately strong ground motions to occur along Segment 7, Alternatives A and B, and the relative potential impact of ground shaking in this segment, presented in Table 18, is considered low. Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.1g to

0.2g could be anticipated along this segment. The potential for relatively moderate seismic accelerations will need to be evaluated in the design of the proposed improvements, as described in Section 6.1.2. Mitigation of the potential ground shaking hazard can be achieved through measures described in Section 6.1.2.

Liquefaction

Since Segment 7, Alternatives A and B, travels across the Las Vegas Valley where the potential for shallow groundwater underlying the segment and soils with a potential for liquefaction exist, the relative potential impact of liquefaction in this segment, presented in Table 18, is considered moderate. Liquefaction could cause significant damage to the proposed rail improvements, as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

Based on information reviewed, the potential for dam inundation to affect Segment 7, Alternatives A and B is remote. Accordingly, the potential dam inundation hazard discussed in section 4.1.4., is not anticipated to affect Segment 7, Alternatives A and B.

4.3.7.2. Construction Period Segment 7, Alternatives A and B

Settlement (Natural Soils and Undocumented Fills)

As indicated on geologic maps reviewed, the surficial geology of Segment 7, Alternatives A and B, is variable and predominantly includes younger and older alluvial deposits. The alluvium may contain compressible layers. Areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate.

Compressible natural soils and undocumented fills pose the risk of adverse settlement under static loads imposed by new embankment fills, shallow foundations for proposed rail system and associated structures. As discussed is Section 4.2.1., differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1., to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Corrosive Soils

Potentially corrosive soils may be present along Segment 7, Alternatives A and B. Corrosive soils, especially in areas of shallow groundwater that are reported in portions of Segment 7, Alternatives A and B, can present a corrosion hazard to concrete and metal foundations, utilities, and other buried improvements. A more detailed evaluation, as described in Section 4.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

Potentially expansive soils may be present along Segment 7, Alternatives A and B. The relative potential impact of expansive soils in this segment, presented in Table 18, is considered moderate. Expansive soils can undergo volumetric changes in response to moisture changes and could cause detrimental damage to improvements. Accordingly, a more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Landslides

Segment 7, Alternatives A and B travel across areas of relatively gentle topography in the Las Vegas Valley, and the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered low. Stability analysis of proposed cut slopes, fill slopes and rail embankments should be performed during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Caliche/Hard Rock Excavation

Caliche layers may be present in Segment 7, Alternatives A and B in the Las Vegas Valley based on the geologic references reviewed for the study area, and the relative potential impact for excavation difficulties due to caliche in Segment 7, Alternatives A and B, presented in Table 18, is considered high. Caliche layers contain calcareous cementation which can be moderately hard, hard, and very hard and may range in thickness from a few inches to several feet. These soils may be resistant to excavation, and may pose an impact on construction techniques for both shallow and deep improvements for the rail system in the Las Vegas Valley.

Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered. A more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

Ground Fissures

Ground fissures have been mapped in portions of the Las Vegas Valley in the vicinity of Segment 7, Alternatives A and B on the geologic references reviewed for the study area. Accordingly, the relative impact of potential ground fissure hazard in this segment, presented in Table 18, is considered high. A more detailed evaluation, as described in Section 6.2.6., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential ground fissure hazard. Mitigation of the potential ground fissure hazard can be achieved through measures described in Section 6.2.6.

Shallow Groundwater

Shallow groundwater may be anticipated along Segment 7, Alternatives A and B, and the relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered moderate. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations such as for aerial guideways; and can impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation as described in Section 6.2.7., should be undertaken to assess the groundwater conditions along the Alignment so that earthwork and foundation systems can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.7.

4.3.7.3. Operational Period Segment 7, Alternative C

Surface Fault Rupture

Based on geologic and seismic maps reviewed, no active faults cross the Alignment in Segment 7, Alternative C. Accordingly, the potential surface rupture hazard discussed in Section 4.1.1. is not anticipated to affect Segment 7, Alternative C.

Ground Shaking

There is a potential for moderately strong ground motions to occur along Segment 7, Alternative C, and the relative potential impact of ground shaking in this segment, presented in Table 18, is considered low. Based on the information provided on Figure 14, peak horizontal ground accelerations on the order of 0.1g to 0.2g could be anticipated along this segment. The potential for relatively moderate seismic accelerations will need to be evaluated in the design of the proposed improvements, as described in Section 6.1.2. Mitigation of the potential ground shaking hazard can be achieved through measures described in Section 6.1.2.

Liquefaction

Since Segment 7, Alternative C, travels across the Las Vegas Valley where the potential for shallow groundwater (at the north end of the segment) and soils with a potential for liquefaction exist, the relative potential impact of liquefaction in this segment, presented in Table 18, is considered moderate. Liquefaction could cause significant damage to the proposed rail improvements, as discussed in Section 4.1.3. Accordingly, the liquefaction potential of the soils should be evaluated during the design phase of the project, as described in Section 6.1.3. Mitigation of the potential liquefaction hazard can be achieved through measures described in Section 6.1.3.

Dam Inundation

Based on information reviewed, the potential for dam inundation to affect Segment 7, Alternative C is remote. Accordingly, the potential dam inundation hazard discussed in Section 4.1.4., is not anticipated to affect Segment 7, Alternative C.

4.3.7.4. Construction Period Segment 7, Alternative C

Settlement (Natural Soils and Undocumented Fills)

As indicated on geologic maps reviewed, the surficial geology of Segment 7, Alternative C is variable and predominantly includes younger and older alluvial deposits. The alluvium may contain compressible layers. Areas of previous development exist along this segment, and undocumented fill soils may exist. Due to the potential presence of compressible alluvium and undocumented fill along this segment, a potential for settlement under load of proposed new improvements exists, and the relative potential impact of settlement of these soils in this segment, presented in Table 18, is considered moderate.

Compressible natural soils and undocumented fills pose the risk of adverse settlement under static loads imposed by new embankment fills, shallow foundations for proposed rail system and associated structures. As discussed is Section 4.2.1., differential settlement of soils can cause damage to project improvements including concrete structures and foundations, railway alignment, retaining walls, associated station and maintenance structures and pavements. Prior to design and construction, a geotechnical evaluation should be performed as described in Section 6.2.1, to evaluate the potential settlement hazard. Mitigation of the potential settlement hazard can be achieved through measures described in Section 6.2.1.

Landslides and Surficial Slope Failures

Much of Segment 7, Alternative C travels across areas of relatively gentle topography in the Las Vegas Valley, and the relative potential impact of landslides and surficial slope failures in this segment, presented in Table 18, is considered low. Stability analysis of slope areas within the project study area, including proposed cut slopes, fill slopes and rail embankments should be evaluated during the design phase of the project, as described in Section 6.2.4. Mitigation of the potential hazard of landslides and surficial slope failures can be achieved through measures described in Section 6.2.4.

Corrosive Soils

Potentially corrosive soils may be present along Segment 7, Alternative C. Corrosive soils, especially in areas of shallow groundwater that are reported in portions of Segment 7, Alternative C, can present a corrosion hazard to concrete and metal foundations, utilities, and other buried improvements. A more detailed evaluation, as described in Section 6.2.2., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential corrosive soil hazard. Mitigation of the potential corrosive soil hazard can be achieved through measures described in Section 6.2.2.

Expansive Soils

Potentially expansive soils may be present along Segment 7, Alternative C. The relative potential impact of expansive soils in this segment, presented in Table 18, is considered moderate. Expansive soils can undergo volumetric changes in response to moisture changes and could cause detrimental damage to improvements. Accordingly, a more detailed evaluation, as described in Section 6.2.3., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential expansive soil hazard. Mitigation of the potential expansive soil hazard can be achieved through measures described in Section 6.2.3.

Caliche/Hard Rock Excavation

Caliche layers may be present in Segment 7, Alternative C in the Las Vegas Valley based on the geologic references reviewed for the study area, and the relative potential impact for excavation difficulties due to caliche in Segment 7, Alternative C, presented in Table 18, is considered high. Caliche layers contain calcareous cementation which can be moderately hard, hard, and very hard and may range in thickness from a few inches to several feet. These soils may be resistant to excavation, and may pose an impact on construction techniques for both shallow and deep improvements for the rail system in the Las Vegas Valley.

Depending on the depth of excavation into these materials, moderate to difficult excavation may be encountered. A more detailed evaluation, as described in Section 6.2.5., should be performed during the design phase of the project to evaluate the impacts associated with potential excavation difficulties. Mitigation of potential excavation difficulties can be achieved through measures described in Section 6.2.5.

Ground Fissures

Ground fissures have been mapped in portions of the Las Vegas Valley in the vicinity of Segment 7, Alternative C on the geologic references reviewed for the study area. Accordingly, the relative impact of potential ground fissure hazard in this segment, presented in Table 18, is considered high. A more detailed evaluation, as described in Section 6.2.6., should be performed during the design phase of the project to evaluate the impacts and risks associated with the potential ground fissure hazard. Mitigation of the potential ground fissure hazard can be achieved through measures described in Section 6.2.6.

Shallow Groundwater

Shallow groundwater may be anticipated along northern portions of Segment 7, Alternative C, and the relative potential impact of shallow groundwater in this segment, presented in Table 18, is considered moderate. As discussed in Section 4.2.7., shallow groundwater can impact excavations for deep foundations, and other deep structures; and can impact ground stability, and foundation design of proposed improvements, as well as the methods and costs of construction. Prior to design and construction, a geotechnical engineering evaluation as described in Section 6.2.7 should be undertaken to assess the groundwater conditions along the Alignment so that earthwork and foundation systems can be appropriately designed and constructed. Mitigation of the potential shallow groundwater hazard can be achieved through measures described in Section 6.2.7.

5. RELATIVE EFFECTS OF ENVIRONMENTAL CONSEQUENCES

The DesertXpress alternatives cross differing terrain and geologic environments that include a variety of potential seismic and geologic hazards. The following Table 18 summarizes the relative potential impacts for the alternative segments. A ratings system has been established in which the seismic and geologic consequences have been categorized by relative impact. A rating of 1 represents a relativity high potential impact, a rating of 2 represents a relatively moderate impact, and a rating of 3 represents a relatively low potential impact.

Table 18 – Relative Effects of Environmental Consequences

Segment Alternative	Potential Geotechnical Consequence										
	Surface Fault Rupture[1]	Ground Shaking[2]	Liquefaction[3]	Dam Inundation[4]	Settlement/ (Natural & Fill Soils)[5]	Corrosive Soils[6]	Expansive Soils[7]	Landslides[8]	Excavation[9]	Ground Fissures[10]	Shallow Groundwater[11]
1A	2	1	1	2	2	2	1	3	2	3	1
1B	1	1	2	3	2	2	2	2	2	3	3
2A	1	1	1	2	2	2	1	2	2	3	1
2B	3	1	1	2	2	2	1	3	2	3	1
3A and B (southwest of Baker)	1	1 to 2	1 to 2	2 to 3	2	2	2	2	2	3	1 to 2
3A and B (northeast of Baker)	3	2	1 to 2	3	2	2	2	2	2	3	1 to 3
4A	3	1 to 2	3	3	2	2	2	2	2	3	3
4B	3	1 to 2	3	3	2	2	2	1	1	3	3
5A and B	3	1 to 3	3	3	2	2	2	2	2	2	3
6A and B	3	3	2	3	2	2	2	3	1	1	2
6C and D	3	3	2	3	2	2	2	2	1	1	2
7A and B	3	3	2	3	2	2	2	3	1	1	2
7C	3	3	2	3	2	2	2	3	1	1	2

Notes:

1 Rating 1 = Route crosses active fault or very close to an active fault; Rating 2 = Route crosses potentially active fault; Rating 3 = Route crosses inactive fault or does not cross any known fault.

2 Rating 1 = Estimated peak horizontal ground acceleration (PGA) of 0.4g to 0.6g; Rating 2 = Estimated PGA of 0.2g to 0.4g; Rating 3 = Estimated PGA of 0.1g to 0.2g.

3 Rating 1 = Areas of known, reported shallow groundwater and potentially liquefiable soils; Rating 2 = Areas of potentially shallow groundwater and potentially liquefiable soils; Rating 3 = Areas with no reported shallow groundwater and with potentially liquefiable soils.

4 Rating 1 = Areas of reported dam inundation; Rating 2 = Areas near reported potential dam inundation; Rating 3 = Areas with no reported potential for dam inundation.

5 Rating 1 = Areas of reported compressible/collapsible soils; Rating 2 = Areas with potential for compressible/collapsible soils; Rating 3 = Areas with no potential for compressible/collapsible soils.

6 Rating 1 = Areas of reported corrosive soils; Rating 2 = Areas with potential for corrosive soils; Rating 3 = Areas with no potential for corrosive soils.

7 Rating 1 = Areas of mapped clay units or known expansive soils; Rating 2 = Areas with potential for expansive soils; Rating 3 = Areas with no potential for expansive soils.

8 Rating 1 = Areas of known steep terrain with relatively higher potential landslide hazard; Rating 2 = Areas of potential landslide hazard; Rating 3 = Areas of little potential landslide hazard.

9 Rating 1 = Areas of reported hard rock or caliche with anticipated difficult excavation; Rating 2 = Areas of potentially difficult excavation; Rating 3 = Areas of no potential difficult excavations.

10 Rating 1 = Areas of known, reported ground fissures in site vicinity; Rating 2 = Areas with potential for ground fissures; Rating 3 = Areas with no reported ground fissures.

11 Rating 1 = Areas of known, reported shallow groundwater; Rating 2 = Areas of potentially shallow groundwater; Rating 3 = Areas with no reported shallow groundwater.

6. MITIGATION MEASURES

A summary of mitigation measures for the potential environmental consequences related to geotechnical considerations for the proposed DesertXpress rail line is presented below. Additional evaluation of the potential geotechnical hazards and consequences discussed in this report could include geologic site reconnaissance, subsurface exploration and laboratory testing. Based on the findings from site evaluations, appropriate site specific recommendations and mitigation measures for the potential hazards and considerations can be provided.

6.1. Operational Mitigation Measures

6.1.1. Surface Fault Rupture

The regional effects and environmental consequences of potential surface fault rupture of active faults have been discussed in Section 4.1.1., and the consequences of surface fault rupture for each segment of the Alignment have been discussed in Section 4.3. To further evaluate the fault-rupture hazard along the proposed segments, surface reconnaissance and subsurface evaluation could be performed. Evaluation of fault-rupture hazard should be performed prior to design and construction so that, in the event a fault-rupture hazard exists, mitigation techniques can be implemented. Mitigation measures for potential fault rupture hazard would typically include locating rail system features away from the fault, designing for an acceptable amount of movement, or implementing systems to maintain safety and allow for displacement that could be repaired to make the system operational.

Surface reconnaissance to evaluate potential surface fault rupture would include visual observation of the earth units and geomorphology, and checking of geologic maps in order to map the estimated location and condition of faults relative to the Alignment. Ground features that may indicate the location of active faults may be concealed by natural soils, fill soils or manmade improvements, and surface reconnaissance may not be adequate to locate faults with potential for surface rupture. Consequently, subsurface exploration may be needed to evaluate fault locations and conditions. Subsurface evaluation might include the excavation and detailed logging of exploratory trenches and/or borings, geophysical studies such as high resolution seismic reflection, seismic refraction, ground penetrating radar, gravity and/or magnetic profiling or other applicable methods.

Public transportation systems throughout California and Nevada cross active faults. With the prevalence of active faulting in this seismically active region, the crossing of active faults is unavoidable. In this regard, mitigation of the surface fault hazard in some areas of the Alignment may not involve avoiding the fault, but would involve designing the system for the anticipated displacement, avoiding as much damage as possible while providing for the safety of passengers.

Mitigation measures for potential fault-rupture hazard could include various techniques. Foundations for bridges and elevated guideways, shallow rail system foundations, and foundations for stations or other structures can be located away from the fault trace to avoid the fault. Locating rail improvements a sufficient distance from active faults would limit damage to the system as long as the fault ruptures along the identified surface and does not rupture a new surface. Locating these improvements away from the fault or designing for the anticipated displacement may minimize damage to the system and non-operational time.

Measures could also be implemented to reduce the impact from surface rupture while the train is in operation. For instance, a monitoring system could be designed to monitor seismic activity in the region and provide advanced early warning of a seismic event. The monitoring system could be designed so that when strong ground shaking occurs beyond a pre-selected level, a signal could immediately be transmitted to the operating system to allow time for the train to stop. A system such as this could significantly reduce the length of time the train is in motion during a large seismic event, thus reducing the potential for derailment as a result of ground displacement caused by surface rupture.

6.1.2. Ground Shaking

The regional effects and environmental consequences of potential seismic ground shaking has been discussed in Section 4.1.2., and the consequences of ground shaking for each segment of the Alignment have been discussed in Section 4.3. Site-specific evaluation of the potential ground shaking hazard should be performed prior to design and construction so that appropriate structural design and mitigation techniques can be implemented. Site-specific geotechnical evaluations to assess the characteristics of the on-site soils with regard to ground shaking would include drilling of exploratory borings and laboratory testing of soils. Site-specific evaluation of the potential ground shaking hazard would also involve computer software evaluation to develop seismic design parameters for use by the project structural engineer.

Mitigation of the potential impacts of seismic ground shaking can be achieved through project design, construction, and maintenance. During the final design phase, site-specific geotechnical evaluations will be performed to obtain detailed subsurface soil and geological data, including the site-specific ground motion anticipated for the site. Structural elements of the rail system can then be designed to resist or accommodate appropriate site-specific ground motions and to conform to the current seismic design standards. In addition, implementation of an earthquake early warning system as described in the previous section could be used to reduce the potential impact of strong ground shaking.

6.1.3. Liquefaction

The regional effects and environmental consequences of potential liquefaction have been discussed in Section 4.1.3., and the consequences of liquefaction for each segment of the Alignment have been discussed in Section 4.3. To further evaluate the potential liquefaction hazard along the proposed segment subsurface evaluation could be performed. Site-specific evaluation of the potential liquefaction hazard should be performed prior to design and construction so that, in the event a liquefaction hazard exists, appropriate structural design and mitigation techniques can be implemented.

Site-specific geotechnical evaluations to assess the liquefaction and dynamic settlement characteristics of the on-site soils would include drilling of exploratory borings, evaluation of groundwater depths, and laboratory testing of soils.

Mitigation for liquefaction may include in-situ ground modification, removal of liquefiable layers and replacement with compacted fill, or support of piles at depths designed specifically for liquefaction. Pile foundations can be designed for liquefaction hazard by supporting the piles in dense soil or bedrock below the liquefiable zone or other appropriate methods as evaluated during the site-specific evaluation. Additional mitigation measures for liquefaction may include densification by installation of stone columns, vibration, deep dynamic compaction, and/or compaction grouting.

6.1.4. Dam Inundation

The regional effects and environmental consequences of potential dam inundation along the Mojave River have been discussed in Section 4.1.5., and the consequences of dam inundation for each segment of the Alignment have been discussed in Section 4.3. To further evaluate the potential for dam inundation to occur along the proposed segments, detailed hydrologic evaluation could be performed to assess the risks and potential effects of inundation to the Alignment. Evaluation of potential dam inundation hazard at site-specific locations could be performed prior to design and construction so that, in the event of dam inundation, measures could be in place to mitigate the effects.

Measures to mitigate the potential dam inundation could include raising the elevation of the railway at needed locations to keep the tracks above the inundation level, and/or construction of levees or walls to prevent inundation from reaching the tracks. The inundation effects are anticipated to be temporary, and may necessitate minor maintenance in the affected segments to make the rail system operational.

6.2. Construction Mitigation Measures

6.2.1. Settlement (Natural Soils and Undocumented Fill)

The regional effects and environmental consequences of settlement (of both natural soils and undocumented fill) have been discussed in Section 4.2.1., and the consequences of settlement for each segment of the Alignment have been discussed in Section 4.3. To further evaluate the potential for settlement along the proposed segments, surface reconnaissance and subsurface evaluation could be performed. Evaluation of the potential settlement hazard should be performed prior to design and construction so that, in the event the hazard exists, mitigation techniques can be implemented.

During the design phase of the project, site-specific geotechnical evaluations would be performed to assess the settlement potential of the on-site natural soils and undocumented fill. This would include drilling of exploratory borings and laboratory testing of soils, in addition to surface reconnaissance to evaluate site conditions.

Examples of possible mitigation measures for soils with potential for settlement include removal of the compressible/collapsible soil layers and replacement with compacted fill; surcharging to induce settlement prior to construction of improvements; allowing for a settlement period after or during construction; and specialized foundation design including the use of deep foundation systems to support structures. A variety of in-situ soil improvement techniques are also available, such as dynamic compaction (heavy tamping) or compaction grouting.

6.2.2. Corrosive Soils

The regional effects and environmental consequences of potential corrosive soils have been discussed in Section 4.2.2., and the consequences of corrosive soils for each segment of the Alignment have been discussed in Section 4.3. To further evaluate the potential for corrosive soils along the proposed segments, subsurface evaluation including laboratory testing could be performed. Evaluation of the potential corrosive soils hazard should be performed prior to design and construction so that, in the event the hazard exists, mitigation techniques can be implemented.

Evaluation of the corrosive soil potential can be accomplished by testing and analysis of soils at design depths. The laboratory tests conducted on the soils prior to construction and improvement plan preparation should include corrosivity tests to evaluate the corrosivity of the subsurface soils. Review of these data by a corrosion engineer would result in corrosion protection measures suitable to the project elements.

Mitigation of corrosive soil conditions may involve the use of concrete resistant to sulfate exposure. Corrosion protection for metals may be needed for underground structures in areas where corrosive groundwater or soil could potentially cause deterioration. Typical mitigation measures include epoxy and metallic protective coatings, the use of alternative (corrosion resistant) materials, and selection of the appropriate type of cement and water/cement ratio. Specific measures to mitigate the potential effects of corrosive soils will be developed in the design phase.

6.2.3. Expansive Soils

The regional effects and environmental consequences of potential expansive soils have been discussed in Section 4.2.3., and the consequences of expansive soils for each segment of the Alignment have been discussed in Section 4.3. To further evaluate the potential for expansive soils along the proposed segments, subsurface evaluation including laboratory testing could be performed. Evaluation of the potential expansive soils hazard should be performed prior to design and construction so that, in the event the hazard exists, mitigation techniques can be implemented.

Site-specific, subsurface evaluation would be conducted during the design phase of the project to evaluate the extent of which expansive soils are present along the alternative segments. Where expansive soil conditions are found to occur and are considered detrimental to proposed improvements, mitigation measures can be implemented.

Mitigation measures for expansive soils would typically include techniques such as overexcavation and replacement with non-expansive soil, chemical treatment (e.g., lime or cement), moisture control, and/or specific structural design for expansive soil conditions will be developed during design of the segment.

6.2.4. Landslides

The regional effects and environmental consequences of potential landslides and surficial slope failures have been discussed in Section 4.2.4., and the consequences of landslides and surficial slope failures for each segment of the Alignment have been discussed in Section 4.3. To further evaluate the potential for landslides and surficial slope failures along the proposed segments, surface reconnaissance and subsurface evaluation could be performed. Evaluation of the landslide and surficial slope failure hazard should be performed prior to design and construction so that, in the event the hazard exists, mitigation techniques can be implemented.

Surface reconnaissance to evaluate potential for landslides and surficial slope failures would be performed in the design phase and would include visual observation of the earth units and geomorphology, and checking of geologic maps in order to evaluate the condition of slopes relative to the Alignment. Subsurface exploration may be needed to evaluate the potential of slopes for landslides and surficial slope failures. Subsurface evaluation might include the excavation and detailed logging of exploratory trenches, test pits and/or borings. Slope stability computer analyses may be performed to address the stability of slopes in the project area.

Measures to mitigate potentially unstable slope conditions and mitigate the potential for landslides and surficial slope failures include: excavating potentially unstable material resulting in a flatter more stable slope configuration; construction of buttress and/or stabilization fills; construction of retaining walls; installation of rock bolts on the face of the slope, installation of protective wire mesh on the slope face, and/or the construction of debris impact walls at the toe of the slope to contain rock fall debris.

6.2.5. Caliche/Hard Rock Excavations

The regional effects and environmental consequences of potential caliche/hard rock presenting excavation difficulties during construction have been discussed in Section 4.2.5., and the consequences of caliche/hard rock during construction for each segment of the Alignment have been discussed in Section 4.3. To further evaluate the potential for caliche/hard rock during construction along the proposed segments, surface reconnaissance and subsurface evaluation could be performed. Evaluation of the potential for caliche/hard excavation should be performed prior to design and construction so that, in the event the condition exists, mitigation techniques can be implemented.

During the design phase of the project, site-specific geotechnical evaluations would be performed to assess the excavatibility of the earth units. This may include drilling of exploratory borings and/or test pits to evaluate ground conditions for excavation capability.

Mitigation for caliche and other hard rock excavation may involve several techniques. Rock excavation may involve equipment such as a rock-saw, trencher, or heavy-duty Hoe-ram. Blasting may also be involved for very hard conditions. The use of blasting or breakers, if required, will produce temporary noise and dust hazards, which will need to be appropriately addressed during construction.

6.2.6. Ground Fissures

The regional effects and environmental consequences of potential ground fissures have been discussed in Section 4.2.6., and the consequences of ground fissures for each segment of the Alignment have been discussed in Section 4.3. To further evaluate the potential for ground fissures along the proposed segments, surface reconnaissance could be performed. Evaluation of the potential ground fissure hazard should be performed prior to design and construction so that, in the event the hazard exists, mitigation techniques can be implemented.

Surface reconnaissance to evaluate potential for ground fissures would be performed in the design phase and would include visual observation of the earth units, manmade features and geomorphology, and checking of geologic maps in order to evaluate the surface conditions relative to the Alignment.

Where ground fissures are found to occur and are considered detrimental to proposed improvements, mitigation measures such as overexcavation of the soils and replacement with compacted fill, chemical or compaction grouting, or other in-situ soil improvement techniques could be performed.

6.2.7. Shallow Groundwater

The regional effects and environmental consequences of shallow groundwater have been discussed in Section 4.2.7., and the consequences of shallow groundwater for each segment of the Alignment have been discussed in Section 4.3. To further evaluate the potential for shallow groundwater along the proposed segments at locations where groundwater may affect construction, subsurface evaluation could be performed. Evaluation of the potential shallow groundwater hazard should be performed prior to design and construction so that, in the event the hazard exists, mitigation techniques can be implemented.

Site-specific geotechnical evaluations to assess the groundwater characteristics would include drilling of exploratory borings, evaluation of groundwater depths, and possible installation of groundwater monitoring wells, where needed.

Measures to mitigate potential shallow groundwater conditions would include: shoring/casing of excavations below the groundwater table; pumping groundwater from excavations to keep levels below a specified depth; using dewatering wells to pump groundwater out of the ground and lower the groundwater table at specified locations; and, where needed, utilizing more advanced, and costly techniques to control groundwater such as the use of subsurface grout curtains or soil/cement walls.

Excavations for the underground structures will need to be performed with care to reduce the potential for lateral deflection of excavation sidewalls and/or shoring, which could also cause differential movement of structures located near the excavation. To reduce the potential for damage to improvements and structures resulting from dewatering operations, the ground surface and/or structures around the excavation could be monitored for movement with a variety of instrumentation. If, during the course of construction, the instrumentation detects ground movement that exceeds a pre-specified value, the work would stop and the contractor's methods would be reviewed and appropriate changes would be made, if needed. Typical monitoring methods include installation of ground survey points around the outside of the excavation to monitor settlement and/or placing monitoring points on nearby structures to monitor performance of the structures. Additionally, inclinometers could be installed along the sides of the excavation to monitor lateral deflection of the sidewalls during excavation.

7. LIMITATIONS

The geotechnical evaluation presented in this report has been conducted in accordance with current engineering practice and the standard of care exercised by reputable geotechnical consultants performing similar tasks in this area. No other warranty, implied or expressed, is made regarding the conclusions, recommendations, and professional opinions expressed in this report. Our preliminary conclusions and recommendations are based on a review of readily available geotechnical background literature. Variations in the geotechnical conditions of the Alignment study area may exist and conditions not described in this report may be encountered.

The purpose of this study was to evaluate geologic and geotechnical conditions within the Alignment study area using readily available data and to provide a preliminary geotechnical report which can be utilized in the preparation of planning and environmental impact documents for the project. A more detailed geologic evaluation, including subsurface exploration and laboratory testing, should be performed prior to design and construction of the proposed transportation improvements.

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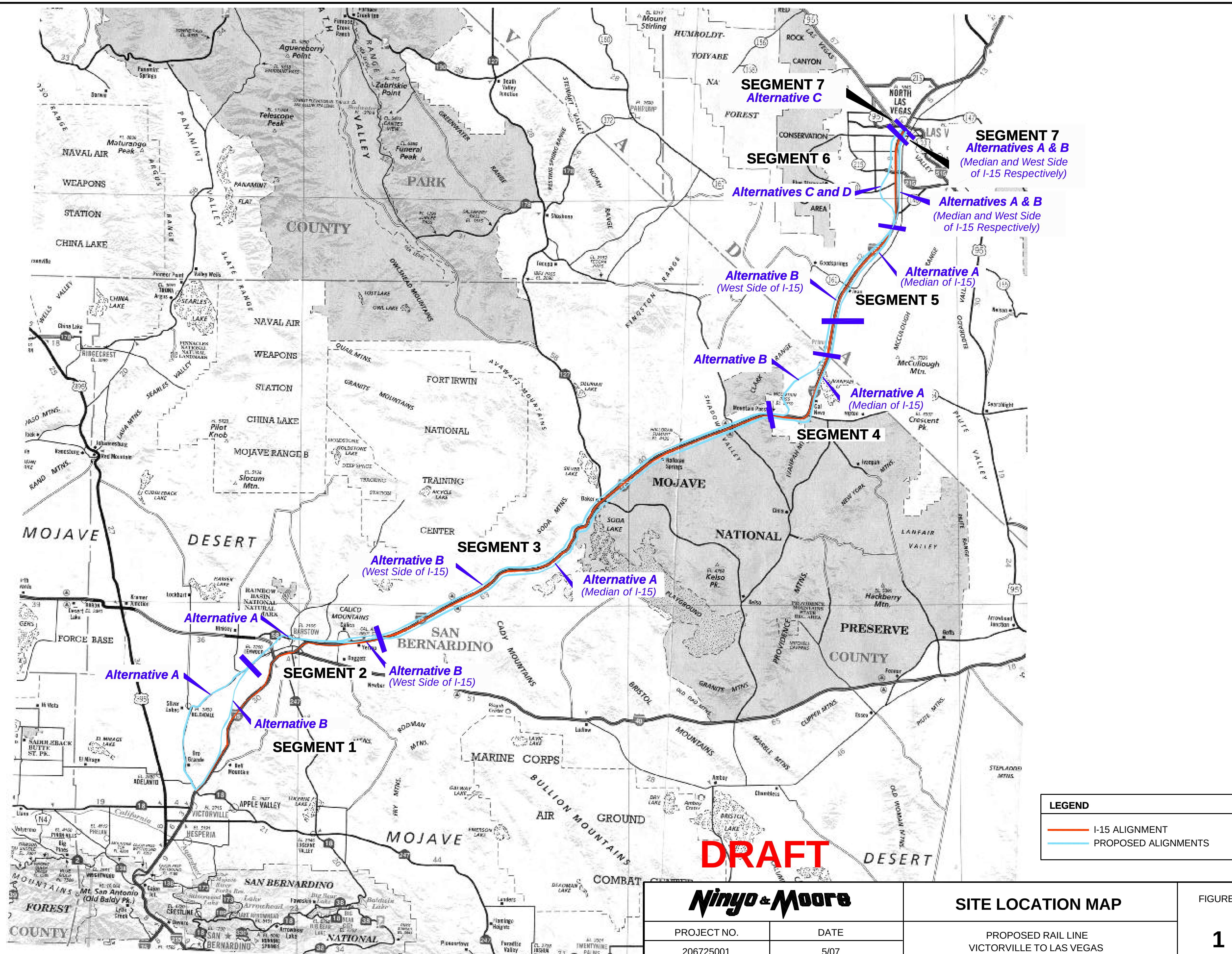
Bridge Name / Number	As Built/Approved Plans	Log of Test Borings	Foundation Recommendations	Preliminary Foundation Report	Foundation Report	Preliminary Seismic Design Recommendations	Seismic Design Recommendations	Final Seismic Design Recommendations	Preliminary Geologic Report	Hydrologic/Scour Report	Pile Driving Records	Miscellaneous			
Stoddard Wells Overcrossing/ 54-535		Oct. 1956	3/8/2000		10/24/1956		3/31/2000								
Cement Co. Undercrossing/ 54-517		3/14/1956, 3/14/2001	7/13/2001	9/27/1999, 11/22/1999	7/12/1956	12/27/1999	4/13/2000	3/29/2001				6/3/1999 Planning Study			
Bell Mountain Wash Bridge/ 54-499	10/1957 (set of 11), 3/1/99 (Widening); 3/26/1969	10/4/1957, 2/15/01 (set of 7)	2/6/1968	11/22/1999	1/12/1956 10/9/1969 7/30/2001	10/3/1955 (1 of 11), 12/27/1999		3/29/2001	7/24/1995	8/8/2000					
Wild Wash O.C./ 54-565	9/27/1967				4/20/1959						Undated				
Road Cut Near Powerline Rd.									10/13/1998			10/16/1998 Rippability Study			
Wild Wash Bridge Widening/ 54-500	May-69	3/15/56, 2/20/2001	3/1/1960, 8/20/2001	11/22/1999	3/28/1956	12/23/1999		3/29/2001	9/6/1977		5/2/1972				
Wild Wash O.C. Retaining Wall #250		3/2/2001	9/13/2001												
Hodge Road Overcrossing/ 54-566			7/22/1970 9/27/1967		3/12/1959										
Hodge Road O.C. Retaining Wall #319 & #320		3/5/2001	8/30/2001												
Sidewinder Road OC/ 54-567			3/12/1959, 10/22/1970												
Mojave River Bridge/ 54-548	7/13/1998 1/10/1994	12/1938, 2/9/1959, 7/13/1998	5/20/1958 8/19/1997		1/22/1958				3/28/1997		5/1939 4/22/1999	10/6/1997 Corrosion Test Results			
Hiker Ditch Bridge/ 54-1165 (new), 54-212F (old)	3/29/1999	3/29/1999	11/16/1994		3/29/1999										
Calico Road Undercrossing/ 54-627			5/10/1961 8/30/1961		3/29/1961										
Yermo-Calico Road Overcrossing/ 54-628			5/10/1961 8/30/1961		3/29/1961										
First Street Overcrossing/ 54-629			5/10/1961 8/30/1961		3/29/1961										
Yermo Ditch Bridge/ 54-630	7/30/1962	7/30/1962	5/10/1961 8/30/1961		3/29/1961										
East Yermo Overcrossing/ 54-631		7/30/1962	5/10/1961 8/30/1961		3/31/1961	7/11/1995									
Minneola Road Overcrossing/ 54-632		7/30/1962	5/10/1961 8/30/1961		3/30/1961										
Coyote Lake Road Overcrossing/ 54-633		7/30/1962	5/10/1961 8/30/1961		3/29/1961										
Harvard Road Overcrossing/ 54-634		7/30/1962	5/10/1961 8/30/1961		3/30/1961										
Alvord Road Overcrossing/ 54-635			5/10/1961 8/30/1961		3/29/1961										
West Manix Wash/ 54-636		7/30/1962	5/10/1961 8/30/1961		4/3/1961							2/1/2002 Photographs			
East Manix Wash/ 54-637		7/30/1962	5/10/1961 8/30/1961		3/30/1961										
Mound Wash/ 54-638		7/30/1962	5/10/1961 8/30/1961		3/29/1961										
Flat Ditch/ 54-639		7/30/1962	5/10/1961 8/30/1961		3/29/1961										
Field Road Overcossing/ 54-640		7/30/1962	8/30/1961		3/30/1961										

Bridge Name / Number	As Built/Approved Plans	Log of Test Borings	Foundation Recommendations	Preliminary Foundation Report	Foundation Report	Preliminary Seismic Design Recommendations	Seismic Design Recommendations	Final Seismic Design Recommendations	Preliminary Geologic Report	Hydrologic/Scour Report	Pile Driving Records	Miscellaneous			
Afton Road Overcrossing/ 54-364					2/27/1958				9/8/1977						
Mojave River Overflow Bridge/ 54-642		5/6/1963			8/10/1961										
Basin Road Overcrossing/ 54-383					2/26/1958				9/8/1977						
Cronise Valley Road Overcrossing/ 54-382					2/27/1958										
Razor Road Overcrossing/ 54-391					2/19/1958				9/8/1977						
Soda Road Overcrossing/ 54-398			3/25/1996		2/18/1958	1/24/1995			8/21/1964 9/8/1977						
Oat Ditch Bridge/ 54-0270R	10/27/2003	12/9/1963 9/11/2003	10/24/2003						12/13/2000						
Case Ditch/ 54-273		12/16/1957			2/11/1958										
Mobi Ditch/ 54-0277	12/9/1963	1/31/1957								2/23/2001 1/11/2002					
West Baker Overcrossing/ 54-609		12/9/1963	7/18/1960 8/21/1964 3/25/1996		10/22/1959	1/24/1995			9/8/1977						
Mojave River (Baker) Bridge/ 54-278	12/9/1963	12/9/1963	1/7/2000		10/23/1959	2/10/1999									
Route 127/15 Separation/ # 54-610		12/9/1963	8/21/1964 3/25/1996		10/23/1959	1/24/1995			9/12/1977						
Baker Inn Ditch/ #54-279R/L		8/19/1959			10/23/1959										
East Baker O.C./ #54-611		12/9/1963	8/21/1964 3/25/1996		10/23/1959	1/24/1995			9/12/1977						
Pano Ditch/ #54-281	12/9/1963 7/2/2001	12/9/1963 7/2/2001	4/3/2000		10/30/1959 11/2/1959 12/3/1963 10/4/2000	4/21/2000	10/27/1999 9/20/2000		10/21/1999	2/11/2000					
Berry Ditch Bridge/ 54-282	2/8/1960, 7/2/2001	2/8/1960 7/2/2001	3/13/2000		7/28/1958 1/30/1957, 10/10,18,&2 3/2000	4/21/2000	10/29/1999	10/6/2000	9/12/1977, 10/21/1999	10/19/2000					
Hack Wash Bridge/ 54-283	7/2/2001	2/8/1960 7/2/2001	1/26/2000 3/20/2000 3/27/2000		10/5/2000, 10/11/2000, 10/18/2000		10/27/1999, 4/21/2000	10/6/2000	9/12/1977, 10/21/1999	1/7/2000, 4/18/2000					
Halloran Springs OC/ 54-338		12/15/1957	1/22/1958			1/24/1995			1/22/1958, 8/9/1977						
Valley Wells Ditch Bridge/ 54-297	1/24/2000	2/8/1960 1/24/2000		9/6/1998	4/23/1999, 5/20/1999 (Ret. Wall)	9/24/1998		4/20/1999	8/9/1977	11/10/1998		2/11/1999 Geophysical Study			
Windmill Station Ditch Bridge/ 54-299	1/24/2000	2/8/1960 1/24/2000	2/21/1958	9/6/1998	2/21/1958 4/23/1999, 5/20/1999 (Ret. Wall)	9/24/1998		4/20/1999	8/10/1977	9/9/1998					
Wells Ditch Bridge/ 54-300	1/24/2000	2/8/1960 1/24/2000		9/6/1998	2/21/1958 4/23/1999, 5/20/1999 (Ret. Wall)	9/24/1998		4/20/1999	8/10/1977	11/10/1998		2/11/1999 Geophysical Study			
Dale Ditch Bridges/ 54-288	7/2/2001	2/8/1960 7/2/2001		3/20/2000	10/18/2000	10/27/1999	4/21/2000	10/6/2000	8/9/1977, 10/20/1999	1/11/2000, 11/13/2000	10/13/2000				
Kali Ditch Bridge/ 54-294	7/2/2001	2/8/1960, 7/2/2001	3/16/2000		3/27/1958, 10/11/2000, 11/20/2000	10/27/1999	4/21/2000	9/20/2000	8/9/1977, 10/20/1999	1/11/2000, 11/13/2000		Undated Photographs			
Halloran Summit O.C./ 54-347		2/8/1960			1/20/1958				8/9/1977						
Various Rest Areas (Halloran Spring)	5/8/1964						8/11/1966		5/8/1964 7/29/1968			3/21/1964, 8/11/1966, 9/19/1968 Planning Studies			

Bridge Name / Number	As Built/Approved Plans	Log of Test Borings	Foundation Recommendations	Preliminary Foundation Report	Foundation Report	Preliminary Seismic Design Recommendations	Seismic Design Recommendations	Final Seismic Design Recommendations	Preliminary Geologic Report	Hydrologic/Scour Report	Pile Driving Records	Miscellaneous			
Hot Wash Bridge/ 54-544	1/24/2000	2/8/1960 1/24/2000		9/6/1998	4/23/1999, 5/20/1999 (Ret. Wall)	9/24/1998		4/20/1999	8/9/1977	9/4/1998					
West Valley Wells Ditch Bridge/ 54-296	1/24/2000	1/24/2000	5/22/1978	9/6/1998	4/23/1999, 5/20/1999 (Ret. Wall)	9/24/1998		4/20/1999	8/9/1977	9/9/1998					
Cima Road O.C./ 54-363		2/8/1960			3/7/1958	8/27/1992			8/10/1977						
Mescal Ditch Bridge/ 54-303		10/9/1961 7/12/2001	1/23/1961, 1/8/2001, 1/12/2001		11/4/1960 6/29/2001	9/27/2000, 10/10/2000			11/27/2000						
Clark Mountain Ditch Bridge/ 54-304		10/9/1961 7/12/2001	1/20/61, 6/30/1967, 1/12/2001		11/14/1960 6/21/2001	10/10/2000			11/27/2000						
Mohawk Ditch/ 54-618		10/9/1961	1/23/1961		11/16/1960										
Micro Ditch Bridge/ 54-619		10/9/1961	1/23/1961		11/16/1960										
Bailey Road O.C./ 54-613		10/9/1961			11/4/1960				8/10/1977						
Cenda Ditch Bridge/ 54-620			6/26/1967 12/19/2000		11/4/1960	9/27/2000, 10/10/2000	5/1/2001	5/1/2001	11/2/2000	2/2/2001					
Wheaton Wash Bridge/ 54-624	2/19/1968	10/9/1961	1/25/1961, 6/26/1967		11/4/1960	9/27/2000, 10/10/2000	5/1/2001	5/1/2001	12/19/2000	8/12/1998, 2/22/1999					
Wheaton Springs Wash Bridge/ 54-315	Mar-06	10/9/1961 8/19/2004	1/25/1961, 7/25/1967, 1/12/2001		11/29/1960, 2/27/2006	9/27/2000, 10/10/2000		5/1/2001	11/27/2000	2/26/1999	7/3/1968, 2/26/1999				
Nipton Road O.C./ 54-612	12/6/1993	10/9/1961			11/29/1960	8/27/1992			8/10/1977						
Ivanpah Ditch Bridge/ 54-316	3/1/2006	10/9/1961	1/23/1961, 6/26/1967, 1/12/2001		11/3/1960	9/27/2000, 10/10/2000	5/1/2001	5/1/2001	11/27/2000						
Mountain Pass JPOE Commercial Vehicle Enforcement Facility		7/16/2002			6/26/2002										
Mountain Pass JPOE Agricultural Inspection Facility		7/29/2002			6/26/2002										
Dry Lake Ditch Bridge/ 54-317	1961 3/1/2006	10/9/1961, 8/19/2004	1/23/1961, 12/19/2000		11/4/1960, 7/6/2006	9/27/2000, 10/10/2000		5/1/2001							
Yates Well Road O.C./ 54-542		10/9/1961			11/4/1960				8/10/1977						

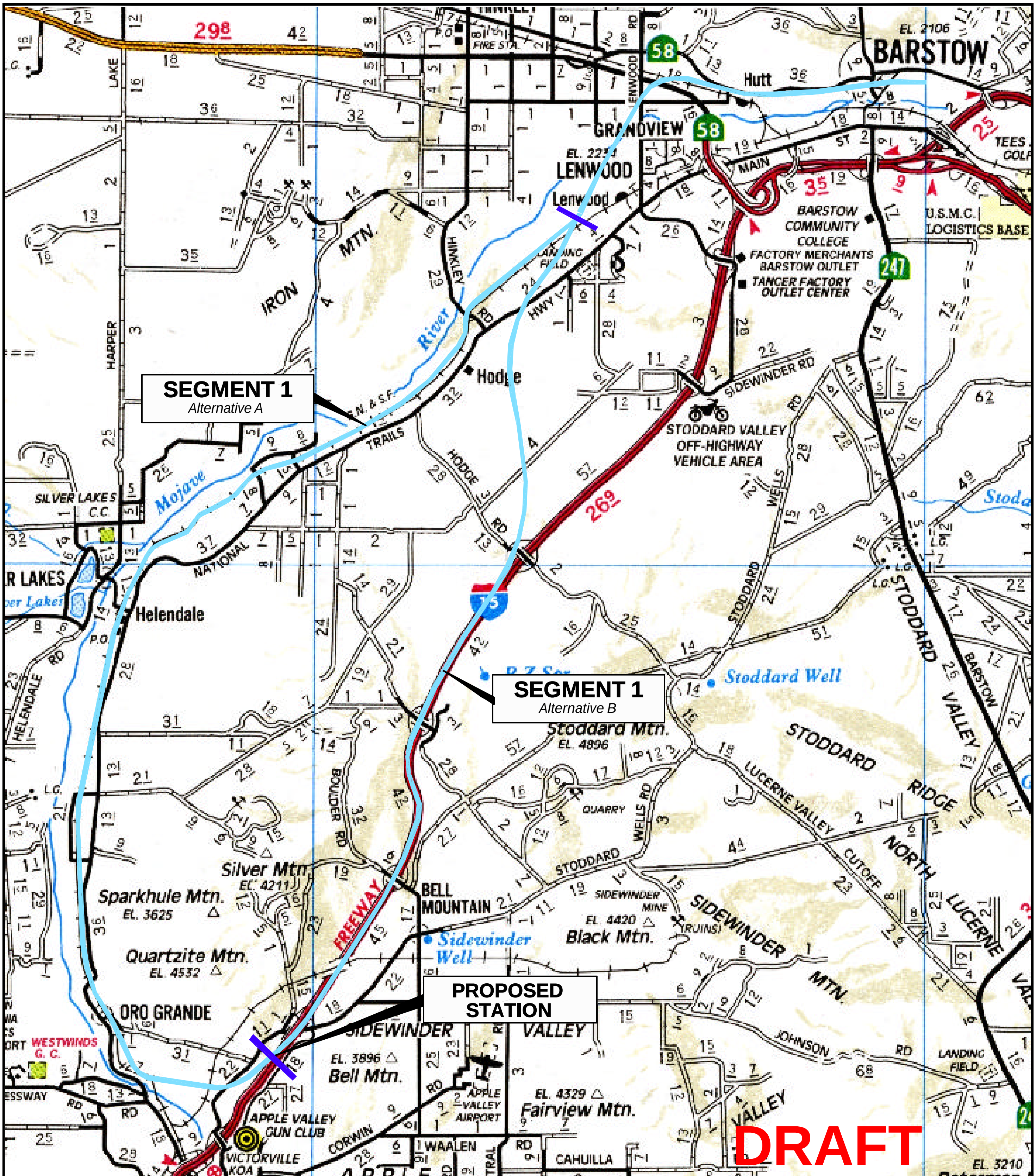


NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

206725-B1.DWG

Ninyo & Moore

SITE LOCATION MAP		FIGURE
PROJECT NO. 206725001	DATE 5/07	1
PROPOSED RAIL LINE VICTORVILLE TO LAS VEGAS		



APPROXIMATE SCALE IN MILES

0 5 10

N

REFERENCE: AUTOMOBILE CLUB OF SOUTHERN CALIFORNIA, 2002.
NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

2067250-A1.DWG

Ninyo & Moore		SEGMENT 1 VICINITY MAP	FIGURE
PROJECT NO.	DATE	PROPOSED RAIL LINE VICTORVILLE TO LAS VEGAS	2
206725001	5/07		

APPROXIMATE SCALE IN MILES

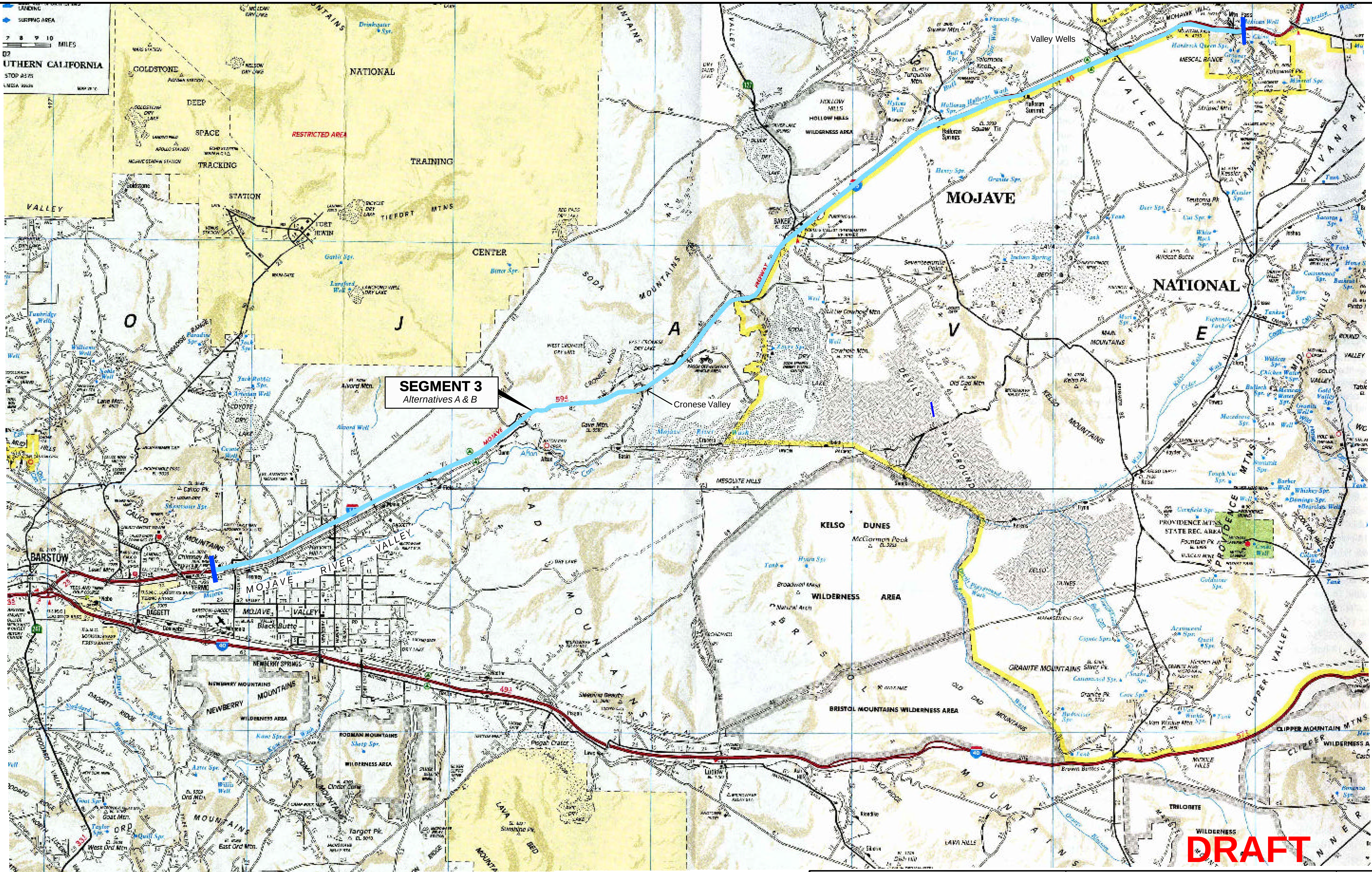
0 5 10

N

REFERENCE: AUTOMOBILE CLUB OF SOUTHERN CALIFORNIA, 2002.
NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

206725O-A2.DWG

Ninyo & Moore		SEGMENT 2 VICINITY MAP	FIGURE
PROJECT NO.	DATE	PROPOSED RAIL LINE VICTORVILLE TO LAS VEGAS	3
206725001	5/07		



APPROXIMATE SCALE IN MILES

0 5 10

REFERENCE: AUTOMOBILE CLUB OF SOUTHERN CALIFORNIA, 12-2004.
NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

N

LEGEND

PROPOSED ALIGNMENTS

Ninyo & Moore

PROJECT NO.	DATE
206725001	5/07

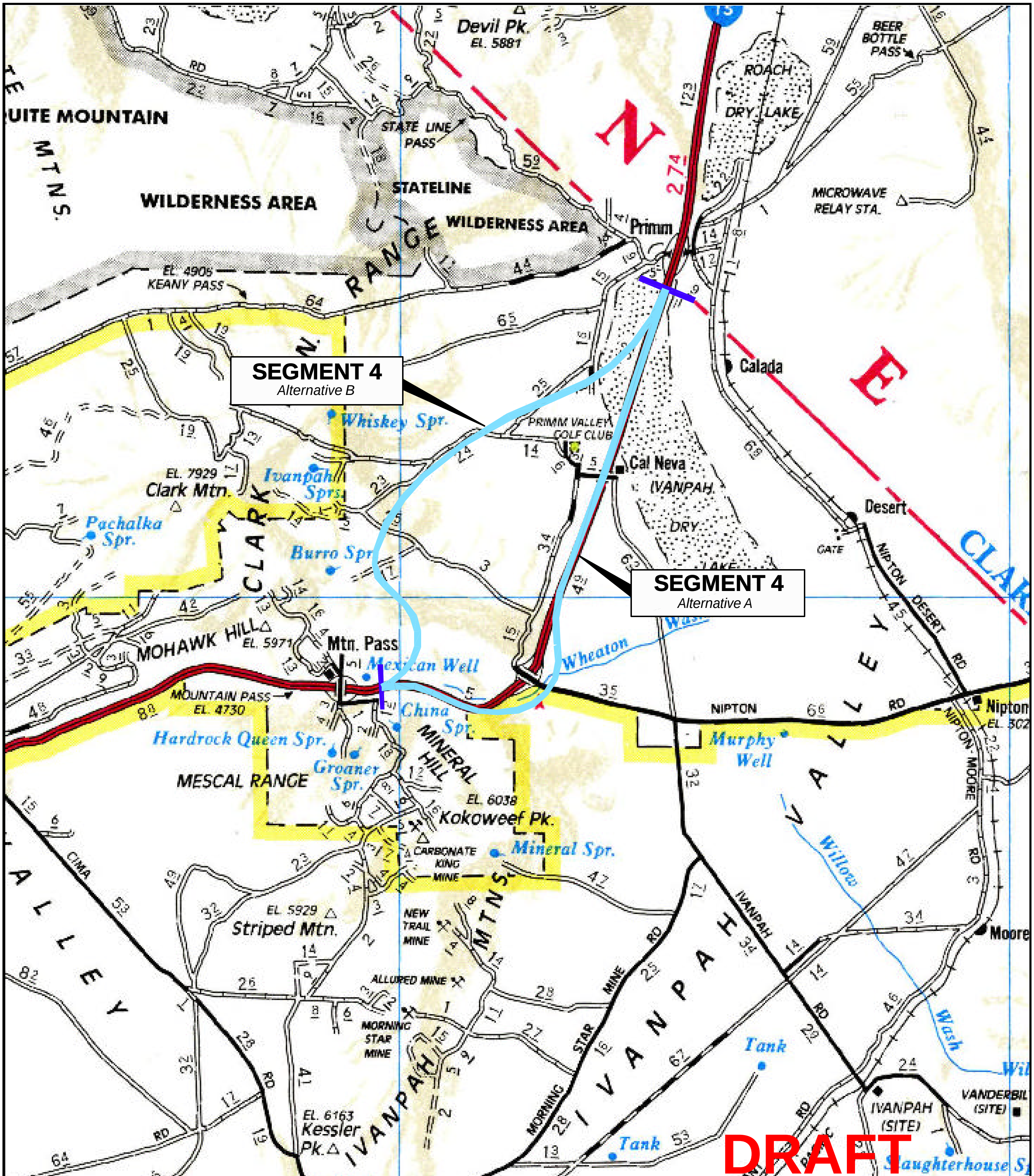
SEGMENT 3 VICINITY MAP

PROPOSED RAIL LINE
VICTORVILLE TO LAS VEGAS

FIGURE

4

206725-B2.DWG



APPROXIMATE SCALE IN MILES

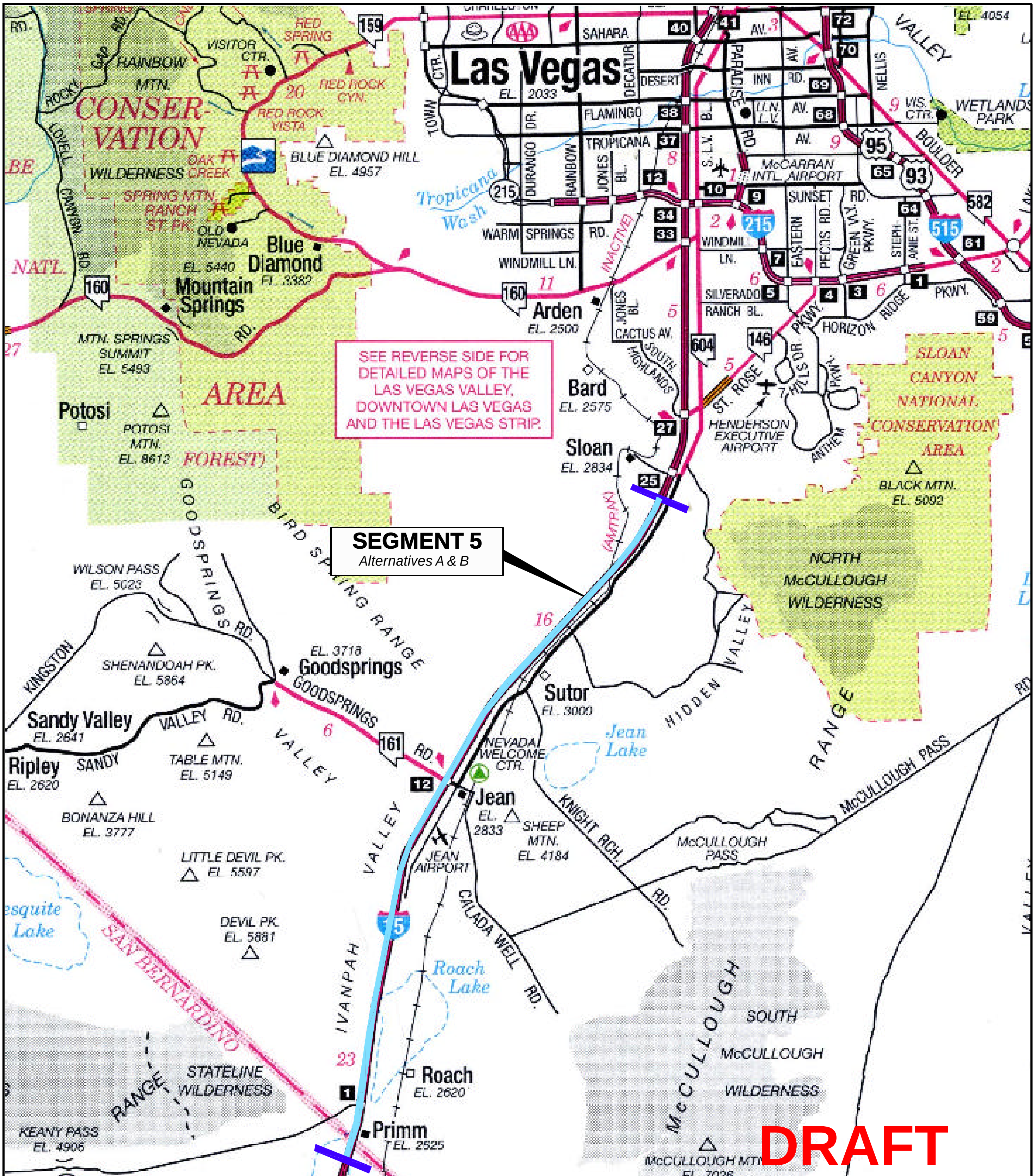
0 5 10

N

REFERENCE: AUTOMOBILE CLUB OF SOUTHERN CALIFORNIA, 2002.
NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

2067250-A3.DWG

Ninyo & Moore		SEGMENT 4 VICINITY MAP	FIGURE
PROJECT NO.	DATE	PROPOSED RAIL LINE VICTORVILLE TO LAS VEGAS	5
206725001	5/07		



APPROXIMATE SCALE IN MILES

0 9 18

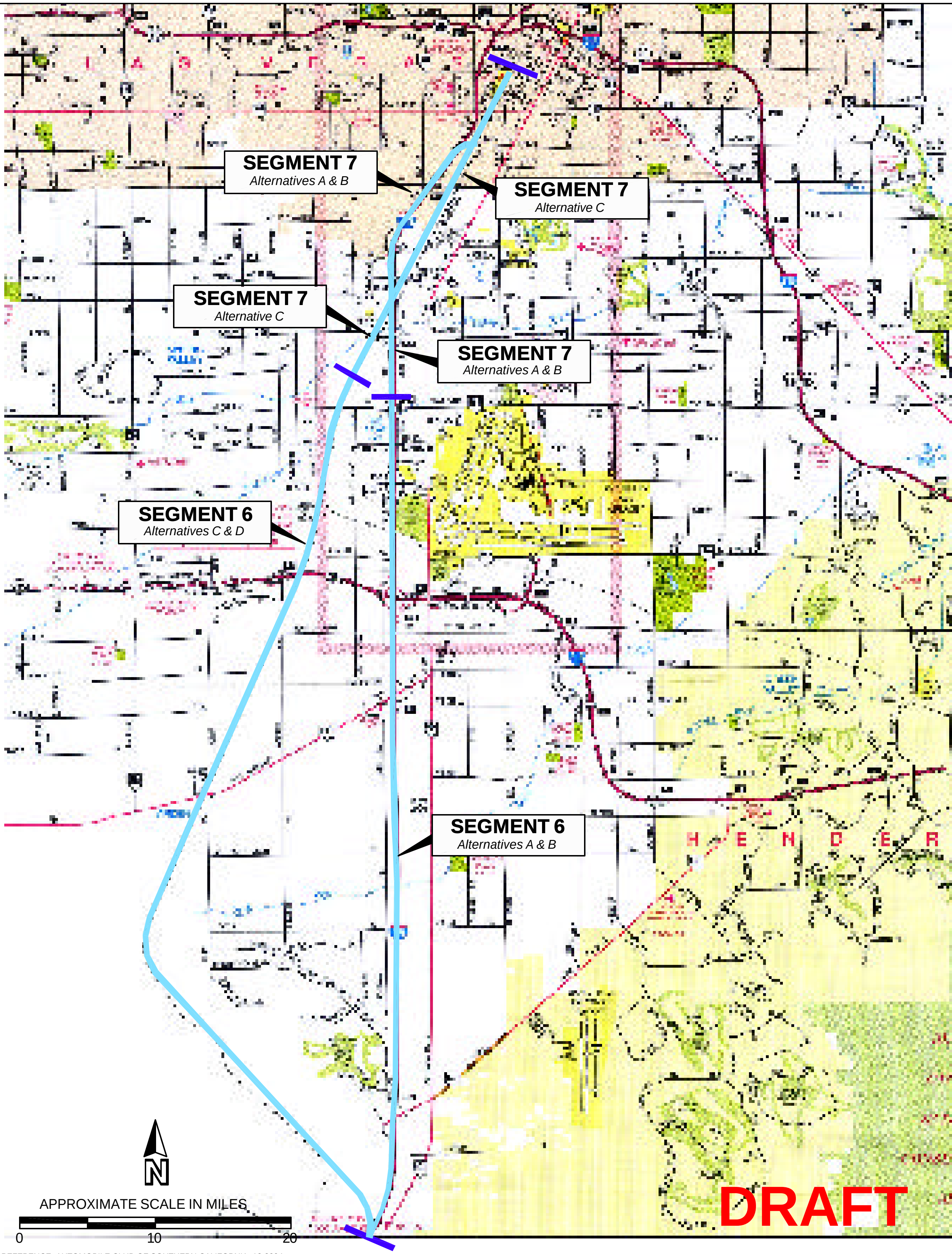
REFERENCE: AUTOMOBILE CLUB OF SOUTHERN CALIFORNIA, 12-2004.
NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

N

206725O-A4.DWG

Ninyo & Moore

PROJECT NO.	DATE	SEGMENT 5 VICINITY MAP	FIGURE
206725001	5/07	PROPOSED RAIL LINE VICTORVILLE TO LAS VEGAS	6

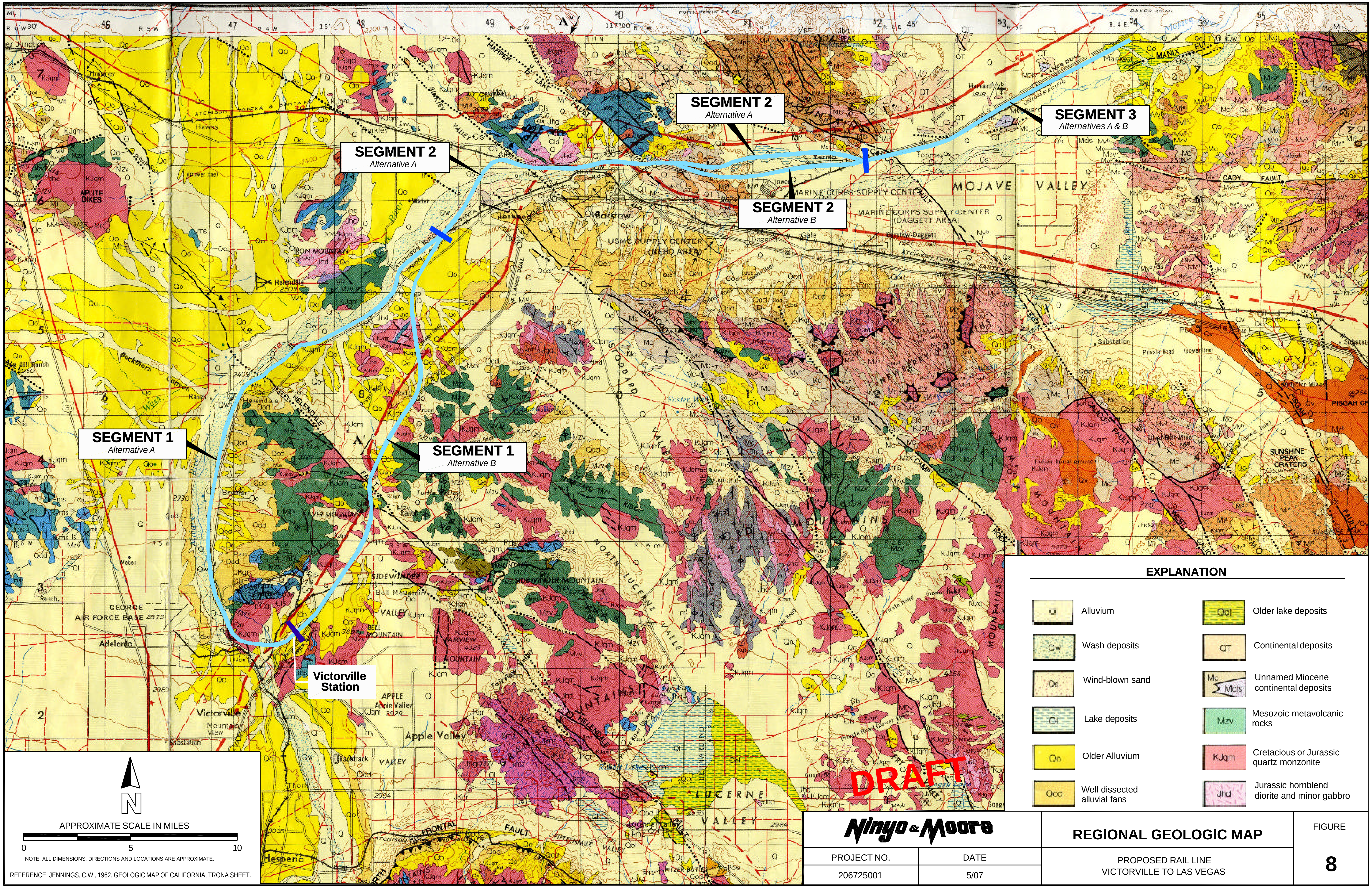


REFERENCE: AUTOMOBILE CLUB OF SOUTHERN CALIFORNIA, 12-2004.
NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

206725O- A5.DWG

Ninyo & Moore

PROJECT NO.	DATE	SEGMENT 6 & 7 VICINITY MAP	FIGURE
206725001	5/07	PROPOSED RAIL LINE VICTORVILLE TO LAS VEGAS	7

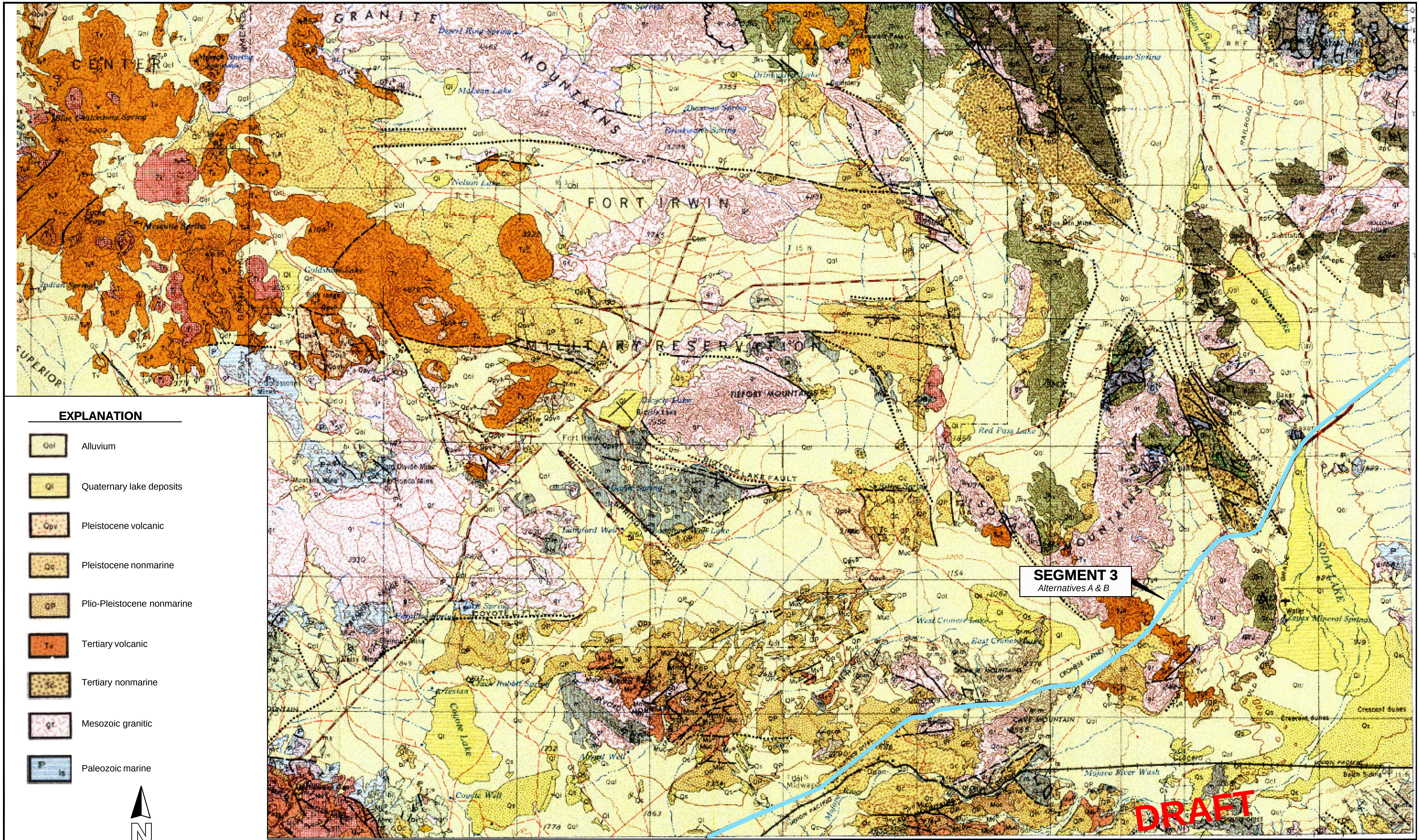


EXPLANATION

Symbol	Description	Symbol	Description
Q	Alluvium	Qol	Older lake deposits
Qw	Wash deposits	QT	Continental deposits
Qs	Wind-blown sand	Mc / Mcls	Unnamed Miocene continental deposits
Ql	Lake deposits	Mzv	Mesozoic metavolcanic rocks
Qo	Older Alluvium	KJqm	Cretacious or Jurassic quartz monzonite
Qoc	Well dissected alluvial fans	Jhd	Jurassic hornblend diorite and minor gabbro

Ninyo & Moore	REGIONAL GEOLOGIC MAP	FIGURE
PROJECT NO. 206725001 / DATE 5/07	PROPOSED RAIL LINE VICTORVILLE TO LAS VEGAS	8

203320-B15.DWG



EXPLANATION

- Qal — Alluvium
- Ql — Quaternary lake deposits
- Qpv — Pleistocene volcanic
- Qc — Pleistocene nonmarine
- QP — Plio-Pleistocene nonmarine
- Tv — Tertiary volcanic
- Tc — Tertiary nonmarine
- gr — Mesozoic granitic
- P ls — Paleozoic marine

N

APPROXIMATE SCALE IN MILES

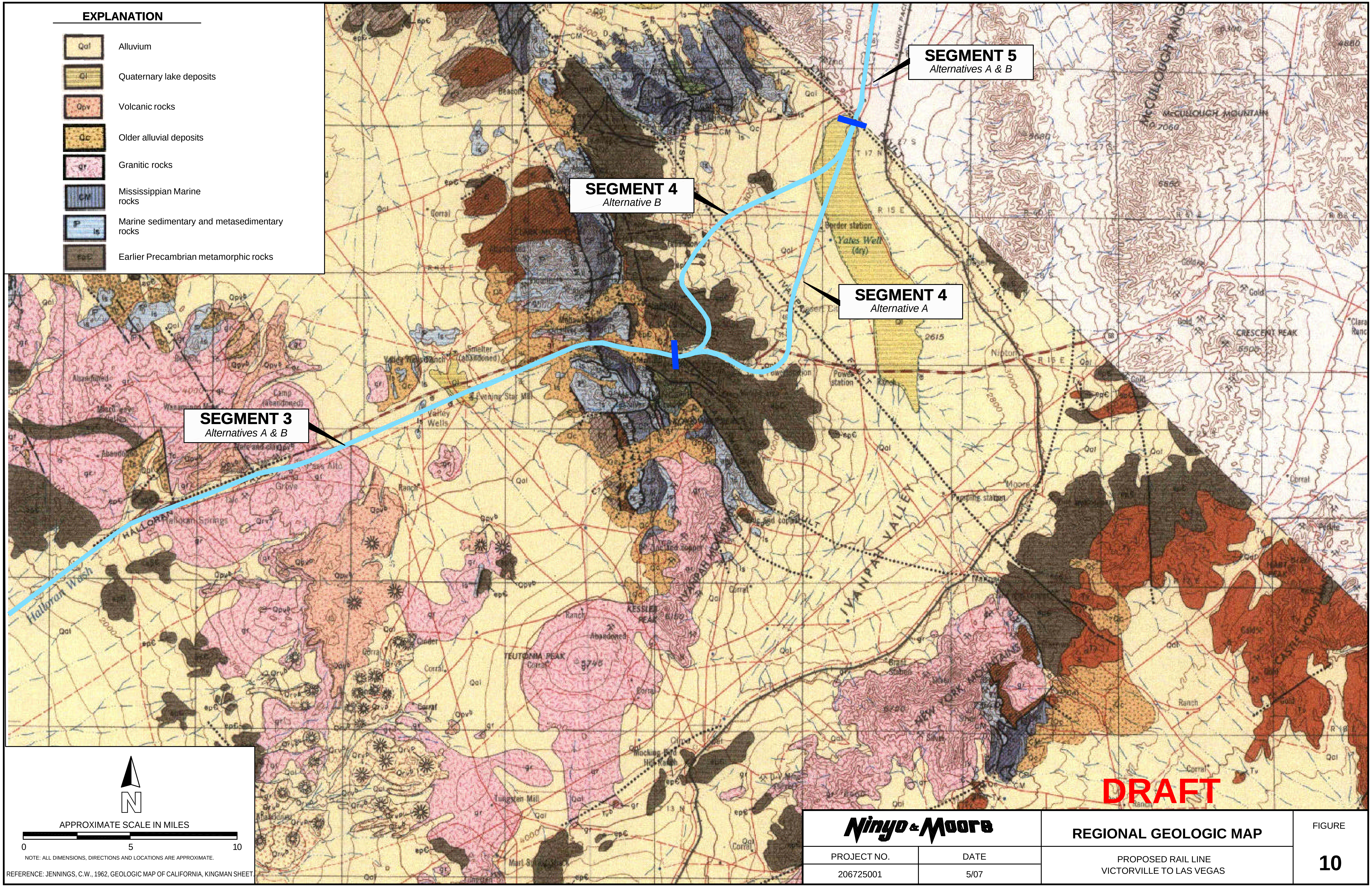
0 5 10

NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

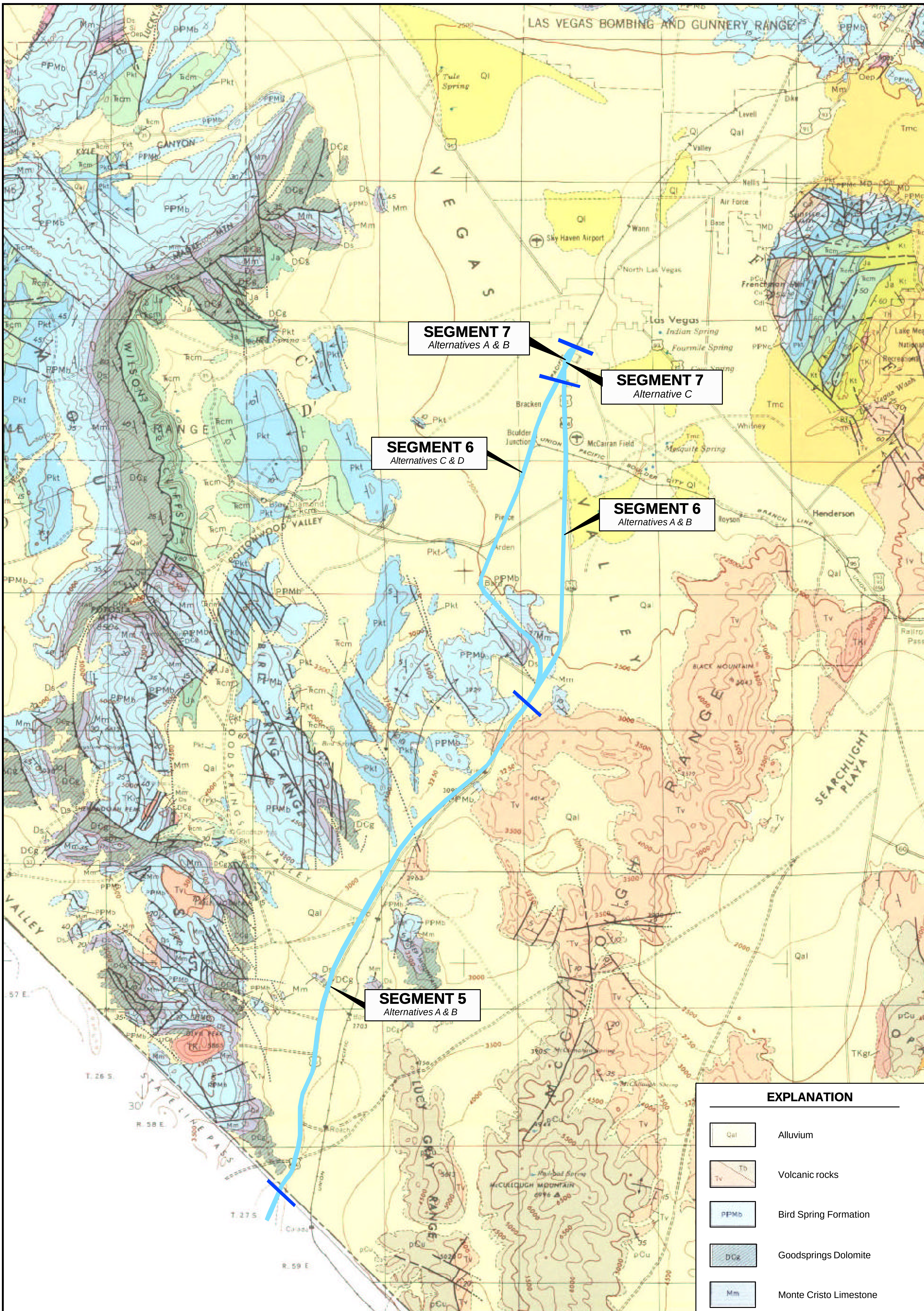
REFERENCE: JENNINGS, C.W., 1962, GEOLOGIC MAP OF CALIFORNIA, TRONA SHEET.

206725-B17.DWG

Ninyo & Moore		REGIONAL GEOLOGIC MAP	FIGURE
PROJECT NO.	DATE	PROPOSED RAIL LINE VICTORVILLE TO LAS VEGAS	9
206725001	5/07		



EXPLANATION
Qal Alluvium
Ql Quaternary lake deposits
Qpv Volcanic rocks
Qc Older alluvial deposits
gr Granitic rocks
CM Mississippian Marine rocks
P ls Marine sedimentary and metasedimentary rocks
pϵC Earlier Precambrian metamorphic rocks
SEGMENT 5
Alternatives A & B
SEGMENT 4
Alternative B
SEGMENT 4
Alternative A
SEGMENT 3
Alternatives A & B
DRAFT
N
APPROXIMATE SCALE IN MILES
0
5
10
NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.
REFERENCE: JENNINGS, C.W., 1962, GEOLOGIC MAP OF CALIFORNIA, KINGMAN SHEET.
Ninyo & Moore
PROJECT NO.
206725001
DATE
5/07
REGIONAL GEOLOGIC MAP
PROPOSED RAIL LINE
VICTORVILLE TO LAS VEGAS
FIGURE
10



206725-B18.DWG

APPROXIMATE SCALE IN MILES

0 5 10

NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCE: LONGWELL, C.R., PAMPEYAN, E.H., AND BOWER, B., 1964, GEOLOGIC MAP OF CLARK COUNTY, NEVADA.

DRAFT

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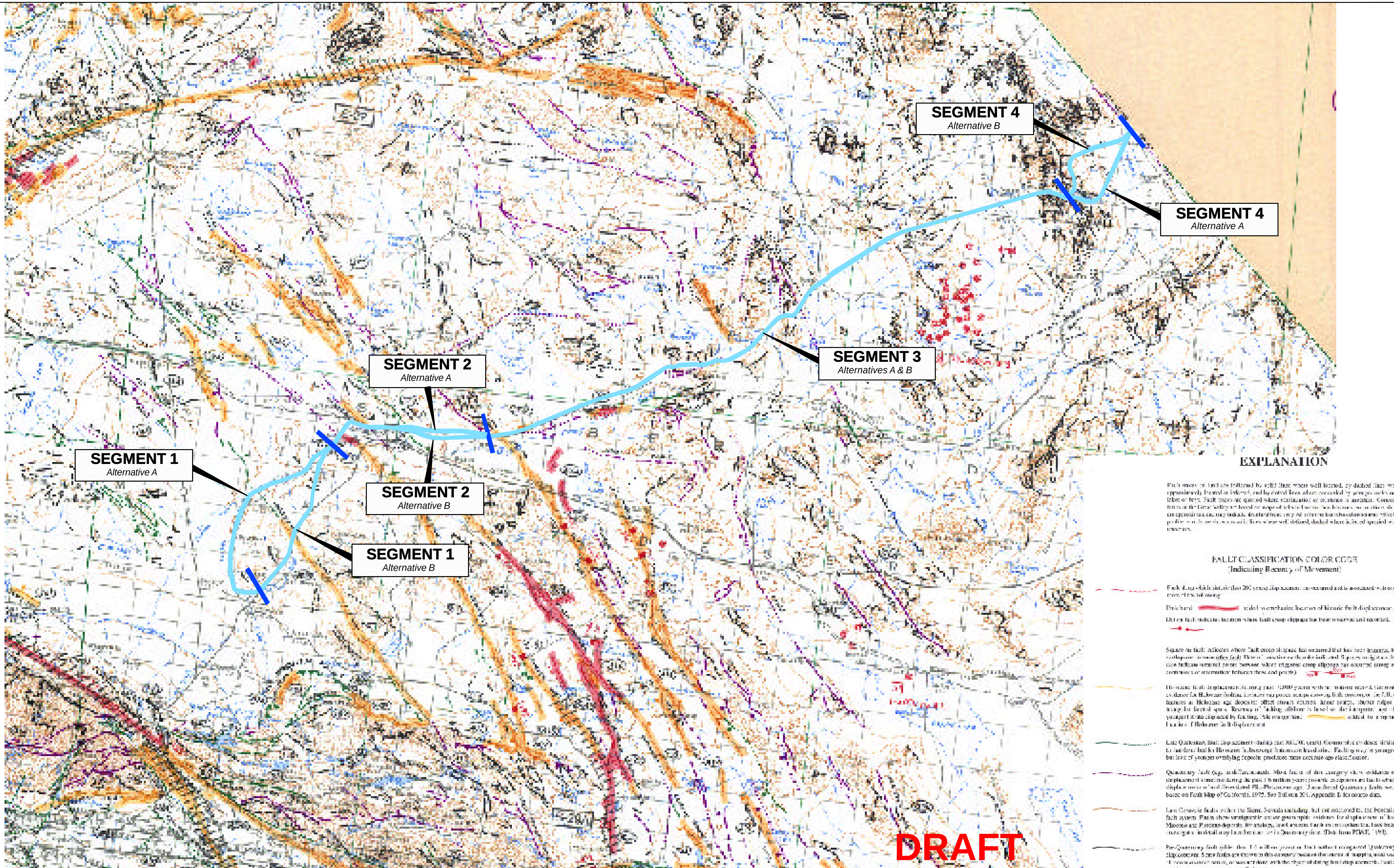
PROJECT NO.	DATE
206725001	5/07

REGIONAL GEOLOGIC MAP

PROPOSED RAIL LINE
VICTORVILLE TO LAS VEGAS

FIGURE **11**



APPROXIMATE SCALE IN MILES

0 12 24

NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCE: Jennings, C. W., 1994, Fault Activity Map of California, and Adjacent Areas: California Survey, California Geological Map Series.

N

LEGEND

PROPOSED ALIGNMENTS

Ninyo & Moore

PROJECT NO.	DATE
206725001	5/07

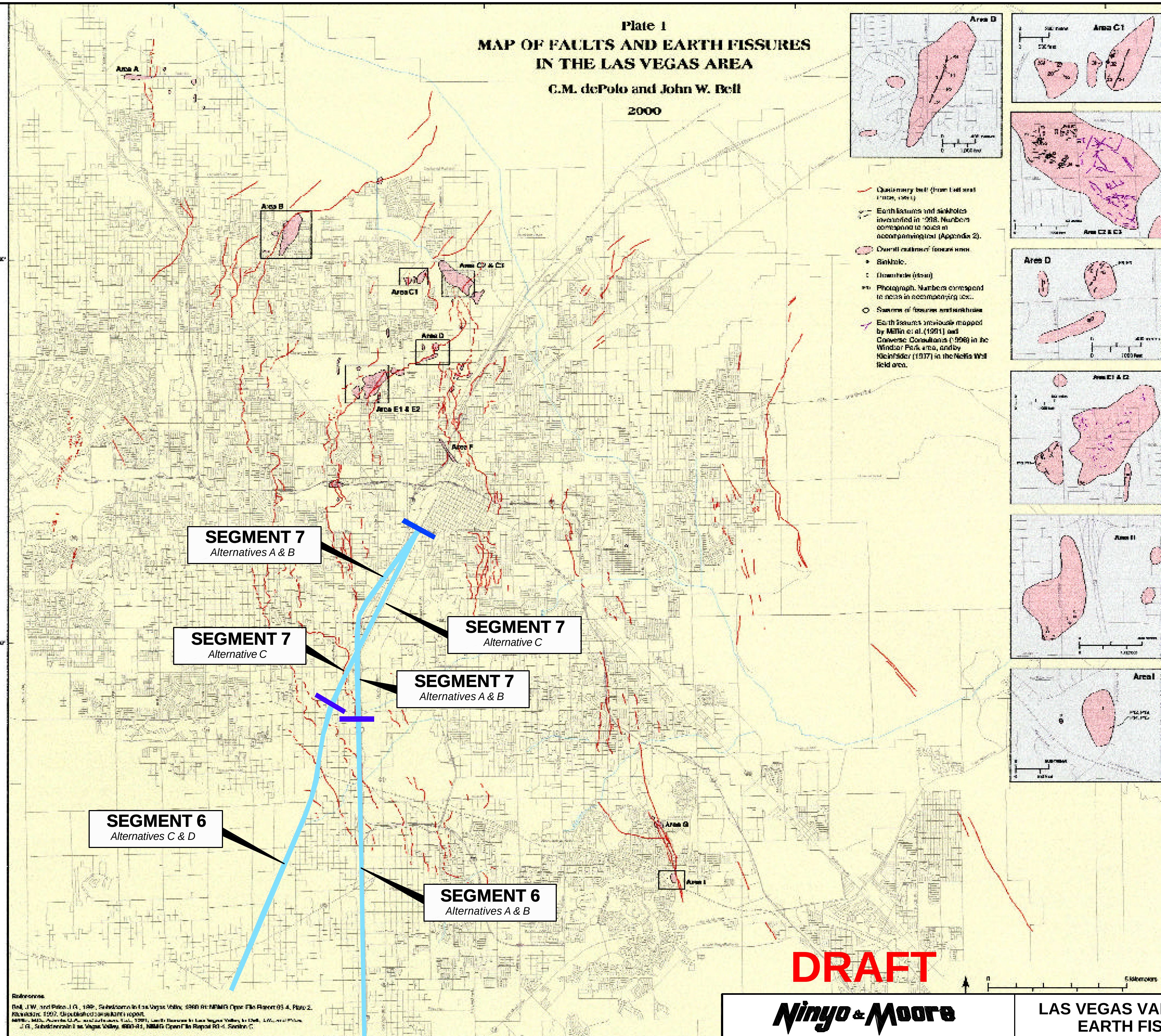
REGIONAL CALIFORNIA FAULT MAP

PROPOSED RAIL LINE
VICTORVILLE TO LAS VEGAS

FIGURE

12

206725-B3.DWG



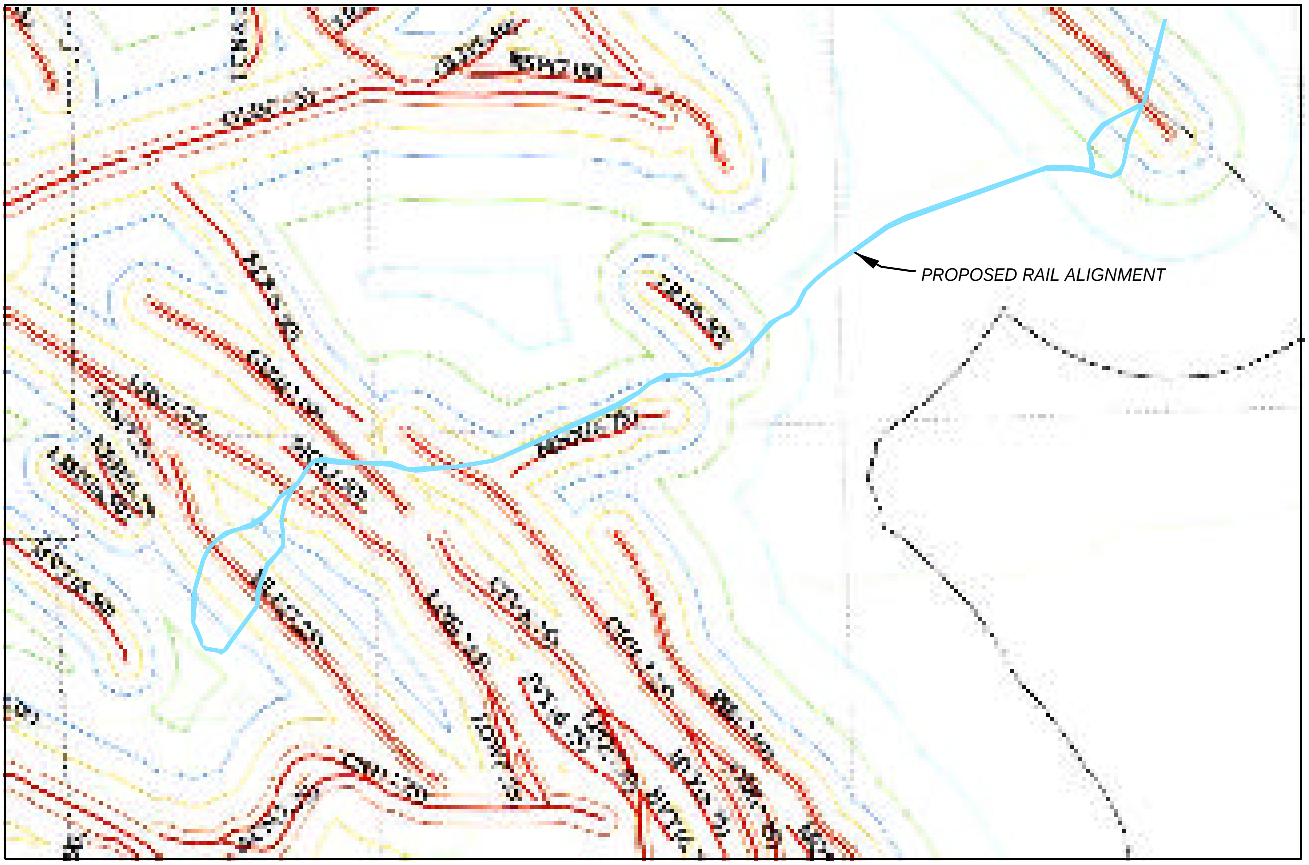
APPROXIMATE SCALE IN MILES

0 1 2 3

NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore		LAS VEGAS VALLEY FAULT AND EARTH FISSURES MAP	FIGURE
PROJECT NO.	DATE	PROPOSED RAIL LINE VICTORVILLE TO LAS VEGAS	13
206725001	5/07		

206725-B4.DWG



LEGEND

N

APPROXIMATE SCALE IN KILOMETERS

0 50 100

NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

206725-B5.DWG

REFERENCE:
STATE OF CALIFORNIA, DEPARTMENT OF TRANSPORTATION, CALIFORNIA SEISMIC HAZARD MAP, 1996.
OFFICE OF EARTHQUAKE ENGINEERING, LALLIANA MUALCHIN ENGINEERING SEISMOLOGIST.

DRAFT

Ninyo & Moore		ESTIMATED PEAK HORIZONTAL GROUND ACCELERATION CONTOURS	FIGURE
PROJECT NO.	DATE	PROPOSED RAIL LINE VICTORVILLE TO LAS VEGAS	14
206725001	5/07		