Memorandum

To: MR. SAVAT KHAMPHOU - 08
Office Chief
Design N, MS 1164

Attn: Mr. Fred Asef

Date: April 14, 2009

File: 08-SBd-138-PM 0.0/R15.2
07-LA-138-PM 69.4/74.9

EA: 08-3401U0

From: **DEPARTMENT OF TRANSPORTATION**
DIVISION OF ENGINEERING SERVICES
Geotechnical Services
Office of Geotechnical Design South 2

Subject: Amended Geotechnical Design Report

As per your request, our Office prepared this amended memorandum for the above referenced project. The previously prepared Geotechnical Design Report (GDR) for EA 4697U1, dated September 30th, 2002, covered PM R0.0/R15.2 in San Bernardino County, and PM 65.4/79.0 in Los Angeles County. This GDR is considered to be still valid for the subject area with the provided geotechnical and geologic information and recommendations, with the new EA: 08-3401U0.

If the project scope with the structural or roadway scope is modified in the future, our Office needs to be notified to make our GDR revision as deemed necessary.

If you have any question, please do not hesitate to contact Mr. Chris Hoadley at (916) 227-4515.

Chris Hoadley, CEG
Engineering Geologist
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CC: AAbghari
SWei
Project File

GEOTECHNICAL DESIGN REPORT

For

Converting the Existing Two-Lane Highway

To

A Four-Lane with a Median Left-Turn Lane

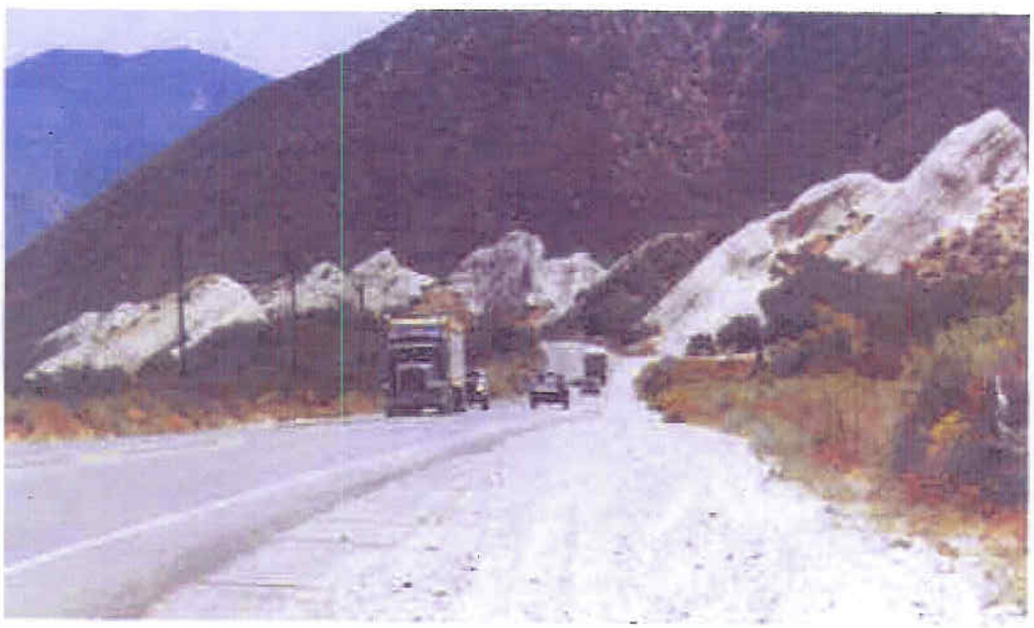
On

State Route 138

08- SBd-138- KP 0.0/22.85 &

07-LA-138-KP 111.7/120.7

EA: 08- 4697U1



DIVISION OF ENGINEERING SERVICES

Geotechnical Services

Branch C of Geotechnical Design – South

September 2002

Caltrans

GEOTECHNICAL DESIGN REPORT

State Route 138

For

Converting the Existing Two-Lane Highway

To

A Four-Lane Highway with a Median Left-Turn Lane

On

State Route138 in San Bernardino and Los Angeles Counties
08-SBd-138-KP 0.0/22.85
AND
07-LA 138 KP 111.7/120.7
EA: 08-4697U1

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DIVISION OF ENGINEERING SERVICES
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Office of Geotechnical Design - South
September 2002

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1. Introduction

This Geotechnical Design Report (GDR) is for the proposed widening of the existing two-lane State Highway 138 (Antelope Highway) to a four-lane facility with a median left-turn as shown on the attached Typical Section, provided. Widening will be offset to the north or south relative to the present centerline. The original proposed project included three segments. Segment 1 extended southeasterly from the Los Angeles/San Bernardino County Line (KP 0.0/PM 0.0) and extends to Deer Haven Road (KP 7.4 /PM 4.6) in the community of Phelan. Segment 2 extended from a point approximately two miles east of Route 2 (KP 13.8/ PM 8.6) to Interstate 15 (KP 24.5/ PM15.2). Both Segments 1 and 2 are in San Bernardino County, California. In addition, Segment 3 lies between Pearblossom Highway (Route 18 - KP 111.7/PM 69.4) and the San Bernardino/Los Angeles County line (KP 120.7/PM 75.0) in Los Angeles County, California. Plate 17.1 is a vicinity map showing the boundaries of the project on Antelope Highway.

District 8 requested a Preliminary Design Report (PGR) on March 7, 2001 for both the San Bernardino and Los Angeles County segments. A subsequent memo dated May 11, 2001 was received from District 7, requesting a separate PGR for widening the Los Angeles portion of the existing two-lane State Route 138 to a four-lane facility with a median left-turn lane (07-LA-138 PM 69.44/74.97-07241-340110) from State Route 18 to Los Angeles/San Bernardino County Line. The previous report addressed both the Los Angeles County (Segment 3) and San Bernardino County (Segments 1 & 2) portion and there was also a separate PGR for Los Angeles County, District 7. This report addresses the above segments and also addresses the portion between Segments 1 & 2, called in this report 1-2.

This gap, 1-2, between Segments 1 and 2 extending from KP R7.4 to R13.8 and Segments 1 and 2, have been addressed in a Geotechnical Investigation (File: 08-SBd-138 KP 0/22.85 "Construct Truck Climbing Lane, Shoulder Widening and Misc. Safety Improvements 08220-46970K/08220-359700, June 28, 2001"), prepared by Mr. Chris Hoadley of the Office of Geotechnical Design. That report, which overlaps areas addressed at Segment 2, includes a rippability study of the conglomerate and sandstone rocks (Punchbowl Formation) also known as Mormon Rocks at KP 21.4 to 21.75 (PM13.3 to 13.5).

Our Office prepared this GDR based on a surface reconnaissance of the site, literature study, including reports on highway projects and bridges adjacent to and along this project site, and on local geology.

2. Pertinent Report and Investigations

District 8 has provided us with a route map of Antelope Highway that shows the proposed four-lane widening with a median left-turn lane, including proposed typical section, layout plans and profile plans. Our literature search yielded several reports and maps, which were utilized in preparing this report and are cited in the attached List of References.

3. Description of Existing Facilities

Within the project limits, the existing two-lane highway is generally well maintained (See Materials Report). There are varied widths of paved shoulders (up to 3.5 m) on both sides of the existing alignment. There is a passing lane in Segment 2 approximately between KP 14.0 to 17.3 (PM 8.7 to PM 10.75). Furthermore, at certain local road intersections with Antelope Highway, the two-lane section has been widened to create turn pockets.

The asphalt concrete (AC) has been overlaid in the past in many areas with either a chip seal or thin blanket extending across the lanes but not the shoulder. We observed two types of cracking in the pavement: occasional alligator cracking and minor rutting in the wheel tracks. This most frequently was seen in "at grade" areas of the highway and we consider this type to distress to the pavement structural section. We also observed significant distress (see Exhibit B), where the profile grade rises on the approach embankment for the Sheep Creek Bridge. Cracks extend perpendicularly to the roadway alignment roughly 2.5 to 4.5 m apart. These cracks are generally concealed beneath the overlay in the through lanes but they can be seen extending across both shoulders and into the AC dikes on either side. The cracking is approximately 30 mm wide in the dikes on the Sheep Creek Bridge approach fill. As seen in the photos, these shoulder cracks exist in areas that are essentially at grade (see Exhibit C) as well as on the Sheep Creek approach fill.

There are two areas of major existing cuts, both in Segment 2. The first (see Exhibit D) is a northeasterly facing cut slope commencing at KP 13.9 (PM 8.64) extending for 190 m (624 ft.) to the east along the edge of the eastbound lane. This 1(Vertical):1(Horizontal) cut rises to a maximum height of about 12 m above the roadway. The heavily vegetated natural slope above the top of the cut continues to rise along a 1(V):2(H) slope to an east-west trending ridge about 25 m above roadway elevation. There is no brow ditch at the top of the cut slope and runoff has locally eroded the sparsely vegetated, gravelly silty sand on the face of the cut. This cut will be widened as part of the proposed construction.

The second area of major cuts is at the Cajon Mount Underpass UC. Here, cut slopes on either side of the alignment rise to a maximum height of about 8 m above the roadway at about 1(V):1.5(H) slope ratio (see Exhibit E). The ground above the top of the cuts is fairly flat and do not appear to contribute runoff over the face of the cuts and are performing well with a moderate growth of vegetation. In this area the widening is proposed on the north side of the highway and has room for added lanes. As such, we do not anticipate the existing cuts in this area to be widened.

There are a few existing fill slopes that should be highlighted along the current alignment. The approach fills to East and West Pine Lodge Overheads are approximately 12 m high and have a slope ratio of about 1(V):2(H). Under the bridge structures themselves and approaching the abutments, the fill slopes have been steepened to 1:1.5 but the steepened areas have been protected from erosion with concrete slope armoring. These fill slopes are in general performing well; we observed no settlement, arcuate cracking or other signs of slope failure either in the roadway above the slopes or on the slopes. The slope surfaces are covered with a moderate growth of desert vegetation and do not appear to be experiencing significant erosion. AC dikes prevent roadlway runoff from flowing over the slope surfaces, contributing to the satisfactory erosion control.

Relatively new, yet minor fill slopes east of the Oasis Road intersection in Segment 1 are contrasted to the performance of the comparatively high 1:2 approach fills at the Pine Lodge Overheads. At the Oasis Road intersection, the roadway appears to have been recently widened to two through lanes with left and right turn pockets (westbound) and 3 m wide shoulders. There are no dikes to control pavement runoff at the Oasis Road intersection. Runoff sheetflows from the widened expanse of pavement over the 1:2 or flatter, fill slopes. Vegetation has not yet been well established nor any other erosion protection . The slopes are, in general, less than about 2 m high and are already experiencing erosion as seen by gullies ranging from about 150 mm to 1 m wide and to about 150 mm deep.

Further to the west, the highway rises on a 2.5 m high embankment at Mescal Creek (see Exhibit F). The embankment side slope ratios are 1(V):2(H) and there are no AC dikes to control runoff. Unlike the fill slopes at Oasis Road, however, the embankment slopes at Mescal Creek appear to be performing satisfactorily. We attribute this to the comparatively narrow width (two-lanes) of tributary pavement runoff and to the developing "desert pavement" exposed on the fill slopes at Mescal Creek. Desert pavement is a surface layer of gravel and cobbles remaining after finer soil particles have been removed by wind and water. In this case, it appears the more coarse grained materials have resisted erosion better than the fill soils used at Oasis Road.

As noted in the following table, there are several existing bridges within the project limits. The discussion of the performance of existing bridges is beyond our purview, however, Log of Test Boring sheets (LOTB's) for these structures provided added information for our assessment of geotechnical conditions in the area.

16.1 Bridges within Project Limits

Segment #	Bridge Name	Bridge Number	KP(PM)
1	Sheep Creek Bridge	54-0810	5.8(3.6)
2	Pine Lodge West Overhead	54-1056	23.0(14.3)
2	Pine Lodge East Overhead	54-1057	23.8(14.8)
2	Cajon Creek Bridge	54-0832	24.0(14.9)
3	California Aqueduct	53-2174	112.8(70.1)

In Segment 3, the highway undulates with the rolling terrain (see Exhibit G). Accordingly, cuts and fills in this segment are usually about 1 to 2 m high or not at all. Runoff from higher terrain offsite to the south flows across the alignment (see Exhibit G1), as there are no culverts except for one at Mescal Creek, KP 72.25 (PM 116.0). These cross-pavement flows occur at about 20 locations in the profile grade. The natural drainage channels cross the alignment as shown for one typical location at KP 119.1(PM 74), see Exhibit H. The dips are located as follows:

16.2 Segment 3 Dip Locations

Nos.	1	2	3	4	5	6	7	8	9	10
KP	113.7	113.9	114.1	114.4	115.2	116.0	116.3	116.5	117.0	117.3
PM	70.65	70.75	70.9	71.1	71.6	72.1	72.25	72.4	72.7	72.9

Nos.	11	12	13	14	15	16	17	18	19	20
KP	73.0	73.25	73.45	73.65	73.75	73.9	74.01	74.13	74.55	74.8
PM	117.5	117.9	118.2	118.5	118.7	118.9	119.1	119.3	120.0	120.4

The vegetation within the project limits includes species associated with well drained areas of the Mojave Desert, such as creosote bush, cheese bush, burro bush, and Mormon tea. Cacti species are more common in the drier valley areas of Segment 1 and 3 but other areas of the San Bernardino segments exhibit varying densities of low lying shrubs and brush.

4. Physical Setting

4.1 Climate

The climatic conditions at the project area are typical of a desert region. This arid region in southeastern California is characterized by extreme variation in daily temperature and has an average annual precipitation of less than 12.7 cm (5 in.), mostly rain with some snow. Almost all the precipitation arrives in winter. Freezing temperatures occur in winter, while summers are hot, dry and windy.

The following tabulated data was obtained from the Webster: http://www.accuweather.com/. This climatology data was recorded for the year 2000 at George AFB, California (Elevation 893 m/2874 ft) which is located Approx. 25 km (15.5 miles) NE of the intersection of the San Bernardino/Los Angeles County line with Rte. 138.

16.3 Climatology

Climatology 2000	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Highest Temp C	21	25	28	31	29	38	41	39	40	33	23	22
(F)	70	77	83	88	103	100	105	103	104	91	73	72
Lowest Temp. C	-3	-3	1	1	6	12	14	13	11	6	-4	-3
(F)	27	27	33	33	42	53	57	56	51	42	25	27
Average Temp. C	7	8	13	14	22	24	27	27	23	17	10	10
(F)	44	46.7	56	56.4	72.1	75.0	80.0	81.2	73.9	62.5	49.4	49.1
Total Precipt. cm	0.56	2.8	0.33	1.32	0.00	0.00	0.00	2.11	0.03	trace	0.00	trace
(in)	0.22	1.12	0.13	0.52	0.00	0.00	0.00	0.83	0.01	trace	0.00	trace
Total Snowfall cm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(in)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Normal Precipt. cm	2.1	2.2	2.2	0.9	0.5	0.1	0.4	0.8	1.0	0.7	1.5	1.8
(in)	0.82	0.88	0.85	0.36	0.18	0.05	0.15	0.31	0.38	0.26	0.58	0.69

4.2 Topography and Drainage

In general the topography for the project area descends gradually from the south/southwest to the north/northeast, from the San Gabriel Mountains (approximate elevation 2134 m/7000 ft.) to the Victor Valley, (approximate elevation 914 m/3000 ft.). Table Mountain and Lone Pine Ridge impede drainage of north-flowing San Gabriel Mountain streams, directing the drainage along Lone Pine Canyon. At several isolated locations, such as Sheep Creek (see Plate No. 17.2A) and Mescal Creek (see Plate 17.2C), the composite ridge is breached and the streams flow north, onto the Mojave Desert. Along Segment 1 the profile grade generally rises from (approximate elevation 1176 m/3858 ft.) at the San Bernardino /Los Angeles County line (KP 0.0/PM 0.0) to elevation 1324 m/4343 ft. at Sheep Creek (KP 5.8 /PM 3.6). The Segment 2 profile grade generally inclines downward to elevation 949 m/3112 ft. at Cajon Creek.

16.4 Ground Elevations

Bridge Name	Bridge Number	KP(PM)	Approx. ground Elevation
Sheep Creek Bridge	54-0810	5.8(3.6)	1324m/4343ft
Pine Lodge West Overhead	54-1056	23.0(14.3)	984m/3229ft
Pine Lodge East Overhead	54-1057	23.8(14.8)	958m/3142ft
Cajon Creek Bridge	54-0832	24.0(14.9)	949m/3112ft
California Aqueduct	53-2174	112.8(70.1)	1062m/3483ft

As mentioned in Segment 3 "Existing Facilities," Segment 3 passes through rolling terrain. Where natural drainage courses descend from the south toward the highway, they flow over the roadway at dips in the profile grade (see Exhibit G1). At most of these dips, minor debris basins from 0.5 m to about 2 m deep have been excavated on the south side of the highway to collect sediments from the storm flow and allow cleaner water to pass over the traveled way. Most of these basins had been cleaned of deposits from last winter's storms at the time of our field review. However, one at KP 118.2 (PM 73.45) contained an approximately 150 mm thick deposit of silt or clayey silt exhibiting desiccation cracks up to 50 mm wide. Such soils will not be acceptable foundation material for new embankment, but might help to retain moisture for establishing vegetation if well dispersed within new embankment fill.

On-site drainage within Segment 3 is controlled by soil berms 0.3 m high at the outer edges of the dirt shoulders. These berms both direct on-site flow to the dips, where the flow then continues northerly in existing natural drainage courses, and also help to direct sheet flow from desert floor areas south of the alignment to the debris basins.

In the San Bernardino County segments, earthen trapezoidal channels locally collect runoff from offsite areas to the south and southwest and direct the flow to cross culverts. An example can be observed between PM 0.0 to 0.5 where a 1 m deep, 2 m (bottom width) channel with 1(V):2(H) or flatter side slopes diverts runoff to a corrugated metal culvert at PM 0.49. These channels are irregular and hard to distinguish due to desert vegetation and disturbance due to either deposition or dumping of debris in the channel and/or maintenance efforts to clear such deposits. There are 104 culverts for unnamed drainage courses that cross the alignment in Segments 1 & 2 (see attached drainage data sheet in appendix).

About 2 m deep, easterly draining drainage course lies approximately 15 m north of the edge of pavement for the existing westbound lane from the beginning of Segment 2 at KP 13.8 (PM 8.6) to a dry wash at KP 14.6 (PM 9.0). This channel is about 4.5 m below the elevation of the existing road surface at the beginning of Segment 2, but it rises up, gets shallower and spreads out wider as it approaches the Cajon wash. The drainage course contains heavy growths of brush and likely contains loose alluvial deposits (see Exhibit H). New embankment placed to widen the highway northerly of its current location will likely encroach into, or bury this drainage course.

The existing drainage courses throughout the project alignment are poorly to well eroded, usually displaying considerable gravel, cobbles and occasional boulders.

4.3 Prior Land Use

To the best of our knowledge, no agricultural land that would contain plowed, loosened surface soils exists close to or along the sides of the current alignment, except for along Segment 2 where the road passes an orchard at approximately KP 18.0 (PM 11.3) and a vineyard at KP 17.7 (PM 11.0). Most of the alignment, and all of Segment 3, passes through vacant high desert. Segment 1 passes through the communities of Pinon Hills and Phelan. Segment 1 - 2 is the Highway 2 interchange and the Summit Restaurant set back from the roadway. Segment 2 passes through lands of the San Bernardino National Forest. Segment 3 passes through the community limits of Llano. However, where the current alignment passes through the communities, residential and commercial facilities are on adjoining land that might be impacted by this project. Right of Way lines shown on plans available at the time of our review show that existing commercial buildings in the area of Segment 1 will not be within the future Right of Way. If existing buildings do exist within the future Right of Way, there could be potential impacts to future highway earthwork due to disturbed soils from building demolition, possible on-site sewage disposal systems, etc.

5. Geology

5.1 Regional Geology

The subject site lies at the boundary between two geomorphic provinces, the Great Basin/Mojave Block Province and the Transverse Range Province. The border between these provinces is in close proximity to the San Andreas Fault, the boundary between the Pacific and North American continental plates. This boundary is strike-slip and has resulted in significant seismic activity in the past, and should be expected to continue to do so in the future (Plate 17.3A).

The upper part of the project, north of the San Gabriel Mountains, lies within the Great Basin/Mojave Block Province, which is characterized by isolated mountain ranges separated by expanses of desert plains (Plate 17.3B). There are two topographic trends within the province, a northwest-southeast trend controlled by the San Andreas Fault along the southwestern border of the province, and a secondary east-west trend controlled by the Garlock Fault, which is the northern boundary of the province. The southern section of the subject site lies within the Transverse Range geomorphic province, a complex series of east-west trending mountain ranges and valleys.

5.2 Site Geology

Segments 1 and 3 of Antelope Highway lie within the Upper Mojave River Valley Basin. The geologic formation through which these segments will pass has been mapped as Quarternary Alluvium as shown on Plate 17.3 A. Deposits at the southeasterly end of Segment 1 are mapped as well dissected alluvial fan deposits, which have much the same character as the previously mentioned alluvial deposits.

Segment 1-2 and Segment 2 passes across the southern edge of the Cajon Basin west of Cajon Pass, the natural pass separating the San Gabriel Mountains from the San Bernardino Mountains. This portion also lies southwesterly and roughly parallel to the flow line of Cajon Canyon, which is also located just beyond the base of Lone Pine Ridge to the southwest. Lone Pine Ridge, underlain by Mesozoic plutonic rock and pre-Mesozoic gneiss and marble, separates Cajon Canyon from Lone Pine Canyon on the southwest. The San Andreas Fault, which trends west-northwest through the Transverse Ranges, lies within Lone Pine Canyon.

As it traverses the floor of Cajon Canyon, Segment 2 is also founded on Quarternary Alluvium. However, two geologic formations were encountered in two locations. As seen on Plate 17.2B, between KP 13.8 to 14.1 (PM 8.63 to 8.76) the northwest end of Segment 2 has been cut into the flank of a northwest trending ridge consisting of Crowder Formation sandstone. This formation is a light tan to gray, fine to coarse, highly weathered, friable sandstone with frequent cobbles (see Exhibit D). Distinct geologic bedding was not discerned in this rock where exposed on the surface of the road cut. However, the geologic map consulted depicts bedding as dipping down to the northeast at 20 degrees from the horizontal. At that angle, the bedding is dipping slightly out of slope in the present cut, and would be unsupported should the cut be widened at a slope steeper than 20 degrees.

The second location of formational rock along Segment 2 occurs at KP 21.4 to 21.66 (PM 13.3 to 13.46) where the highway threads between outcrops known as the Mormon Rocks (see Exhibit C). The Mormon Rocks belong to the Punchbowl Formation of sandstone and conglomerate, very hard, unfractured, gravelly, coarse sandstone with laterally discontinuous cobble lenses that dips to the northeast at 40 to 60 degrees (see Plate 17.2B). A bedding measurement taken during our rippability study found the bedding to be dipping at 45 degrees to the northeast.

For confirmation of the types of soils to be encountered along the project alignment, we compared the soil descriptions listed in the Log of Test Boring (LOTB) sheets (attached) for the five bridges on the existing highway to the material types depicted by the geologic mapping. The borings encountered alluvial deposits of interbedded layers of slightly compact to very dense silty sand, sand, gravelly sand, and sandy gravel with scattered cobbles.

6. Geologic Considerations

6.1 Mineral Resources

Other than soil (alluvial) deposits that might be processed to generate sand, no known mineral resources were identified within the project limits.

6.2 Aggregate/Construction Material Source

The alluvial soils within the project limits could potentially be used as a source of sand and aggregate for construction.

At this time no specific borrow sites have been identified nor tested. However, during our reconnaissance we noted trapezoidal shaped stockpiles of silty sand with gravel adjacent to the

California Aqueduct near KP 112.8 (PM 70.1) in Segment 3 (see Exhibit I). The stockpiled soils were likely removed during excavation of the aqueduct and placed as mounds on either side of the aqueduct (see Exhibit I). We do not know if these mounds serve other purposes than simply a means of disposing of the excavated soil during aqueduct construction, but the District could inquire with the Department of Water Resources about the availability of that material for use as common borrow.

6.3 Excavation Characteristics

For most of the project length, we expect that excavation of alluvial soil required for constructing the two new lanes and the median left-turn lanes can be carried out by conventional earth moving equipment. Based on our surficial observations and on the geologic mapping, as substantiated by the Log of Test Borings for the five bridges, sandy gravel with scattered cobbles and boulders will be encountered to depths of at least 2 m to 3 m below ground surface.

Other than at two locations, we do not anticipate cuts, if any, to be deeper than 0.5 to 1.0 m for the new lanes. However, if occasional boulders are encountered during excavations, they will need to be separated from the rest of the excavated material, treated as "surplus material" and handled as per Standard Specification 19-2.06, assuming the proposed fills will be too thin to accommodate the boulder/cobble dimensions.

At the time of this report, the depth of excavation to widen the existing northeasterly facing cut slope at PM 8.64 was not known to us. Nevertheless, it appears that the Crowder Formation sandstone is highly weathered. We expect that excavation can be conducted with conventional earthmoving equipment, perhaps with heavy ripping at times.

The Mormon Rocks (KP 22/PM 13.4) outcrop is very hard, unfractured, gravelly, coarse sandstone with laterally discontinuous cobble lenses that dip to the north at 45 degrees (see Exhibit J). These outcrops contain a weathered horizon that appears rippable to a depth of approximately 2 meters. Depths greater than 2 meters are unrippable mechanically to subgrade elevation. Blasting to a subgrade elevation may be considered as an option, or alternatively evaluate realignment. The hardness of this formation, the favorable bedding dip relative to the orientation of the proposed cuts and the lack of other discontinuities enable us to tentatively recommend cut slope ratios in the Mormon Rock outcrops steeper than the other cuts on the project.

6.4 Erosion

The performance at the existing embankments for the Pine Lodge Overheads, the Oasis Road intersection and the Mescal Creek culvert shows that the erosion performance of embankments constructed at 1(V):2(H) or flatter slope ratios can be dependent on effective landscaping treatments (vegetation), width of paved area providing tributary runoff, prevention of both concentrated flows and sheet flow over the face of the slope, and the amount of gravel and cobble on the slope surface. As the proposed widened highway will create a paved width similar to that existing at the Oasis Road intersection, runoff from the pavement could erode unprotected fill slopes. Asphalt concrete dikes that prevent sheet flow of water from the pavement and over the slope appear to be highly effective in preventing erosion, even where they are cracked as has occurred at the Sheep Creek Bridge. However, AC dikes would require provisions to collect the flow from the pavement and discharge it in a non-erosive manner. For fill slopes of minor height that can be easily accessed for maintenance, flatter slope ratios and landscaping measures could serve satisfactorily.

We anticipate that the proposed cut in the Mormon Rocks will not be subject to erosion due to the hardness of the rock. These outcrops stand naturally at steep slope ratios with little vegetation, their continued existence showing the erosion resistant nature of the rock.

While the existing 1(V):1(H) cut in the Crowder Formation sandstone at KP 13.9 (PM 8.64) has apparently stood well since the construction of the highway without significant gross failure, the bedrock is friable and subject to surficial erosion as the rock weathers. Erosion of the present cut is evident (see Exhibit D). Increasing the height and exposed surface of the cut face will subject the cut to added runoff, therefore, increasing the potential for erosion. If the top of the future widened cut does not extend to the top of the southwesterly adjacent ridge where the proposed R/W line is shown, then we recommend provisions be provided to prevent runoff from the superjacent natural slope from flowing over the cut face.

Minor cuts in the alluvium have been made at about 1:2 slope ratios such as on the south side of the intersection at Oasis Road. Where the ground surface above the top of such cuts is relatively flat and no concentrated flows are directed toward the top of the cut, they appear to perform well with minor erosion. Where such cuts are planned across even minor drainage courses on the desert floor, provisions should be made to prevent the intermittent flows in the gullies from flowing over the cut face.

Erosion mitigation measures are proposed under Section 12.4 "Slope Stability." Nevertheless, District Landscaping should be made aware of this project and request provisions to prevent and/or control erosion.

Erosion of offsite areas to the south may also have an effect on the design of offsite drainage systems. Observation of sharply incised existing drainage courses and the sand/gravel/cobbles exposed in those courses infers that culverts will be subjected to heavy bedload and potential scour. We defer to the Hydrology Section for the design measures to accommodate stream bedload.

6.5 Scour

All creeks and streams, which lie within the project, were dry during our site reviews (April and July 2001). The bridges listed in chart 16.5 are not scour critical as per Mr. Mark Palmer, Senior Engineering Geologist, Scour Critical Program. (Ref. 15)

7. Groundwater Conditions

Our inquiry (Ref. 5) with Department of Water Resources revealed six wells located near the project limits:

16.5 Groundwater Elevation from Department of Water Resources

Well	Approx. groundwater Elevation	Approx. ground Elevation	Date
04N06W23M01S	895m/2937ft	1195m/3920ft	02/11/ 98
04N08W07C01S	1212m/3976ft	1281m/4202ft	03/17/99
05N09W25A01S	897m/2944ft	1042m/3417ft	11/26/56
05N07W30D02S	890m/2919ft	1033m/3390ft	10/2098

Note: Wells 04N07W35G01S and 04N07W27A01S reported by DWR are not included because no ground water was encountered. For well locations, see "Groundwater Level Data Retrieval Map Interface," attached in the appendices.

Groundwater was also encountered at different elevations during soil investigation, drilling, or construction of the existing bridges along the alignment as follows:

16.6 Groundwater Elevation at Bridges Along the Alignment

Bridge Name	Approx. groundwater Elevation	Approx. ground Elevation	Date	KP(PM)
Sheep Creek Bridge	Not encountered	1324m/4343ft	March 1966	5.8(3.6)
Pine Lodge West Overhead	974m/3194.5ft	984m/3229ft	1979/1980	23.0(14.3)
Pine Lodge East Overhead	952m/3125ft	958m/3142ft	1979/1980	23.8(14.8)
Cajon Creek Bridge	941m/3088ft	949m/3112ft	March 1966	24.0(14.9)
California Aqueduct	Not encountered	1062m/3483ft	Sept 1967	112.8(70.1)

We do not anticipate that groundwater will be encountered during earthwork operations. However, groundwater levels fluctuate by season and might be expected to be higher near the mouth of Cajon Canyon in Segment 2.

Availability of groundwater for use in construction operations has not been investigated. In Segments 1 and 3, water for earthwork and other construction purposes might be available from public hydrants in the communities adjoining the alignment.

8. Seismicity

Historical records indicate that the area has been subjected to a number of seismic events over the course of the last 182 years. Strong ground motion (defined as a horizontal ground acceleration in excess of about 0.5 g) was likely experienced in the project area in 1812, 1827, 1852, 1855, 1857, 1893, 1936, 1952, 1956, 1965, 1971, 1974, 1977, 1991, 1992, 1994 and 1999. The 1812 and 1857 events (estimated to have had moment magnitudes of approximately 7.0, and 8.0, respectively) are thought to have occurred along the Mojave segment of the San Andreas fault and caused significant damage to developed areas of southern and central California. Similarly, the 1992 Landers earthquake and the 1999 Hector Mine earthquake had magnitudes of 7.5 and 7.1 respectively, however these latter two events did not damage existing Route 138 within the project limits (Ref. 16).

The geologic processes that have caused earthquakes in the past should be expected to continue. Seismic Map (Plate 17.4) is an excerpt from the Department's "California Seismic Hazard Map" of 1996. It depicts the location of the project and nearby State routes (route numbers shown in boxes) to nearby faults that might affect the site, and gives contours of peak bedrock accelerations. From the map we anticipate the project area could experience peak bedrock accelerations of 0.55g to 0.7g.

16.7 Seismicity

Fault Name	Type	Magnitude	Peak acceleration	Dist. to Fault	KP/PM
San Andreas/C (SAC)	Strike-Slip	8.00	0.7	2.6km/1.6mi	22.8/14.2
Cleghorn-North (CNF)	Reverse	7.75	0.7	1.9km/1.2mi	23.6/14.7
Llano Fault (LLO)	Unknown	6.00	0.6	3.8km/2.4mi	112.8/70.1

As shown on the California Seismic Hazard Map of 1996, the closest fault to the project site is the Cleghorn-North Frontal fault, a reverse-thrust fault thought capable of generating a Magnitude 7.75 event. That fault is 1.9 km (1.2 miles) from the alignment of Route 138. As such, it is unlikely that surface rupture will cause significant horizontal and vertical surface displacement at the site.

Engineering implications of the site seismicity are discussed in Section 12.2.

9. Landslides and Rockfall

Neither landslides nor rockfall are anticipated within the three project segments in San Bernardino and Los Angeles Counties, because of the generally flat topography of the area. Proposed cuts in bedrock in Segment 1-2 are expected to perform well at 1(V):2(H) slope ratios, as judged by either the performance of the existing cut slopes and natural slopes above at PM 8.64±, or due to the hardness of the rock exposed at the Mormon Rocks. Slope failures are not likely on proposed fill slopes graded at 1(V):2(H) or flatter assuming they are constructed in accordance with the Standard Specifications of earth materials generated from the vicinity of the project alignment, and are of heights less than or similar to the existing embankments at the Pine Lodge Overheads (10± m).

10. Snow Avalanches

Although snow does fall within the project limits, a snow avalanche is highly unlikely due to the generally flat topography of this project and the distance from the neighboring mountains. This project lies approximately 8 km(5 mi.) northeast of the base of the San Gabriel Mountains, so even the potential run-off zone from a very large snow avalanche is considered very low.

11. Geothermal Activity

No known geothermal activity was identified within the project limits.

12. Geotechnical Considerations

12.1 Embankment

The geotechnical aspects discussed in this section are based on review of the existing facilities plus the previous Log of Test Borings for five bridges on the project site. In general, alluvial soils encountered at the site and excavation from the proposed cut slopes at Mormon Rocks and PM 8.64 can be used as fill for embankments. Depending on how the contractor rips or blasts the rock at Mormon Rocks, oversized fragments may be generated that may be unsuitable either for incorporating into the embankment, or requiring additional effort to to break up for placement in the fill.

For Segments 1 and 2, we anticipate the height of embankment will generally be less than 1 to 1.5 m except near PM 8.75 (Segment 2), where we anticipate the embankment will be about 5 m above the drainage course. Fill depths within the existing drainage course (see Exhibit H) may be deeper such as Segment 1-2 where the fill is a maximum of 20 m deep. Within Segment 2, existing approach fills to the Pine Lodge Overheads will be widened and will have a height of about 10± m. For Segment 3, we anticipate new embankment heights up to 5± m.

The Earthwork Factor (EWF) for the alluvial soils may be assumed to be 0.8 and for materials derived from the Mormon Rocks EWF may be assumed to be 1.15. Occasional boulders can be expected in the alluvial soils of Segment 1, 1-2 and 3.

12.2 Ground Shaking and Liquefaction

Ground shaking is expected to occur at the site considering the predicted magnitude and peak ground accelerations of earthquakes along nearby faults. Ground shaking could cause densification of loose soil layers and consequently some distress to the roadway structure. However, the potential for liquefaction is not anticipated based on ground water depth and generally dense nature of the subsurface granular soils. Furthermore, a nearly at-grade highway with flexible pavement is less susceptible to the effects of earthquake induced ground shaking than perhaps any other types of highway.

Surface fault rupture is not anticipated to affect the roadway.

12.3 Settlement

Embankment settlement from foundation compression will not be a major issue for the project due to deep groundwater level, granular foundation soils and low to moderate embankment heights. In the absence of high groundwater and fine grained foundation soils, we anticipate that settlement will occur as the embankments are being constructed. Waiting periods are not expected. However, loose alluvial deposits in drainage courses to be filled or, in the bottoms of existing debris basins in Segment 1-2 and 3 should be at least partially subexcavated. Depths of subexcavation will be explored in the design phase, but are not anticipated to exceed 0.5 to 1 m.

12.4 Slope Stability

In general, with future cut and fill slopes being graded at 1:2 or flatter and being constructed of, or in, granular materials to moderate slope heights of 20± m for fills and 67 m for cuts, slopes should be stable against deep seated failure. However, for the cut slope at KP 13.9 to KP 14.0 (PM 8.64 to PM 8.71) the geologic map depicts the bedding as dipping at 20 degrees to the north. Our field investigation revealed the bedding dipping to the northeast away from the roadway. As this slope is currently stable, we feel with the flattening, this slope will be stable at 1(V):2(H).

With the bedding plane orientation in the Mormon Rocks dipping favorably to the north (the roadway turns to the east), and in the absence of other, adversely oriented rock discontinuities, the rock hardness and geologic structure appear to be favorable for making a steep cut. Accordingly, it is our opinion that this cut may be made at a slope ratio of 1:0.5 or flatter, but that a catchment area be provided along the toe of the cut in conformity with the Ritchie criteria (see Appendix).

13. Corrosion

Seven soil samples were collected at selected sites for a few proposed culverts and structures and tested for corrosion potential as per Caltrans Corrosion Guidelines 1996. The test results show soils to be noncorrosive.

16.8 Corrosion Test Results Summary

Sample Identification	KP/PM	Depth (ft)	pH	Minimum Resistivity (Ohm-cm)	Sulphate Content (ppm)	Chloride Content (ppm)
LA3-1	112.65/70	.5 to 2	7	12000	N/A	N/A
LA3-2	117.48/73	.5 to 2	7.1	12000	N/A	N/A
SBd1-3	1.61/1	.5 to 2	7.5	22000	N/A	N/A
SBd1-4	3.22/2	.5 to 2	7.9	9000	N/A	N/A
SBd1-5	4.83/3	.5 to 2	7.7	11000	N/A	N/A
SBd2-6	16.09/10	.5 to 2	7.5	18000	N/A	N/A
SBd2-7	19.31/12	.5 to 2	8.6	12000	N/A	N/A

Note: Samples were obtain from Soil Profiler/hammer and shovel in zip bags

District Materials Report has additional corrosion information.

14. Hazardous Waste Impact

As of the time of writing this report, we were not aware of any locations along the proposed alignment suspected of containing hazardous materials. We will need information from the District Hazardous Waste Unit about the location of any hazardous materials prior to conducting our subsurface exploration.

15. Recommendations

15.1 Exploration and Investigations

The granular nature of the material for the project will provide an acceptable base for a roadway. As LOTB sheets already exists for the existing bridges, this exploration is already done. At the location of the proposed cut at PM 8.6±, if during grading adverse bedding is discovered, please contact this Office for additional exploration.

15.2 Cut Slopes

The cut slope at Segment 2 KP 13.9 (PM 8.6) may be designed at a 1(V):2(H) slope ratio. If the top of the cut will daylight with the natural rising slope above, a brow ditch is to be installed. Slopes refered to in the "Geotechnical Investigation", June 28, 2001, Segment 1-2, Cuts 1L, 6L, 7L, 8L, 9L, 11L, 29L, 35L, 36L, 38L, 6bR, 14R and 15R shall have a brow ditch installed. Cuts 18L,19L, 20L, 6aR, 6bR, 6cR and PM 8.6 shall have an erosion mat installed on the entire slope face not just intermittent straw wattle.

The cut slope at the Mormon Rocks may be graded at a slope ratio of 1:0.5 or flatter to a height of 12 m. A 4.5 m wide catchment area should be graded between the toe of the cut and the edge of the traveled way. The catchment area should be graded uniformly from the edge of shoulder to the toe of cut, and the toe of the cut slope should be 0.5 m below the edge of traveled way elevation.

15.3 Embankment

Embankment slopes should be graded at 1(V):2(H) or flatter. Measures such as AC dikes at the top of embankments are recommended to prevent flow from the roadway over the slope face; however, dikes may be omitted where erosion control measures, as selected by the District Landscape Architects, are used.

Embankment foundations shall be prepared in accordance with Section 19 of the Standard Specifications. For estimating purposes, assume 0.5 m of alluvium must be subexcavated from embankment foundation areas in drainage course channels and replaced as compacted fill.

15.4 Excavation Techniques

Excavations can be accomplished by conventional techniques for the project, except for cuts in the Mormon Rocks in Segment 2. Seismic Refraction Surveying has been performed to provide an assessment of the rippability of these resistant sandstone features. These outcrops contain a weathered horizon that appears rippable to a depth of approximately 2 meters. At depths greater than 2 meters, the outcrop is unrippable to subgrade elevation and blasting will likely be required. If blasting is not viable then realignment of the proposed road should be considered.

References

1. File and Minch, Geology and Mineral Wealth of the California Transverse Ranges, Mason Hill Volume, South Coast Geological Society, 1982, p. 148 to 169.

2. California Division of Mines and Geology, Geologic Map of the San Bernardino Quadrangle, Compiled by E.J. Bortugno and T.E. Spittler, 1986 (Second printing, 1998).

3. John Foster, Late Cenozoic Tectonic Evolution of Cajon Valley, Southern California, p.67 to 73.

4. Gary S. Rasmussen, Geologic features and rate of movement along the south branch of the San Andreas Fault, San Bernardino, California, p.108 to 114.

5. Gary Gilbreath and David Singh, Department of Water Resources, Division of Planning and Local Assistance.

6. Topographic Map (7.5 Minute Series), Mescal Creek, Phelan, Telegraph Peak, Cajon Quadrangle, San Bernardino County, California. Department of the Interior Geological Survey, United States.

7. Memorandum dated July 3, 2000 for Sheep Creek Bridge (Bridge No. 54-0810), Pine Lodge East Overhead (Bridge No. 54-1057), for Pine Lodge West Overhead (Bridge No. 54-1056) From M.A. Willian, Senior Engineering Geologist, Project & Resource Coordination Branch and Muhammad Luqman, Associate Engineering Geologist to Mike Van De Pol, Senior Bridge Engineer, Division of Structure Design.

8. Memorandum dated July 10, 2000 for Cajon Creek Bridge (Bridge No. 54-0561). From M.A. Willian, Senior Engineering Geologist, Project & Resource Coordination Branch and Muhammad Luqman, Associate Engineering Geologist to Mike Van De Pol Senior Bridge Engineer, Division of Structure Design.

9. Memorandum dated Nov 6, 1967 for California Aqueduct Antelope (Bridge No. 53-2174). From C.E. Marek and C.G. Bemis to T.L. Sommers.

10. Angel Perez-Cobo and Jinxing Zha, Geotechnical Earthquake Engineering, Geotechnical Service, Division of Engineering Services, California Department of Transportation, Caltrans.

11. Mualchin, L., A Technical Report to Accompany the Caltrans California Seismic Hazard Map 1996 (Based on Maximum Credible Earthquakes): California Department of Transportation, Office of Earthquake Engineering, 1996

12. Memorandum dated Nov 6, 1967 for California Aqueduct Antelope (Bridge No. 53-2174). From C.E. Marek and C.G. Bemis to T.L..Sommers.

13. Memorandum dated June 13, 2001 for Seismic Refraction Survey to determine rippability of outcrop at Mormon Rocks, Highway 138, San Bernardino County, California. From William Owen, CEG, Chief, Geophysics and Geology Branch and Dennison K. Leeds, Engineering Geologist, Geophysics and Geology Branch, Geotechnical.

14. Memorandum to Mark Lancaster, District 8, Office of Design A., for Geotechnical Investigation (08-SBd-138-KP 0/22.85 OGE No. 53-2174). from Mr. Chris Hoadley, RG, Associate Engr. Geologist, and Ms. Martha Merriam, CEG, Senior Engr. Geologist, Geotechnical Section B, Geotechnical Services.

15. Scour Critical Program, Mark Palmer-Sr Engr Geologist Spc, Geotechnical Service, Division of Engineering Services, California Department of Transportation, Caltrans.

16. Personal Communication, Orville Nelson, Area Maintenance Superintendent, July 19, 2001.

17. Memorandum to Mike Beauchamp, Design A, for Materials Report (08-SBd-138-KP 0/22.85) from Bruce Kean, District Materials Engineer, July 11, 2001.