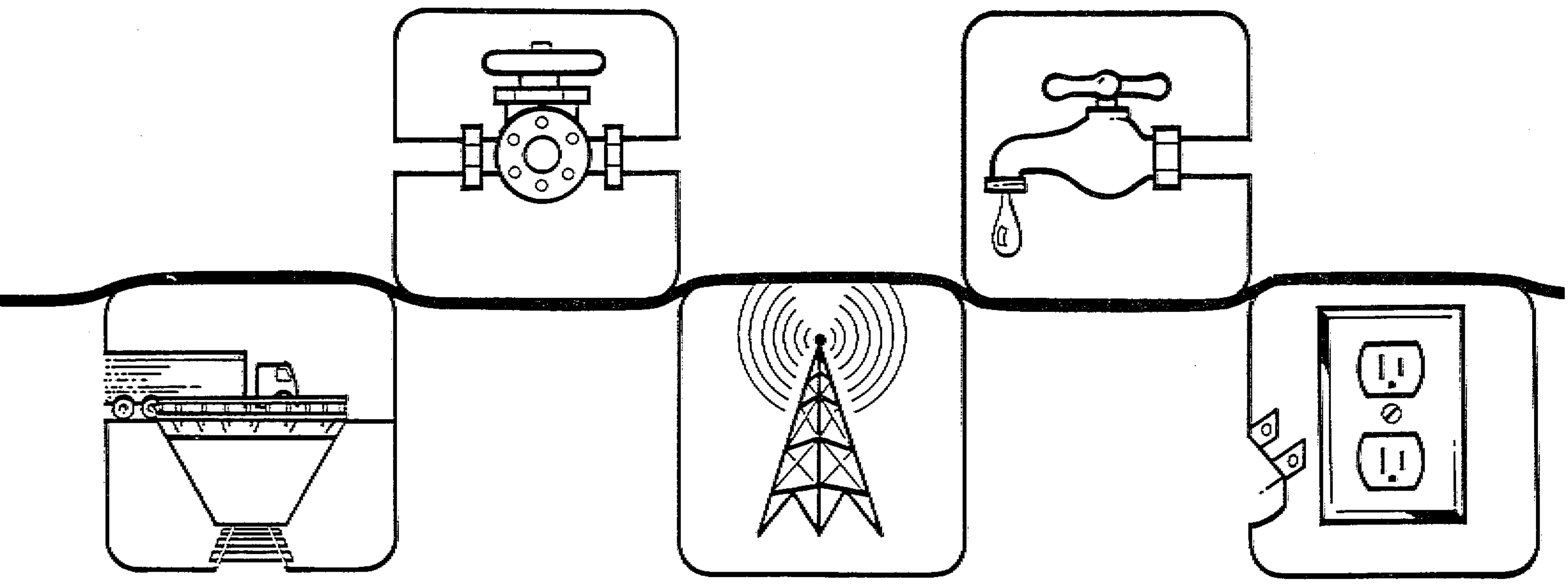
FEDERAL EMERGENCY MANAGEMENT AGENCY FEMA 225 / February 1992

Inventory of Lifelines in the Cajon Pass, California



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Earthquake Hazard Reduction Series 60

Inventory of Lifelines in the Cajon Pass, California

Submitted to the Federal Emergency Management Agency
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INVENTORY OF LIFELINES IN THE CAJON PASS, CALIFORNIA

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INVENTORY OF LIFELINES IN THE CAJON PASS, CALIFORNIA

1.0 INTRODUCTION AND BACKGROUND

1.1 BACKGROUND

Lifelines (e.g., communication, electric power, liquid fuels, natural gas, transportation, water and sewer systems, etc.) are presently being sited in "utility or transportation corridors" to reduce their right-of-way environmental, aesthetic, and cost impacts on the community and on land use. The individual lifelines are usually constructed or modified at different time periods, resulting in their being built to different standards and in different siting criteria being applied to different segments of an individual lifeline or to different lifelines that provide similar functions. Presently, the siting review usually does not consider the impact of the proximity or collocation of one lifeline upon the risk to or vulnerability of other lifelines from natural or manmade hazards or disasters, either because the other lifelines have not yet been installed or because such a consideration has not been identified as a factor in the siting evaluation.

In August 1988, a train derailment in northern California also damaged a petroleum pipeline which was buried along the railroad right-of-way. The result was a spill of the pipeline fluids in addition to the derailment (but no significant loss of property and no injuries to or casualties)(1-1)[1]. The State of California Office of the Fire Marshall became involved as it is the California agent responsible for the inspection and enforcement of safety criteria for pipelines that transport liquids. When another derailment in San Bernardino occurred in May 1989(1-2), which resulted in severe property damage and the loss of life, the Office of the Fire Marshall also responded to see if the derailment had impacted a petroleum products pipeline that was buried along the railroad right-of-way. It was decided that the pipeline was not damaged, and the fire and safety personnel turned over the site to the railroad to allow them to clean up the site. About a week later the pipeline ruptured and the resulting fire caused considerable property damage and loss of life. The subsequent investigation(1-2) concluded that the pipeline may have been damaged during the derailment, but that the most probable cause of its damage was the derailment clean up operations.

In a similar sense, communication lines along a highway bridge would be vulnerable to failure if the bridge were to displace or fail during a disaster event. In fact, frequently highway bridges and overpasses are used to route other lifelines, such as communications and pipelines, over causeways and water bodies. Such lifelines can be damaged by failure of the superstructure, bridge foundation movement, or ground deformation

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[1]Numbers in parentheses refer to the bibliography found at the end of each major report section.

along the approaches to the bridge. Settlement and lateral displacement adjacent to abutments have been especially troublesome because such movements tend to impose deformations on the lifelines where they are locally constrained at the attachment or penetration of the abutment.

There are many such examples of lifeline interdependency that occurred during the 1989 Loma Prieta earthquake. For example[1-3,1-4], the lack of fire fighting water in the Marina district resulted from pipeline failures. Failed water pipelines have caused ground erosion that has failed the foundations of other lifelines. Loss of electric power prevented the fire department from closing remote, electrically-controlled valves that were intended to isolate damaged portions of the water lifeline system. This resulted in the loss of the use of storage reservoirs and the ability to provide critically needed, fire fighting water. Electrical failures and shorts have ignited leaks from fuel pipelines, increasing the level of damage associated with the failed flue delivery lifeline.

In response to these types of situations, the Federal Emergency Management Agency (FEMA) is focusing attention on the use of such corridors, and they initiated this study to examine the impacts of siting multiple lifeline systems in confined and at-risk areas.

1.2 PURPOSE, GOALS, AND STUDY APPROACH

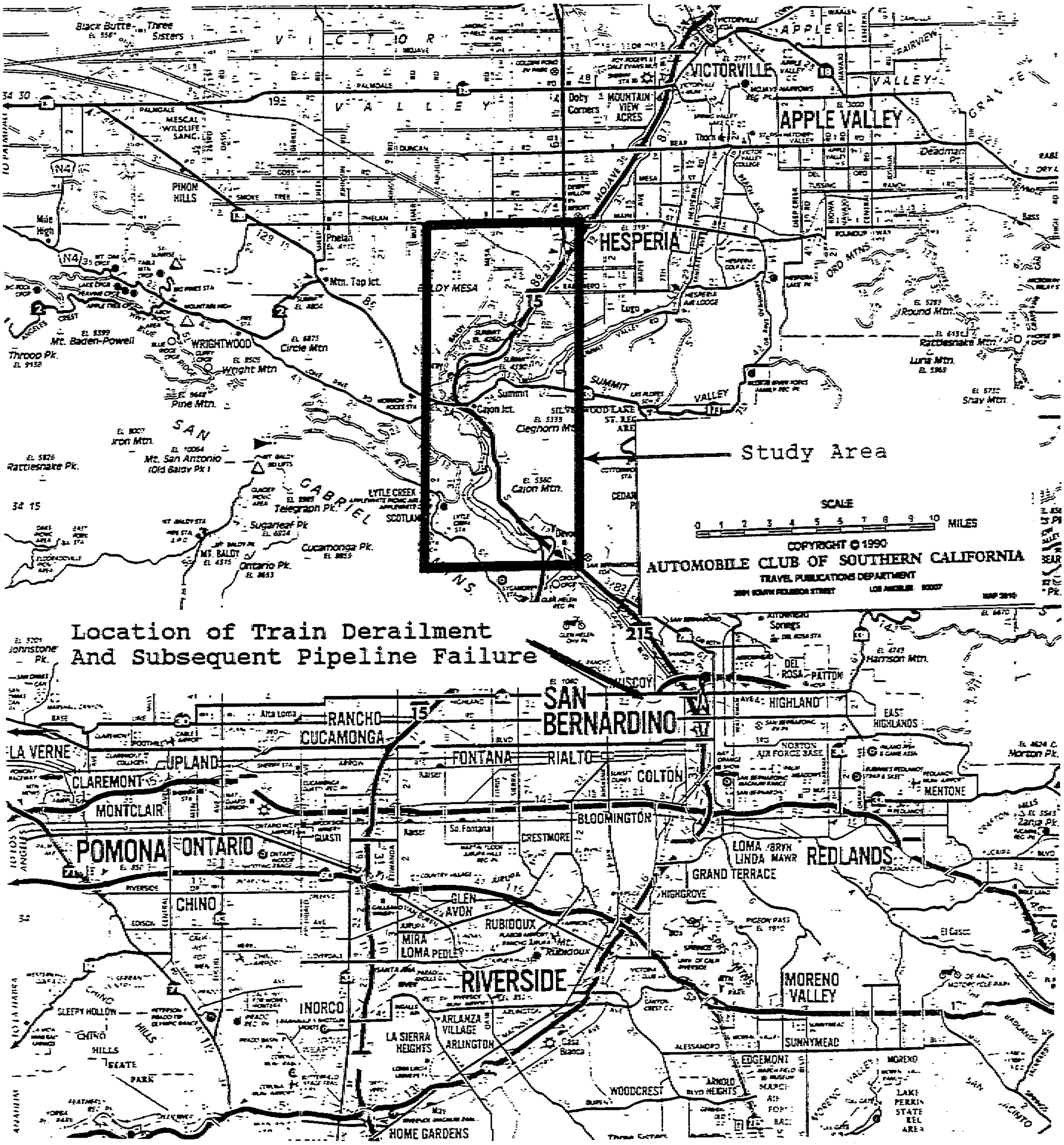
The overall FEMA project goals are to develop, for multiple lifeline systems in confined and at-risk areas, a managerial tool that can be used to increase the understanding of the lifeline systems' vulnerabilities and to help identify potential mitigation approaches that could be used to reduce those vulnerabilities. The goals also are to identify methods to enhance the transfer of the resulting information to lifeline system providers, designers, builders, managers, operators, users, and regulators.

To provide a specific example of how the managerial tool can be used, it was decided that the methods should be applied to the lifelines in the Cajon Pass, California, for an assumed earthquake event at the Pass.

The purpose of this report is to provide an inventory of the major lifeline systems in the Cajon Pass and the earthquake and geologic analysis tools available to identify and define the level of seismic risk to those lifelines. The information in this report can then become a validated data base for use in the development of the required analysis methodology for evaluating the impact of proximity or collocation of lifelines on the vulnerability of nearby lifelines.

Figure 1-1 is a reproduction of a highway map (courtesy of the Automobile Club of Southern California) of the San Bernardino, California, area (1:250,000-scale). The locations of the Cajon Pass study area and the May 12, 1989, train derailment and the subsequent May 25, 1989, petroleum products pipeline rupture are identified on the map.

Figure 1-1, Map of the Cajon Pass Area



The methodology used in developing the information for this report is as follows. Site reconnaissance surveys of the Cajon Pass were made to familiarize the researchers with the specific site conditions and to identify areas of special interest. Contacts were then made with each lifeline system owner and the study information needs were explained. The owners responded with engineering data on their specific system(s). Contact also was made with the regulatory agencies as well as with appropriate emergency planners. Those direct contacts provided basic data on each lifeline system, and they provided validation of the data (or in some cases raised questions as to our understanding of the data). Additional site visits were then made to confirm and further validate the available data. This report was then prepared, with heavy reliance on the validated data or on the data provided by each lifeline owner. As a final validation of the work, the draft report was submitted to each organization that provided information for the report with the request that it review the material to assure that the information provided was not misunderstood or to provide additional clarification data when appropriate.

Section 2.0 of this report presents an executive summary of the study. It also adds a discussion in which all of the separate data are combined onto a single map to identify the regions of greatest congestion. Section 3.0 presents the specific data for the lifeline systems and the seismic data and codes available to determine the earthquake impact on those lifelines. Section 4.0 presents a list of the organizations contacted during this study.

1.3 BIBLIOGRAPHY FOR SECTION 1.0

1-1 Source of information: conversations with the State of California Office of the Fire Marshall, Office of Pipeline Safety.

1-2 National Transportation Safety Board Railroad Accident Report NTBS/RAR-90/02 (PB90-916302), June 19, 1990.

1-3 T.D. O'Rourke, et. al., "Geotechnical and Lifeline Aspects of the October 17, 1989, Loma Prieta Earthquake in San Francisco", Technical Report NCEER-90-0001, National Center for Earthquake Engineering Research, January 1990.

1-4 T.D. O'Rourke, et al., "Response of the San Francisco Water Supply System During the 1989 Loma Prieta Earthquake", presented at the conference Putting the Pieces Together, San Francisco, CA, October 1990.

2.0 EXECUTIVE SUMMARY

2.1 SUMMARY

This report is the first phase of a study commissioned by the Federal Emergency Management Agency (FEMA) to evaluate the vulnerabilities occurring from the siting of multiple lifeline systems in confined and at-risk areas due to their interactions from natural and manmade disasters. The goals of the overall study are to identify the lifeline systems' vulnerabilities, to identify potential mitigation approaches that could be used to reduce those vulnerabilities, and to identify methods to enhance the transfer of the resulting information to lifeline system providers, designers, builders, managers, operators, users, and regulators.

The purpose of this report is to provide an inventory of the major lifeline systems in the Cajon Pass and the earthquake and geologic analysis tools available to identify and define the level of seismic risk to those lifelines. The Cajon Pass and an earthquake event will be used as a suitable test case for applying the evaluation methodology which will be developed as a part of the overall study. However, the overall program goal is to provide a methodology that can be readily applied to other regions and locations in the United States and that is adaptable to disaster conditions in addition to earthquakes. The information in this report can be used as a validated data base for use in the development of the required analysis methodology for evaluating the impact of proximity or collocation of lifelines on the vulnerability of nearby lifelines.

Figure 1-1 also shows that the Cajon Pass is a natural topographical opening between the San Bernardino and the San Gabriel mountain ranges. As such, it has been used for years as the major route for lifelines between the Los Angeles coastal plain and the high desert regions. Within the Pass the following lifeline systems (see Figure 2-1, it is provided in full-size in Volume 2 of this report) shows the lifelines that have been examined for the current study:

Communication Lifelines -- fiber optic cables, radio, cellular telephone, and microwave towers;

Electrical Lifelines -- high voltage transmission systems, a hydroelectric generation station, and a transmission system electric power substation;

Fuel Pipeline Lifelines -- natural gas transmission and petroleum products pipelines;

Transportation Lifelines -- interstate highways, state highways, bridges associated with the highways, passenger and freight railroad lines, and the bridges and tunnels associated with the railroad lines.

Although Figure 2-1 shows that the lifeline routes are often focused in a narrow band, the topology of the region is not the only reason for that as the Pass is generally several miles wide (it is about 1/2 mile wide at its narrowest at Blue Cut) and many of the lifeline routes could have been placed on the slopes of the mountains that form the edges of the Pass. There are large subregions in which there are only one or no lifelines in the overall study region. However, most of the lifeline systems are located near or in the foot of the Pass itself. This is the congested lifeline area. The figure shows a major focusing of the rail,

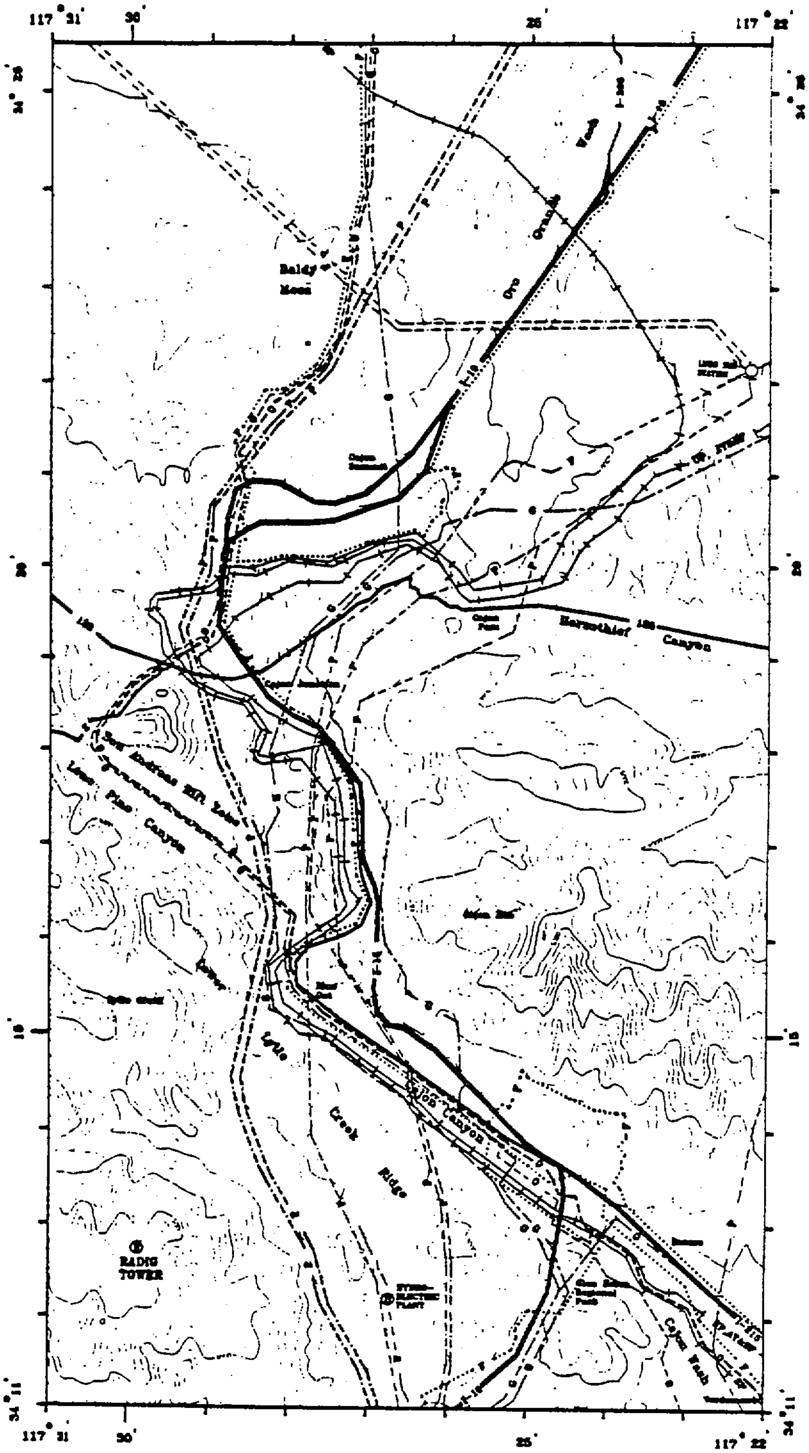


Figure 2-1 Composite Map of Lifelines In the Cajon Pass Study Areas

SCALE

0 1 2 MILES

0 1 2 KILOMETERS

N

CONTOUR ELEVATIONS IN FEET

CONTOUR INTERVAL 200 FEET

EXPLANATION

I-15	INTERSTATE
2	PAVED HIGHWAY
	RAILROAD
P	POWER LINES
W	FLUME-PENSTOCK
O	PETROLEUM PRODUCT PIPELINES
G	NATURAL GAS PIPELINES
F	FIBER OPTIC CABLE

Larger Scale Figure Located at End of Document

highway, communication, and fuel pipelines in the southern part of the Pass near the community of Devore, another congested area involving all of the lifeline systems near Blue Cut (which is also traversed by the San Andreas fault zone), and another congested area near and north of Cajon Junction. Above the summit of the Pass (in the high desert area), the lifeline systems spread out, although the communications and fuel pipeline lifelines remain collocated in that region.

In studying the Cajon Pass area, it has become apparent that the objectives considered in siting the lifelines were weighted heavily towards minimizing the lifelines' immediate impact on the aesthetics and the surface environment of the area and on the costs associated with acquiring the rights-of-way and installing of the lifelines. In a number of instances, the siting route was a response to Federally-imposed routing criteria. Thus, in may parts of the study area the lifelines are in parallel or coincident paths, thereby reducing the amount of land disturbed by their construction and the costs for acquiring the required rights-of ways. Very limited, documented analyses or considerations of the impact of the failure of one lifeline upon the operation and reliability of another lifeline were found during the current study. Part of the reason for this appears to be that a number of different agencies and offices are responsible for the siting design and approval for the individual lifelines. Each such authority does not have direct responsibility or authority for the evaluation of the other facilities in close proximity to the lifeline for which they are responsible. It is believed that this siting approach is representative of most lifeline siting situations within the United States, although that question has not been examined during this study.

Chapter 3.0 of this report provides more detailed maps. Figures 3.2-1, 3.3-1, 3.4-1, and 3.5-1 (for the communications, electrical, fuel pipeline, and transportation lifelines, respectively) show the routes of the separate lifeline systems. Figures 3.1-2, 3.1-3, 3.1-4, and 3.1-7 (for the earthquake fault zones, geologic conditions, landslide areas, and water table (e.g. potential soil liquefaction zones)) show the regions where seismic conditions could induce forces and stresses on the individual lifelines. All of these items must be examined together to obtain a realistic estimate of the probable failure conditions exerted on individual lifelines.

In the subsequent analysis of the potential hazards to and vulnerabilities of the lifeline systems from earthquakes (to be reported in a following report "Collocation Impacts on the Vulnerability of Lifelines During Earthquakes With Application to the Cajon Pass, California") it will be necessary to relate the composite of lifeline locations with geologic areas subject to landslides and liquefaction as well as to identify their physical relationship to the contours of equal earthquake shaking intensity. A part of that study will be to select and justify the appropriate earthquake event to be analyzed. As discussed in Section 3.1, the earthquake fault locations are well mapped and are available for use in the current study. The soil and bedrock conditions can be based on the United States Geological Survey (USGS) data[2-1]. That information will provide input to the QUAK2NW3 earthquake shaking intensity model developed at the USGS[2-2]. Landslide potential can be determined by applying the USGS models[2-3,2-4] with the results supplemented by the data of Figure 3.1-5. Liquefaction potential can be determined by applying the USGS methodology[2-5] with the results supplemented by the data of Figure 3.1-8. Thus, there are sufficient data and models available to allow the calculation of the earthquake and geologic impacts on the lifeline systems.

The study presented in this report was prepared by obtaining data from the lifeline system owners and regulators and by conducting numerous on-site examinations. The data were further validated by having the draft report reviewed by those who supplied the input data to assure that they were not misunderstood and that they were complete. As such, the information can be considered as a reliable data base upon which the rest of the FEMA-sponsored study can be built. Chapter 3.0 presents the results obtained, Chapter 4.0 identifies the organizations and offices contacted during the study.

2.2 BIBLIOGRAPHY FOR SECTION 2.0

2-1 J. Davis, et. al., "Earthquake Planning Scenario for a Magnitude 8.3 Earthquake in the San Andreas Fault in Southern California", California Division of Mines and Geology, Special Publication 60, 1982.

2-2 J. Evernden, et. al., "Seismic Intensities of Earthquakes of Conterminous United States - Their Prediction and Interpretations", USGS Professional Paper 1272, 1981, and "Predictive Model for Important Ground Motion Parameters Associated with Large and Great Earthquakes", USGS Bulletin 1838, 1988.

2-3 M. Legg, et. al., "Seismic Hazard for Lifeline Vulnerability Analysis", Proceedings of the Third International Conference on Microzonation, Seattle WA, 1982.

2-4 R.C. Wilson and D.K Keefer, "Predicting Earthquake-Induced Landslides with Emphasis on Arid and Semi-Arid Environments", Landslides in a Semi-Arid Environment with Emphasis on the Inland Valley of Southern California, Editors: P. Sadler & D. Morten, 1989.

2-5 T.L. Youd and D.M. Perkins, "Mapping of Liquefaction Severity Index", Journal of Geotechnical Engineering, V 113, No. GT 11, 1987, and "Mapping Liquefaction-Induced Ground Failure Potential", Journal of Geotechnical Engineering, V 104, No. GT 4, 1978.

3.0 SITE CONDITIONS AND LIFELINES

3.1 SITE CONDITIONS

This report section presents geologic and geotechnical information for the Cajon Pass Study Area including:

- Fault information and ground rupture (displacement) potentials
- Seismic events
- Soil and bedrock conditions
- Ground shaking hazards
- Topographic and ground relief features and landslide hazards
- Hydrologic and ground water conditions and liquefaction potentials

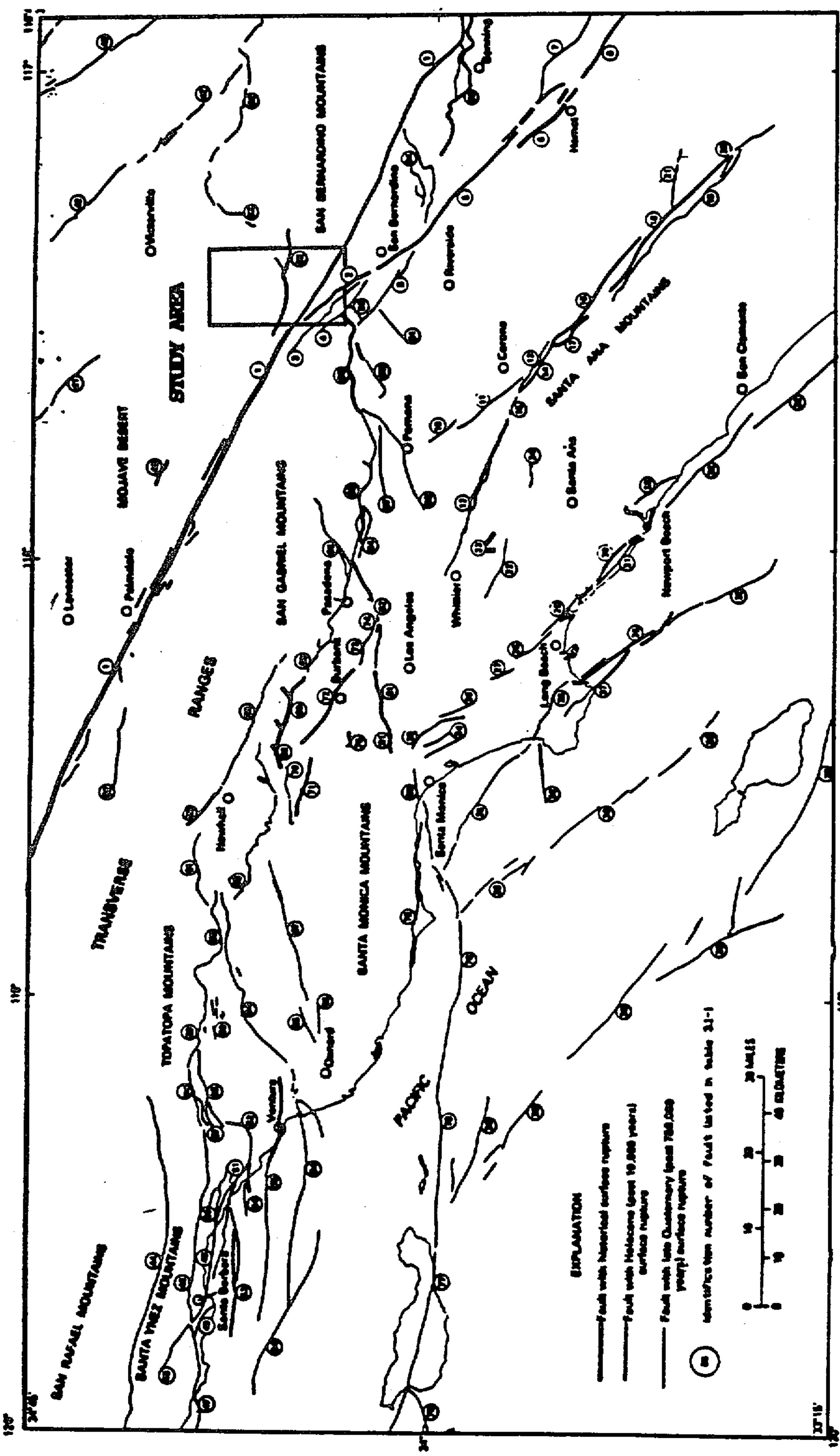
Discussions will also be presented on the earthquake hazards and predictive models that can be used to evaluate the damage potentials associated with the various earthquake hazards including: ground shaking, landslide, and liquefaction hazards. In addition, data (geologic, geotechnical, hydrological, and groundwater) gathered in the course of the project is presented. Actual applications of the predictive models to analyze the damage potentials on the lifeline systems at the study area will be provided in a separate, vulnerability analysis report to be issued.

As shown in Figure 2.1, the study area covers approximately a 9.2 miles by 17.4 miles area (Longitude ranging from about 117° 21.9'W to 117° 31.4'W; Latitude ranging from about 34° 10.7'N to 34° 26'N). The study area covers portions of nine 7.5 minute quadrangles (as designated by U.S.G.S.): Phelan, Telegraph Peak, Cucamonga Peak, Baldy Mesa, Cajon, Devore, Hesperia, Silverwood Lake, and San Bernardino North. As shown in the figure, most of the lifelines at Cajon Pass generally follow the Cajon Canyon corridor in the southern part of the study area. The San Andreas rift zone intersects that lifeline corridor at the middle to southern part of the Cajon Pass study area. In the high desert region in the northern part of the study area the lifelines are spread apart to a greater degree than is found in the southern regions.

3.1.1 Fault Information and Ground Rupture (Displacement) Potential

An excellent compilation of information on potential active faults that could generate damaging earthquakes in Southern California has been presented by Ziony and Yerkes[3.1-1]. Figure 3.1-1 and Appendix A (which defines the terms used in Figure 3.1-1) are extracted from their work. They show that a number of different geologic faults can affect the Cajon Pass. Also, many of the faults shown in Figure 3.1-1 but which are not located directly within the Cajon Pass area still could present earthquake hazards in terms of ground shaking to the lifelines in Cajon Pass. Figure 3.1-2 is presented to provide a more detailed map of the active faults located within the study area that could present hazards related to surface fault rupture or relative ground displacements.

Figure 3.1-1, Regional Fault Map



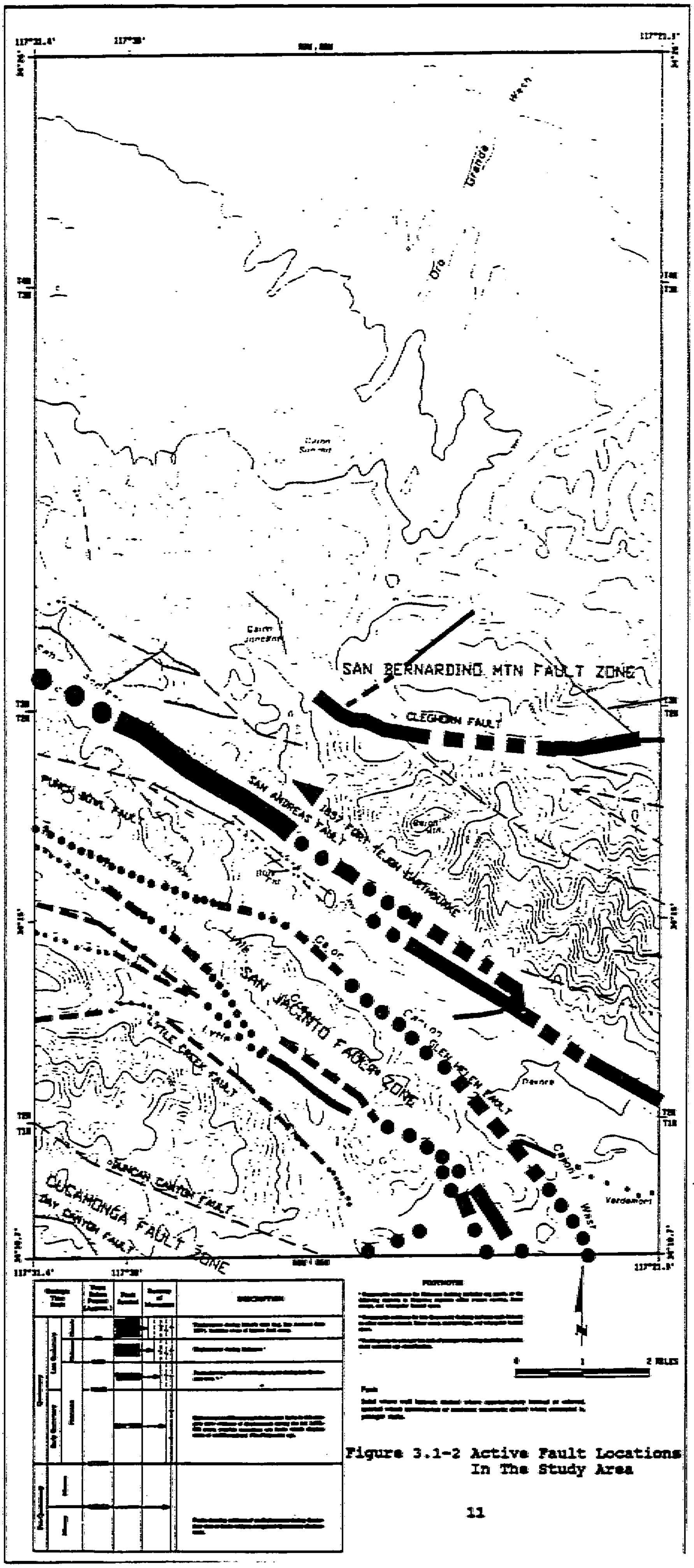


Figure 3.1-2 Active Fault Locations In The Study Area

Larger Scale Figure Located at End of Document

It can be seen from Figure 3.1-2 that the faults which are located within the study area are:

(1) San Andreas fault zone (which is in Lone Pine Canyon).

(2) The San Jacinto fault zone (which generally follows Lytle Creek Canyon and is south and parallel to the San Andreas fault), including the following strands within the fault zone: (a) Glen Helen fault, (b) several strands of San Jacinto fault, (c) Lytle Creek fault, and (d) Punch Bowl fault.

(3) Faults along the southern margin of Transverse Ranges, especially the Cucamonga fault which is further south of the San Jacinto fault zone and which has two to three subparallel strands located within the study area including the (a) Duncan Canyon fault and the (b) Day Canyon fault.

(4) Faults along the margins of San Bernardino Mountains, the Cleghorn fault (which is north and approximately parallel to the San Andreas fault zone).

A discussion of each of the above four fault zones is presented below. Aspects related to potential surface fault ruptures that are directly relevant to lifeline damage evaluations are emphasized.

San Andreas Fault Zone. A very complete discussion on the San Andreas fault can be found in California Department of Conservation, Division of Mines and Geology (CDMG) reports[3.1-2, 3.1-3] and USGS reports[3.1-4, 3.1-5]. The San Andreas fault zone is the most dominant active fault in California. It is the main element of the boundary between the Pacific and the North American tectonic plates. Two great historical earthquakes have occurred along this fault: the renowned 1906 San Francisco earthquake and the lesser known but possibly more severe 1857 Fort Tejon earthquake. These two earthquakes were selected to serve as a basis for emergency planning in Northern California[3.1-6] and Southern California[3.1-7]. Approximately 400 km of the San Andreas fault between Parkfield-Cholame (e.g., Central California) and Cajon Junction (Southern California) ruptured during the 1857 Fort Tejon earthquake, which had an estimated magnitude of 8.3. The southern end of the fault rupture during the Fort Tejon earthquake is located within the study area (between Cajon Junction and Blue Cut). At Cajon Pass, the San Andreas fault zone generally has been reported to range from 0.3 to 1.5 km wide (0.2 to 0.9 miles). Bennett and Rodgers[3.1-2] reported that although very pronounced surface crustal movements can be observed north of Cajon Pass along the San Andreas fault, very little movement has been recorded along the segment of the San Andreas fault south of Cajon Pass.

San Jacinto Fault Zone. Echelon segments (including: the Glen Helen, the various strands of San Jacinto faults, Punch Bowl fault, and the Lytle Creek fault) of the San Jacinto fault zone system extend southeastward for more than 300 km through the Imperial Valley and into northern Baja California, Mexico. The zone at its northern end appears to merge with the San Andreas fault at around the Cajon Pass region. For the past century, the San Jacinto fault zone has been the most active earthquake-generating feature in southern California; it has produced at least 10 earthquakes of about local magnitude 6.0 or greater since 1890. The maximum credible earthquake associated with the San Jacinto fault zone is a magnitude 7.5 earthquake[3.1-8].

<u>Southern Margin of the Transverse Ranges.</u> The southern boundary of the western Transverse Ranges is formed by an overlapping group of west- to east-northeast-trending, late Quaternary faults. These faults, which dip steeply to moderately northward, comprise an essentially continuous narrow belt more than 300 km long that adjoins many of the major urban centers of the Los Angeles region extending from Santa Barbara on the west to San Bernardino on the east[3.1-9]. Two to three subparallel strands of the Cucamonga fault rift (the Duncan Canyon fault and Day Canyon fault), which may be as wide as wide as 1 km, are located at the southern part of the study area. The maximum credible earthquake associated with this fault system is a magnitude 6.5 earthquake.

<u>Faults along the margins of the San Bernardino Mountains.</u> The northern edge of the San Bernardino Mountains is delineated by an arcuate group of discontinuous faults that have various trends and that generally dip southward into the mountain mass. The distribution and history of these faults are poorly understood but are the subject of several current investigation by State and Federal geological offices. The Cleghorn fault, a single strand of the San Bernardino Mountain fault zone, is located within the study area.

Figure 3.1-2 shows the fault locations within the study area. The fault activities (expressed in terms of how recent has been the fault movement) are depicted on the figure in terms of the thickness of the line. Fault traces are indicated by solid lines where well located, by dashed lines where approximately located or inferred, and by dotted lines where concealed by younger rocks. From the referenced literature, it can be concluded that zones of ground ruptures could be as wide as 1 to 1.5 km along the depicted fault lines when the map is used to evaluate potential damage to lifelines because of ground displacements related to fault rupture.

A number of researchers[3.1-10, 3.1-11, 3.1-12, 3.1-13, 3.1-23] have related actual rupture data (both length of break, displacement amount, and width of the displacement zone) to the earthquake magnitude. Slemmons[3.1-12] provides log-log plots of data for North America. Bonilla[3.1-14] also reported that the maximum main fault zone (e.g., the width of the disruption) for strike-slip faults is 320 feet. Rojahn[3.1-13] also provides equations and plots that relate the maximum fault displacement to the earthquake magnitude. These sources can be used in the current study to estimate the ground rupture potential once the seismic event has been selected (see Section 3.1.4).

3.1.2 Soil and Bedrock Conditions

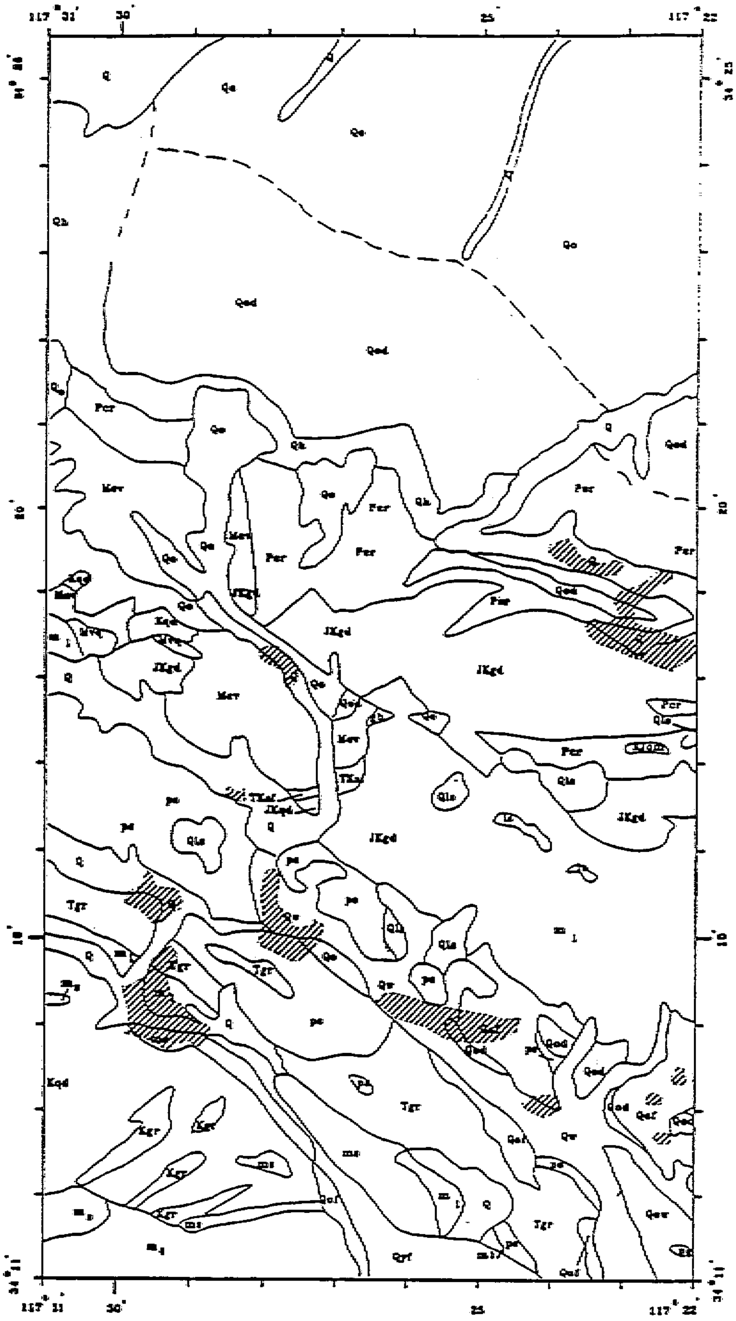
Areal differences in damage caused by shaking from earthquakes can be related to variations in soil conditions, especially to those near the surface (also see articles by Tinsley and Fumal and by Evernden in reference 3.1-1). A comparison[3.1-13, 3.1-15, 3.1-16, 3.1-17] of the earthquake shaking intensity maps of the 1906 San Francisco earthquake and that of the 1989 Loma Prieta earthquake reveals that severe damage occurred to the same locations where poor soil conditions exist, even though the epicenters of the two earthquakes were physically removed for each other.

A number of recently completed studies on geologic mapping at the Cajon Pass[3.1-18, 3.1-19, 3.1-20, 3.1-21] along with some traditional sources of information[3.1-2, 3.1-22, 3.1-9] offers detailed information on the geologic conditions at various locations in the study area. A number of scientific research programs, including the first deep scientific drill hole in Cajon Pass and the deep crustal seismic reflection profile at the western San Bernardino Mountains, have recently been completed. Unfortunately, most of the above studies cover a relatively small portion of the study area.

Traditional geologic mapping emphasizes the distribution and character of bedrock units, including lithology, age, and rock structure (bedding foliation, lineation, fractures, folds, faults, etc.). Areas underlain by flood plain and other water-laid sediments commonly are depicted as a single map unit, termed alluvium. Variation in the physical properties of alluvial deposits that pertain to hazards of interest to earthquake evaluations, such as ground shaking and ground failure, are not usually distinguished on the standard geologic maps. Therefore, conventional geologic maps have limitations with respect to evaluation earthquake hazards.

In the past two decades, specialized mapping techniques directed specifically at identifying and evaluating earthquake hazards in alluvial deposits have evolved[3.1-23, 3.1-24, 3.1-25, 3.1-26, 3.1-27], all of which are summarized in reference 3.1-1. However, such maps have only been presented for urban development areas and are not available for Cajon Pass.

For the above reasons, the geologic maps of the San Bernardino Quadrangle compiled by Bortugno and Spittler[3.1-36] were selected for the present study. An enlarged geologic map (scale: 1 inch = 1 mile) for the study area is presented in Figure 3.1-3. The age of the bedrock and soil deposit units denoted in the figure refers to various geologic times. Some common terminology used to denote geologic time scales are summarized in Appendix A, which is copied from reference 3.1-1. In general, alluvium, especially the Holocene alluvium, denoted as Unconsolidated Alluvium, Q; Wash Deposits, Qw; Older Wash Deposits, Qow; Younger Alluvium, Qya; Younger Fan Deposits, Qyf, Fan Deposits, Qf; Wind-Blown Sand, Qs; Large Landslide Deposits, Qls and lake Deposits, Ql would present the most seismic hazard potentials (in terms of ground shaking, liquefaction and landslide and ground failure). For convenience, the locations of high ground water table have been identified in the figure.



SCALE

0 1 2 MILES

0 1 2 KILOMETERS

N

Figure 3.1-3 Cajon Pass Region Geologic Units
With High Water Table Regions Identified

EXPLANATION

HIGH WATER TABLE

Larger Scale Figure Located at End of Document

Q	ALLUVIUM	Mvq	VAQUEROS (?) FORMATION
Qw	WASH DEPOSITS	Tgr	TERTIARY GRANITIC ROCKS
Qow	OLDER WASH DEPOSITS	TKsf	SAN FRANCISQUITO (?) FORMATION
Qls	LANDSLIDE DEPOSITS	ps	PELONA SCHIST
Qyf	YOUNGER FAN DEPOSITS	Kgr	CRETACEOUS GRANITIC ROCKS
Qof	OLDER FAN DEPOSITS	Kqd	CRETACEOUS QUARTZ DIORITE
Qo	OLDER ALLUVIUM	KJqm	CRETACEOUS OR JURASSIC QUARTZ MONZONITE; QUARTZ MONZONITE OF PLEASANT VIEW RIDGE
Qod	WELL DISSECTED ALLUVIAL FANS	JKgd	JURASSIC OR CRETACEOUS GRANODIORITE
Qh	HAROLD FORMATION AND SHOEMAKER GRAVEL	gb	GABBRO OF PLEASANT VIEW RIDGE
Pcr	CROWDER FORMATION	ms, ls	METASEDIMENTARY ROCKS OF UNCERTAIN AGE ls = LIMESTONE AND MARBLE
Mcv	PUNCHBOWL (?) FORMATION OF CAJON VALLEY	m_1, m_4	SHEARED AND DEFORMED METAMORPHIC ROCKS (AGE UNCERTAIN) m_1 = GNEISS m_4 = HIGH-GRADE METAMORPHIC ROCKS

——— — —? GEOLOGIC CONTACT OBSERVED OR APPROXIMATELY LOCATED; QUERIED WHERE GRADATIONAL OR INFERRED.

West of the San Andreas fault, a basement rock unit referred to as the "Pelona Schist", or "ps", is the most landslide prone basement rock unit in the Inland Valley region of Southern California[3.1-19]. A number of major deep-seated landslides[3.1-17, 3.1-28] in the region are underlain by the Pelona Schist. The Pelona Schist is comprised of several rock types but is mainly a fissile, white mica-albite-quartz schist that is relatively weak and distortable. A variety of landslides, regardless of the physically setting, have been recorded at the Pelona Schists. The landslides that have impacted the Cajon Pass electrical lifelines (see Section 3.3) and the natural gas pipeline lifeline (see Section 3.4) have occurred in schist deposit areas.

3.1.3 Seismic Events

Four seismic source zones have been identified within the study area and have been discussed in the preceding section (Section 3.1.1). Although other nearby faults or seismic source zones need to be considered when hazards associated with ground shaking are studied, the main hazards would be associated with the four fault zones within the study area. Furthermore, the San Andreas fault, which is highly active and could generate significantly larger magnitude earthquakes, would dominate the seismic loading considerations. Although the San Andreas fault has a total fault length exceeding 1000 km, seismologists and geologists anticipate that only a portion of the San Andreas fault would rupture in a single event. The fault is divided in three major segments which could generate very large magnitude earthquakes: (1) the northern segment from Point Delgada to San Juan Bautista (roughly coincident with the 1906 San Francisco earthquake fault rupture), (2) the central segment from around Parkfield to Cajon Pass (coincident with the 1857 Fort Tejon earthquake), and (3) the southern (Mojave) segment from Cajon Pass to Salton Sea. The maximum credible earthquakes associated with the central and the southern segment of the fault is a magnitude 8.25 and a 7.5 event[3.1-8], respectively. Both the central and the southern segments have been judged to be highly active[3.1-29], with a probability of sizable earthquakes exceeding a 40 percent chance over a 30-year exposure time. However, since Cajon Pass marked the end points of fault rupture associated with the two events, the damage scenario for the Southern California region as a whole due to disruption of major lifelines may be remarkably different depending on which event is chosen for damage evaluation. A potentially more damaging third event scenario associated with a fault rupture centered roughly at Cajon Pass and extending both northward beyond Palmdale (where another major natural gas pipeline crosses the San Andreas fault) and southward to beyond Thermal, California (where still another major power transmission line and also a natural gas pipeline cross the San Andreas fault) could be a plausible event.

Lifelines in general and especially electric power towers and buried lifelines, with the exception of highway and railroad bridges, have survived ground shaking effects remarkably well. Surface fault rupture and ground failure (including landslides and liquefaction) potentially would be more damaging to lifelines. Therefore, although the San Andreas fault would present the most intense ground shaking damage, other smaller faults which could generate surface ruptures at locations within the study area will need to be evaluated in terms of ground displacement effects.

3.1.4 Ground Shaking Hazards

Various models can be adopted to predict ground shaking for a given seismic event depending on the desired ground shaking parameters, including:

- o seismic intensity;
- o peak ground acceleration, velocity and displacement;
- o ground shaking durations; and
- o frequency content.

Models to predict fairly detailed ground shaking parameters, including peak ground acceleration, velocity, duration, and frequency content in terms of overall the overall shape of spectral intensity magnitude at various period ranges have been developed[3.1-23]. However, while such a model would be ideal for a local site-specific evaluation, they are not suitable for use in regional analysis such as being performed in this study.

A model[3.1-30, 3.1-31] which has been developed can be used to predict seismic intensities in terms of both Rossi-Forell (RF) and Modified Mercalli Intensity (MMI) scales for regional risk evaluations. Other ground motion parameters (e.g., peak ground acceleration, velocity and displacement) and the damage potential to a variety of structures can then be postulated from correlation of the intensity at the structure's location by using historical data on intensity-failure effects[3.1-13]. This approach has been used by Davis et. al.[3.1-6, 3.1-7] to estimate the general effects of hypothetical great earthquakes along the San Andreas fault on the lifeline systems in the Los Angeles and San Francisco metropolitan areas. This approach is expected to be used to predict the seismic intensity and resulting Cajon Pass lifeline damage from the various postulated earthquake events associated with the San Andreas fault and the other fault zones identified in Section 3.1.1.

The USGS seismic shaking intensity model[3.1-30, 3.1-31] has been coded in a computer program QUAK2NW3. Input to the program consists of:

(1) A fault data file, which represents the fault to be analyses, as a series of uniform point sources spaced as closely as desirable.

(2) A ground condition data file which performs two functions. It establishes each calculation point with respect to the fault, and it provides the soil condition at each calculation point. Ground conditions are typically discretized into 0.5 minute latitude by 0.5 minute longitude grids by the code developers.

(3) A pseudodepth term "C" which is chosen to give proper near-field die-off of the shaking intensities as a function of distance from the fault.

(4) An attenuation parameter "k" which controls the rate of die-off of peak acceleration as a function of distance from the fault.

With the above input data, the computer program QUAK2NW3 computes the acceleration associated with the energy release at each point source along the fault(3.1-32). Then, the shaking intensity value is computed from the acceleration value. The shaking intensity is first calculated for a standard reference ground unit condition (e.g. saturated alluvium). Then, the intensity value at each grid point is adjusted for the actual ground condition specified in the ground condition input data file. Using this model, the model developer has predicted the patterns of intensity for many of the large earthquakes occurred throughout the United States. Many of these predictions compared favorably with the intensity iso-seismal maps estimated from historical records(3.1-31).

The USGS model will be used to predict the shaking intensity at the Cajon Pass region for all the referenced faults identified in Section 3.1.1. Several analyses will be conducted to evaluate the sensitivities of the various event scenarios postulated for the San Andreas fault, so that an appropriate scenario can be selected for the subsequent vulnerability analysis.

3.1.5 Topographic and Ground Relief Features and Landslide Hazards

A number of publications(3.1-19, 3.1-30, 3.1-38, 3.1-39) were reviewed and observed relics of landslides were used to develop a landslide map at Cajon Pass; this is shown in Figure 3.1-4. It was concluded that earthquake shaking will be one of the main triggering agents for landslides in the Cajon Pass area. A photograph showing very significant recent landslide scars where the Southern California Power Edison Co.'s power line transmission towers are located is presented as Figure 3.1-5. Figure 3.1-6 shows a typical landslide scar in the Lone Pine Canyon, the canyon which contains the San Andreas fault rift zone. It can be seen on Figure 3.1-4 that there are numerous landslide features at the Cajon Pass especially at areas where the Pelona Schist, ps, is the basement bedrock geologic unit. As discussed earlier, the Pelona Schist is the most landslide prone bedrock unit known in the study area(3.1-33). This landslide map is presented to serve as an inventory of observed or recorded landslide features at the study area. It also can be used to validate landslide prediction models and analyses to be conducted in the subsequent damage evaluation report.

Although there are numerous analysis methods to analyze landslides for a variety of loading conditions (gravity, ground water seepage forces, and earthquake) in the literature, they are almost exclusively intended to be used for site specific studies. A frequently used analysis model for evaluating earthquake induced landslides that can be used in regional evaluations is a model presented by Wilson and Keefer(3.1-38, 3.1-40). Their model has been used to analyze and correlate with slope failures from the

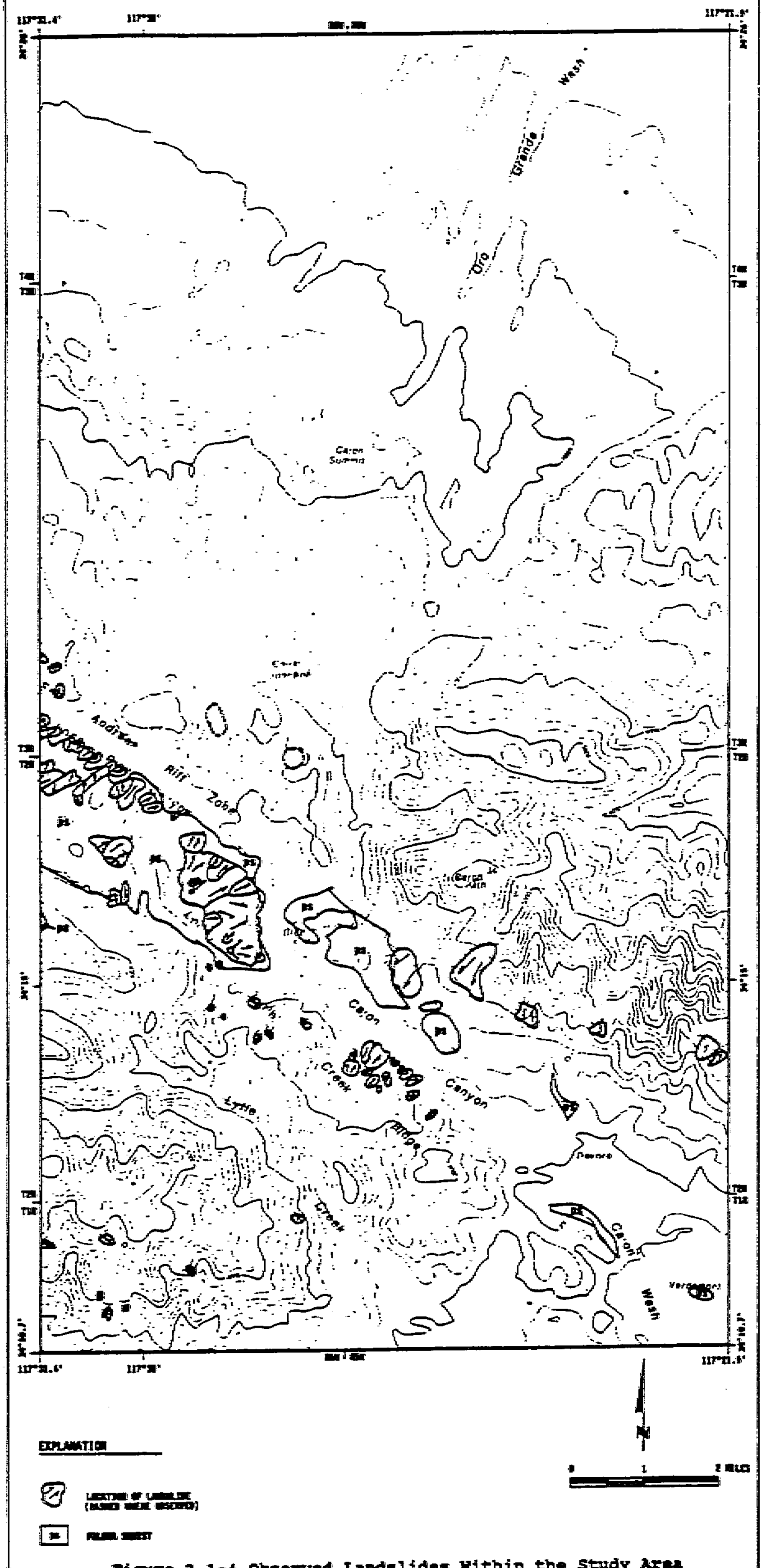


Figure 3.1-4 Observed Landslides Within the Study Area

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August 6, 1979, Coyote Lake, California, earthquake and the 1989 Loma Prieta earthquake. Preliminary information indicates that there is good agreement for the prediction with the Loma Prieta earthquake landslide data. Wieczorek[3.1-37] applied the analysis method to develop a map of relative landslide potential during earthquakes in San Mateo County, California. Nilsen, et. al.[3.1-39] also applied the method in a project jointly supported by USGS and the Department of Housing and Urban Development to develop maps of relative slope stability for land-use planning in the San Francisco Bay region, California.

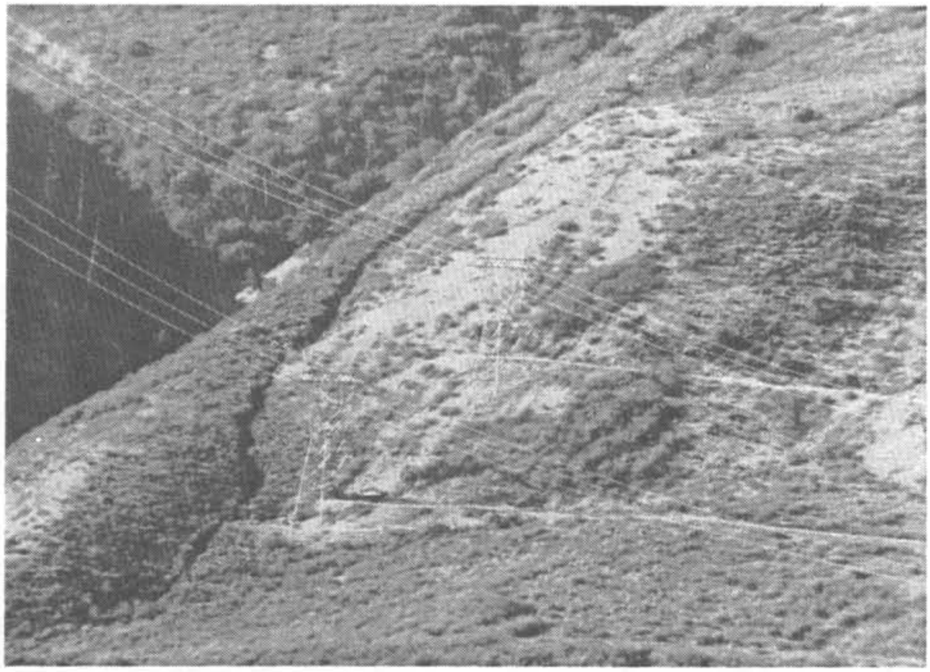

Figure 3.1-5 Rebuilt Power Transmission Towers on a Landslide Scar

Figure 3.1-6 Landslide Scar in Lone Pine Canyon Along The San Andreas Fault Zone

Wilson's method consists of the following basic steps:

Step-1 Solve for the factor of safety of the slope for a given combination of slope angle and soil strength.

Step-2 Using the Newmark method[3.1-43] and the factor of safety from Step-1, calculate the critical acceleration value which is the level of ground acceleration required to initiate downward slope movement.

Step-3 The above critical acceleration value can then be used in conjunction with a given design earthquake to solve for the magnitude of accumulated downslope movement associated with the design earthquake. This magnitude of accumulated slope movement is then used as an indicator of the potential for slope failure.

Wilson has presented several simplifying charts to facilitate application of the above procedures and they are summarized by Rojahn[3.1-13].

Existing information indicates that earthquake-induced landslides could pose significant damage to the lifelines at Cajon Pass. An evaluation of landslide potential will be very important in the current project. Wilson's method will be used to develop a map of the landslide potential at Cajon Pass. The digital elevation model data acquired in the course of the project will be used to develop a topographic map and subsequently a map of the ground relief data. Shear strength values will be assigned to each of the geologic units on the Cajon Pass geologic map. The ground relief and the shear strength maps will be used to calculate the critical acceleration value at each grid point in the study area. The critical acceleration and the MMI index value can be used to enter the tables provided by Rojahn to identify the slope failure state. The slope failure state can then be related to the lifeline damage state. This is similar to the analysis method of Wieczorek[3.1-37], where the landslide susceptibility was estimated in terms of a critical ground acceleration and a calculated slope displacement value. One advantage of this proposed method is that it relates the landslide susceptibility to the Modified Mercalli Indices as well as the geology and the slope of the surface formations.

3.1.6 Hydraulic, Groundwater Conditions, and Liquefaction Potential

The study area is situated far from oceans. There are also no major hydrologic features (lakes, rivers) within the study area. There are a number of minor creeks and streams (e.g. Lytle Creek Wash, Cajon Wash within the study area) which could be carrying large volume surface water during the rainy season (winter) or during flash floods. Therefore, areas where liquefaction could occur in the study area would be locations where the water table is close to the surface. The ground water table at Cajon Pass could fluctuate in relation to precipitation and ground-water management[3.1-34]. As an example from outside of the study area in the City of San Bernardino, the regional long-term trend is a lowering of the ground-water table due to withdrawal from water wells, although the City of San Bernardino is currently experiencing a rise in the depth-to-ground-water due to the reduction in agriculture and its impact on reducing the withdrawal rate of ground water in that specific local region. Available depth-to-ground-water maps[3.1-35] indicate that, in general, the water table will be relatively deep (over 100 feet) over most of the study region. However, perched water tables (5-20 feet deep) exist at isolated pockets within the study area.

In an effort to locate these pockets of higher perched water table zones, water-well data from the Department of Water Resource was examined. Locations of the water wells are identified in a map presented in Figure 3.1-7. Detailed information for the water well, including depth of the water table and date of the observation, are tabulated in Table 3.1-1. The water-well data were then divided into two categories:

- o Shallow water table (depth less than 30 feet).
- o Deep water table (depth more than 30 Feet).

Locations of shallow water table conditions are identified in Figure 3.1-4. and Figure 3.1-7. These are the locations where liquefaction could occur during an earthquake. It should be noted that due to the rugged terrain and sparse population in the study area, there is simply no well water data available over much of the Cajon Pass area. Therefore, it is fair to say that the map is incomplete and other locations with high perched ground water table could be present within the study area. Also, the dominance of fault features in the region adds complexities to the evaluation of the ground-water table conditions. Major faults appear to act as barriers to downslope movement of ground water, especially the San Andreas fault, as indicated by seeps and springs along many parts of the fault, particularly where it transects alluviated flood plains of canyons or alluvial slopes. In many instances along major faults, the ground water on the upslope side apparently backs up against the fault, which acts as an "underground dam", and the overflow reaches the ground surface as springs. The water table on the upslope side of the fault could be several tens of feet higher than on the downslope side of the fault. An example of this in the study area is the gravel pit located just south of Cajon Junction. On the upstream side of an apparent schist "dam" the water table is within 5-7 feet of the surface. Downstream of the schist the gravel pit operator had removed gravel at 50-70 feet below the surface and the pit was dry (when observed in the fall of 1990).

Although, widespread liquefaction is not expected at the study area, at local sites where the lifelines are collocated it can be anticipated that liquefaction could be the major factor for imposing collocation loads on the individual lifelines.

There are several liquefaction analysis approaches that can be used for regional evaluations. The most recognized model is the one by Youd and Perkins[3.1-41, 3.1-42]. The procedure used to determine areal variations in liquefaction potential requires the development of a liquefaction

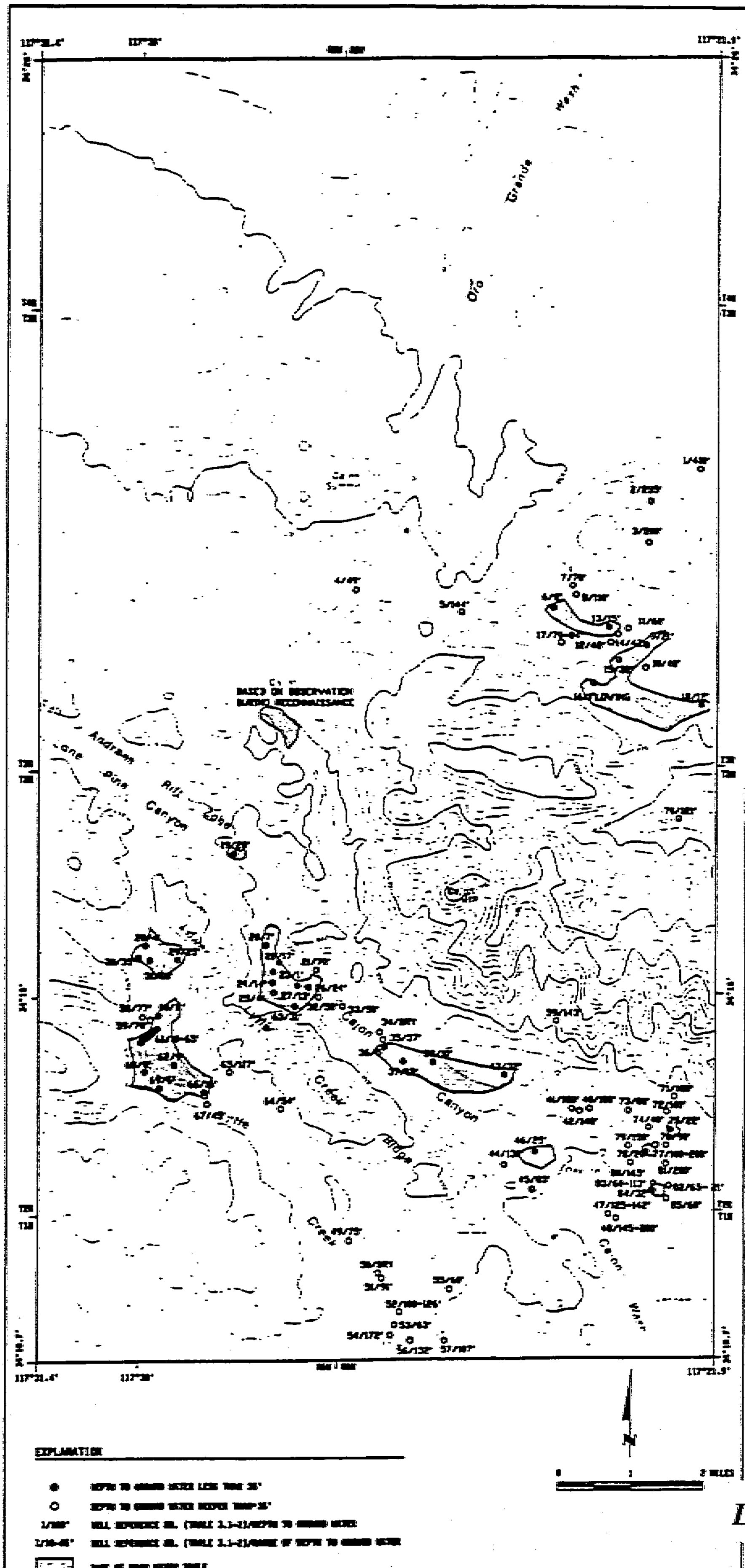

Figure 3.1-7 Location of Shallow Water Table Conditions

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Table 3.1-1, Depth to Ground Water Measured From Wells

Reference No.	Township & Range Section No.	State Well No.	Year	Depth (ft)
1	3N5W/11	R2	1984	410
2	14	D1	1963	255
3	14	N1	1984	200
4	19	M1	1986	49
5	20	Q1	1964	144
6	21	R1	1963	8
7	22	E2	1974	70
8	22	M1	1978	110
9	26	E1	1980	21
10	26	M1	1988	40
11	27	A1	1963	60
12	27	B1	1964	48
13	27	B3	1963	15
14	27	B4	1988	42
15	27	G1	1979	30
16	27	P1	1987	FLOWING
17	28	A6	1972	84
17	28	A7	1974	60
17	28	A8	1977	70
18	35	A1	1988	12
19	2N5W/11	B1	1955	28
20	13	E1	1967	7
21	13	K1	1951	70
21	13	K1	1960	70
22	13	M1	1967	17
23	13	M2	1967	1
24	13	N1	1967	14
25	13	N2	1967	4
26	13	Q1	1964	24
27	13	Q3	1967	13
28	15	F3	1964	4
29	15	J1	1980	25
30	15	L1	1986	35
31	15	L2	1985	30
32	24	A1	1985	50
33	19	D1	1979	50
34	19	K1	1970	DRY
35	19	K2	1987	37
36	19	Q1	1983	5

Table 3.1-1, Depth to Ground Water Measured From Wells
(Continued)

Reference No.	Township & Range Section No.	State Well No.	Year	Depth (ft)
37	2N5W/19	R1	1967	13
38	20	P1	1967	10
39	22	E1	1975	143
40	27	K1	1978	100
41	27	L1	1974	180
42	27	L2	1974	140
43	28	C1	1956	32
44	33	F1	1950	130
45	33	K1	1950	83
45	33	K1	1983	84
46	33	M1	1979	25
47	1N5W/ 3	A1	1927	125
47	3	A1	1982	142
48	3	A2	1952	145-200
49	6	G1	1987	75
50	6	K1	1953	DRY
51	6	K2	1987	91
52	7	H1	1931	126
52	7	H1	1977	117
52	7	H1	1987	100
53	7	H2	1918	63
54	7	J1	1918	172
55	8	B1	1938	60
56	8	N1	1918	132
57	8	Q1	1918	107
58	2N6W/22	F1	1988	77
59	22	F2	1987	70
60	22	G1	1988	11
61	22	L1	1988	52
61	22	L2	1987	35
61	22	L3	1986	38
61	22	L4	1985	60
61	22	L5	1985	64
61	22	L6	1985	60
61	22	L7	1985	25
61	22	L8	1985	10
61	22	L9	1985	60
61	22	L10	1987	50

Table 3.1-1, Depth to Ground Water Measured From Wells
(Continued)

Reference No.	Township & Range Section No.	State Well No.	Year	Depth (ft)
61	2N6W/22	L11	1986	40
61	22	L12	1987	65
61	22	L13	1986	32
62	22	P1	1986	9
63	24	C1	1967	31
64	25	L1	1985	54
65	26	B1	1978	117
66	26	L1	1982	15
67	26	L2	1973	45
68	27	C1	1985	8
69	27	G1	1985	6
70	1N5W/ 2	K1	1988	121
71	2N5W/26	G2	1979	180
72	26	K1	1978	100
73	26	M1	1977	80
74	26	P1	1979	40
75	26	Q2	1978	22
76	35	B1	1978	90
77	35	C1	1977	200
77	35	C2	1978	100
78	35	C3	1979	20
79	35	D1	1980	150
80	35	E1	1979	165
81	35	G1	1977	200
82	35	K1	1988	121
82	35	K2	1978	90
82	35	K3	1978	65
83	35	L2	1980	60
83	35	L3	1978	85
83	35	L4	1978	95
83	35	L6	1985	113
84	35	L5	1979	32
85	35	Q1	1977	60

susceptibility map and a liquefaction opportunity map. A liquefaction susceptibility map delineates areas where liquefiable materials are most likely to be present and is based chiefly on generalizations pertaining to the geology and hydrology of late Quaternary deposits in a sedimentary basin. The liquefaction opportunity map shows regions of earthquake shaking strong enough to generate liquefaction in susceptible materials and is based on an appraisal of regional earthquake potential. These two maps are then considered together to determine liquefaction potential, the relative likelihood that an earthquake will cause liquefaction in water-saturated cohesionless silts and sands that may be present. The use of this approach can also be validated with the analysis of Rojahn[3.1-13] where the liquefaction potential has been presented in a table and alternatively by the standard penetration resistance (e.g., blow count data) of the soils.

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3.2 COMMUNICATION LIFELINES

The Cajon Pass region includes hardwired and fiber optic telephone systems and microwave and radio towers. The hardwired telephone primarily services the local distribution system. The fiber optic lines primarily are transmission and major trunk lines. The microwave and radio towers serve both local communications within the Pass and transcontinental communication, but separate towers are used to support local or long distance transmission. The tower systems are identified in this study for completeness, but they are mostly isolated and thus have no direct collocation impacts. Figure 3.2-1 is a map of the communication lifelines. For reference purposes, the location of photographs provided in this Section are also shown on the Figure. Consistent with the concept used for evaluating other lifeline systems (that is, this study focuses on the

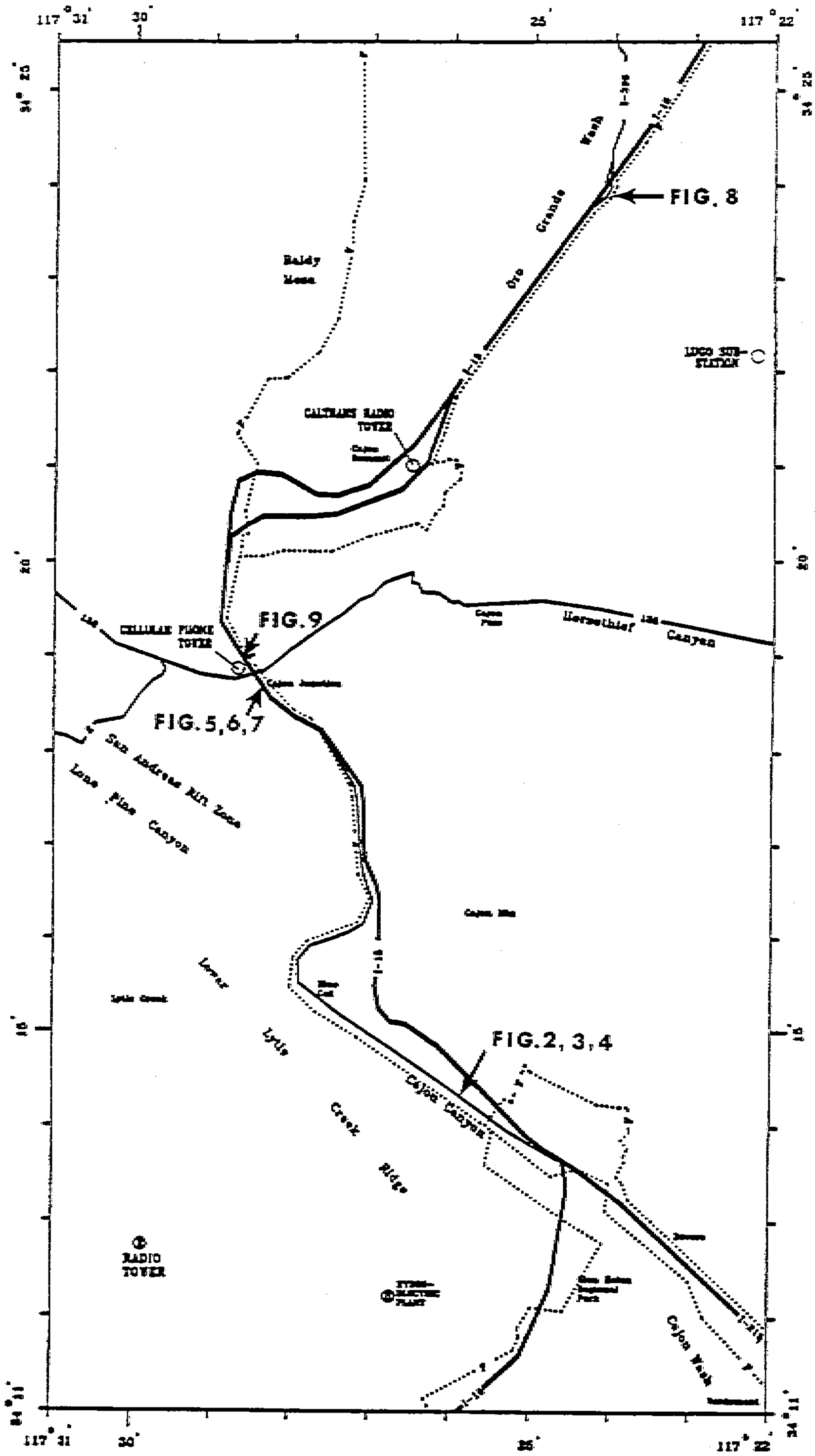

Figure 3.2-1 Map of the Communication Lifelines

SCALE

0 1 2 MILES

0 1 2 KILOMETERS

N

EXPLANATION

I-15 INTERSTATE

2 PAVED HIGHWAY

F F FIBER OPTIC CABLE

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transmission or primary systems and not the local or distribution systems), the hardwired and wooden pole telephone systems were not included in this study. However, the fiber optic systems are similar to a transmission system in that they are used to transfer many calls between the Los Angeles Basin and other regions in the nation. Thus, they were included in detail in this study. There are no state or Federal documented seismic criteria or standards for the installation of fiber optic cables, hence each company is free to include seismic considerations as it determines necessary.

3.2.1 Fiber Optic Cables

On-site surveys identified that five fiber optic systems are located in the study area. They are American Telephone and Telegraph (AT&T), Continental Telephone (CONTEL), MCI Communications (MCI), WilTel (now WTG West), and US Sprint. Contact[3.2-1] was made with these firms, and AT&T, CONTEL, and US Sprint responded with information. Review of the U.S. Forest Service maps, on-site evaluations, and contact with the California Utility Underground Service were used to supplement the information and to obtain additional details on the routing of the various systems.

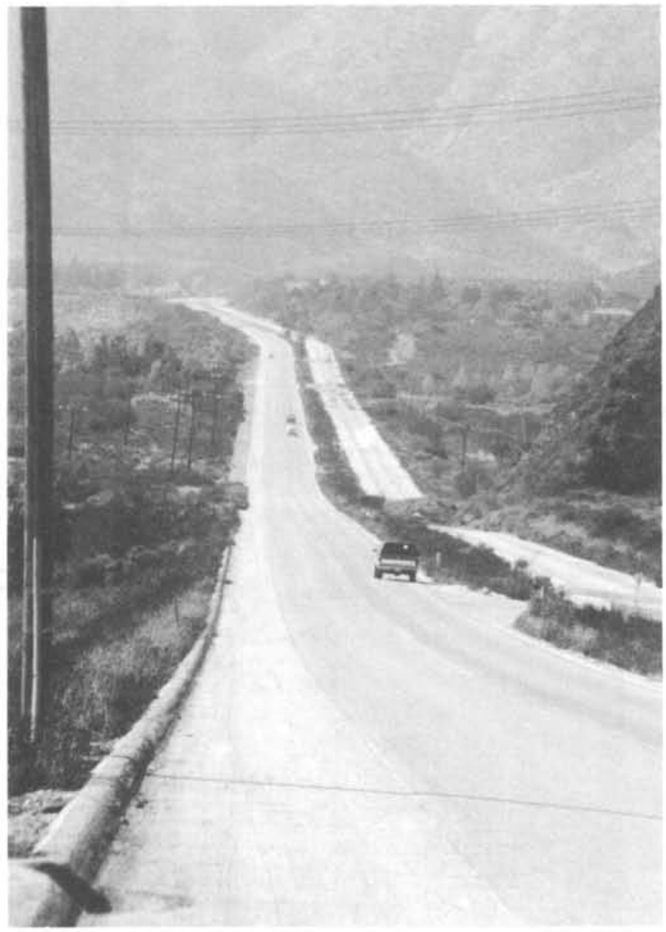

Figure 3.2-2, Looking North on Old Highway 66 (Now Cajon Canyon Rd.)

A fiber optic cable is a multi-layered cable with an inner structure that allows the cable to be pulled and maintained in a state of tension without putting tension on the individual glass fibers. Various materials are used for insulating the glass fibers, including a metal sheath. In the fall of 1986, both MCI and WTG West contacted the U.S. Forest Service to obtain right-of-ways for their cables (See Figure 3.2-1). To reduce the number of locations where trenching would be required, the Forest Service required each of those firms to trench conduits that could support four different fiber optic systems (for a total of eight systems in the two routes). They also required that the routes coincide whenever possible, so from just north of the Cajon Junction to the southern end of the old Cajon Canyon Road the cables are collocated (see Figure 3.2-2 which is a photograph of the old Highway 66, now called Cajon Canyon Rd.. Note that the divided highway has been converted to a two lane highway by blocking the eastern side of the road). Each of the firms installed two metal conduits. They are four inches in diameter and can accommodate up to three separate fiber optic cables in each conduit, although it is anticipated that at most eight separate firms will actually install cable in the conduits. AT&T was the last firm to install their cable, completing the work in late 1989.

The separate telephone connections for AT&T, MCI, US Sprint, and WTG West are parts of a much larger network owned by each of those companies. If there were problems with the cables in the Cajon Pass, the companies indicated that by rerouting the calls they could continue their service. A similar situation exists for CONTEL, except that they do not maintain as many separate lines from their Victorville, California, center to their Los Angeles Basin center. Thus, they may have to reroute their calls using the existing lines of one of the other firms identified above. The exact excess rerouting capacity of each firm is confidential.

Referring to Figure 3.2-1 and starting from the southern edge of the study area, the AT&T cable enters from San Bernardino on the eastern side of the study area. Much of its route is along city streets in San Bernardino and Devore, where AT&T already had existing right-of-ways. Part of the cable path is along the street parallel and next to I-215 (Outer Highway and Little League Drive). It crosses under highway I-15 at the Kenwood exchange. From there it enters the cable conduits installed by WTG West. The US Sprint cable also enters the study area from the Rialto area. It travels north on Sycamore street, then east on Highland Ave., then north on Macy St. until it insects Cajon Boulevard. It travels northwest along Cajon Blvd. parallel to the Atcheson Topeka and Santa Fe (AT&SF) and the Union Pacific railroads. At Devore it turns northeast along Devore Road. It crosses under I-215 along Devore Road and then turns parallel to I-15 along Nedlee Ave.. Just north of the I-15 and I-215 intersection it crosses under I-15 and connects to the existing fiber optics conduit (which was installed by MCI) located along the old Highway 66 (which is parallel and west of I-15). The WTG West cable enters the study area from the western side of the southern boundary. It heads northeast along Devore Road (which is north of and roughly parallel to I-15). It crosses the Lytle Creek Wash, turns south, and then crosses under I-15 where it continues to follow Devore Road. Next it enters Cajon Wash and crosses under the AT&SF and the Union Pacific railroads, then it turns northwest and crosses under I-15 near to the US Sprint cable. It enters the existing conduit at the same location that the US Sprint cable enters it, but it enters a different conduit. Also located in one of those two conduits is the CONTEL cable. The CONTEL fiber optic cable enters the study area from San Bernardino from the southeast study boundary. It moves northwest along Cajon Blvd., turns east on Devore Road and crosses under I-215. It follows Devore Rd., turns west along Kenwood Ave., crosses under I-15 along Kenwood Ave., and enters the conduit installed by MCI.

The fiber optic conduits (four in number) are located together and run mostly along the median region of the old Highway 66 (see Figure 3.2-2 which shows the general nature of the old highway and the wide nature of the Cajon Pass in that region). Again, in order to limit the amount of potential environmental damage due to trenching, the U.S. Forest Service had the fiber optic cables located parallel and near to the existing two petroleum product pipelines (an eight and a 14-inch line). The are routed in the median zone of the old Highway 66. The cables are located from one to four feet from the pipelines and are buried three to four feet deep (during the cable trenching, the pipeline operator indicated that the trencher struck the pipeline on at least two occasions, requiring repair efforts by the pipeline owner).

Figure 3.2-3 Fiber Optic Conduits Crossing a Cajon Canyon Road Bridge

However, at bridge or culvert locations they are routed above ground along the bridge or above the culvert but still underground. Figure 3.2-3 is a typical example of the supports used to hang the cable conduits from the bridge. Earthquake criteria were not used in designing these supports. It is noted that this

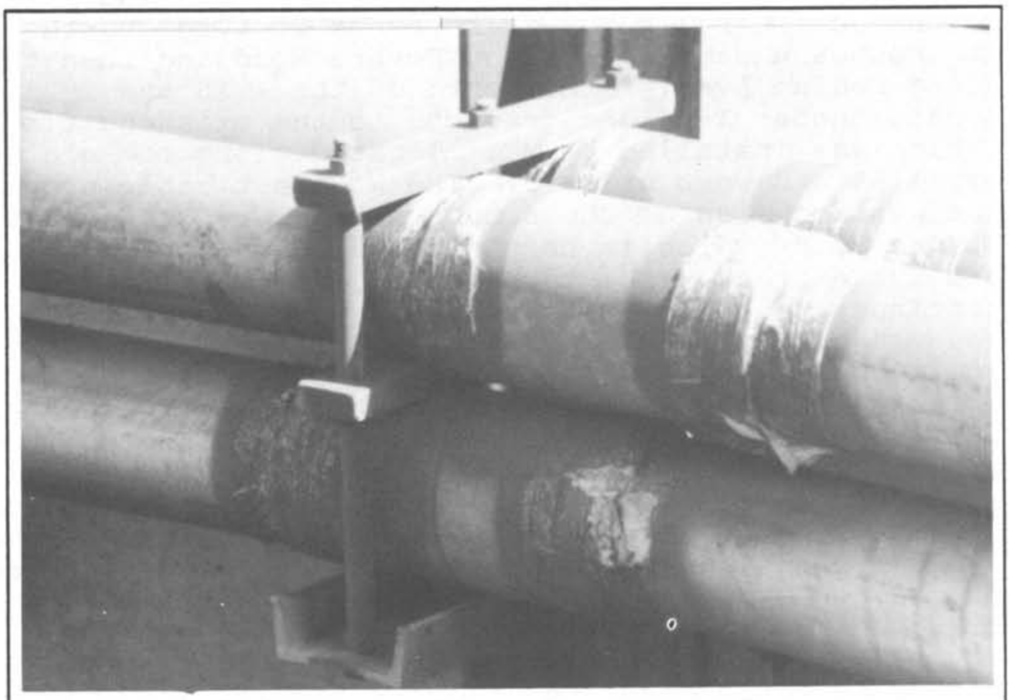

Figure 3.2-4 Details of the Fiber Optic Conduits and Hangers on a Cajon Canyon Road Bridge

side of the Cajon Canyon Road and the bridge are "abandoned" and some concrete spalling of the piers was noted during the site inspections. Figure 2.3-4 gives further details of the conditions of the conduits and their wall supports.

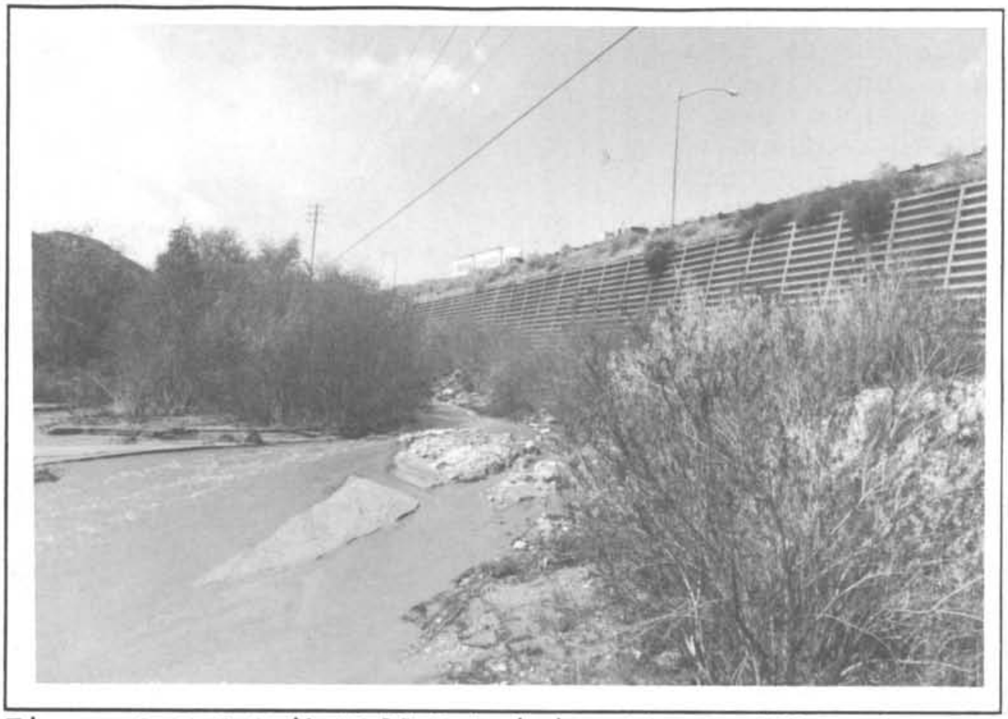

Figure 3.2-5 Crib Wall Retaining the Southbound Lanes of I-15 With Fiber Optic Conduits Buried at the Wall Toe

Continuing north, the cables pass at the toe of a crib wall used to retain the southbound lanes of I-15 (see Figure 3.2-5). That site is a potential liquefaction site due to the high water table and alluvium deposits. Immediately north of the crib wall the conduits are brought to the surface and hung from a concrete wall that forms a culvert under I-15. Figure 3.2-6 shows details of how the conduits are hung from the concrete, and Figure 3.2-7 shows then entering the culvert as they head north and under I-15. On the eastern side of I-15 they are again buried and routed north along Baldy Mesa Rd. (an unimproved dirt road at this location).

Figure 3.2-6 Details of Fiber Optic Conduits Supports on a Concrete Culvert Wall

North of Cajon Junction, as the

fiber optic conduits follow Baldy Mesa Rd., they cross under several old AT&SF, Southern Pacific, and Union Pacific railroad bridges (which are discussed in Section 3.5 of this report). After crossing under the Southern Pacific railroad bridge the conduits separate. Two conduits containing CONTEL, MCI, and US Sprint continue northward along Baldy Mesa Road. AT&T and WTG West conduits turn east and follow parallel to the Southern Pacific railroad line along an unimproved access road.

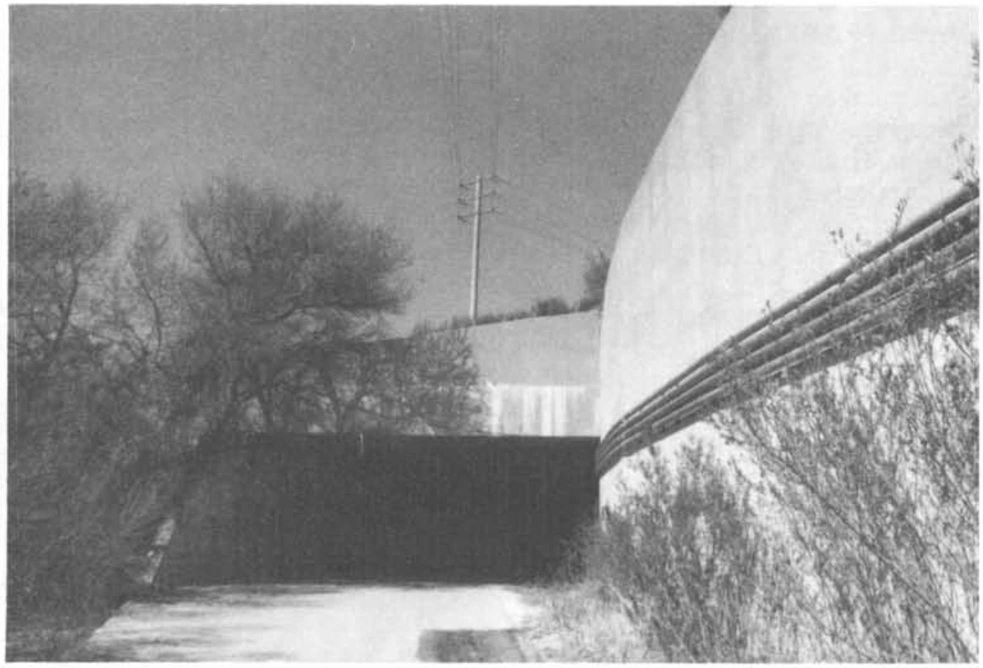

Figure 3.2-7 Fiber Optic Conduits Heading Under I-15, Attached to a Concrete Culvert Wall

After about 2.25 miles the unimproved road (and AT&T and WTG West conduits) turn north by northeast. The conduits follow this winding road and approach the north bound section of I-15 about 0.5 miles south of the first I-15 intersection north of the Cajon Summit (the Caliente and Mariposa intersection) where they connect with and then follow the route of Mariposa Road. Mariposa Road runs parallel and east of the northbound lanes of I-15. As was done on the old Highway 66, whenever there is a bridge on the Mariposa Road the conduits are placed above ground on the bridge. Figure 3.2-8 shows a typical conduit routing at a bridge. The figure shows an additional pipe (believed to be an unidentified water distribution pipe) hung directly above the conduit.

The CONTEL, MCI, and US Sprint conduits, after separating from the AT&T and WTG West conduits, continue to follow Baldy Mesa Road. The cross under the north bound lanes of I-15 next to the location where two petroleum products pipelines cross under the highway. They then separate from the products pipelines and continue north until they approach the south bound lanes of I-15. Again, they combine with the petroleum products pipelines to cross under I-15. Thereafter, they continue within the petroleum products pipeline rights-of-way. This route also places them (and the petroleum products pipelines) parallel and near to the Los Angeles Department of Water and Power's two high voltage transmission lines. When the power transmission lines join with Baldy Mesa Road the conduits (and the petroleum products pipelines) are routed along the road next to and between the two power transmission lines. After about 2 miles, Baldy Mesa Road turns due north and leaves the power transmission lines. The fiber optic cables and the pipelines continue along Baldy Mesa Road. About 1.5 miles further north they are joined by a 36-inch natural gas transmission line, and all of these lifelines continue along Baldy Mesa Road until they leave the study area. It is instructive, however, to examine how the cables and pipelines cross over the California Aqueduct (about another 2 miles north of the study northern boundary. All of the lifelines are brought to the surface to cross the aqueduct. One fiber optic cable conduit is hung from the side of the bridge with light fasteners as was done on other bridges. The other conduit is hung under the bridge. The petroleum products pipelines also are hung from the bottom of the bridge while the natural gas pipeline separately spans the aqueduct (see Section 3.4 for photographs of how these fuel pipeline lifelines cross the aqueduct).

Figure 3.2-8 A Fiber Optic Conduit Hung From a Bridge With a Water Distribution Pipe Directly Above It

3.2.2 Microwave and Radio Towers

Because of their remote locations and the need to use trucks with winches in order to assure travel to their sites, the radio and microwave towers that support regional communications were not examined during the site visits. The cellular phone and radio towers which are used by CALTRANS and PAC TEL for local communications within the Cajon Canyon Pass itself were examined during the site visits. Refer to the map of Figure 3.2-1 for the following discussions.

Starting from the southern boundary of the Cajon Pass study region, a radio tower is located at the western edge of the study boundary about two miles west of the Los Angeles Department of Water & Power's high voltage transmission lines and about 2.5 miles north of the southern edge of the study boundary. It is serviced by an unpaved road and distribution electric power lines. Plans call for the expansion of this site into a much larger communications center. At that time the collocation of the communications equipment with the electric and telephone service may create some at-risk siting conditions. However, for the present study it is an isolated communications facility.

East of Interstate I-15 and about 4.5 miles east of the western edge of the study boundary and 6.3 miles north of the southern edge of the study boundary is a microwave tower (it is sited near the Cajon Mountain Lookout station). Access to this remote site is by unpaved roads from the Silverwood Lake State Recreation Area, which is to the east of the study area. This tower is part of the regional telephone communications system, but its isolated site means that it does not cause impacts due to collocation of lifelines.

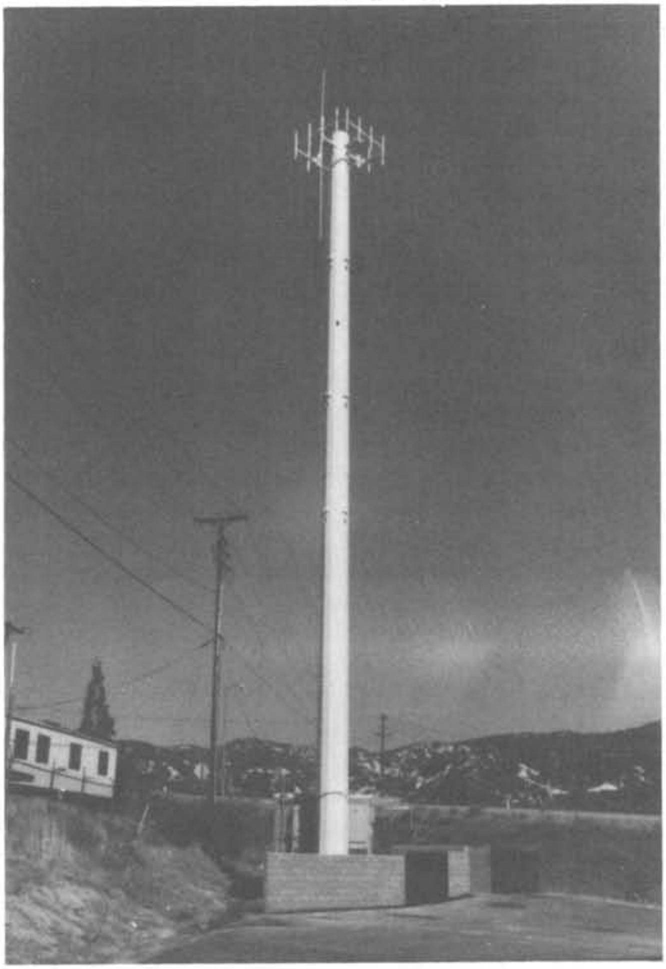

Figure 3.2-9 Cajon Junction Cellular Phone Antenna

The cellular phone antenna is located behind a motel at the Cajon Junction for highways I-15 and 138. Figure 3.2-9 is a photograph of the tower. It is located near to a motel and a large motel water storage tank (which isn't shown in the figure). Seismic design criteria were not specified for the cellular phone antenna or the water storage tank. The tower provides for stationary and mobile cellular phone communications within the Cajon Canyon area, which otherwise would be in a dead band area for such communications.

At the Cajon Summit located between the north and south bound sections of I-15 (about 11.7 miles north of the southern edge of the study boundary and 3.5 miles east of the western edge of the study boundary) there are two communication towers. One tower provides for microwave telephone communications on the AT&T system. It is aligned with other microwave towers outside the study boundaries, and it connects the high desert region with the Los Angeles Basin microwave systems. The second tower is used by CALTRANS[3.2-2] to provide a communications link between the maintenance facility and radios installed in their service vehicles. It allows the Cajon Junction maintenance station to communicate both southward through the Cajon Canyon and northward to regions below the Cajon Summit (without the tower the summit would shadow the northern regions from a communications viewpoint).

3.2.3 Bibliography for Section 3.2

3.2-1 Source of information: discussions with US Sprint, discussions and construction drawings and routing maps from AT&T, CONTEL, and discussions with and routing maps from the US Forest Service.

3.2-2 Source of information: discussions with the CALTRANS staff at the maintenance station at Cajon Junction.

3.3 ELECTRICAL POWER LIFELINES

The electric power lifelines (See Figure 3.3-1) located in the Cajon Pass study area include a hydroelectric power generation station, high voltage transmission lines, a transmission system substation, and wood pole distribution lines and transformers. For reference purposes, the locations of the photographs provided in this Section are shown on the Figure. In accordance with the basis for this study, only the facilities that relate to regional or bulk transfer of electrical energy are being examined. Thus, the distribution systems are not described.

Some of the electric power towers have two circuits of three wires each and some have one circuit of three wires. In conversation, the circuits are often referred to as "lines". Multiple circuits on a single tower save right-of-way acquisition and construction costs, but the towers are larger and cost more. Wind loading criteria generally control the tower designs. Specific earthquake design criteria usually are not applied. However, operating experience throughout the industry has confirmed that towers so designed will perform well under earthquake conditions.

The maps of the U.S. Geological Survey were used as a starting point to locate the appropriate electrical power lifelines. An initial site survey confirmed that not all of the transmission lines were identified on the maps. Subsequent meetings with the lifeline owners were held to gather detailed information, and that information was validated by additional site visits, meetings with regulators, and examination of the right-of-way files of the U.S. Forest Service.

The City of Los Angeles Department of Water and Power is self-regulating with respect to applying, implementing, and inspecting the application of seismic hazard standards. The California Public Utilities Commission regulates the activities for the Southern California Edison Company facilities in the Cajon Pass. However, their criteria are general and non-specific in nature, mostly requiring that the consequences of earthquake events be accounted for in the design, siting, and operation of the electric lifelines. Consequently, the transmission systems are not designed to specific seismic standards, but are designed to standards, including wind loading, which have been accepted as "being more restrictive than would be seismic standards alone".

3.3.1 Los Angeles Department of Water & Power Facilities

The Los Angeles Department of Water and Power owns two 287.5 kV

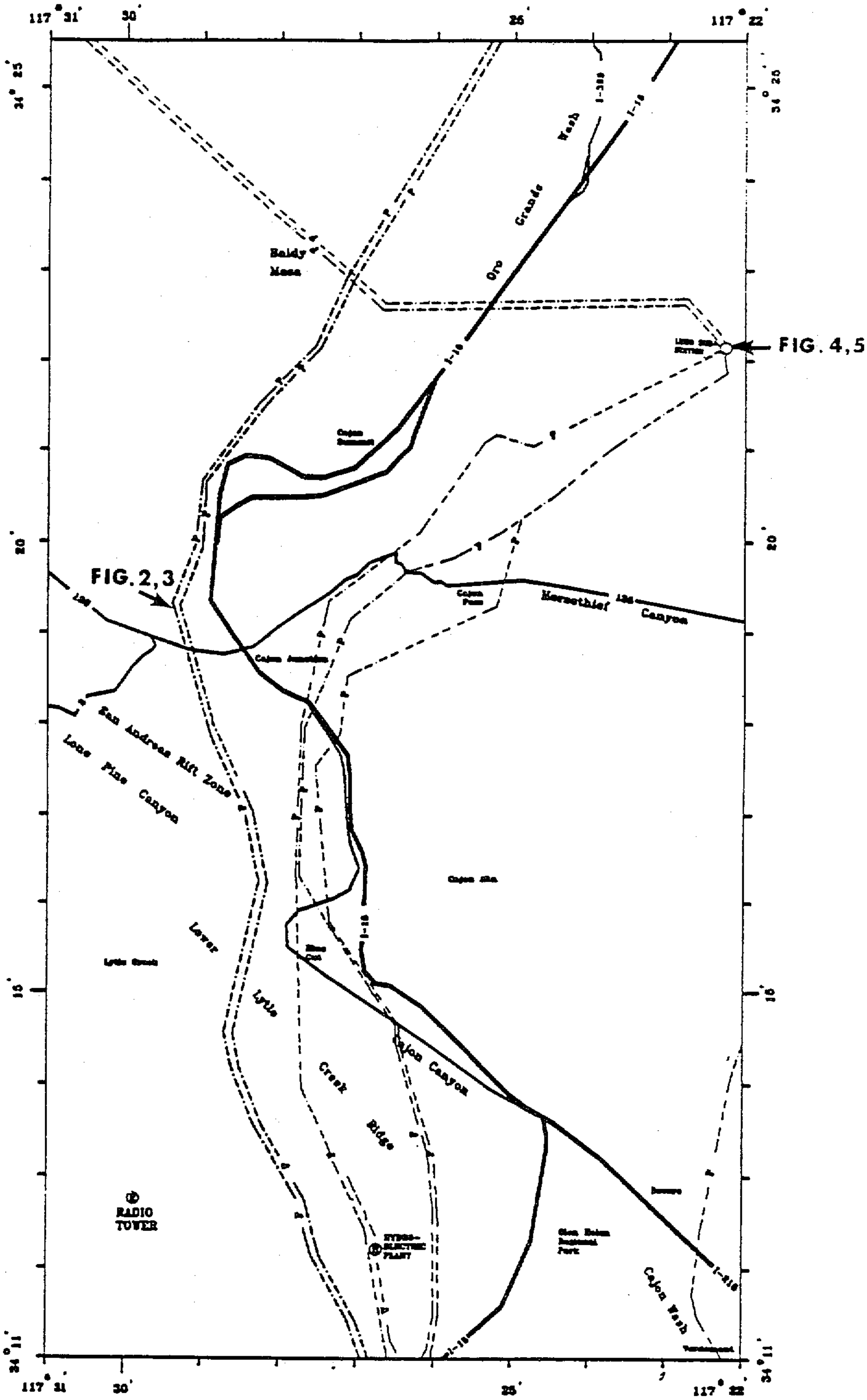

Figure 3.3.1 Map of the Electric Power Lifelines

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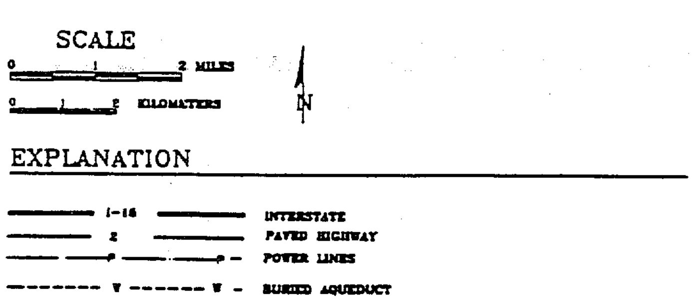

transmissions lines that pass through the study area. They were installed in 1936 to transmit power from the Hover Dam hydroelectric project in Nevada. At that time they were the highest voltage, long distance transmission lines in the world. Although seismic design criteria were not explicitly considered, the transmission system was at the leading edge of technology at that time, and it was conservatively designed. It has performed well except for some local impacts due to soil flow, landslides, and brush fires. The conductor is an air insulated, hollow, segmented copper cable. The system is considered by the Department to be more than adequately designed when compared to current Department design standards.

Today, these lines can transmit up to about 600 MW of power. They transmitted 95% of the City of Los Angeles' power supply when they were built, they now transmit about 5% of the City's power needs. However they are also important in assisting in voltage control and in maintaining transmission system reliability.

North of the study area the transmission lines are connected to the Victorville Substation, south of the study area they are connected to the Century Substation in Los Angeles. Originally completed in 1936, the Victorville Substation has been updated in 1970, 1974, and 1980 to add switching capabilities between the 287.5 and 500 kV lines as well as other system controls. Seismic criteria have increased over this time period, and the 1985 Adelanto converter and switching station (which permits switching to and from the Victorville station) included subjecting full-scale equipment to shaker table tests before accepting the equipment.

Figure 3.3-1 shows the route of the transmission lines. Starting from the southwest border of the study area, the transmission lines move northeast along the foothills of the National Forest. The two transmission lines are routed parallel throughout the study area. An access road is provided along the route. In this region, prior brush fires have annealed the copper conductor cables causing them to sag. Repairs have restored their ground clearance. At the edge of the

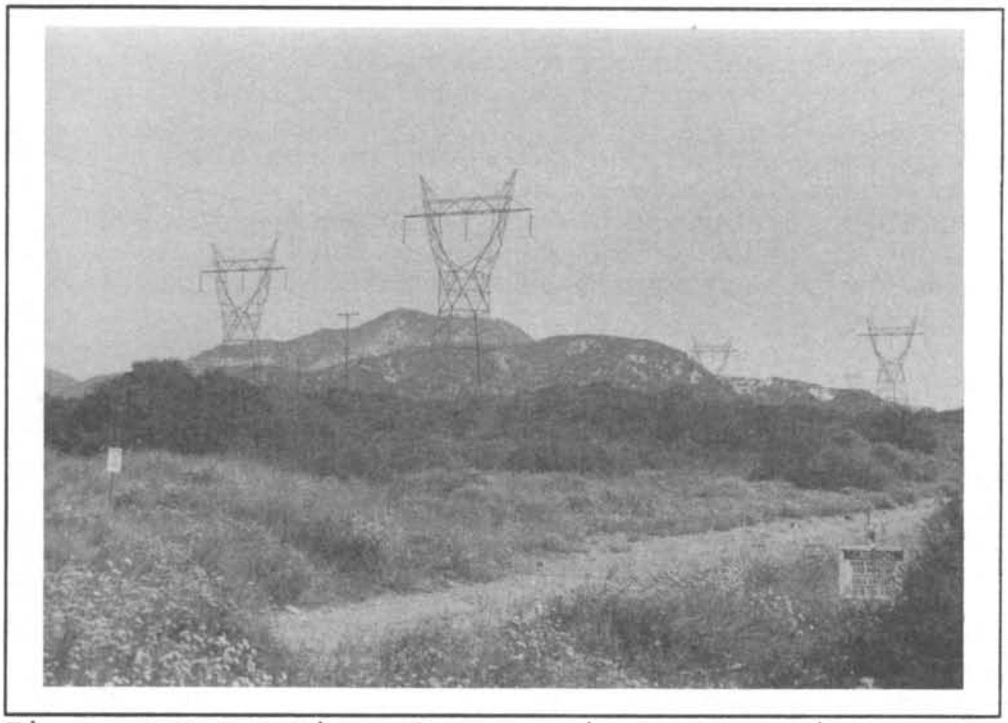

Figure 3.3-2 A View of Power Lines and Buried Fuel Pipelines Crossing the San Andreas Fault Zone

foothills and the Lytle Creek Wash they turn north by northeast and are routed in the steep portions of the west side of Lytle Creek Canyon. The October 1990 and August 1991 brush fires in Lytle Creek annealed parts of these lines, causing them to sag. The repairs are implemented by retensioning and replacement/retensioning, as appropriate.

Just south of the Lytle Creek Ranger Station the lines turn north and cross Lytle Creek Canyon. They are routed through steep, difficult to access terrain. It was reported that there have been rain-induced landslides in this area that have impacted towers, necessitating repairs. These locations were not observed during the site visits. The lines turn lightly north east and descend down from the higher mountains to the Cajon Canyon floor near Blue Cut. There they also pass near the railroad lines. They continue north by north west across the Lone Pine Canyon, which also contains the San Andreas Rift Zone. They cross the Rift Zone in a north west direction, indicating that fault movement can be expected to add slack to the lines crossing the fault (the San Andreas is a right lateral fault). Figure 3.3-2 shows the power lines where they cross the San Andreas Fault. They are located above and close to a 36-inch buried natural gas pipeline and the 8-inch and 14-inch petroleum products pipelines (they actually cross over the petroleum products pipelines and are roughly parallel to the path of the natural gas pipeline). Figure 3.3-3 is a photograph taken in the opposite direction to Figure 3.3-2. It shows that the power tower immediately before the intersection of the power lines and the fuel pipelines is located at the edge of a steep ravine. Also, the tower shown is typical of the design used at Cajon Pass.

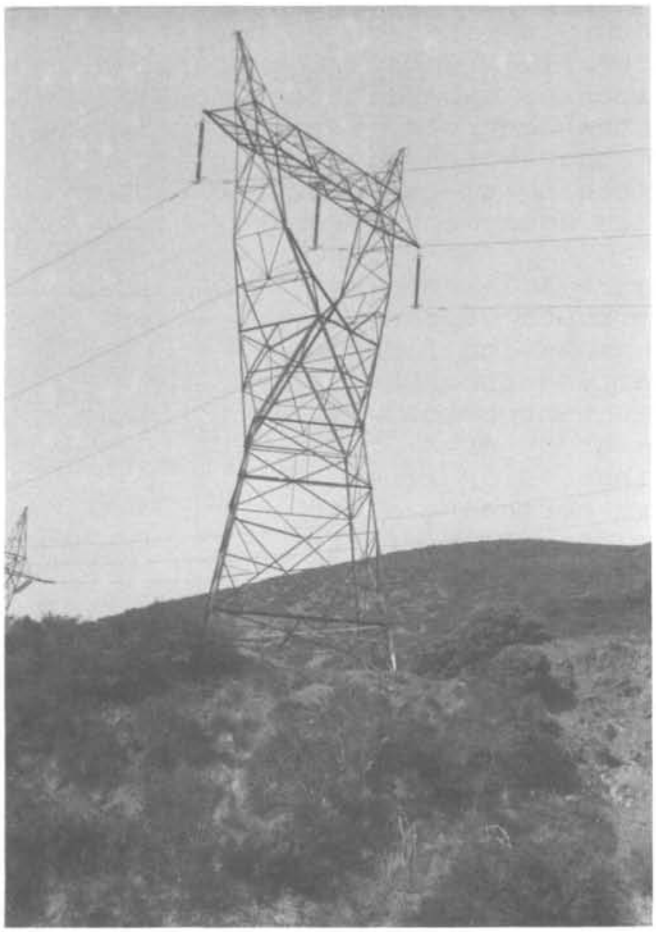

Figure 3.3-3 Power Towers At The Edge Of A Steep Ravine Near The San Andreas Fault Zone

About 0.75 miles south and west of Cajon Junction the lines cross over a small bowl. This region experienced slow ground sliding towards the center of the bowl. Over 15-20 years the movement was enough to put slack into lines within the bowl and tension on the lines just outside the bowl. The Department has reset the towers and placed soil-concrete mixtures and drains on the bowl surface. It appears that by moving surface waters out of the bowl the slow sliding has been arrested. However, during an earthquake liquefaction or ground sliding might occur in this region.

The lines cross the railroad tracks south of Highway 138 and west of I-15 near the Cajon Junction. Next they continue north by northwest, turn northeast, and again cross the railroad tracks. They then approach parallel to the south bound route of I-15 (just south of where I-15 divides into widely separated north and south bound segments). Thereafter, they continue north parallel to the southbound segment of I-15 and the petroleum products pipelines. When I-15 turns east the transmission lines turn northeast and connect with the general route of Baldy Mesa Road. The terrain is very steep as they move up the Baldy Mountain slope, and surface erosion is a continuing problem. In this area and along the Baldy Mesa Road the power transmissions lines are parallel to petroleum products and fiber optic lifelines. After the Cajon Summit the power lines proceed northeast and continue in a straight path until they leave the study area. In this downslope side of the high desert region they also cross under two 500 kV Southern California Edison power lines and over the Southern Pacific Railroad line.

3.3.2 Southern California Edison Company Facilities

Figure 3.3-1 also shows the location of the Southern California Edison (SCE) electric power lifeline facilities. This includes a hydroelectric power generation station in Lytle Creek, a major Substation (Lugo Substation) in the northeast portion of the study area, and a number of high voltage power lines. Three 500 kV transmission lines (the Lugo:Mira-Loma lines) run north-south through the Cajon Pass, a short segment of the Arrowhead:Calectric Shannin 115 kV line passes through the southeast section of the study area in the Devore-San Bernardino area, and two Lugo:Vincent 500 kV transmission lines pass from east to west through the northern half of the study area (north of the Cajon Summit in the high desert region). The high voltage transmission lines are air insulated aluminum lines with a steel core that provides the needed tensile strength.

The Lytle Creek Hydroelectric power generation station (located about two miles north of the study southern boundary) uses the surface runoff of Lytle Creek for its water supply. There is some capability to pump from deep wells to add water flow to this station, if needed. The station was built in 1904 and has operated since then. It directs the Lytle Creek through a 3,092 foot channel to the buried penstocks. From there, the water is directed underground in a piping system through the Lytle Creek Wash to a second hydroelectric station at Fontana just outside the southern boundary of the study area. Afterwards the water is treated and distributed to local water districts for their subsequent use. The Lytle Creek substation is rated at 680 kW, but in 1989 it generated at an average daily power level of just under 300 kW. Its output is transmitted at 12 kV on a wood pole distribution system.

The Lugo Substation is located at the eastern edge of the study boundary