and about 4.5 miles south of the northern boundary. It is just south of the City of Hesperia. It is a major lifeline facility, it handles over 2,500 MW of power, and it provides interconnections and switching between five 500 kV SCE transmission lines and a 500 kV Los Angeles Department of Water and Power line (that line's connection to City ownership is north and outside of the study boundaries). Figure 3.3-4 shows the administrative and control facilities housed a brick building, the communications microwave tower that provides SCE with a secure, direct, communications link with the substation, and some of the station equipment. Most of the facility was designed for a 0.2g horizontal load. Figure 3.3-5 shows the circuit breakers in more detail. After the 1971 San Fernando earthquake the circuit breakers were retrofit with earthquake resistant bases and their clamp anchorage was welded to their skid frames for more positive anchorage. The transformers

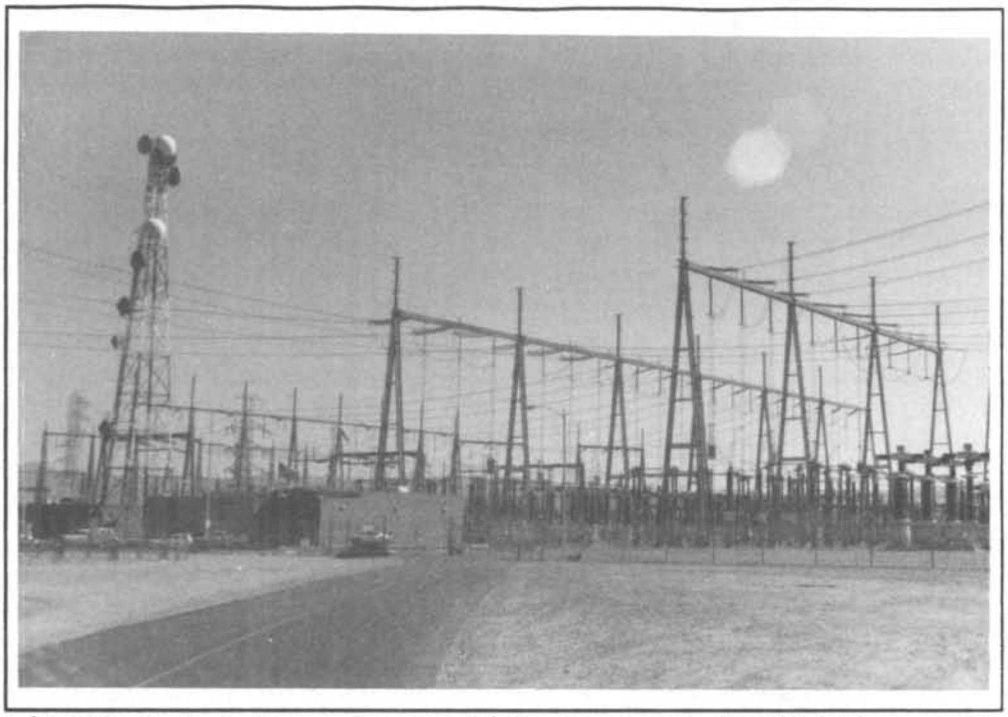


Figure 3.3-4 Lugo Substation Control Facilities and Equipment

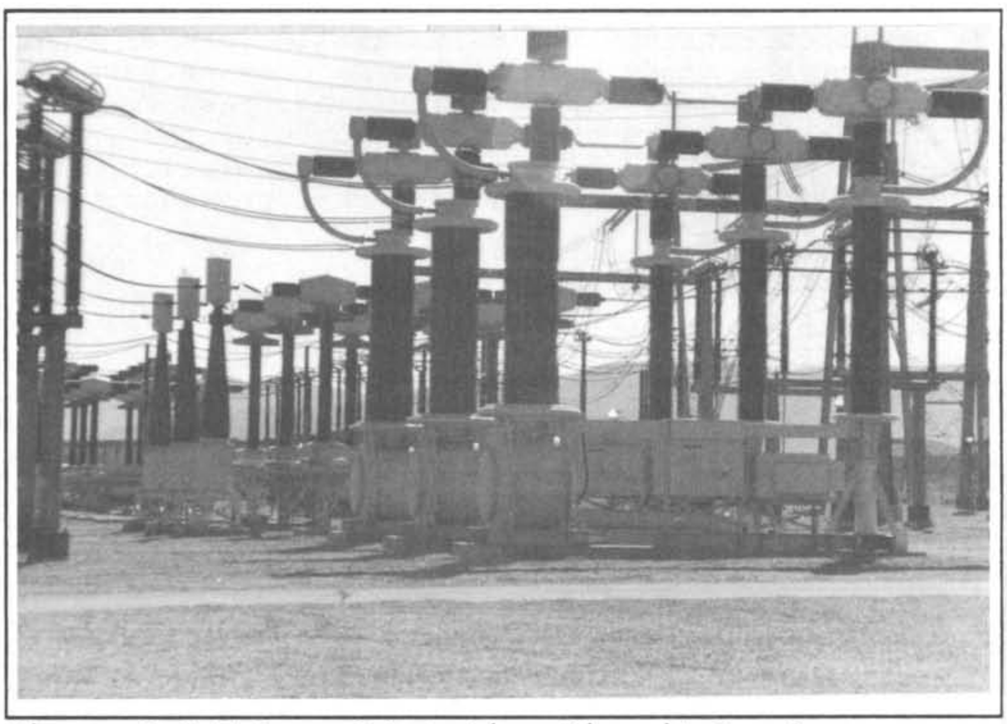


Figure 3.3-5 Lugo Substation Circuit Breakers

have also had their anchorage improved with welding and clamping to their skids. Recent purchases for the station have been designed against a 0.5g dynamic evaluation criteria. Although SCE recognizes that the station is still subject to equipment failures during an earthquake, they have extensive plans for mitigating the impact of such an event (e.g., managing the risk of failure). For example, they have alternative plans that could keep the substation on line under emergency conditions using as few as about 10% of the circuit breakers.

Starting from the southern boundary of the study area, SCE has three 500 kV transmission lines that connect the Lugo and Mira-Loma substations. Two of the lines were installed in the early 1960s for about 300 kV service. They were upgraded to 500 kV service in the early 1970s, and the third line was added in 1983. A single tower system brings the lines north by northeast to the study boundary. The original two lines split into separate tower systems just inside the study boundary. Just outside the study boundary the new line separates from the single tower system and heads due east. It turns north at the Lytle Creek Wash and rejoins the most eastern of the two original lines. The western line heads approximately due north crossing the railroads (several times) and the old Cajon Pass highway near Blue Cut. North of Blue Cut it is rejoined by the second original line and both head due north.

The new transmission line joins the most eastern of the original lines in a parallel tower system just north of the southern boundary of the study area at the mouth of Lytle Creek. Together they head up the steep slopes of the lower Lytle Creek Ridge and then descend to the floor of Cajon Pass. In the 1970s there was a landslide on the slope just before where they reach the Cajon Pass floor. It damaged the towers and they had to be repaired. Figure 3.1-5 shows the landslide scar and the towers that were rebuilt on the scar.

After the landslide area, the two lines cross over the Cajon Canyon and run approximately parallel to the west side of I-15. Figure 3.3-6 shows typical tower footings. SCE reported that mostly bell

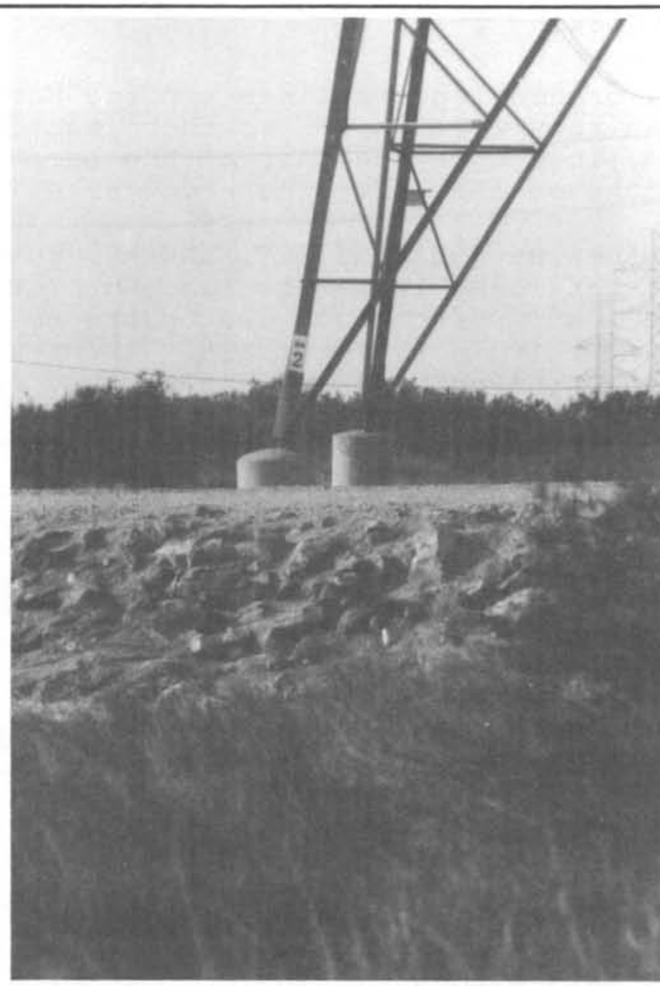


Figure 3.3-7 Typical Electric Transmission Tower Footings

foundations are used, and if they can't be formed then deep column footings are used. At Blue Cut the new line separates from the older original line while the older line continues northwest until it joins the other original line. The new line crosses over the railroads and Highway I-15 about 2 miles north of where it separated from the original line. It then travels on the east side of I-15 by itself until it joins the eastern most of the original lines north of the railroad summit and north of highway 138. All of the power lines cross the San Andreas Rift Zone just north of Blue Cut. Fault movements should put slack into the lines that bridge the fault.

After they rejoin just north of Blue Cut, the two original lines travel north for about two miles. This takes them back into steep terrain. Just before they redescend to the Cajon Pass floor about 0.5 mile south of Cajon Junction, they approach the railroads, petroleum pipelines, fiber optic lines, and highway I-15. It is noted that just before the location where the towers descend in this region there was some surface erosion or displacement near the tower foundations. SCE has protected those towers by covering the ground surface with a soil-cement to seal the surface material.

The original power lines proceed northeast but are more widely separated than they were in the southern section of the study area. All three of the lines come together at the Lugo Substation. Then they continue northeast and leave the study area.

Another set of two, SCE, 500 kV, power transmission lines (the Lugo-Vincent line) leave the Lugo Substation heading northwest, then they turn due west. Since they are on the north side of the Cajon Summit they are in relatively flat terrain. About 1.25 miles after they cross I-15 they turn northwest and leave the study area. They are connected to the Vincent Substation to the northwest.

The third SCE transmission system is the 115 kV line that enters and exits the study area in the Devore region. This lifeline was not examined in detail, but it is interesting to note that in November 1990 a high wind caused a power line in the foothills behind Devore to break. The downed line ignited a brush fire which burned about 200 acres, destroyed four homes, and damaged others. The towers, however, were not damaged by the wind. That incident points out that the danger to transmission lifelines is not just a tower failure, but also a line break.

3.3.3 Bibliography For Section 3.3

No reports were used for this section of the report, the information was obtained during direct discussions with the lifeline owners.

3.4 FUEL TRANSPORTATION LIFELINES

The fuel pipeline lifelines (see Figure 3.4-1) in the Cajon Pass study area include two high pressure petroleum products transmission lines, two high pressure natural gas transmission lines, and an intermediate pressure

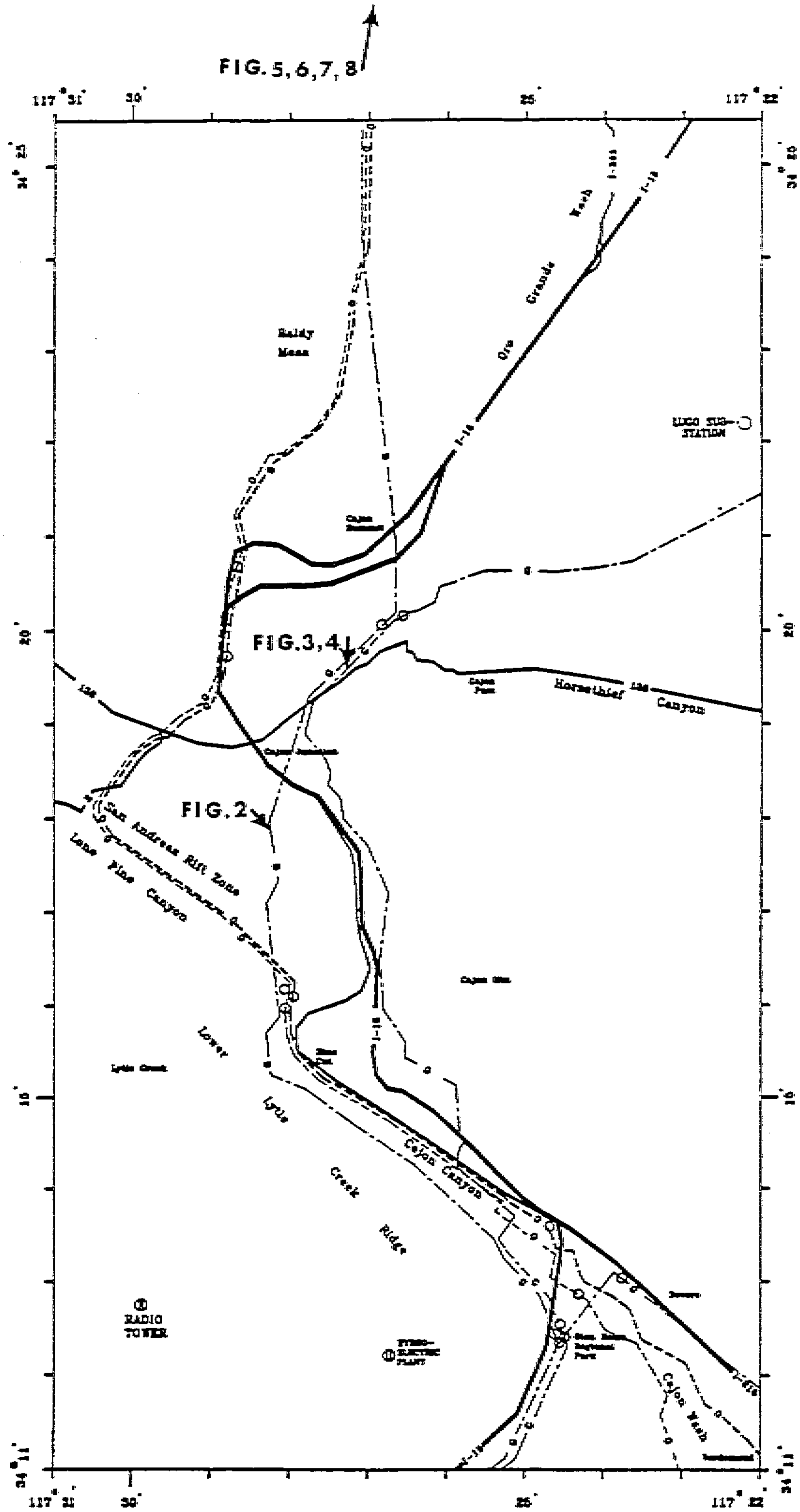
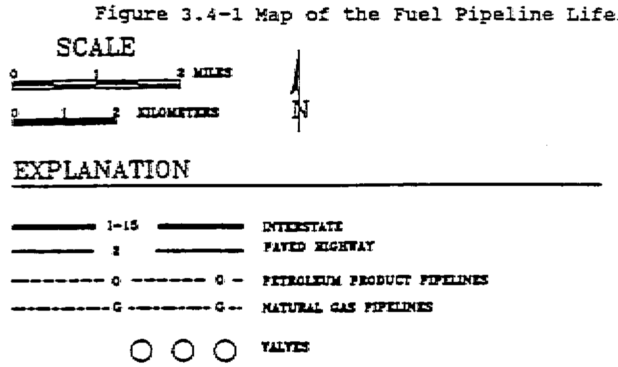


Figure 3.4-1 Map of the Fuel Pipeline Lifelines



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natural gas distribution line. For reference purposes, the locations of the photographs provided in this Section are shown on the Figure. Also included are a number of valve stations in each pipeline system. Responsibility for the independent for inspection and safety monitoring (including accounting for seismic safety) these lifelines lies with the U.S. Department of Transportation Office of Pipeline Safety. They, in turn, have delegated their authority for petroleum products pipelines to the California Office of the Fire Marshal, and for natural gas pipelines to the California Public Utilities Commission. The Office of Pipeline Safety's seismic hazards mitigation requirements are very broadly stated in such terms as "earthquakes should be considered during the design and installation of such systems". The Office of the Fire Marshal has retained the broad language in its requirements. The Public Utility Commission has specific, detailed, seismic design criteria for liquified natural gas facilities, but the requirement for natural gas pipelines retains the broadly stated guidelines.

3.4.1 Natural Gas Pipelines

Southern California Gas Co. operates two 36-inch high pressure (about 845 psig) natural gas transmission lines in the Cajon Pass and a 16-inch intermediate pressure (350 psig) trunk line that delivers natural gas from the two 36-inch lines to the San Bernardino region (see Figure 3.4-1 which is a map of the fuel transmissions lines in the study area). A third north-south gas pipeline (which on the map appears to be an extension of the more western 36-inch pipeline) is a 36-inch line to the high desert region. It operates at 936 psig and is connected through a valving station directly to the two 36-inch high pressure lines. In the study area, one of the transmission lines is routed on the west side of highway I-15, the other on the east side. At Cajon Junction the western pipeline crosses under I-15 and joins the eastern pipeline and the north-south pipeline at a valving station. There is another valving station near Devore that connects the two transmission lines and the trunk line.

Piping wall thicknesses are in accordance with the California Public Utilities Commission General Order No 112-D[3.4-1]. Spacing between the pipeline valves and separately the pipe wall thickness are controlled by criteria which in turn are controlled by the population density of the area. Retrofits requiring more frequent valves and thicker wall pipes can be required by changes in the population density. Although no changes have been required in the study area, it appears that business growth plans near the Cajon Junction and residential population growth in the high desert region of the study area may require such modifications in the near future.

The eastern most transmission line (line 4000) was installed in 1966 using X-60 grade pipe with wall thicknesses ranging from 0.375-0.438 inches. It operates between the Newberry Compressor station to the north of the study area and the Fontana pressure limiting station south of the study area. The western most transmission line (line 4002) was installed in 1960 (it was the original line) using X-52 and X-60 grade pipe with wall thicknesses ranging from 0.375-0.500 inches. It operates between the

Cajon summit valving station north and east of the Cajon Junction and the Fontana station south of the study area. The north-south line (line 1185) was installed in 1976 using X-60 grade pipe and wall thicknesses ranging from 0.391-0.562 inches. It runs from the Cajon Summit valving station north to the Adelanto Compressor Station.

Southern California Gas Company operates another 36-inch pipeline that crosses the San Andreas fault zone north and west of the Cajon Pass. The three transmission lines (the 1185 and 4002 lines and the 4000 line in the study area and the third lines west of the study area) supply about 90% of the Company's natural gas to the Los Angeles Basin. The transmission lines in the study area presently provide about 750 million cubic feet of natural gas each day, although their combined total capacity is up to 1 billion cubic feet per day. In addition, the Company maintains natural gas storage in the coastal area that could provide 30-90 days supply for its core customers.

Maintenance staff and supplies are maintained in the Los Angeles Basin and in Victorville. The emergency planning assumes that up to 1/2 mile of pipeline on either side of the San Andreas fault zone could be failed during a major earthquake. They maintain prepositioned material to replace that piping, if needed, they have written procedures for responding to such a requirement, and they have existing agreements with a helicopter company to provide helicopters for their use during such times.

The following discussion tracks the pipelines from the south of the study region to the north. This is counter to the flow direction of the natural gas, but it is consistent with the descriptions provided for the other lifelines. The 36-inch transmission lines enter the study area southern boundary in the Lytle Creek Wash just west of I-15. They also pass under the new SCE 500 kV transmission line where they enter the study area. Block valves are used to sectionalize the line. Just south of the study area is the Fontana valving station that can be used to control the pressure in each line and to cross-connect the

Figure 3.4-2 Natural Gas Pipeline Crossings Under Two Railroads

lines. In the study area, they proceed east by northeast for about two miles. At the western edge of the Cajon Wash there is another valving station and that is where the 16-inch trunk line to San Bernardino takes gas from the 36-inch lines. The 36-inch lines then turn northeast and approximately due west of the I-15/I-215 junction they separate.

Figure 3.4-3 An Exposed Section Of The Natural Gas Pipeline

The western line (line 4002) follows the Southern Pacific and Atcheson Topeka & Santa Fe (AT&SF) railroad right-of-ways to Blue Cut. It crosses the Southern Pacific railroad track several times, running either parallel and west of the track or in the space between the tracks of those two railroads. These crossings are buried but uncased. From Blue Cut the line heads generally north. It runs parallel and near to the Los Angeles Department of Water and Power's two high voltage transmission lines for about one mile. In the Lone Pine Canyon it crosses the San Andreas fault zone very close to two power transmission lines. It also crosses the two petroleum products pipelines at that location. This crossing is discussed in more detail in Section 3.3.

Further north (just south of the Cajon Junction) the 36-inch natural gas pipeline crosses the Southern and the Union Pacific railroad lines. Figure 3.4-2 shows the pipeline right-of-way descending to and then under those railways. The crossing under the Southern Pacific is uncased, it is cased under the Union Pacific. Between Blue Cut and the railroad crossings south of Cajon Pass there are five sections of exposed line with spans ranging from 57-118 feet. Figure 3.4-3 shows one of the longer exposed sections, and Figure 3.4-4 shows a close of up the pipe exiting the ground. It shows the connection of the pipe corrosion protection material wrapping (the gray line) as it is connected to the pipe. The pipe crosses under the AT&SF railroad and I-5 and continues parallel to the eastern pipeline to the Cajon summit valving station located north of highway 138. In this route there are two more exposed sections with 68 and 80 foot spans. A recent realignment of Highway 138 brings it very close to one of the exposed crossings. At that location, the two 36-inch pipelines are located parallel. The line to the left is exposed, the one to the right is buried.

Figure 3.4-4 Details of the Ground Support For Exposed Sections Of Natural Gas Pipelines

When the eastern natural gas pipeline (line 4000) separates from the western one near the junction of I-15 and I-215 it turns northeast and crosses under the Southern Pacific and AT&SF railroads and the Cajon Wash. The pipeline then runs parallel and west of the old highway for about 0.75 miles, then crosses under the old highway and I-15. When it crosses the old highway it also crosses perpendicular to the two petroleum products pipelines. This region also has a high water table and could be subject to liquefaction during an earthquake event.

The 36-inch pipeline continues roughly parallel to I-15 on the eastern side of I-15. In these steep mountains there have been a number of times when fires have burned off the vegetation and surface erosion and stream-bed erosion have occurred, and in the 1970's a landslide after heavy rains damaged such a portion of this pipeline. Just north and east of the Cajon Junction the routing turns north by northeast and the pipeline crosses Highway 138. It runs parallel and north of the highway, and new highway crossings will result when Highway 138 is rerouted in 1991. Between the Cajon Junction and the summit valving station there are five separate locations of exposed pipeline, with the spans ranging from 98-138 feet. After the valving station, the pipeline (line 4000) turns east and then northeast and leaves the study area. Twice it crosses the three railroads in this section. The highway, railroad, and power line crossings are a mixture of cased and uncased crossings.

The third pipeline (line 1185) is routed north from the Cajon Summit valving station. It crosses under the railroads next to short railroad bridges. It continues north, crossing under the northbound and then the southbound portions of I-15. All of these crossings are cased. Continuing north, it crosses under power transmission lines and then connects to and runs parallel to Baldy Mesa Road. It is routed on the east side of the road, the petroleum products pipelines and three fiber optic cables are also routed parallel to this road. A valve station is located on the shoulder of Baldy Mesa Rd., and Figure 3.4-5 shows the posts installed around the valves to protect them from a vehicle accidently crashing into them.

North of the study boundary it crosses the California Aqueduct. Figure 3.4-6 shows that crossing.

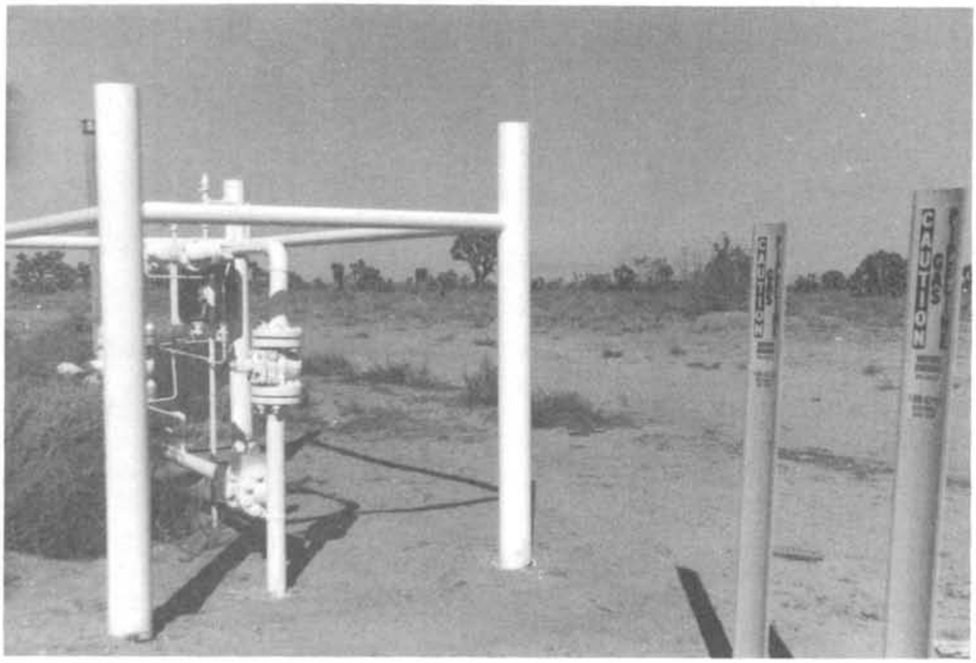

Figure 3.4-5 Natural Gas Pipeline Valve Station On Baldy Mesa Road

Figure 3.4-6 The Natural Gas Pipeline Crossing the California Aqueduct

3.4.2 Liquid Fuel Pipelines

There are two petroleum products pipelines operated by CALNEV Pipe Line Company in the study area. Figure 3.4-1 shows the routes of these lifelines. In 1960 an 8-inch pipeline was installed, in 1969-70 a second 14-inch pipeline was installed, and in 1980 several miles of the 8-inch line that were installed in the Cajon Wash were rerouted to be parallel to the 14-inch line located east of the Wash (it was reported[3.4-2] that the 8-inch line in Cajon Canyon Wash frequently would be uncovered during the spring runoff, and that the Forest Service requested and CALNEV concurred that it would be safer to move the line to a region where water runoff would be less troublesome). The lines are about 250 miles long and were installed in accordance with the then current American Petroleum Institute's standards. Those standards required that reasonable protection for anticipated and unusual external conditions be included in the design, but specific earthquake criteria were not identified in the standards. In California, the Office of the Fire Marshall is responsible for the inspection and enforcement of the federal and California pipeline safety standards[3.4-3]. For the federal requirements, they are the agent for the U.S. Department of Transportation Office of Pipeline Safety, who has statutory safety responsibilities.

The fuel pipelines are buried 3-14 feet deep, depending on their location. When they cross state highways or railways they are normally cased. When they cross unpaved roads they may not be cased. They operate at 1060-1690 psig. The pipe outside is coated with coal tar and impressed cathodic corrosion protection is used, the locations for impressing the required voltage on the pipeline are at the pipeline terminuses. Check valves and motorized valves are installed on the pipelines, there is no backup emergency driver if the electricity fails. However, each motorized valve can be manually operated. The operations are controlled by computers in the San Bernardino station, there is 100% redundancy in the computer controls. Twice a year the company conducts training for emergency response, they fly over the line route every other week, they drive most of the line route weekly, and they conduct an annual inspection of the line route. Extra pipe for emergency repairs is stored at various cities along the route path. There are pump stations in San Bernardino and Barstow, CA.

The lines pump about 80,000 barrels (bbl)/day of product. The product provides about 90% of the Las Vegas area fuel and 100% of the fuel for three Air Force bases. They have 560,000 bbl of storage at the San Bernardino terminal (normally this capacity is mostly full), and they have 237,000 bbl of gasoline and 106,000 bbl of diesel storage in Las Vegas, 105,000 bbl of storage in Barstow, and 64,000 bbl of jet fuel storage on one of the Air Force bases.

As a result of the May 1989 derailment and subsequent pipeline failure/fire in San Bernardino, the side hinged check valves (which had failed to close during that accident) were replaced with top hinged check valves. However, the check valve near the accident site was replaced with a motorized control valve. In early 1990 another train derailment in which the engine and cars came to rest over the pipeline occurred in Las Vegas. It was reported(3.4-4) that as was the case in San Bernardino, the derailment itself did not rupture the pipeline. A 100% pipeline excavation and inspection at Las Vegas indicated that the pipeline was not damaged by the derailment. In 1988-89 when the fiber optic cables were installed in the pipeline right-of-way, it was reported(3.4-4) that on at least two occasions the trencher struck the pipeline, requiring piping repairs (the location of these incidents was not identified).

The 8-inch pipeline enters the study area on the western side of the Cajon Wash. Just south of the study area there is a check valve (located east of the San Bernardino County Prison Farm). The pipeline runs north along the western edge and within the Cajon Wash. Just after it passes under Devore Road there is another check valve. It continues in a north west direction crossing under I-15 before the I-15/I-215 intersection, turns north and crosses under the Union Pacific, Southern Pacific, and AT&SF railroads. It then continues for about 1 mile along the eastern edge of the AT&SF right-of-way. After it crosses the natural gas pipeline it turns north east, crosses the Cajon Canyon floor and connects with the existing 14-inch pipeline right-of-way along the old Cajon Canyon highway. From there it and the 14-inch pipeline are routed in parallel trenches.

The 14-inch pipeline enters the study area in the southeast corner. About two miles south of the study area there is a motorized check valve just north of Duffey St. The 14-inch pipeline follows the Southern Pacific railroad right-of-way, sometimes crossing under the tracks, most of the time parallel to and outside of the tracks. When the AT&SF and Southern Pacific railroads come together south of Devore Road, the pipeline's route is between the tracks of the two railroads. It leaves the railroad right-of-ways just past Devore Road, turns north east and crosses under I-15 at the I-15/I-215 intersection. It continues north east and joins the old Cajon Canyon highway. Just as it enters under the median strip there is another check valve. It is joined

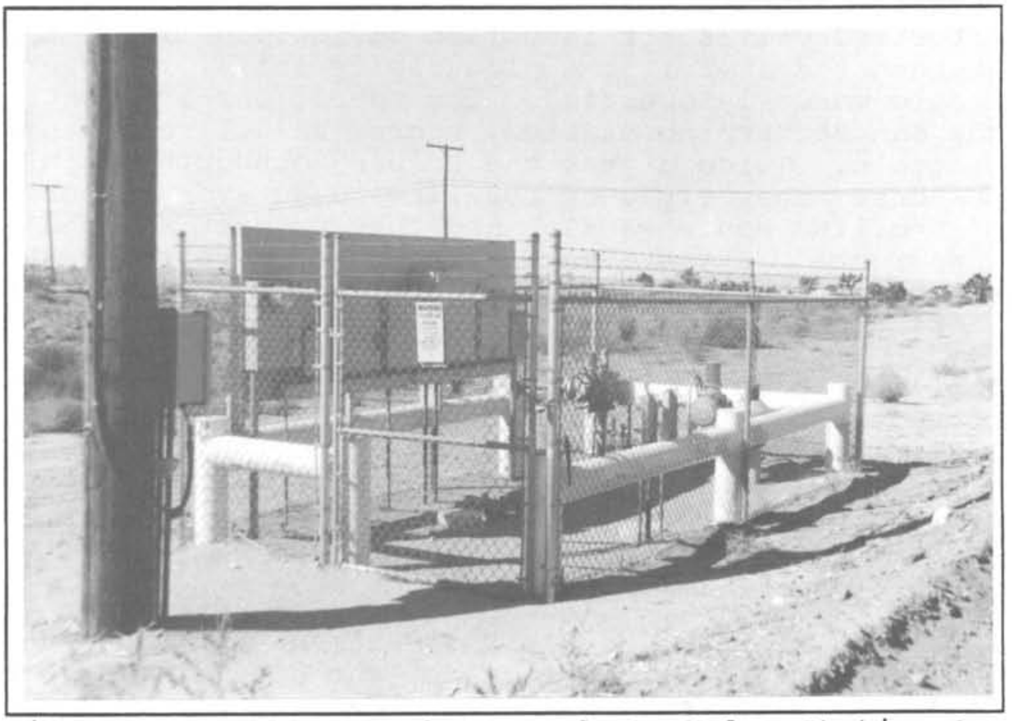

Figure 3.4-7 The Petroleum Products Valve Station On The Shoulder of Baldy Mesa Rd.

by the 8-inch pipeline at about Kenwood Road. The pipelines (and the fiber optic conduits) follow the old highway along a northwest route until they reach the point at Blue Cut where the old highway makes a broad right turn. There the pipelines turn north for about 0.5 miles. Both the 8- and the 14-inch lines have check valves in this region. When the route reaches Lone Pine Canyon (which is also the San Andreas Fault Zone) they turn left and follow the canyon floor for about 3 miles. This was the original route of the 8-inch pipeline, and the same right-of-way was used when the 14-inch line was installed. It is parallel to a dirt road. When the road connects with Lone Pine Canyon Road the pipelines turn northeast. They cross the Lone Pine Canyon Road several times in cased and uncased crossings. They continue in their northeast route until they cross under I-15, where they turn north. Just prior to crossing the railroads, there is another check valve on the 14-inch line. They follow the general route of Baldy Mesa Road and cross under I-15 again. In the region between the north and southbound sections of I-15 there is a check valve on the 8-inch pipeline. After crossing under the southbound section of I-15 the pipeline turns northeast and is parallel to the Los Angeles Department of Water and Power's two 287.5 kV electric power transmission lines. At the summit of Mt. Baldy there was a pressure reading station. Vandalism has caused CALNEV to move the gauges to a less prominent location, but the pressure stems off of the pipelines to the valves are still exposed and it appears that vandals have been trying to rupture them. When Baldy Mesa Road separates from the electric power transmission lines the pipelines follow the road in a northern direction. There they are joined by one of the natural gas transmission lines, with the pipelines on the western side of the road and the natural gas pipeline on the eastern side of the road. About two miles north of the northern boundary of the study area the pipelines cross the California Aqueduct. Just before the crossing there is another valve station for each of the pipelines. Figure 3.4-7 shows the above ground valve station that is on the shoulder of Baldy Mesa Rd.. The barriers were installed to protect the valves from vehicles. At the

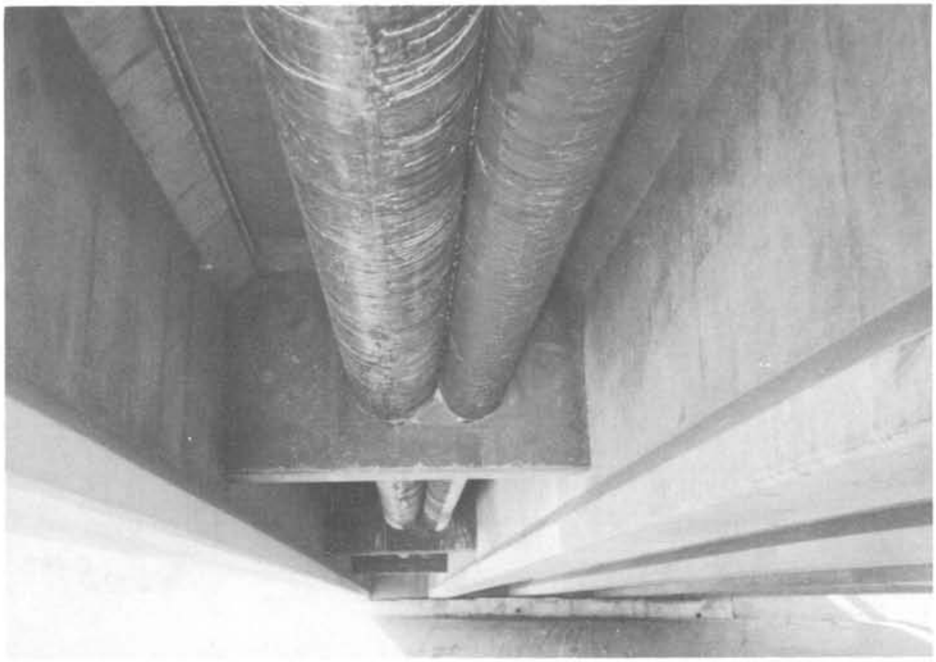

Figure 3.4-8 Petroleum Products Pipelines Hung Under The Baldy Mesa Rd. Bridge Over the California Aqueduct

aqueduct crossings the pipelines are hung exposed under the Baldy Mesa Road bridge over the aqueduct, and Figure 3.4-8 shows this.

3.4.3 Bibliography for Section 3.4

3.4-1 Public Utilities Commission of the State of California General Order No. 112-D, "Rules Governing Design, Construction, Testing, Maintenance and Operation of Utility Gas Gathering, Transmission and Distribution Piping Systems", November 1988.

3.4-2 Source of information: meetings with the US Forest Service at the Lytle Creek station.

3.4-3 Source of information: meetings with the US Office of Pipeline Safety and separately with the California Office of the Fire Marshall, Pipeline Safety Division.

3.4-4 Source of information: conversations with CALNEV Pipeline Company.

3.5 TRANSPORTATION LIFELINES

The Cajon pass has served as a route for passage of people and goods between the Los Angeles basin and the high desert region from earliest times, since it is the only relatively easy penetration of the San Gabriel and San Bernardino mountains. One of the old main transcontinental highways, Route 66, used this route, as did the Atcheson, Topeka and Santa Fe (Santa Fe) railroad. At the present time, the old Route 66 has been replaced by Interstate Highway 15 (I-15) with a spur into San Bernardino (I-215), and Route 66 in the southern portion of the Cajon Pass has since become a county road restricted to two lane, opposing traffic. A primary State highway, Route 138, runs east-west from the Silverwood and Arrowhead Lake recreation areas in the east to Palmdale in the northwest. Route 138 intersects with I-15 at Cajon Junction. There are also three mainline railroads in the study area: the Santa Fe, the Union Pacific, and the Southern Pacific. Under emergency conditions it might be possible to route all railroad traffic on one rail line because their close proximity could facilitate making such connections. However, this possibility was not examined during the present study. Figure 3.5-1 shows the transportation lifeline routes in the study area. For reference purposes, the locations of the photographs provided in this Section are also shown on the Figure.

3.5.1 Highways

The interstate highway through the Cajon Pass was originally completed in the era of 1965-1969. It follows the old alignment of Route 66, except for the section through the steeper part of the route in the pass itself, where the new interstate highway is laid on an improved alignment which begins its climb earlier and yields lesser grades and more gentle curves. It also increased the traffic capacity, with up to four lanes in each direction in the sections with greatest grades. The traffic on I-15 has

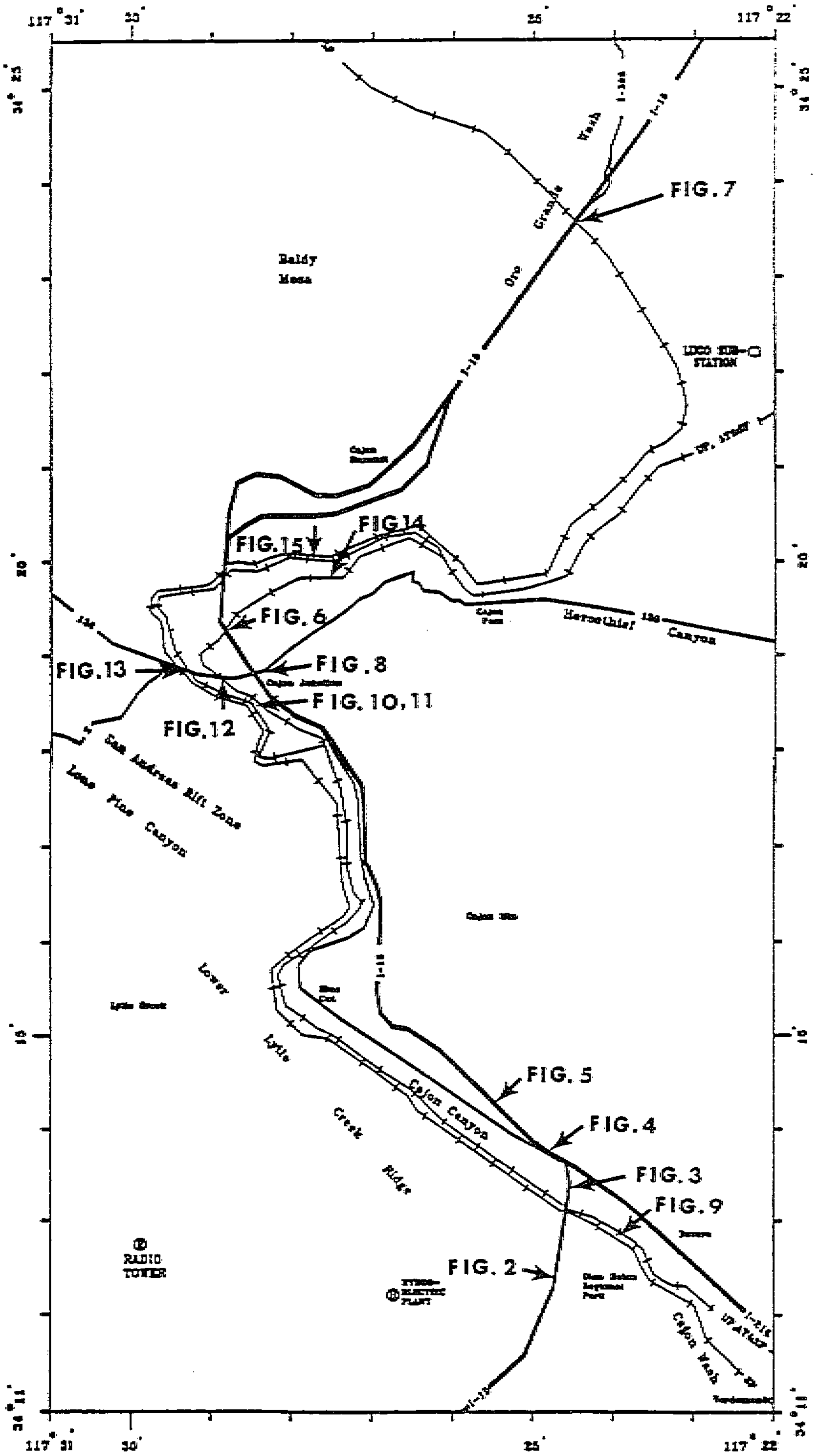

Figure 3.5-1 Map of the Transportation Lifelines

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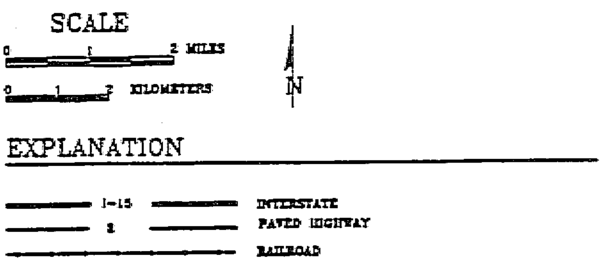

increased over recent years, with the average daily traffic now approaching 60,000 vehicles/day in the section below Cajon Junction. On weekdays, this traffic includes about 28% large trucks.

In 1975, a new interstate section was completed connecting the area near Devore at the south end of the Pass directly with I-10 near Ontario, thus bypassing the city of San Bernardino for traffic bound for the Los Angeles area farther west. The existing I-15 section from Devore to San Bernardino was redesignated as I-215.

The highway lifelines would be of major value to the immediate recovery phase after an earthquake or other disaster, since they provide access to the area from supporting communities to the north. Also, they provide a vital link to the several military airfields in the high desert area which are likely to be less affected than the airports in the Los Angeles-San Bernardino corridor.

Damage to the highway lifelines may result from several aspects of the earthquake. The bridges are vulnerable to forces generated by ground shaking. The roadway itself may be interrupted by landslides coming down onto the roadway or by the failure of man-made fill sections. There are also some areas where there is a potential for liquefaction of the ground, with loss of both structures and embankments: for example, at the Cajon Wash at the southerly entrance to the Pass just south of the I-15/I-215 intersection, and separately, just north of that intersection; near Blue Cut; and at the alluvial deposits in Cajon Creek just south of the junction of I-15 and Route 138. The highways cross the San Andreas fault trace, and the traces of other numerous faults in the area. In those locations there is the potential for direct shearing ground displacements. There is also a significant possibility for interaction with other lifelines, since the highways cross over or pass under major rail lines at ten points, cross over natural gas and petroleum products pipelines and communications lines at numerous points, and cross under the high voltage power transmission lines, as discussed in previous sections of this report.

The main highways operated by the California Department of Transportation (CALTRANS) include 55 bridges in the study area. CALTRANS has been evaluating all of the thousands of highway bridges under its jurisdiction for earthquake vulnerability, using a special screening technique[3.5-1, 3.5-2, 3.5-3] for the first level evaluation in order to identify the most hazardous in proper priority for their retrofit program. This screening work has been completed on 28 of the 55 bridges in the study area as of the fall of 1990. For the 28, there has been a tentative decision to retrofit or replace 12, leave 13 as is, and hold 3 for further consideration. Screening of the remaining 27 is in process.

Fortunately many of the bridges could be easily bypassed for limited emergency traffic. Most of the interchanges on I-15 are of the "diamond" type, so that if the main route bridge is damaged, limited traffic could be routed on the existing ramps down to and across the intersecting roadway, and then back up onto the Interstate. There are some cases where this will not be possible, such as at the longer bridges and separation structures at the I-15/I-215 junction at Devore. There are some local roads in the area which also could be used for bypass, and there is a long section of old Highway Route 66 which has been partially abandoned and which parallels the lower southbound section of I-15 for about 7 miles from Devore to just south of Cajon Junction. This old facility was a four lane divided highway, but now only the west roadway is in service. Unfortunately, sections of this roadway are, no doubt, more vulnerable to earthquake damage than is the new Interstate, especially at Blue Cut, where it passes over trace of the San Andreas fault. It should be noted that the bridges on this old alignment carry conduits for a number of fiber optic communication lifelines, and the two petroleum product pipeline lifelines are located in the center median of the alignment. Because of the semi-desert climate of the region, it may also be possible to route some detour traffic across open off-highway areas, especially in the

Figure 3.5-2 I-15 Bridge Over Lytle Creek Wash

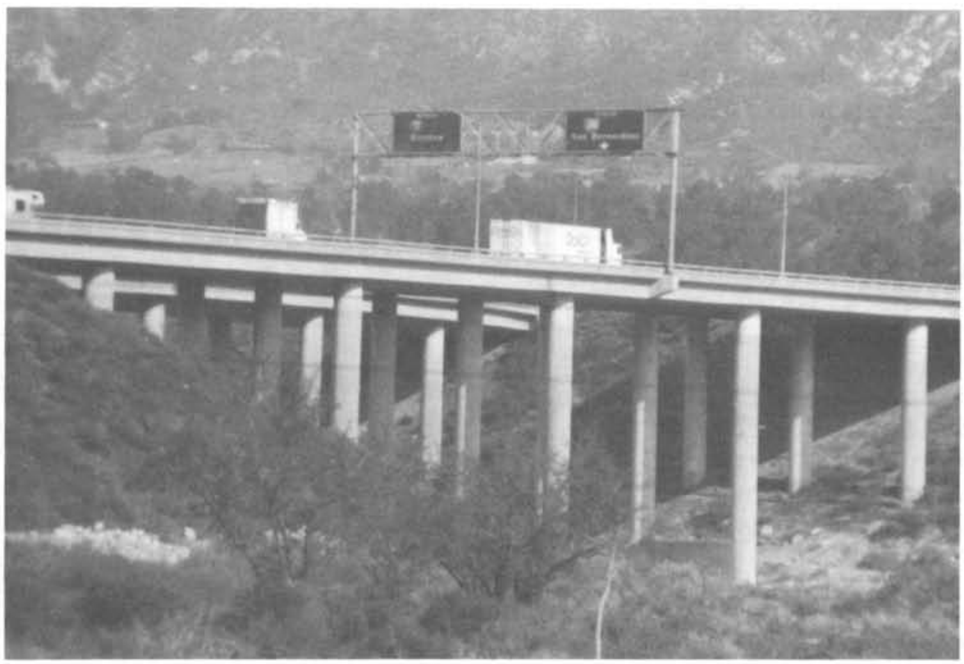

Figure 3.5-3 I-15 Bridge Over Cajon Creek Wash

northern portions of the study area.

CALTRANS has a District Maintenance Station just west of the Cajon Junction interchange off of Route 138. Considerable construction equipment and some limited supplies of repair materials are stored there. There is a small commercial sand and gravel operation in the Cajon Junction area. The maintain a radio transmission tower near the highway summit to aid in radio communication with their transportation equipment operators.

Interstate Highway 15 (I-15) enters the study area from the southwest as two four lane separate roadways near Nealyes Corner, where it crosses Sierra Avenue just west of Lytle Creek Wash. The pavement is concrete. There is a grade separation structure for each of the I-15 roadways (Bridges No.54-0891R and L), consisting of cast in place pre-stressed concrete girders. The highway continues northeast on a long viaduct of concrete box girders, each continuous over several spans (Bridge No.54-0982R and L), crossing Lytle Creek Wash and the San Jacinto fault zone in this area (see Figure 3.5-2). It then ascends the west slope of Lytle Creek Ridge across Sycamore Flats, crossing over Devore Road just west of the ridge on a concrete box girder (Bridge No. 54-0779R and L). It then descends and crosses Glen Helen Road on Bridge No. 54-0780R and L, and the rights-of-way of the Southern Pacific, the Union Pacific, and the Santa Fe railroads on Bridge No. 54-0818R and L. It then crosses the Cajon Wash on a set of continuous concrete box girder structures designated as Bridge No. 54-0781 (see Figure 3.5-3), which carries the north and southbound main roadways, the west-south connector, and the east-south connector roadways. At this point, I-15 joins I-215 coming up from the southeast from San Bernardino at a complex set of separation structures (Bridge Nos. 54-0782, -0783, and -0771). All of these bridges are constructed from prestressed concrete. The taller separation structures are supported on multiple column bents.

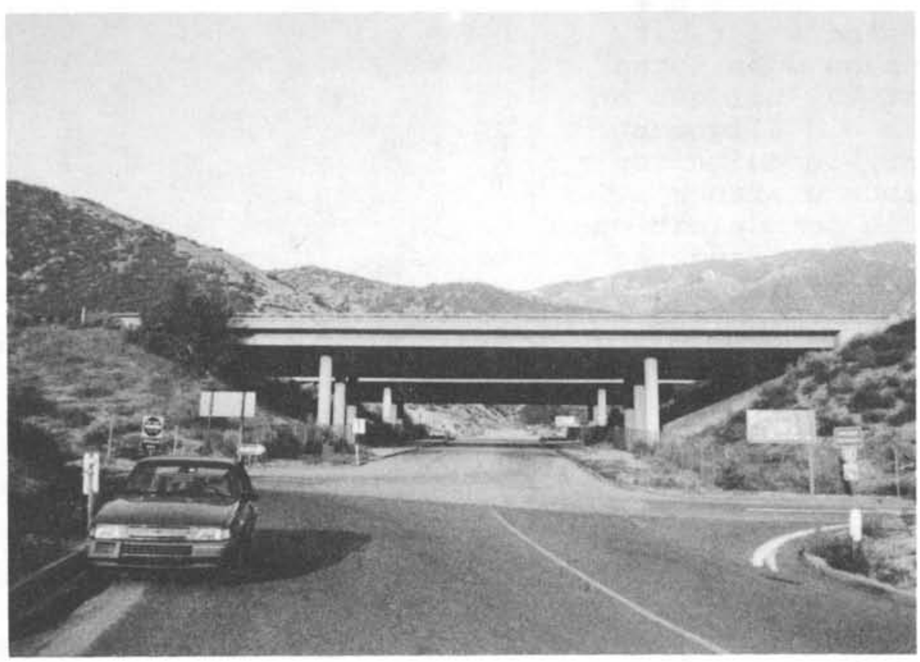

Figure 3.5-4 I-15 Bridge Over Kenwood Avenue

On the section of I-215 coming up from San Bernardino, which enters the study area at Verdemont, there are three concrete box girder bridges on the main three lane roadways, which are at Palm Avenue, Cypress Avenue, and Devore Road (Bridge Nos. 54-0532, 54-05433, and 54-0525), and one prestressed concrete structure on the east-south connection and collector roadway at Devore (Bridge No. 54-0844).

Figure 3.5-5 I-15 Arch Bridge Over Matthews Rd.

As the I-15 highway continues north from its junction with I-215, it is two independent roadways of four lanes each, concrete paved. It passes over Kenwood Avenue on a continuous box girder (Bridge No. 54-0772), with a typical diamond type interchange. Kenwood Avenue connects with the old alignment of Route 66 about 0.2 miles further west (see Figure 3.5-4).

I-15 continues over Matthew Road with a 21 ft. span, multiplate arch (Bridge No. 54-0915, Figure 3.5-5). I-15 then passes through a steep cut about 1.5 miles north of this point, and on the north side of the ridge swings to the east away from the old alignment. Both the old and the new alignment cross the trace of the San Andreas fault in this vicinity. At mile 18.48, I-15 crosses Cleghorn Creek on another concrete box girder (Bridge No.54-0773) just east of the settlement of Cosy Dell, north of which it again runs parallel with the old alignment for 1.5 miles but at a higher elevation. It crosses debris-filled Cone Creek at mile 19.29 on a prestressed concrete structure (Bridge No. 54-0774), Brush Creek on a concrete box girder (Bridge No. 54-0775), and then Cleghorn Road at mile 20.0 on another concrete box girder (Bridge No. 54-0776). This is another diamond type interchange with connections to Cleghorn Road, the old alignment of Route 66, the settlement of Cajon, and the railroads to the west of the highway.

Just south of Cajon Junction, I-15 spreads out to accommodate north and southbound truck weighing stations. The roadway is on a moderately high fill, supported on the west side by a metal crib retaining wall approximately 18 feet high (see Figure 3.2-5). The East Fork of Cajon Creek passes under this fill through a large concrete box culvert designated as Bridge No. 54-0777. This structure is on a curved alignment and is 39 feet wide and 15 feet high, with a length of 440 feet along the center line. As noted in Section 3.2.1 above, four communications conduits are attached high on the east wall of the culvert waterway (see Figure 3.2-7). The outlet end of the culvert directs the creek flows into the railroad bridges of the Sante Fe and Union Pacific. The ground water is close to or at the surface in this entire region, and lush plant growth indicates that the high water table extend at least to the foot of the metal retaining wall crib.

Figure 3.5-6 I-15 Box Bridge Over the Railroad

Approximately 0.7 miles northwest of the weighing station, I-15 passes under Route 138, which is carried on a two span, welded steel girder with a central pier located in the median of I-15). There are steep slopes just to the east of this junction, and construction is underway on the realignment of Route 138 to the east. From this point, I-15 climbs steeply toward Cajon Summit, crossing the Union Pacific at mile 22.0, the Sante Fe at mile 23.7, and the Southern Pacific at mile 22.7 at Alray. These crossing structures are all tunnel-like box structures (see Figure 3.5-6), with lengths from 250 to 300 feet, crossing the highway fill at a skew. Beyond the last of these rail crossings, the northbound and southbound roadways of I-15 separate. The northbound lanes swing to the east sooner than the southbound and run along the steep slopes at an elevation about 200 feet lower and on an alignment about one thousand feet south of the southbound roadway. The petroleum products pipelines and some of the fiber optic communication lifelines pass under the highways in this region. Also, an unimproved road used for access to those lifelines (the Baldy Mesa Road) crosses under I-15 in cement'culverts. The northbound roadway of I-15 climbs to rejoin the southbound roadway at the Oak Hill Road interchange at mile 28.7. This interchange structure (Bridge No. 54-0740) is a steel girder which provides for connections with local roads and the service roadways which parallel I-15 from this point to the north in the relatively flat high desert land.

At mile 31.1, I-15 again crosses the tracks of the Southern Pacific at

Bridge No. 54-0664, a continuous slab structure supported on multiple column bents (see Figure 3.5-7). This bridge is flanked by others which carry the service roads over the railroad, the easterly bridge has water pipelines and fiber optic communication conduits attached (see Figure 3.2-8). There is a grade separation structure of welded steel girders (Bridge No. 54-0665) at mile 31.8 which connects the northbound lanes of I-15 to the northbound lanes of I-395 leading north to Adelanto, and 0.5 miles further north, I-15, now reduced to three lanes in each direction, is crossed by Phelan Road on a concrete box girder (Bridge No. 54-0624). Just at the north end of the study area, I-15 and both frontage roads are carried over the California aqueduct on a double box, concrete culvert (Bridge No. 54-0828). I-15 continues northeast out of the study area towards Victorville and Barstow.

Figure 3.5-7 I-15 and Access Road Bridges Over the Railroad

Route 138 enters the study area from the west, joining the I-15 at Cajon Junction. Approximately one

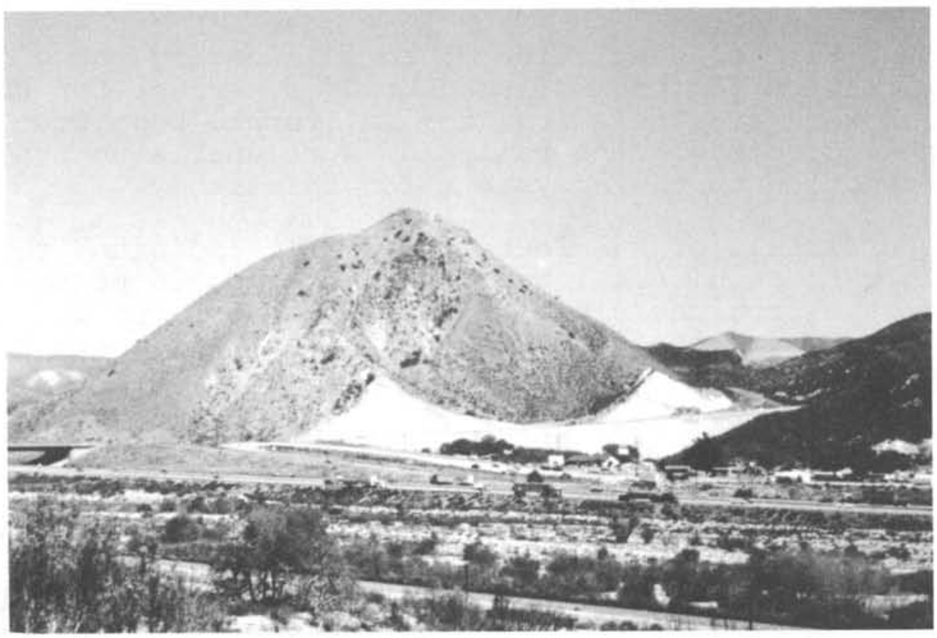

Figure 3.5-8 Highway 138 Cut & Fill At Cajon Junction

mile west of this point, it passes under the Southern Pacific, which is carried on a steel, through-plate girder (Bridge No. 54-0832), then over the eastbound and westbound combined tracks of the Sante Fe and Union Pacific on Bridges No. 54-1056 and -1057 respectively, and then over the upper reaches of Cajon Creek on Bridge No. 54-0561. It crosses over I-15 on a steel girder structure as indicated above, and then continues along the south side of steep slopes to the east. This section of Route 138 has been recently reconstructed to improve its grade and alignment, since it carries heavy recreational traffic to the Arrowhead and Silverwood Lakes. The new alignment includes large cut and fills next to I-15 (see Figure 3.5-8). Plans for 1991-92 include extending the realignment for another 2-3 miles to remove the numerous switch backs and their supporting fills. Observations of a number of those fills indicates that they have settled, causing surface cracking of the roadway pavement.

3.5.2 Railways

The main lines of the Atcheson, Topeka and Santa Fe (Santa Fe), the Southern Pacific, and the Union Pacific railways all run through Cajon Pass in close vicinity to each other. In fact, there is some mutual use of the right-of-ways, and a short section near Cajon Junction where interconnection of the Santa Fe and the Union Pacific is possible (but there is little special construction there). The Santa Fe and Union Pacific presently jointly use the Union Pacific tracks for eastbound traffic up the Pass, and the Santa Fe tracks for westbound traffic down the pass. The rail traffic in the Cajon Pass is about 75 trains per day and they experience about one minor derailment each year. The traffic also includes four AMTRAC passenger service runs per day. The Southern Pacific has major yard operations and repair facilities at their Coulton Yard in San Bernardino.

At the time of completion of this inventory phase of the project, the information for the railroad bridges, except for the highway crossings which were available from the California Department of Transportation, were incomplete. The railroads were unable to provide detailed information on their systems for this study.

The officials of the Southern Pacific indicated that it was standard policy to require all pipeline crossings to be cased, and the field data and data from the pipeline utilities confirms this. Most of the pipeline crossings for the Santa Fe and Union Pacific are cased, but not all of them are.

The Southern Pacific enters from the southeast corner of the study area from San Bernardino in the vicinity of Verdemont, and runs northwest parallel to and about 0.2 miles west of Cajon Blvd. along Cajon Wash. The Union Pacific and Sante Fe enter near the same point, but run, adjoining each other, on the east side of this same roadway. The 14-inch petroleum products pipeline is buried in the Santa Fe and Union Pacific right-of-ways, and periodically runs on the east side and then in the space between the railroad beds.

The Santa Fe and Union Pacific cross over to the west side of Cajon Blvd. just south of its junction with Kendell Drive. There the track expand to a four track section about 1.2 miles long ending at Devore. This section allows the railroads to switch back to their own tracks after they have descended the Cajon Pass. They then continue together with the Southern Pacific over bridges across Cajon Creek and under highway I-15. Figure 3.5-9 shows the railroad bridges in the wash area with the I-15 bridge in the background. All three lines then continue northwest along the west side of Cajon Wash close to the steep slopes, crossing several culverts and small bridges up to Blue Cut. While in the region of the steep slopes, one of the 36-inch natural gas pipelines is buried west of and in the right-of-way of the Southern Pacific. Occasionally, it crosses under the Southern Pacific and is buried between the beds of the Southern and Union Pacific railroads.

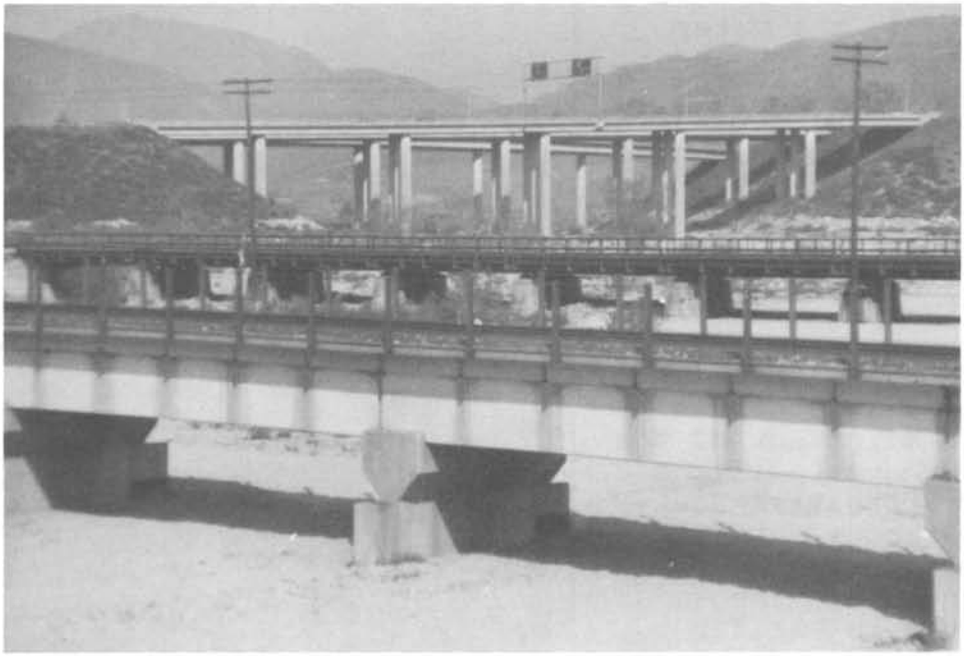

Figure 3.5-9 Railroad Bridges In Cajon Wash, I-15 Bridge In The Background

At Blue Cut the Sante Fe and the Union Pacific are close together on the west bank of Cajon Creek in the narrow gorge region, while the Southern Pacific has begun to diverge slightly to the northwest. All three lines cross Lone Pine Creek and the San Andreas fault zone in this general vicinity, and then continue northward next to the steep slopes on the west side of Cajon Canyon to the vicinity of Cajon Junction. Here the Southern Pacific is on a new alignment which begins the climb to the summit west of Cosy Dell, and is some 100 feet higher than the other two railroads when it swings west from Cajon Creek.

The Sante Fe and the Union Pacific cross to the east bank of Cajon Creek on a steel girder bridge, and have a section about one mile long which is four tracked in the flat land west of the Cajon community (it allows for siding a slow train to allow an express to pass, etc.). The Santa Fe and Union Pacific return to only two tracks, with the eastbound crossing Cajon creek to the west on a concrete deck structure supported on steel piles (see Figure 3.5-10) and the westbound a steel girder bridge on rubble concrete piles (see Figure 3.5-11). In the areas of the bridges of

Figures 3.5-10 and 3.5-11, the water table is high as indicated by the lush plant growth in the figure (also see Figure 3.2-5).

The railroad then climbs the hills west of Cajon community in a long "S" curve where it joins and parallels the alignment of the Southern Pacific as it approaches Route 138 about one mile west of Cajon Junction. The Southern Pacific track crosses over Route 138 on a new steel through girder with a ballasted deck (see Figure 3.5-12). This skewed, single span bridge potentially could fail during an earthquake. From there the railroads cross over the upper reaches of Cajon Creek on a multi-span, steel deck, girder bridge, and then head eastward under I-15 at Alray.

The eastbound Sante Fe and Union Pacific track passes under Route 138 about 0.1 mile east of the Southern Pacific bridge, then Cajon Creek on an old, multispan, steel deck, girder bridge. It then parallels

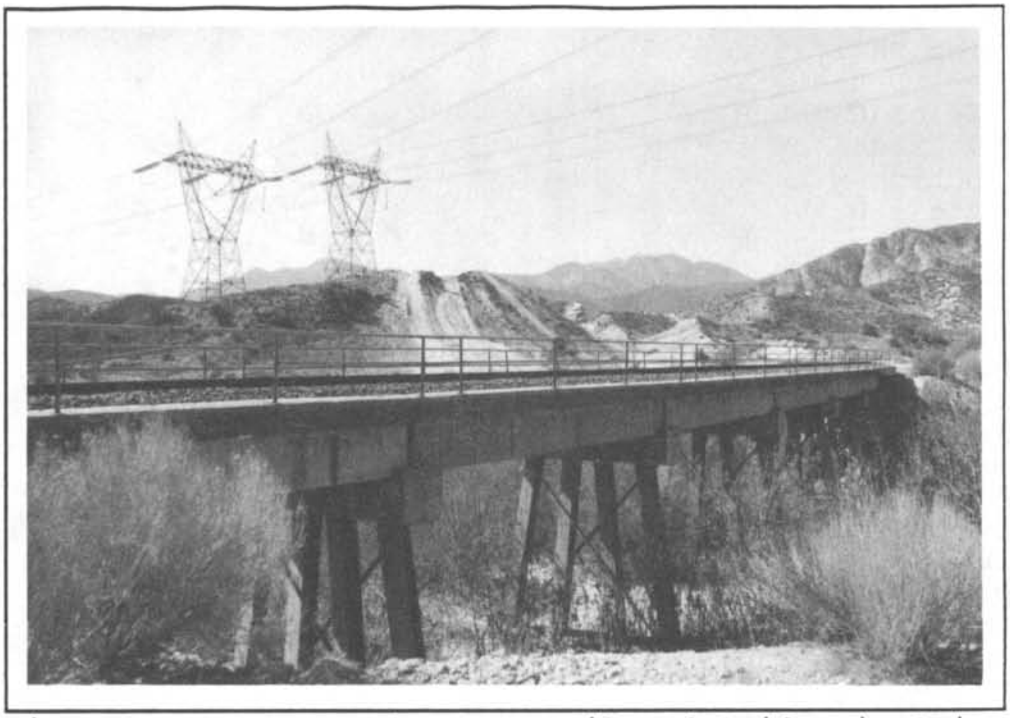

Figure 3.5-10 Concrete Beam Railroad Bridge in Cajon Creek Near Cajon Junction

Figure 3.5-11 Rubble Pier Railroad Bridge in Cajon Creek Near Cajon Junction

the alignment of the Southern Pacific, crossing under I-15 to the east just about 200 feet short of that railroad at Alray. The westbound track of the combined Sante Fe and Union Pacific crosses to the west of Cajon Creek just to the west of the I-15 truck weighing station, and continues northwest to cross under Route 138 about one half mile west of Cajon Junction (see Figure 3.5-13). It then turns east and crosses under I-15 about 0.6 mile south of the eastbound track.

Figure 3.5-12 Ballasted Deck Railroad Bridge Over Highway 138

After the Cajon Junction (heading north), all three rail lines run east, climbing the grade to the railroad Cajon summit near the head of Horsethief Canyon. The Southern Pacific and the eastbound Sante Fe-Union Pacific are on improved alignments, whereas the westbound Sante Fe-Union Pacific still involves a few short tunnels, which were constructed in about 1916, (see Figure 3.5-14) about one mile east of the I-15 crossing. In this region there

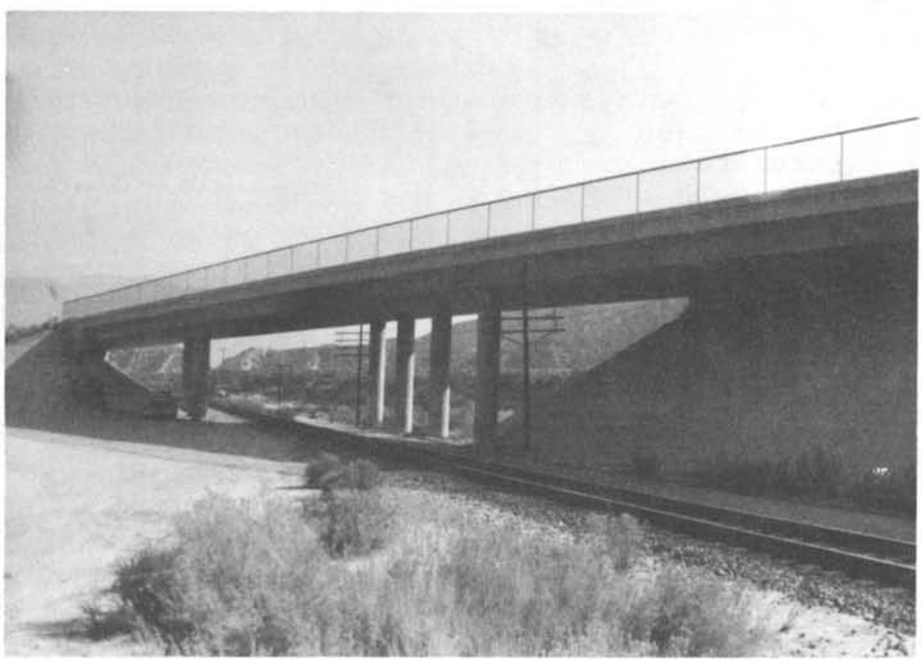

Figure 3.5-13 Highway 138 Bridge Over Railroad At Cajon Junction

are a number of short span bridges (see Figures 3.5-15 which shows two such bridges) on all three lines. They are used to cross unimproved roads and fire roads. In some cases, buried natural gas and petroleum products pipelines and fiber optic cables are located under the embankments next to the bridges. From the summit, the eastbound and westbound tracks of the Sante Fe-Union Pacific run on a common alignment in a northeasterly direction toward Barstow, while the Southern Pacific follows this same direction with a double track section for about one and one half miles, then a single track for about one mile. Afterward, it swings northwest to pass under Interstate I-15 just south of its junction with I-395, and then heads towards Palmdale and out of the study area.

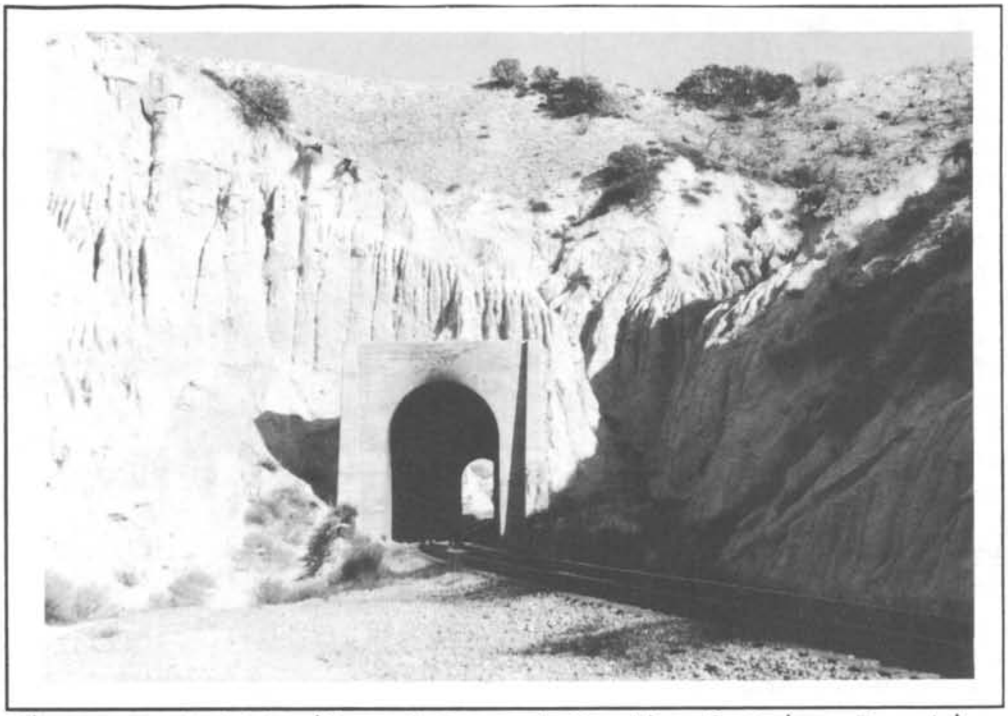

Figure 3.5-14 Railroad Tunnel North of Cajon Junction

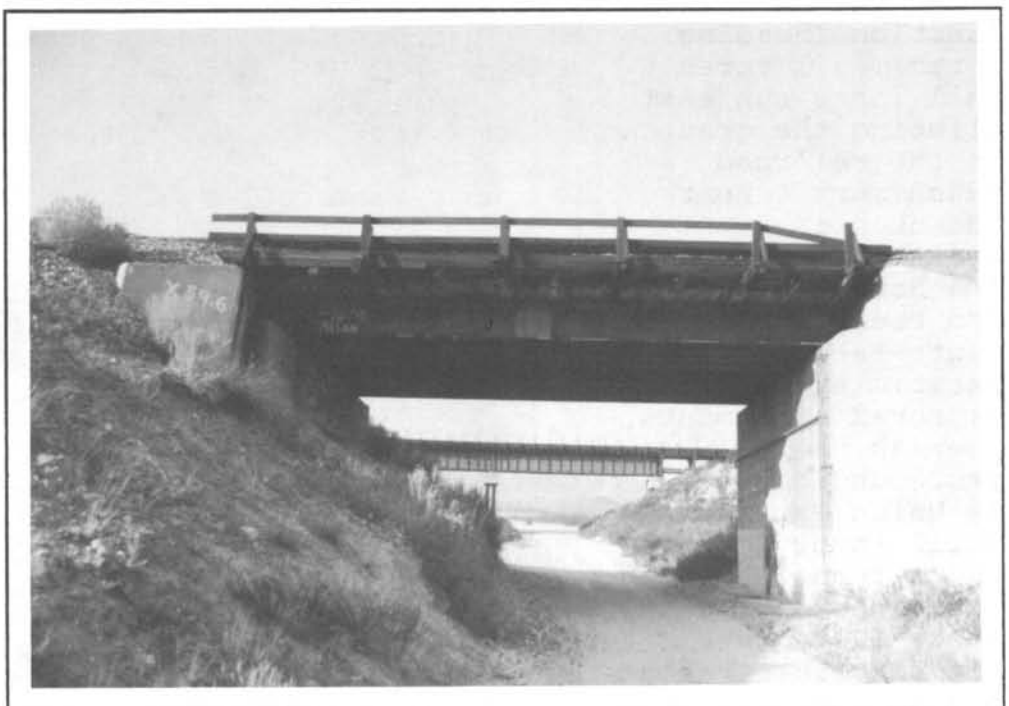

Figure 3.5-15 Typical Short Span Railroad Bridges North of Cajon Junction

3.5.3 Bibliography for Section 3.5

3.5-1 "Seismic Design Procedures and Specifications 1940 to 1968" CALTRANS Division of Structures, undated.

3.5-2 B. Maroney and J. Gates, "Seismic Risk Identification & Prioritization in the CALTRANS Seismic Retrofit Program", undated.

3.5-3 "Seismic Risk Algorithm For Bridge Structures", CALTRANS SASA Division of Structures, June 1990.

4.0 CONTACTS MADE DURING THE STUDY

The following list identifies the offices and organizations contacted during the preparation of this report.

American Telephone & Telegraph, 4430 Rosewood Dr., Pleasanton, CA 94566-9089

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California Department of Transportation (CALTRANS), 1801 30th St. West Bldg, Sacramento, CA 95816

California Department of Water Resources Southern District, 849 So. Broadway, Suite 500, Los Angeles, CA 90055

California Energy Commission, 1516 9th St., Sacramento, CA 95814-5512

California Office of Emergency Services, 2151 East D St., Suite 203A, Ontario, CA 91764

California Public Utilities Commission, 505 Van Ness Ave, San Francisco, CA 94102

California Seismic Safety Commission, 1900 K St. Suite 100, Sacramento, CA 95814

California Utility Underground Service, 3030 Saturn St., Suite 200, Brea, CA 92621

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Earthquake Engineering Research Institute, 6431 Fairmount Ave., Suite 7, El Cerrito, CA 94530

Electric Power Research Institute, 3412 Hillview Ave., Palo Alto, CA 94303

Los Angeles Department of Water & Power, 111 North Hope St., Los Angeles, CA 90051

MCI, 400 International Parkway, Richardson, TX 75081

National Association of Corrosion Engineers, 1440 South Creek Dr., Houston, TX 77084

National Center for Earthquake Engineering Research, Buffalo, NY, 716 636-3391

Northern Telecom Canada Ltd. 2800 Dixie Rd. Brampton, Ontario, Canada L6V 2M6

San Bernardino Valley Municipal Water District, 1350 So. E St., San Bernardino, CA 92412-5906

Southern California Edison Company, 2244 Walnut Grove Ave, Rosemead, CA 91770

Southern California Gas Company, 3208 N. Rosemead Blvd., El Monte, CA 91731

State of California Office of State Fire Marshal, Pipeline Safety Division, 1501 W. Cameron Ave, South Bldg, Suite 250, West Convina, CA 91790.

US Sprint, 521 West Rialto Ave., Rialto, CA 92376

U.S. Department of Transportation, Office of Pipeline Safety, 400 7th St., SW, Washington, DC 20590

U.S. Geologic Survey, 345 Middlefield Rd., Menlo Park, CA 94025

U.S. Forest Service, Cajon Ranger District, San Bernardino National Forest, Star Route Box 100, Fontana, CA 92336-9704

APPENDIX A

DETAILS FOR FIGURE 3.1-1, REGIONAL EARTHQUAKE FAULT DATA

TABLE 3.1–1 Geologic and seimologic characteristics of late Quaternary faults in the Los Angeles region

(Evidence of faulting age: OS, offset stratigraphy; P, fault-produced physiographic features; W, ground-water impediment within late Quaternary alluvial deposits. Type of faulting: R, reverse; N, normal; SR, right-lateral strike slip; SL, left-lateral strike slip; RRO, reverse right oblique; RLO, reverse left oblique; NRO, normal right oblique; NLO, normal left oblique)

Map number and fault	Geometric aspects	Age and evidence of latest surface faulting	Type of late Quaternary offset	Seismicity	Sources of information
1 San Andreas fault zone	Numerous subparallel faults of varied length in zone generally 0.3–1.5 km wide (as wide as 4 km near Palmdale and Lake Hughes). Zone strikes N. 65°–70° W. but near Banning strikes N. 40° W. Most faults are approximately vertical, although SE. from Cajon Pass generally dip 55°–60° NE. The most recently active element within zone typically composed of linear segments 0.5 to 11 km long arranged in echelon manner in belt as wide as 100 m. Scattered splay faults locally diverge from trend of main zone. Subsidiary south-dipping faults common on southern side of zone adjacent to Antelope Valley. Fault zone extends as continuous surface feature from near Banning NW. more than 1,000 km to Cape Mendocino. Connected by Banning fault (95) to Indio segment of San Andreas fault NE. of Imperial Valley.	Historical (1857) SE. to Wrightwood. Holocene (OS, P) from Wrightwood to near Banning. Splay and subsidiary faults chiefly late Quaternary (OS, P).	SR	Source of 1857 Fort Tejon earthquake (estimated *M* 7.9), whose epicenter probably was in the Parkfield–Cholame area of central California. Possible source of July 22, 1899, earthquake (estimated M_L 6.5) near San Bernardino. Diffuse belt of scattered small earthquakes associated with fault zone.	Mapping, Quail Lake–Wrightwood: Barrows and others (1985) Mapping, Quail Lake–Palmdale: Beeby (1979); Kahle (1979); Kahle and others (1977); Kahle and Barrows (1980) Mapping, Palmdale–Wrightwood: Barrows and others (1976); Barrows (1979, 1980); Schubert and Crowell (1980). Mapping, Wrightwood–Banning: J. C. Matti (unpublished data, 1983); Miller (1979); Morton and Miller (1975); Ross (1969) Slip/recurrence: Davis and Duebendorfer (1982); Rasmussen (1982a); Rust (1982); Sieh (1978a, c, 1984); Weldon and Sieh (1981) Seismicity: Green (1983); Hileman and Hanks (1975); C. E. Johnson (unpublished data, 1982).
San Jacinto fault zone:					
2 Glen Helen	Single strand. Strikes N. 40°–60° W. Presumed vertical dip. Length at least 8 km.	Holocene (P, W)	SR	Closely associated small earthquakes. Geometrically compatible fault-plane solutions. Possible source for two damaging earthquakes of $M_L \geq 6$ (1899, 1907).	Cramer and Harrington (1984, in press). Pechmann (in press) Sharp (1972) Thatcher and others (1975)
3 San Jacinto	Several strands in zone as wide as 0.3 km. Strikes N. 40°–60° NW. Dips 35° NE. to vertical. Length approximately 25 km.	Late Quaternary (OS)	SR, RRO	Numerous small earthquakes near fault trace. Geometrically compatible fault-plane solutions.	Cramer and Harrington (1984, in press). C. E. Johnson (unpublished data, 1982). Morton (1975, 1976)
4 Lytle Creek	Single strand. Strikes N. 45° W. Dips 65° SW. Length at least 12 km.	Late Quaternary (OS, W)	RRO	Numerous small earthquakes near fault trace. Geometrically compatible fault-plane solutions.	Cramer and Harrington (1984, in press). C. E. Johnson (unpublished data, 1982). Mezger and Weldon (1983) Morton (1975, 1976)
5 Claremont	Single strand composed of closely overlapping breaks. Strikes N. 40°–55° W. Dip vertical or steeply NE. Length approximately 65 km.	Holocene (OS, P, W); historical creep near Hemet possibly related to subsidence due to ground-water withdrawal.	SR	Scattered small earthquakes near fault trace. Possible source for four damaging earthquakes of $M_L \geq 6$ (1890, 1899, 1918, 1923).	Fett (1967) Given (1981) Green (1983) C. E. Johnson (unpublished data, 1982). Morton (1978) Sharp (1972) Thatcher and others (1975)

TABLE 3.1–1 Geologic and seimologic characteristics of late Quaternary faults in the Los Angeles region–Continued

Map number and fault	Geometric aspects	Age and evidence of latest surface faulting	Type of late Quaternary offset	Seismicity	Sources of information
San Jacinto fault zone—Continued:					
6 Casa Loma	Several closely overlapping echelon strands. Strikes N. 35°–40° W. Dips 50°–70° NE. Length approximately 18 km.	Holocene (OS, P, W); creep movement since at least 1939, possibly related to subsidence due to ground-water withdrawal.	N or NRO	Scattered small earthquakes near fault trace.	Given (1981) Fett (1967) Morton (1978) Proctor (1962, 1974) Rasmussen (1981, 1982b) C. E. Johnson (unpublished data, 1982).
7 Hot Springs	Single strand. Strikes east-west to N. 45° W. Dips steeply NE. Length approximately 29 km.	Probably late Quaternary (P)	R or RRO	Scattered small earthquakes at southern end of fault trace.	Given (1981) Sharp (1967)
8 Clark	Single strand composed of closely overlapping breaks. Strikes N. 50°–60° W. Dips vertically to 60° NE. Length at least 85 km.	Holocene (OS, P)	SR and RRO	Numerous closely associated small earthquakes along northern and southern sectors. Geometrically compatible fault-plane solution. Possible source for M_L 6 earthquake in 1937.	Given (1981) Sanders and Kanamori (1984) Sharp (1967, 1972, 1981a) Thatcher and others (1975)
9 Rialto-Colton	Two echelon strands. Strikes N. 45°–55° W. Presumed vertical dip. Total length 26 km.	Late Quaternary (W); no surface expression.	SR	Numerous small earthquakes nearby.	California Department of Water Resources (1970). C. E. Johnson (unpublished data, 1982).
10 Central Avenue	Presumed single strand. Strikes N. 35° W. Dip unknown. Length at least 8 km.	Late Quaternary (W); no surface expression.	?		Morton (1976) Ziony and others (1974)
11 Chino	Single strand. Strikes N. 35°–50° W. Dips 60°–65° SW. Length at least 18 km.	Late Quaternary (OS, P, W)	RRO	Scattered small earthquakes SW. of fault trace.	Durham and Yerkes (1964) Heath and others (1982) C. E. Johnson (unpublished data, 1982). Weber (1977)
12 Whittier	One to three subparallel strands in zone as wide as 1.2 km. Strikes N. 65°–80° NE. Dips 65°–80° NE. Length at least 40 km.	Late Quaternary (OS, P) NW. of Brea Canyon; Holocene (OS) SE. to near Santa Ana River.	RRO	Numerous small earthquakes closely associated with fault.	Durham and Yerkes (1964) Hannan and others (1979) C. E. Johnson (unpublished data, 1982). Lamar (1972, 1973) Morton and others (1973) Yerkes (1972)
Elsinore fault zone:					
13 Main Street	Several overlapping strands. Strikes N. 60°–80° W. Presumed to dip steeply SW. Length approximately 7 km.	Probably Holocene (P)	R or RRO		Hart and others (1979) Weber (1977)
14 Fresno-Eagle	Single strand. Strikes N. 55°–65° W. Dips 15°–50° SW. Length at least 16 km.	Late Quaternary (P)	R or RRO		Weber (1977)
15 Tin Mine	Single strand. Strikes N. 50° W. Vertical dip. Length approximately 5 km.	Late Quaternary (P)	SR		Weber (1977)

TABLE 3.1-1 Geologic and seimologic characteristics of late Quaternary faults in the Los Angeles region-Continued

Map number and fault	Geometric aspects	Age and evidence of latest surface faulting	Type of late Quaternary offset	Seismicity	Sources of information
Elsinore fault zone—Continued:					
16 Glen Ivy North	Single strand of closely overlapping breaks. Strikes N. 40°–55° W. Dips 70° SW. except for vertical to steeply NE. dip near Lake Elsinore. Length at least 28 km.	Holocene (OS, P)	NRO	Numerous closely associated small earthquakes at northern end. Possible source of M_L 6 earthquake in 1910.	C. E. Johnson (unpublished data, 1982). Langenkamp and Combs (1974). Millman (1985) Rockwell and others (1985) Weber (1977)
17 Glen Ivy South	Single strand. Strikes N. 35°–65° W. Dips 45°–50° SW. Length 7 km.	Holocene (P)	RRO	Numerous closely associated small earthquakes.	C. E. Johnson (unpublished data, 1982). Langenkamp and Combs (1974). Millman (1985) Weber (1977)
18 Wildomar	One to five subparallel strands in zone locally 0.7 km wide. Strikes N. 45°–65° W. Dips steeply SW. Length at least 40 km.	Holocene (OS, P)	NRO	Scattered small earthquakes nearby.	C. E. Johnson (unpublished data, 1982). Kennedy (1977) Lamar and Swanson (1981) Langenkamp and Combs (1974). Weber (1977)
19 Willard	Several discontinuous echelon strands. Strikes N. 50°–55° W. Presumed to dip steeply NE. Total length at least 35 km.	Late Quaternary (OS, P)	NRO	Scattered small earthquakes nearby.	C. E. Johnson (unpublished data, 1982). Hart and others (1979) Langenkamp and Combs (1974). Kennedy (1977) Weber (1977)
20 Wolf Valley	Single strand. Strikes N. 55°–75° W. Presumed vertical dip. Length 6 km.	Late Quaternary (OS, P, W)	SR	Numerous closely associated small earthquakes.	Hart and others (1979) C. E. Johnson (unpublished data, 1982). Kennedy (1977)
21 Murietta Hot Springs.	Several overlapping strands. Strikes N. 80° E. to N. 70° W. Dips 80°–85° S. Length at least 12 km.	Late Quaternary (OS, P, W)	N		Kennedy (1977)
22 Norwalk	Presumed single strand. Strikes N. 65°–85° W. Dips steeply NE. Length at least 14 km.	Possibly late Quaternary (P)	R(?)	Scattered small earthquakes NE. of fault trace. Possible source for damaging 1929 earthquake (M_L 4.7).	Lamar (1973) C. E. Johnson (unpublished data, 1982). Richter (1958) Yerkes (1972)
23 Faults in West Coyote Hills.	Four subparallel faults in zone 2.0 km wide. Strikes N. 10°–45° W. Dips 70° SW. to 55° NE. Lengths from 1 to 1.5 km.	Late Quaternary (OS); historical (1968) surface rupture along westernmost fault probably related to withdrawal of oil and gas.	RLL		Morton and others (1973) Yerkes (1972)
24 Peralta Hills	Single strand. Strikes N. 80° W. to N. 80° E. Dips 0°–60° N. Length at least 8 km.	Late Quaternary (OS, P)	R	Numerous small earthquakes nearby.	Bryant and Fife (1982) Fife and others (1980) C. E. Johnson (unpublished data, 1982). Morton and others (1973) Schoellhamer and others (1981).

TABLE 3.1-1 Geologic and seimologic characteristics of late Quaternary faults in the Los Angeles region—Continued

Map number and fault	Geometric aspects	Age and evidence of latest surface faulting	Type of late Quaternary offset	Seismicity	Sources of information
Newport-Inglewood fault zone:					
25 Inglewood	Single strand locally offset by short north- and NE-trending faults. Strikes N. 5°–30° W. Dips 70° W. Length at least 13 km.	Late Quaternary (OS, P); surface faulting since 1957 locally along north-trending faults in response to withdrawal of oil and gas.	N or NRO	Numerous small earthquakes nearby. Geometrically compatible fault-plane solution. Possible source of 1920 earthquake (M_L 4.9).	Barrows (1974) Buika and Teng (1979) Castle and Yerkes (1976) Poland and others (1959) J. C. Tinsley (unpublished data, 1983).
26 Potrero	Single strand. Strikes N. 25° W. Dips 77° W. at surface, 82° W. at depth. Length 7 km.	Late Quaternary (P, W)	N or NRO	Numerous small earthquakes nearby.	Barrows (1974) Buika and Teng (1979) Poland and others (1959)
27 Avalon-Compton	Single strand. Strikes N. 20°–30° W. Presumed vertical. Length at least 4 km.	Late Quaternary (P, W); historical (1941, 1944) faulting within 1.5 km of surface along subsidiary south-dipping reverse faults.	SR(?)	Scattered small earthquakes nearby. Epicenters of 1941 (M_L 4.9) and 1944 (M_L 4.5) lie SW. of fault trace.	Bravinder (1942) Buika and Teng (1979) Mariner (1948) Poland and others (1959)
28 Cherry-Hill	Single strand. Strikes N. 39°–50° W. Dips 80° E. Length at least 9 km.	Late Quaternary (OS, P, W)	R or RRO	Numerous small earthquakes lie east of trace. Fault overlies aftershock zone of 1933 Long Beach earthquake (*M* 6.2). 1941 Torrance-Gardena earthquake (M_L 5.4) located SW. of fault trace.	Hileman and others (1973) C. E. Johnson (unpublished data, 1982). K. R. Lajoie (unpublished data, 1983). Poland and Piper (1956) Yerkes and others (1965)
29 Reservoir Hill-Seal Beach.	Single strand. Strikes N. 59° W. Dips near vertical. Length at least 12 km.	Late Quaternary (OS, P, W)	NRO or SR	Numerous small earthquakes near trace. Fault overlies aftershock zone of 1933 Long Beach earthquake (*M* 6.2).	Hileman and others (1973) C. E. Johnson (unpublished data, 1982). Poland and Piper (1956)
30 Newport-Inglewood (North Branch).	One to three closely spaced strands. Strikes N. 40°–60° W. Dips steeply SW. Length at least 18 km.	Holocene (OS, W); possible historical surface faulting (1933) at Newport Mesa.	SR	Scattered small earthquakes near trace. Fault is adjacent to aftershock zone of 1933 Long Beach earthquake (*M* 6.2).	California Department of Water Resources (1966, 1968). Guptill and Heath (1981) Hileman and others (1973) C. E. Johnson (unpublished data, 1982).
31 Newport-Inglewood (South Branch).	Single strand. Strikes N. 45° W. Dips steeply SW. Length at least 10 km and possibly joins similarly oriented fault offshore Dana Point.	Late Quaternary (P)	SR	Scattered small earthquakes near trace. Fault is adjacent to aftershock zone of 1933 Long Beach earthquake (*M* 6.2).	California Department of Water Resources (1968) Hileman and others (1973(C. E. Johnson (unpublished data, 1982). Poland and Piper (1956)
32 Faults offshore of San Clemente.	Two echelon strands. Strikes N. 45°–55° W. Dip unknown. Length of each fault at least 25 km.	Late Quaternary (OS, P)	SR(?)	Concentrations of small earthquakes locally along traces.	Clarke and others (this volume). C. E. Johnson (unpublished data, 1982).
33 Pelican Hill	Several strands. Strikes N. 15°–35° W. Dips 75° W. at surface but 45° W. at depth.	Late Quaternary (OS) along subsidiary fault.	N or NRO	Scattered small earthquakes west of trace.	Castle (1966) Morton and others (1973) J. E. Slosson (personal communication, 1973).

TABLE 3.1–1 Geologic and seimologic characteristics of late Quaternary faults in the Los Angeles region–Continued

Map number and fault	Geometric aspects	Age and evidence of latest surface faulting	Type of late Quaternary offset	Seismicity	Sources of information
34 Charnock and Overland Avenue.	Two fault strands. Strikes N. 35° W. Presumed vertical dip. Length at least 10 km.	Late Quaternary (OS); no surface expression.	SR(?)	Numerous small earthquakes nearby. Geometrically compatible fault-plane solutions.	Buika and Teng (1979) Poland and others (1959)
35 Palos Verdes Hills	Several echelon strands locally in a zone as wide as 2 km. Strikes N. 20°–60° W. Onshore segment generally not exposed. Dip 70° SW. in subsurface of Palos Verdes Hills, although exposed subsidiary fault dips 75° NE. Total length at least 80 km.	Holocene (OS) in San Pedro Bay. Late Quaternary (OS, P) onshore and probably overlain by Holocene alluvium. Inferred late Quaternary (OS) in Santa Monica Bay.	R or RRO	Numerous small earthquakes near and west of fault trace. Geometrically compatible fault-plane solution in Santa Monica Bay.	Buika and Teng (1979) Clarke and others (this volume). Hileman and others (1973) Junger and Wagner (1977) Nardin and Henyey (1978) Poland and others (1959) Woodring and others (1946) Yerkes and others (1965)
36 Redondo Canyon	Presumed single strand. Strikes N. 80°–85° E. Dip unknown. Length approximately 13 km.	Holocene (P)	R(?)	Scattered small earthquakes near trace.	Nardin and Henyey (1978) Yerkes and others (1967)
37 Cabrillo	Several echelon strands. Strikes N. 20°–50° W. Dips 50°–75° onshore. Length approximately 18 km.	Holocene (OS) offshore	N or NRO	Scattered small earthquakes near fault trace.	Clarke and others (this volume). Darrow and Fischer (1983) Hileman and others (1973) Lajoie and others (1979) Woodring and others (1946)
38 San Pedro Basin fault zone.	Series of separate, left-stepping echelon strands in zone locally as wide as 5 km. Strikes N. 35°–50° W. Presumed vertical dip. Length of individual strands 4–12 km; length of entire zone at least 70 km.	Late Quaternary (OS)	SR or RRO	Numerous small earthquakes near and east of fault traces. Geometrically compatible fault-plane solutions.	Hileman and others (1973) Junger and Wagner (1977) Nardin (1981) Yerkes and Lee (1979a, b) C. E. Johnson (unpublished data, 1982).
39 Faults of the Santa Cruz–Catalina sea-floor escarpment.	Echelon strands in zone locally 4 km wide. Strikes N. 50°–60° W. Length of individual strands 5 to 40 km; length of entire zone at least 120 km.	Possibly late Quaternary (P)	SR	Source of 1981 Santa Barbara Island earthquake (M_L 5.2) and aftershocks.	Corbett and Piper (1981) C. E. Johnson (unpublished data, 1982). Junger and Wagner (1977) Yerkes and Lee (1979a, b)
Faults of Mojave Desert region:					
40 Llano	Single strand. Strikes N. 65° W. Presumed dip to SW. Length at least 6 km.	Holocene (P) monoclinal folding.	R		Guptill and others (1979) Ponti and Burke (1980)
41 Mirage Valley	Several echelon strands, each 1–7 km long, locally in zone 3 km across. Strike N. 40°–50° W. Presumed vertical dip. Total length of zone approximately 30 km.	Late Quaternary; overlain by unfaulted Holocene alluvial fan deposits.	SR(?)		Ponti and Burke (1980)
42 Helendale	Numerous echelon strands, 1 to 4 km long, forming narrow linear zone as wide as 1 km. Strands strike N. 45°–50° W. Presumed vertical dips. Total length of zone at least 90 km.	Holocene (P)	SR	Closely associated small earthquakes.	G. S. Fuis (unpublished data, 1983). C. E. Johnson (unpublished data, 1982). Miller and Morton (1980) Morton and others (1980)

TABLE 3.1–1 Geologic and seimologic characteristics of late Quaternary faults in the Los Angeles region—Continued

Map number and fault	Geometric aspects	Age and evidence of latest surface faulting	Type of late Quaternary offset	Seismicity	Sources of information
Faults of Mojave Desert region (Continued):					
43 Lenwood	Numerous closely overlapping echelon strands, 1–5 km long, forming continuous narrow zone. Strands strike N. 25°–40° W. Presumed vertical dips. Total length of zone at least 65 km.	Late Quaternary (P). Possible historical fault creep at northern end.	SR	Closely associated small earthquakes.	Church and others (1974) G. S. Fuis (unpublished data, 1983). C. E. Johnson (unpublished data, 1982). Miller and Morton (1980) Morton and others (1980)
Faults within Transverse Ranges:					
44 Santa Ynez	One to seven strands in zone as wide as 0.3 km. Strikes N. 80° W. to N. 85° E. Dips 45°–80° S., generally steepens eastward. Total length 130 km; late Quaternary length approximately 80 km.	Possibly Holocene (OS) along one strand near Lake Cachuma. Late Quaternary (OS, P) as far east as near Wheeler Springs	SL		Darrow and Sylvester (1983) Dibblee (1966) Keaton (1978) Yerkes and Lee (1979a, b) J. I. Ziony (unpublished data, 1981). R. E. Troutman (unpublished data, 1984).
45 San Jose (A)	One to two strands. Strikes N. 60° W. Dip unknown. Length approximately 13 km.	Late Quaternary (OS)	N(?)		Dibblee (1966) Olson (1982)
46 Mission Ridge–Arroyo Parida.	Single strand. Strikes N. 80° E. to N. 85° W. Dips steeply S. near Santa Barbara but dips 60°–80° N. further east. Length approximately 40 km.	Late Quaternary (OS, P); apparently overlain by unfaulted Holocene alluvium.	N	Scattered small earthquakes near trace. Mission Ridge fault possible source of 1978 earthquake (M_L 5.1).	Dibblee (1966) Jackson and Yeats (1982) Yerkes and Lee (1979a, b) Rockwell (1983) Rockwell and others (1984) Yeats and Olson (1984)
47 More Ranch	One to two strands. Strikes N. 80° W. to N. 80° E. Dips 75°–85° S. Length at least 14 km.	Late Quaternary (OS, P)	R	Scattered small earthquakes near trace.	Dibblee (1966) K. R. Lajoie (unpublished data, 1983). Upson (1951) Yerkes and Lee (1979a, b)
48 Mesa–Rincon Creek	Single strand. Strikes N. 60° W. to east-west. Dips 65°–35° S. near surface; probably vertical at depth. Length approximately 37 km.	Late Quaternary (OS, P)	R	Scattered small earthquakes near trace.	Dibblee (1966) Jackson and Yeats (1982) Yerkes and Lee (1979a, b)
49 Lavigia	One to two strands. Strikes N. 50°–75° W. Dips 45° SW. Length at least 7 km.	Late Quaternary (OS)	R	Scattered small earthquakes near trace.	Dibblee (1966) Olson (1982)
50 Shepard Mesa	Single strand. Strikes N. 60°–70° W. Dips 70° S. Length 6 km.	Late Quaternary (OS, P)	R		Jackson and Yeats (1982)
51 Carpinteria	Single strand. Strikes N. 75° W. Dips 40° S. Length 4 km.	Late Quaternary (OS)	R		Jackson and Yeats (1982) K. R. Lajoie (unpublished data, 1983). A. M. Sarna-Wojcicki (unpublished data, 1982).

TABLE 3.1-1 Geologic and seimologic characteristics of late Quaternary faults in the Los Angeles region-Continued

Map number and fault	Geometric aspects	Age and evidence of latest surface faulting	Type of late Quaternary offset	Seismicity	Sources of information
Faults within Transverse Ranges—Continued:					
52 Red Mountain	Several strands in zone 1 km wide. Strikes N. 85° W. to N. 60° E. Dips 55°-65° N. near surface; 70°-75° N. at depth; 85° N. at western end. Length approximately 38 km.	Late Quaternary (OS, P); southern branch overlain by unfaulted Holocene marine terrace deposits (2,000-6,000 yr B.P.).	RLO	Numerous closely associated small earthquakes. Geometrically compatible fault-plane solutions.	Jackson and Yeats (1982) K. R. Lajoie (unpublished data, 1983). A. M. Sarna-Wojcicki (unpublished data, 1982). Yeats and others (1981, in press). Yerkes and Lee (1979a, b)
53 Fault Y	Probably several strands. Strikes east-west to N. 80° E. Dip unknown. Length approximately 33 km.	Holocene (P)	R(?)	Scattered small earthquakes near trace.	Crippen and others (1982) Yerkes and Lee (1979a, b) Yerkes and others (1981)
54 Javon	Single strand. Strikes N. 80° W. Dips 68° S. Length at least 4 km.	Holocene (OS)	R		A. M. Sarna-Wojcicki and others (in press).
55 Pitas Point-Ventura	Presumed single strand. Strikes N. 70° W. to east-west. Dips steeply north. Length at least 50 km.	Holocene (OS, P)	RLO	Closely associated small earthquakes near eastern end. Geometrically compatible fault-plane solutions. Possible source of 1941 Santa Barbara earthquakes (M 6.0). Alternate possible source for 1978 Santa Barbara earthquake (M_L 5.1).	Corbett and Johnson (1982) Greene and others (1978) Lee and others (1978, 1979) A. M. Sarna-Wojcicki (unpublished data, 1976). Yerkes and Lee (1979a, b)
56 Santa Ana	Two strands at western end. Strikes east-west. Dip inferred steeply south. Length 13 km.	Late Quaternary (P, W)	R(?)		Keller and others (1980) Rockwell and others (1984)
57 Faults near Oak View.	Five separate strands. Strikes N. 60° E. Dips 30°-60° SE. May become bedding-plane faults at depth. Length from 1 to 3 km.	Holocene (OS, P)	R		Keller and others (1982) Rockwell (1983) Rockwell and others (1984) Yeats and others (1981)
58 Lion Canyon	Single strand. Strikes N. 80° E. Dips 30°-50° S. Length approximately 15 km.	Late Quaternary (OS, P)	R		Schlueter (1976) Keller and others (1980)
59 San Cayetano	Two strands about 0.5 km apart west from Sespe Creek; single strand to east. Strikes N. 60° W. to N. 70° E. Dips 5°-35° N. near surface, 55°-70° N. at depth. Length approximately 40 km.	Holocene (OS, P)	R	Scattered nearby small earthquakes. Geometrically compatible fault-plane solution.	Cemen (1977) Keller and others (1982) Rockwell (1982, 1983) Schlueter (1976) Yerkes and Lee (1979a, b)
60 Faults of Orcutt and Timber Canyons.	Eight separate strands. Strikes N. 80° E. Dip 55°-70° N. near surface. May become shallow bedding-plane faults at depth. Lengths from 2 to 6 km.	Late Quaternary (OS, P)	R		Keller and others (1980) Rockwell (1983) Yeats and others (1981)

TABLE 3.1-1 Geologic and seimologic characteristics of late Quaternary faults in the Los Angeles region—Continued

Map number and fault	Geometric aspects	Age and evidence of latest surface faulting	Type of late Quaternary offset	Seismicity	Sources of information
Faults within Transverse Ranges—Continued:					
61 Holser	Several closely spaced strands. Strikes N. 80° E. to N. 70° W. Dips 60°–70° S. Length approximately 12 km.	Late Quaternary (OS, P)	R		Cemen (1977) Stitt (1983) Weber (1978, 1982)
62 Clearwater	One to two strands. Strikes N. 80° W. to east-west. Generally dips 70°–80° N. but locally 25°–40° N. Late Quaternary length approximately 14 km.	Late Quaternary (OS) near San Francisquito Canyon but overlain by unfaulted late Quaternary river terrace deposits elsewhere.	R(?)		Los Angeles County Engineer, unpublished data, 1965). Stanley (1966)
63 San Gabriel (central portion).	Several echelon strands in zone 0.5 km wide. Strikes N. 45°–65° W. Dips 50°–80° N. Late Quaternary length at least 32 km.	Holocene (OS, W) near Castaic. Late Quaternary (OS, P) between Newhall and Big Tujunga Canyon.	N or NRO		Cotton and others (1983) Nelligan (1978) Stitt (1983) Weber (1978, 1982; unpublished data, 1984).
64 Oak Ridge	One to three strands in zone as much as 0.5 km wide. Strikes N. 60° W. to N. 50° E. Generally dips 65°–80° S. but south of Fillmore dips 5°–30° S. near surface. Length approximately 100 km.	Late Quaternary (W, P); possibly Holocene south of Fillmore (P) and offshore.	R	Numerous closely associated small earthquakes near western end. Geometrically compatible fault-plane solution south of Santa Paula. Western end possible source of 1925 Santa Barbara earthquake (M 6.8).	Ricketts and Whaley (1975) Rieser (1976) Weber and Kiesling (1975) Yeats and others (1981, 1982) Yerkes and Lee (1979a, b)
65 Springville	Two strands in zone about 0.6 km wide. Strikes N. 65°–75° E. Dips 55°–80° N. Length about 9 km.	Late Quaternary (P, W)	R(?)		Jakes (1979)
66 Camarillo	Single strand. Strikes east-west. Presumed vertical dip. Length at least 6 m.	Late Quaternary (P, W)	R(?)		Gardner (1982) Jakes (1979)
67 Simi	Single strand that bifurcates at western end. Strikes N. 70°–80° E. Dips 60°–75° N. Length approximately 31 km.	Late Quaternary (OS, P); overlain by unfaulted Holocene alluvium (about 4,000 yr B.P.).	R	Closely associated small earthquakes, including M_L 3.1 event in 1969.	Jakes (1979) C. E. Johnson (unpublished data, 1982). Hanson (1981) Weber and Kiesling (1975)
68 Santa Susana	Several strands in zone as much as 1 km wide. Strikes N. 75° W. to N. 50° E. Dips 0°–30° N. near surface; 55°–60° N. at depth. Length 28 km.	Late Quaternary (OS); overlain by unfaulted Holocene stream terrace deposits (approximately 10,000 yr B.P.). Locally at northeastern end, historical surface faulting accompanied 1971 San Fernando earthquake.	RLO	Scattered associated small earthquakes, including M_L 4.6 event near Gillibrand Canyon in 1976. Geometrically compatible fault-plane solutions.	Leighton and others (1977) Lung and Weick (1978) Simila and others (1982) Weber (1975) Yeats and others (1977) Yerkes and Lee (1979a, b)
69 San Fernando	Five major echelon strands. Strikes N. 75° E. to N. 70° W. Dips 15°–50° N. near surface, 35° N. at depth. Total length at least 15 km.	Surface faulting accompanied 1971 San Fernando earthquake.	RLO	Source of 1971 San Fernando earthquake (M 6.6) and aftershocks. Geometrically compatible fault-plane solutions.	Allen and others (1975) Barrows (1975) Bonilla (1973) Kahle (1975) Sharp (1975) U.S. Geological Survey Staff (1971). Weber (1975)

TABLE 3.1−1 Geologic and seimologic characteristics of late Quaternary faults in the Los Angeles region−Continued

Map number and fault	Geometric aspects	Age and evidence of latest surface faulting	Type of late Quaternary offset	Seismicity	Sources of information
Faults within Transverse Ranges—Continued:					
70 Mission Hills	Presumed single strand. Strikes N. 80° E. to east-west. Dips 80° N. near surface, 45° N. at depth. Length at least 10 km.	Late Quaternary or Holocene (OS, P, W).	R(?)		Kowalewsky (1978) Saul (1975) Shields (1978)
71 Northridge	Several echelon strands in zone 0.7 km wide. Strikes N. 70°–80° W. Dips 35° N. near surface, 80° N. at depth. Length approximately 15 km.	Late Quaternary or Holocene (P, W).	R ?	Several aftershocks of 1971 San Fernando earthquake are closely associated with fault.	Barnhart and Slosson (1973) Shields (1978) Weber (1980)
72 Verdugo	Presumed multiple strands in zone 0.5–1.0 km wide. Strikes N. 50°–70° W. Inferred to dip 45°–60° NE. Length at least 20 km.	Holocene (OS, P, W)	R(?)	Scattered small earthquakes near trace.	C. E. Johnson (unpublished data, 1982). Weber (1980)
73 Eagle Rock	Single strand. Strikes N. 60° W. to east-west. Dips 15°–30° N. at western end. Length at least 5 km.	Possibly late Quaternary (OS, P).	R(?)		Weber (1980)
74 San Rafael	Echelon strands. Strikes N. 60°–70° W. Presumed near-vertical dip. Total length approximately 6 km.	Possibly late Quaternary (P)	?		Weber (1980)
75 Possible fault in North Hollywood.	Presumed single strand. Strikes N. 80° E. Presumed vertical dip. Length approximately 2 km.	Possibly Holocene (P)	?		Weber (1980)
Faults along southern margin of Transverse Ranges:					
76 Santa Rosa Island	Single strand. Regionally arcuate, striking N. 50° W. at western end and N. 60° E. at eastern end. Dip unknown. Length at least 72 km.	Late Quaternary (OS, P)	RLO	Probable source of April 1, 1945, earthquake (M_L 5.4).	Hileman and others (1973) Junger (1976, 1979) Kew (1927)
77 Santa Cruz Island	One to three echelon strands in zone as wide as 0.5 km. Strikes N. 70°–80° W. Dips 70°–75° N. Length at least 68 km.	Late Quaternary (OS, P)	RLO	Generally lacks small earthquakes. Possible source of M_L 5.0 earthquake near Anacapa Island in 1973.	Junger (1976, 1979) Patterson (1979) Yerkes and Lee (1979a, b)
78 Anacapa (Dume)	Presumed single strand in west; multiple strands in east. Strikes N. 80° W. to N. 60° E. Inferred to dip moderately north. Length at least 45 km.	Probably late Quaternary (P)	R	Source of 1973 Point Mugu earthquake (M 5.3) and aftershocks. Geometrically compatible fault-plane solution.	Junger and Wagner (1977) Lee and others (1979) Yerkes and Lee (1979a, b)
79 Malibu Coast	Several subparallel strands in zone as wide as 0.5 km. Strikes east-west and dips 45°–80° N. Length at least 27 km.	Late Quaternary (OS)	R	Numerous small earthquakes nearby.	K. R. Lajoie (unpublished data, 1983). Yerkes and Wentworth (1965). C. E. Johnson (unpublished data, 1982).

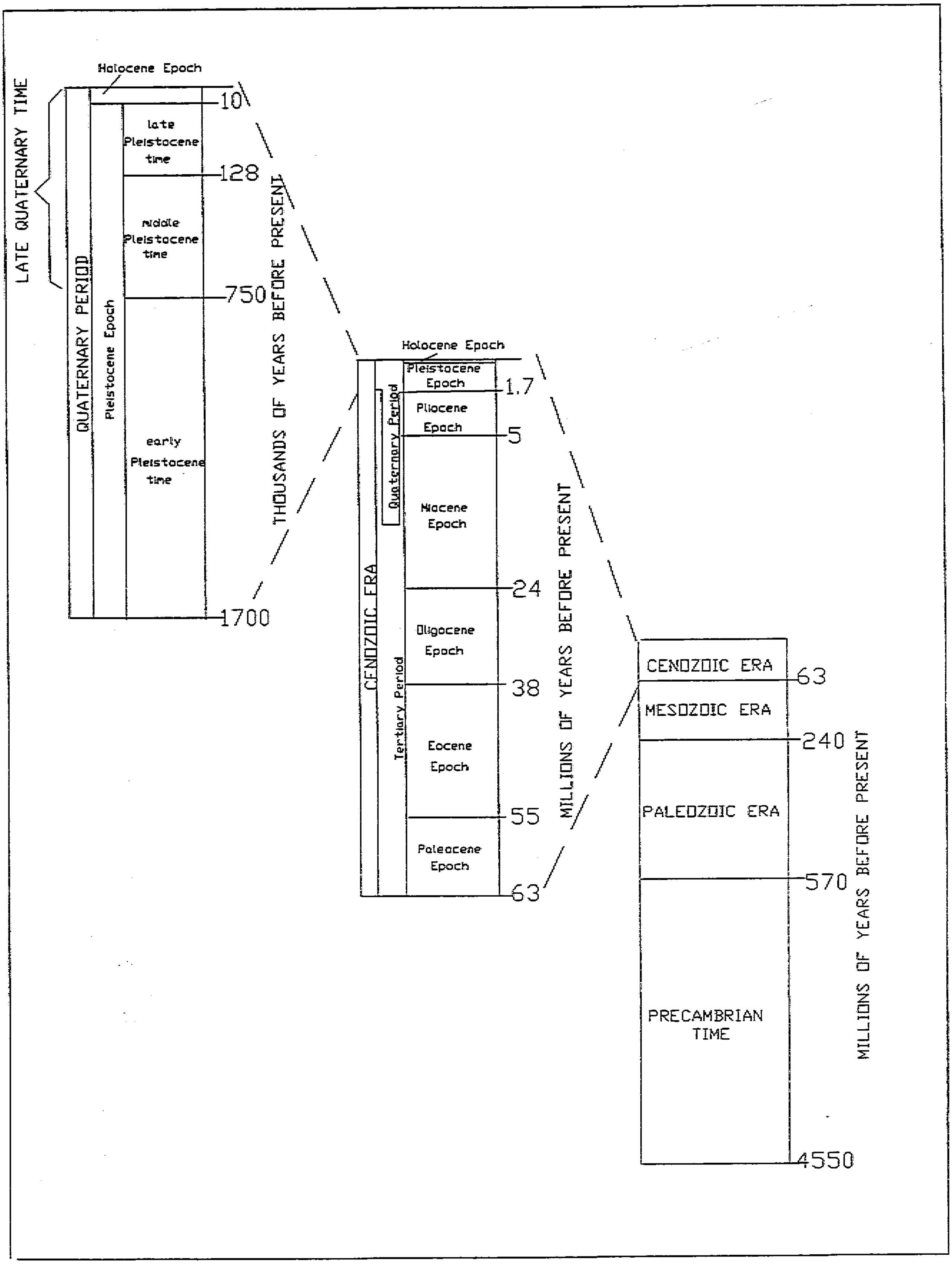
TABLE 3.1–1 Geologic and seimologic characteristics of late Quaternary faults in the Los Angeles region–Continued

Map number and fault	Geometric aspects	Age and evidence of latest surface faulting	Type of late Quaternary offset	Seismicity	Sources of information
Faults along southern margin of Transverse Ranges—Continued:					
80 Santa Monica	One or more strands. Geometry poorly known. Strikes N. 60°–80° E. Presumed to dip 45°–65° NW. at depth; some near-surface traces are vertical. Length at least 40 km.	Late Quaternary (OS, P, W)	RLO	Small earthquakes closely associated with eastern end. Geometrically compatible(?) fault-plane solution.	Buika and Teng (1979) Crook and others (1983) Hill (1979) Hill and others (1979) McGill (1981, 1982) Real (in press)
81 Hollywood	Presumed single strand. Geometry poorly known. Strikes N. 80° W. to N. 60° E. Inferred to dip about 60° N. Length approximately 17 km.	Possibly Holocene (P)	R or RLO	Some small earthquakes associated with eastern end.	Crook and others (1983) Hill and others (1979) Weber (1980)
82 Raymond	One to three strands locally in zone 0.4 km wide. Strikes N. 80° W. to N. 70° E. Dips 50°–55° N. Length 22 km.	Holocene (OS, P, W). Overlain by unfaulted soil (1,600 yr B.P.).	R or RLO	Scattered small earthquakes lie north of fault trace. Possible source of 1855 Los Angeles earthquake (Modified Mercalli intensity VIII). Geometrically compatible fault-plane solution.	Bryant (1978) Crook and others (in press) Real (in press) Weber (1980) Yerkes (this volume)
83 Sierra Madre	One to five anastomosing strands in zone as wide as 1 km. Four distinct salients. Strikes N. 55° W. to east-west. Dips 15°–50° NE. and north. Total length approximately 85 km.	Holocene (OS, P) between Big Tujunga and Dunsmore Canyons. Elsewhere, late Quaternary (OS, P, W). Overlain by unfaulted Holocene alluvium in several places.	R	Few and scattered small earthquakes.	Crook and others (in press) Pechmann (in press)
84 Duarte	One to two subparallel strands locally in zone 1.5 km wide. Strikes N. 60° W. to N. 70° E. Presumed to dip steeply NE. Length approximately 14 km.	Late Quaternary (W); possibly Holocene (P, W) along northern strand near Azusa.	R		Crook and others (in press)
85 Clamshell-Sawpit Zone.	Several subparallel strands in zone as wide as 1 km. Strikes N. 60° E. Dips 35°–70° NW. Length approximately 16 km.	Late Quaternary (OS)	R		Morton (1973) Crook and others (in press)
86 Cucamonga	Two to three subparallel strands in zone as wide as 1 km. Strikes N. 70° E. to east-west. Dips moderately to steeply north. Length at least 25 km.	Holocene (OS, P) along southern strands. Late Quaternary (OS) along northern strand.	R	Numerous small earthquakes. Geometrically compatible fault-plane solutions.	Matti and others (1982, in press) Morton and Matti (in press) Morton and others (1982) Pechmann (in press)
87 Indian Hill	Presumed single strand. Strikes east-west Dip presumed steeply north. Length approximately 9 km.	Late Quaternary (P, W)	SL(?)	Scattered small earthquakes nearby.	California Department of Water Resources (1970). Cramer and Harrington (1984, in press). C. E. Johnson (unpublished data, 1982).

TABLE 3.1–1 Geologic and seimologic characteristics of late Quaternary faults in the Los Angeles region–Continued

Map number and fault	Geometric aspects	Age and evidence of latest surface faulting	Type of late Quaternary offset	Seismicity	Sources of information
Faults along southern margin of Transverse Ranges—Continued:					
88 San Jose (B)	Single strand. Strike N. 45°–80° E. Dip presumed steeply north. Length approximately 22 km.	Late Quaternary (W); overlain by unfaulted Holocene alluvium.	SL(?)	Scattered small earthquakes nearby. Geometrically compatible fault-plane solutions.	California Department of Water Resources (1970). Cramer and Harrington (1984, in press). C. E. Johnson (unpublished data, 1982).
89 Red Hill	Presumed single strand. Strikes N. 20° W. to N. 70° E. Dip inferred steeply north. Length approximately 13 km.	Late Quaternary (P, W) except Holocene (P) at eastern end.	SL(?)	Scattered small earthquakes nearby. Geometrically compatible fault-plane solutions.	California Department of Water Resources (1970). Cramer and Harrington (1984, in press). Hadley and Combs (1974) C. E. Johnson (unpublished data, 1982). Morton (1976)
90 "Barrier J"	Presumed single strand. Strikes N. 45° E. Dip unknown. Length at least 5 km.	Late Quaternary (W); no surface expression.	SL(?)	Numerous closely associated small earthquakes.	California Department of Water Resources (1970). Cramer and Harrington (1984, in press). Hadley and Combs (1974) C. E. Johnson (unpublished data, 1982). Morton (1976)
91 Inferred fault near Fontana.	Presumed single strand. Inferred from seismicity to strike N. 45° E. Dip unknown. Length at least 8 km.	Possibly late Quaternary; no surface expression.	SL(?)	Numerous closely aligned small earthquakes. Composite fault-plane solutions suggest left-lateral strike-slip faulting.	Cramer and Harrington (1984, in press) Hadley and Combs (1974) Morton (1976)
Faults along margins of San Bernardino Mountains:					
92 Cleghorn	Single strand. Strikes N. 60° W. to N. 75° E. Dip near vertical. Length at least 23 km.	Probably Holocene (P)	SL	Numerous small earthquakes near eastern end of trace.	C. E. Johnson (unpublished data, 1982). Meisling and Weldon (1982a, b). Meisling (1984)
93 North Frontal Fault Zone of San Bernardino Mountains.	Numerous discontinuous arcuate strands averaging 2–4 km long, locally in a zone as wide as 6 km. Strikes N. 10° E. to N. 50° W. Dips from 10°–70° SE. or SW. One 5-km-long NW.-striking segment is vertical. Total length of zone at least 50 km.	Late Quaternary (OS, P); overlain by unfaulted active Holocene alluvial fans.	R (except vertical (NW.-striking strand may be SR)	Numerous closely associated small earthquakes near eastern part of zone.	C. E. Johnson (unpublished data, 1982). Meisling (1984) Miller (in press)
94 Faults of the Crafton Hills (Crafton, Chicken Hill, and Casa Blanca faults).	Several arcuate echelon strands, each 2–8 km long. Strikes N. 50°–80° E.	Late Quaternary (OS, P)	N(?)		Green (1983) J. C. Matti (unpublished data, 1983). Morton (1976)
95 Banning	Two to three strands in zone locally 4 km wide. Northern strand strikes N. 70° W. to N. 85° W. and dips 35°–70° N. Southern strands are complex, arcuate segments 3–10 km long that strike N. 65° W. to N. 50° E. and presumably dip moderately north. Total length of zone at least 45 km.	Holocene (OS, P, W)	R (except NW.-striking segments probably SR).	Numerous closely associated small earthquakes. Geometrically compatible(?) fault-plane solutions.	Allen (1957) Green (1983) Matti and Morton (1982) Yerkes (this volume) C. E. Johnson (unpublished data, 1982).

Chart of Quaternary Time Period



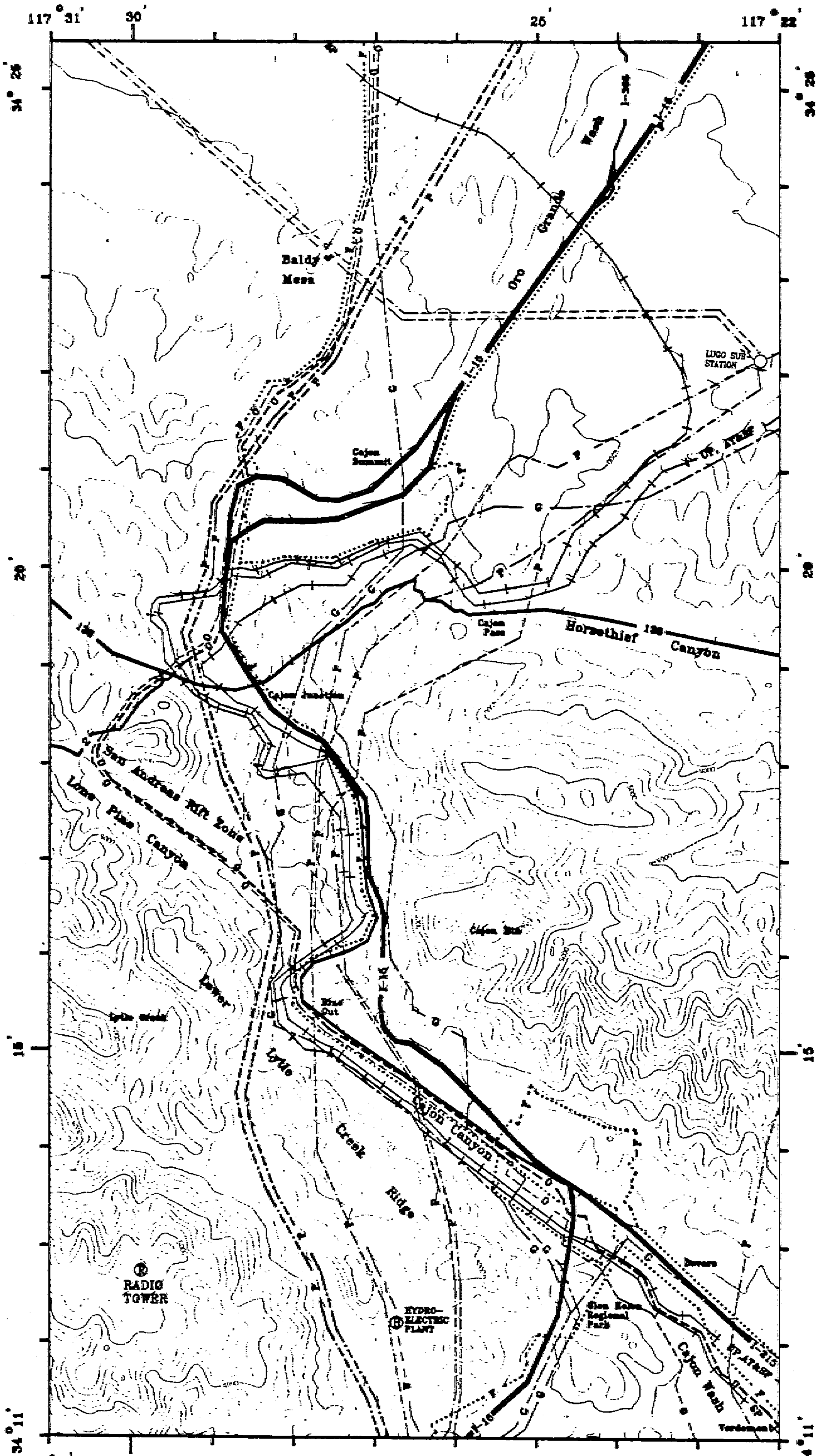


Figure 2-1 Composite Map of Lifelines In the Cajon Pass Study Areas

SCALE

0 1 2 MILES

0 1 2 KILOMETERS

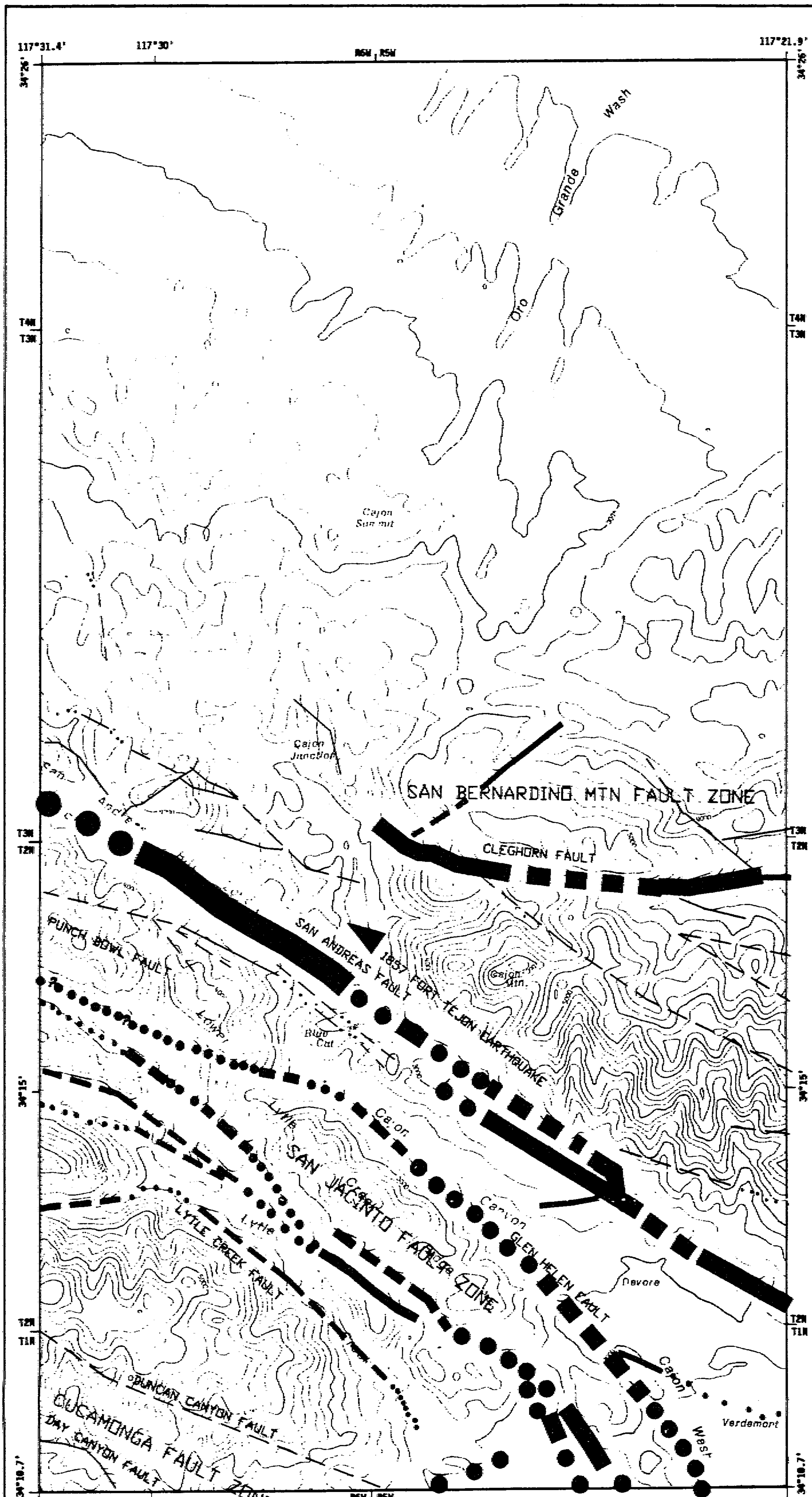
N

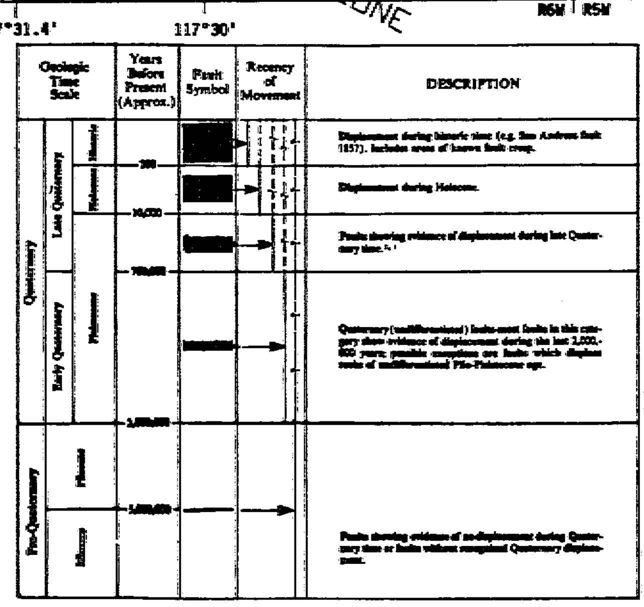
CONTOUR ELEVATIONS IN FEET

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





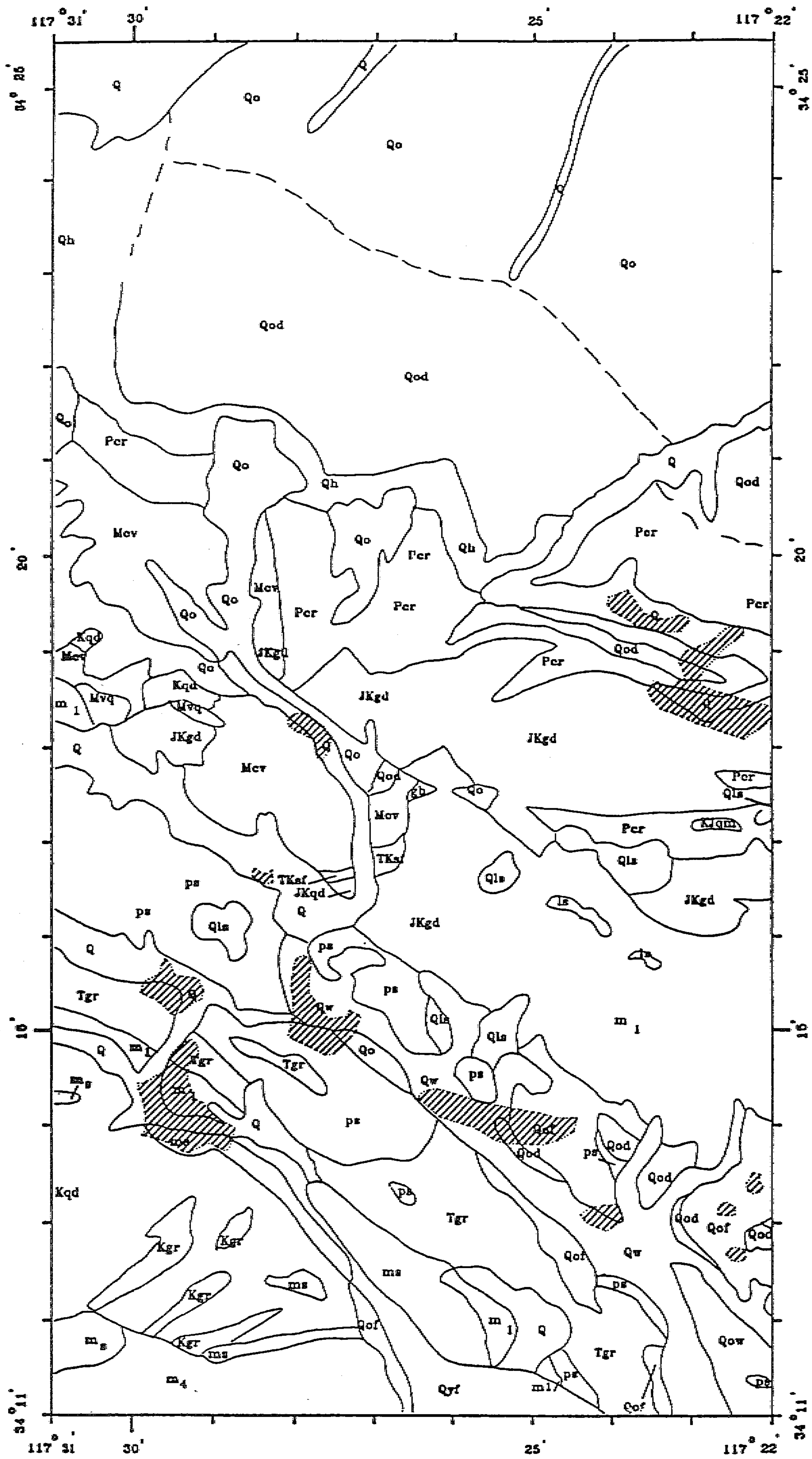
FOOTNOTES

0 1 2 MILES

Fault

Solid where well located; dashed where approximately located or inferred, queried where continuation or existence uncertain; dotted where concealed by younger rocks.

Figure 3.1-2 Active Fault Locations In The Study Area



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

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

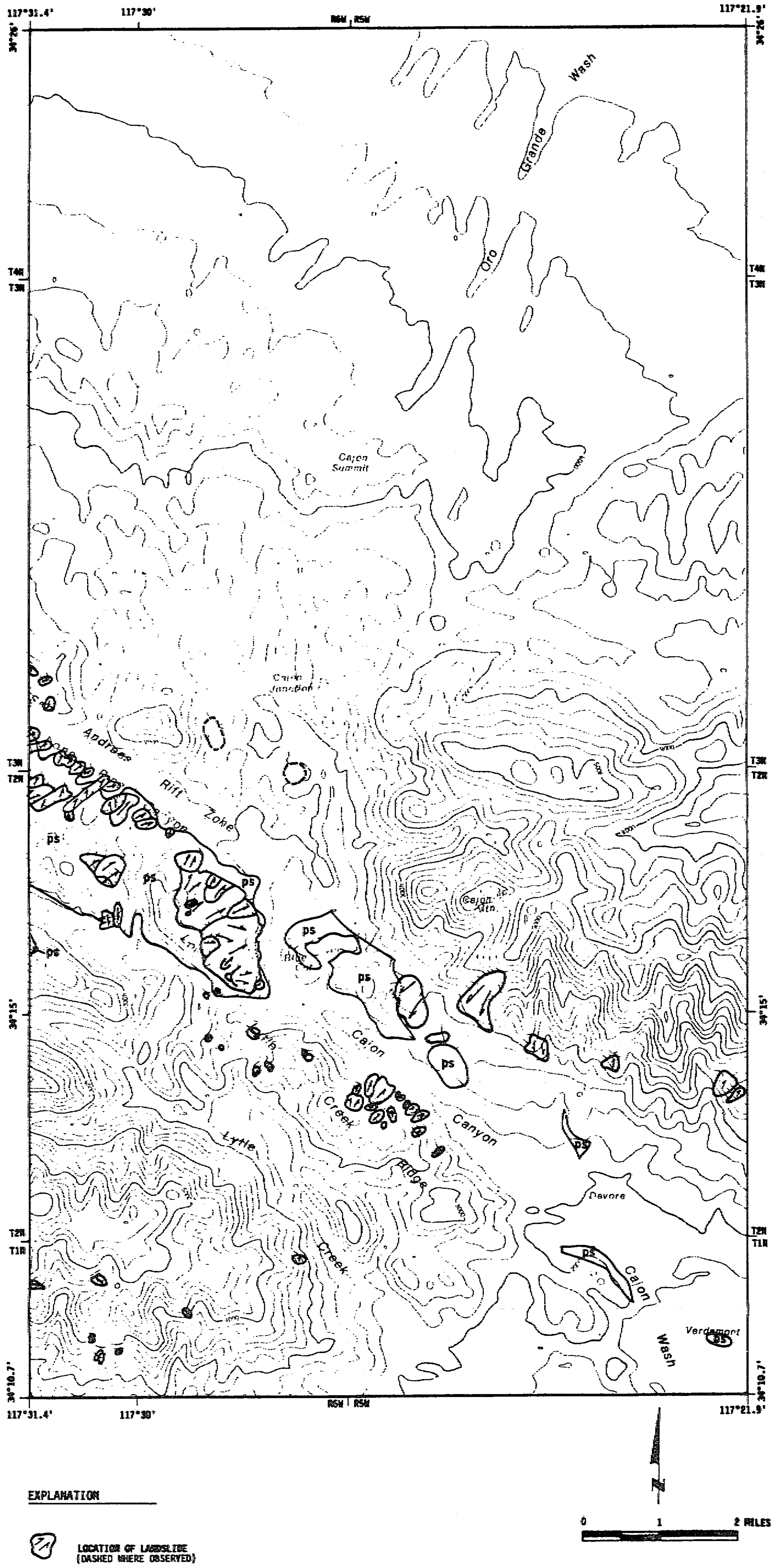
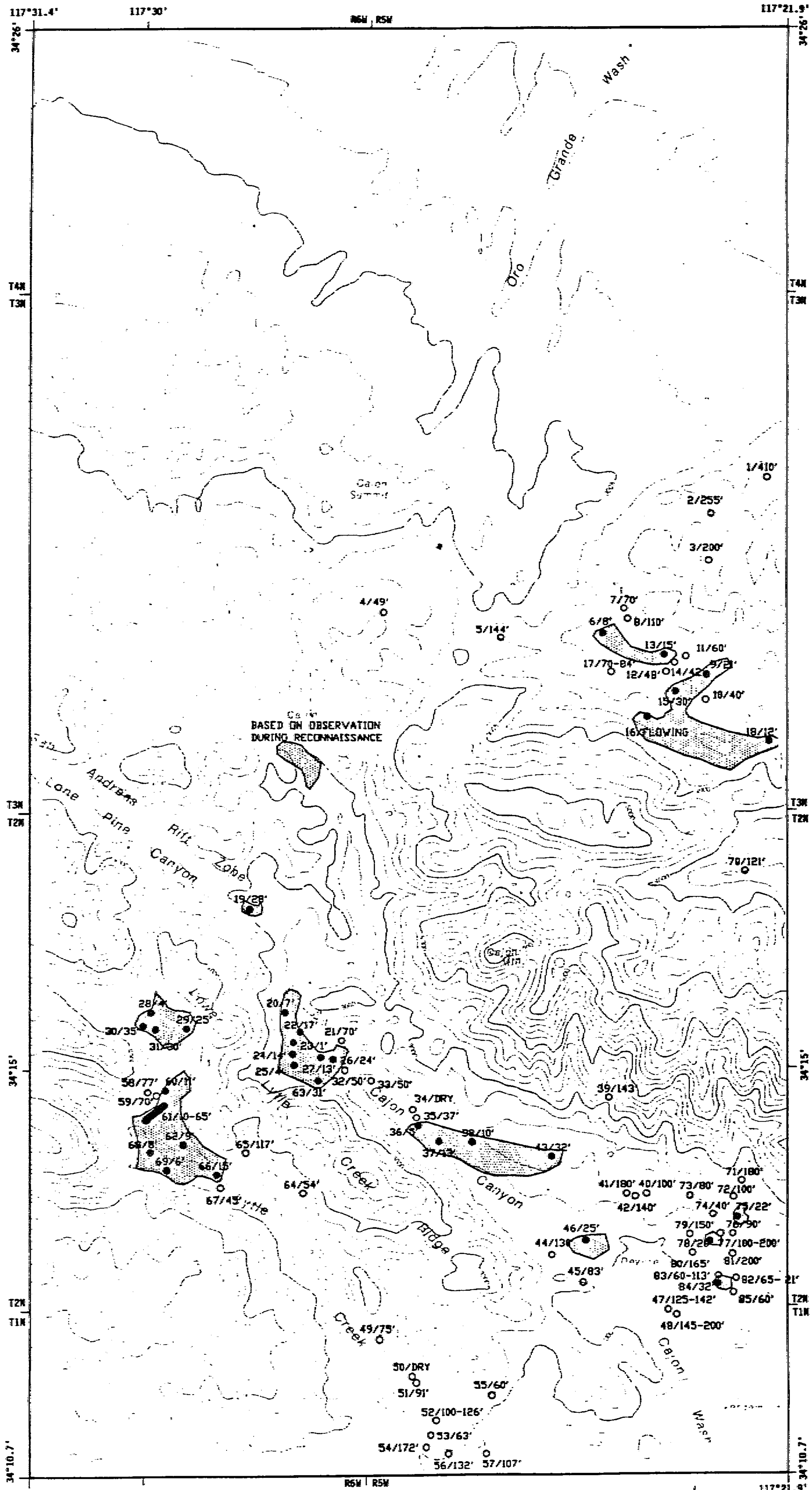


Figure 3.1-4 Observed Landslides Within the Study Area



0 1 2 MILES

EXPLANATION

●	DEPTH TO GROUND WATER LESS THAN 35'
○	DEPTH TO GROUND WATER DEEPER THAN 35'
1/100'	WELL REFERENCE NO. (TABLE 3.1-2)/DEPTH TO GROUND WATER
1/10-65'	WELL REFERENCE NO. (TABLE 3.1-2)/RANGE OF DEPTH TO GROUND WATER
[shaded]	ZONE OF HIGH WATER TABLE

Figure 3.1-7 Location of Shallow Water Table Conditions

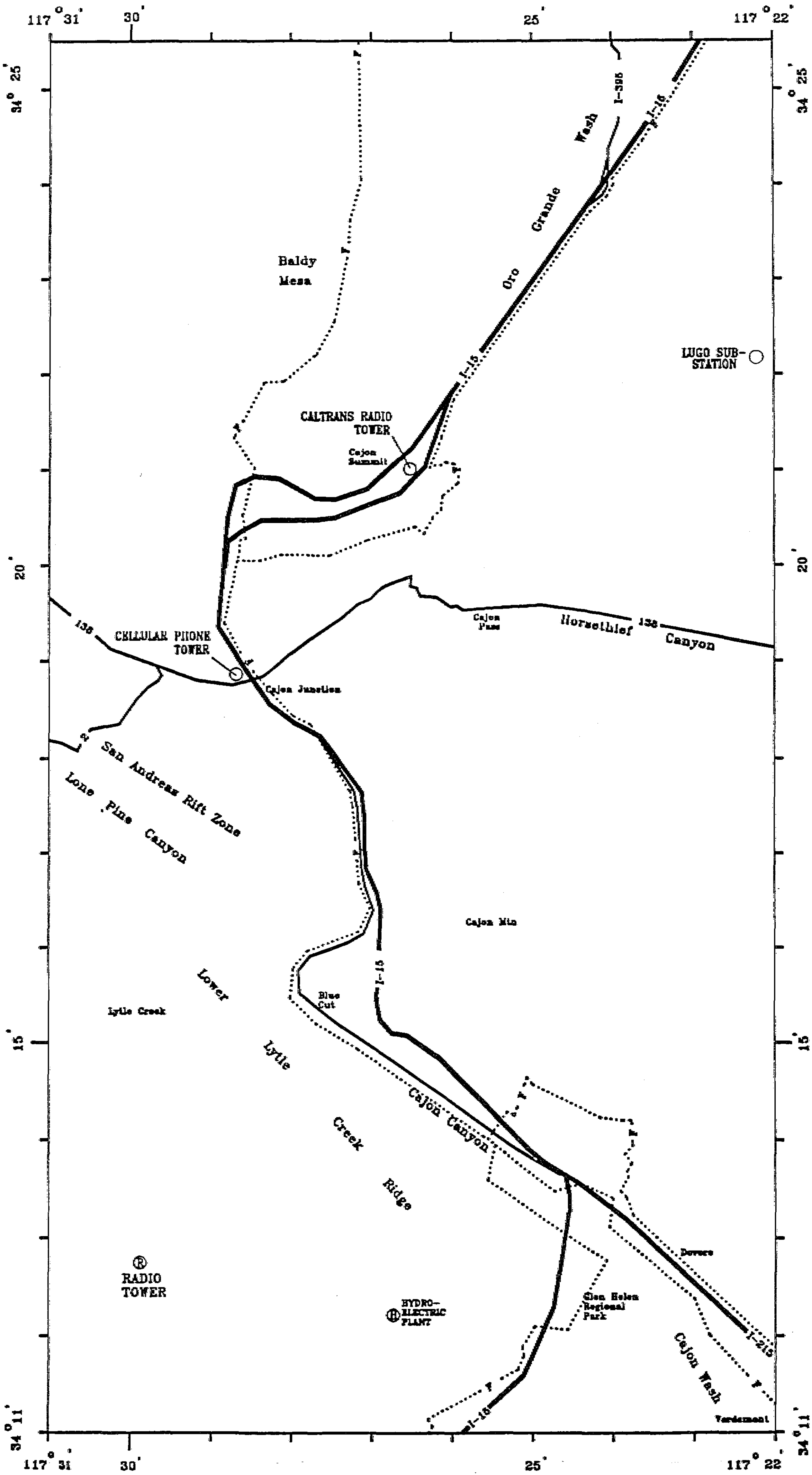
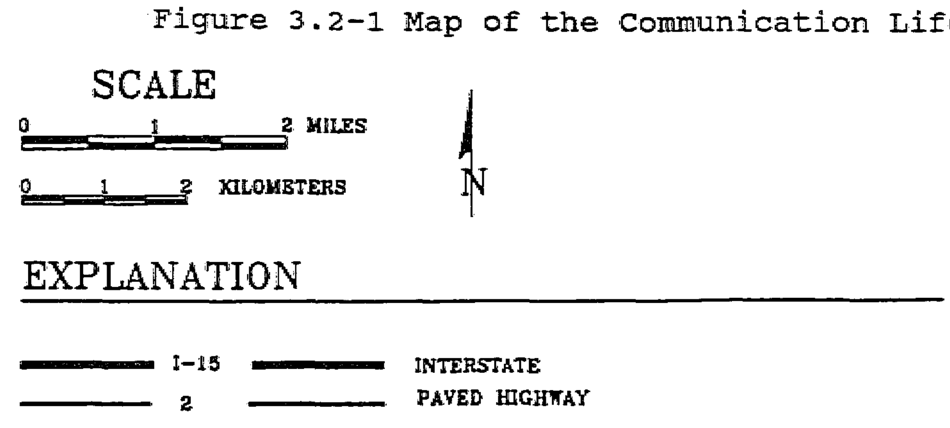


Figure 3.2-1 Map of the Communication Lifelines



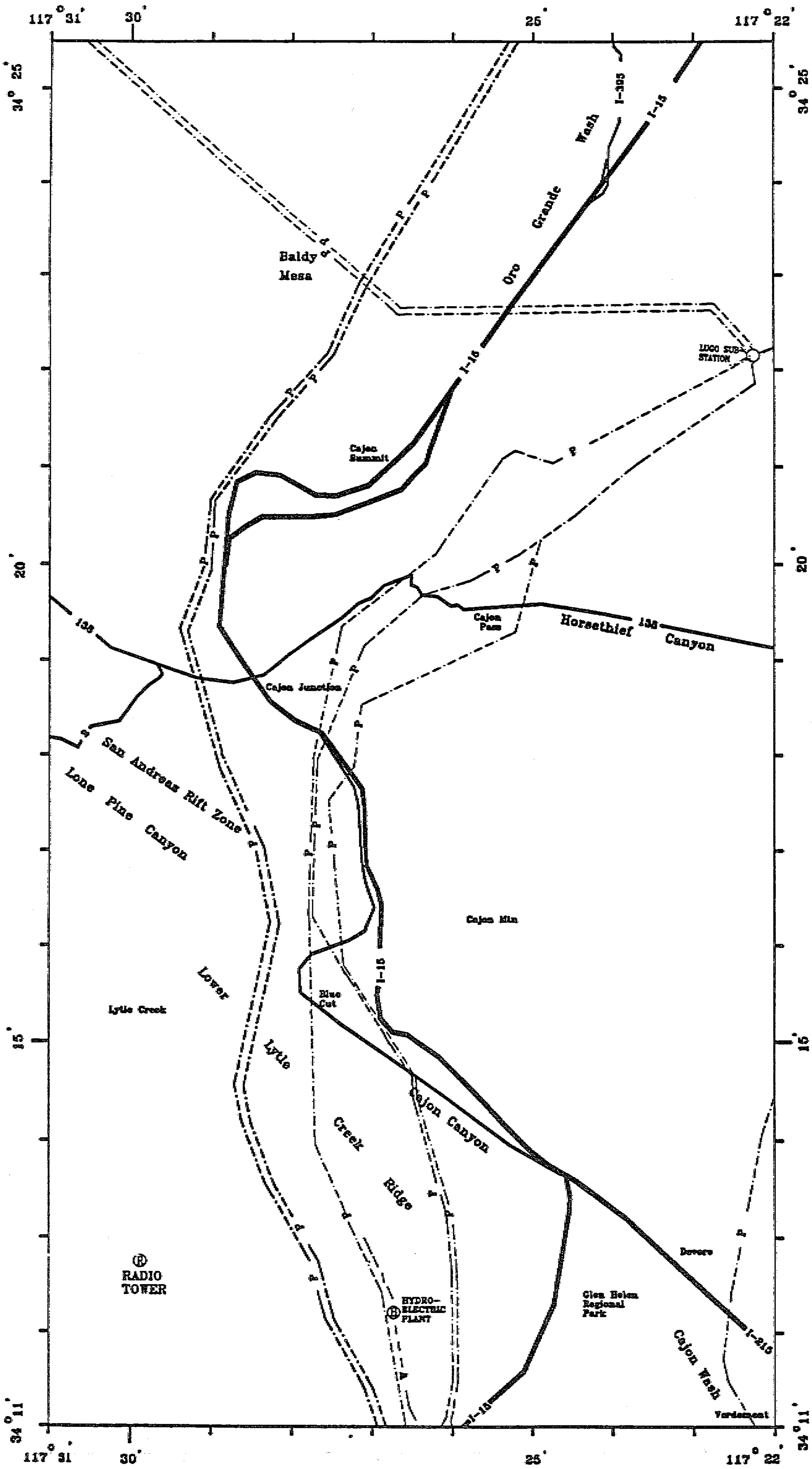
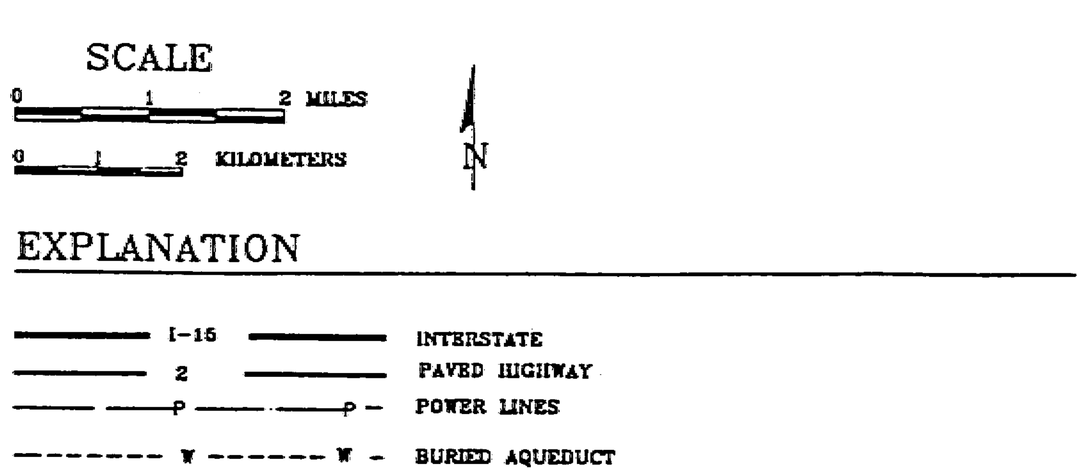


Figure 3.3.1 Map of the Electric Power Lifelines



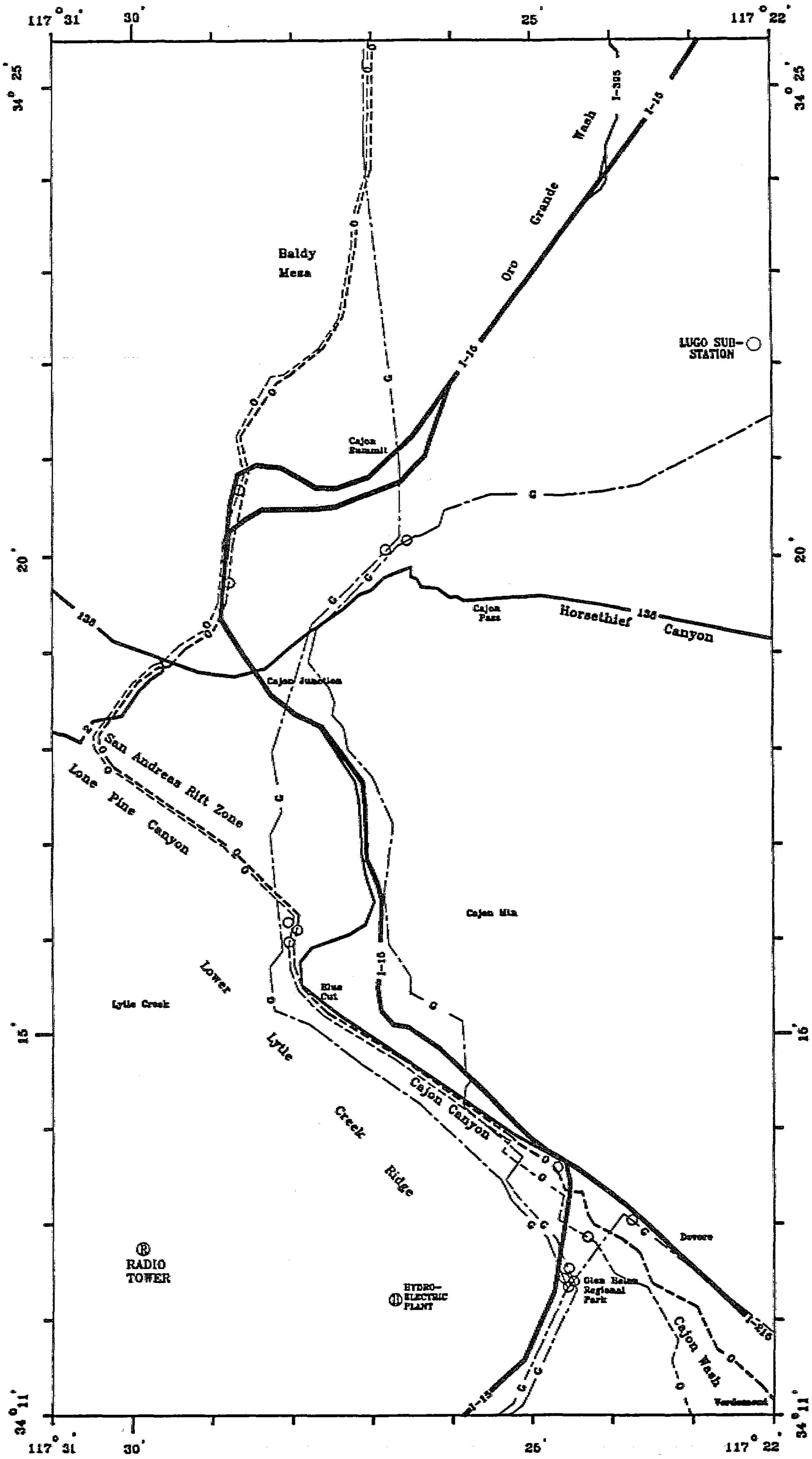
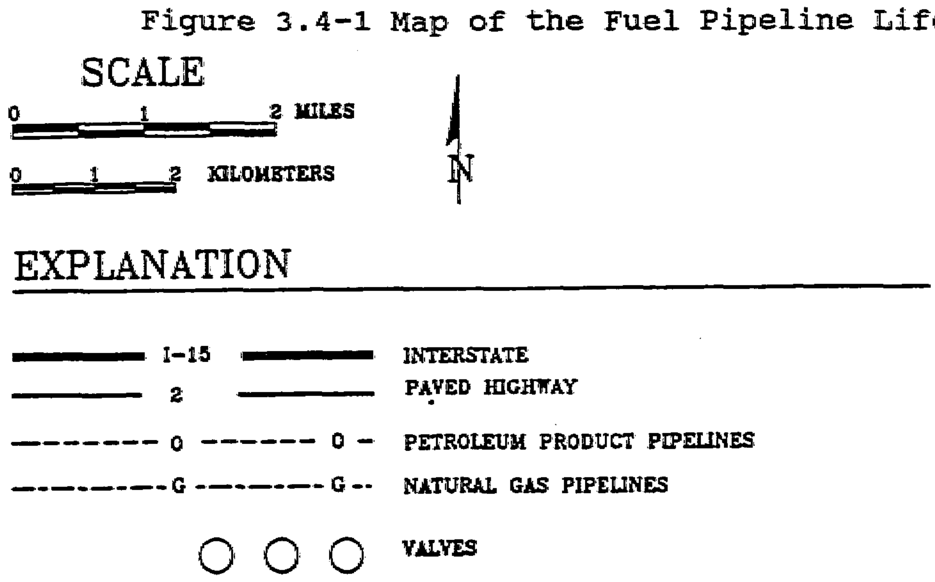


Figure 3.4-1 Map of the Fuel Pipeline Lifelines



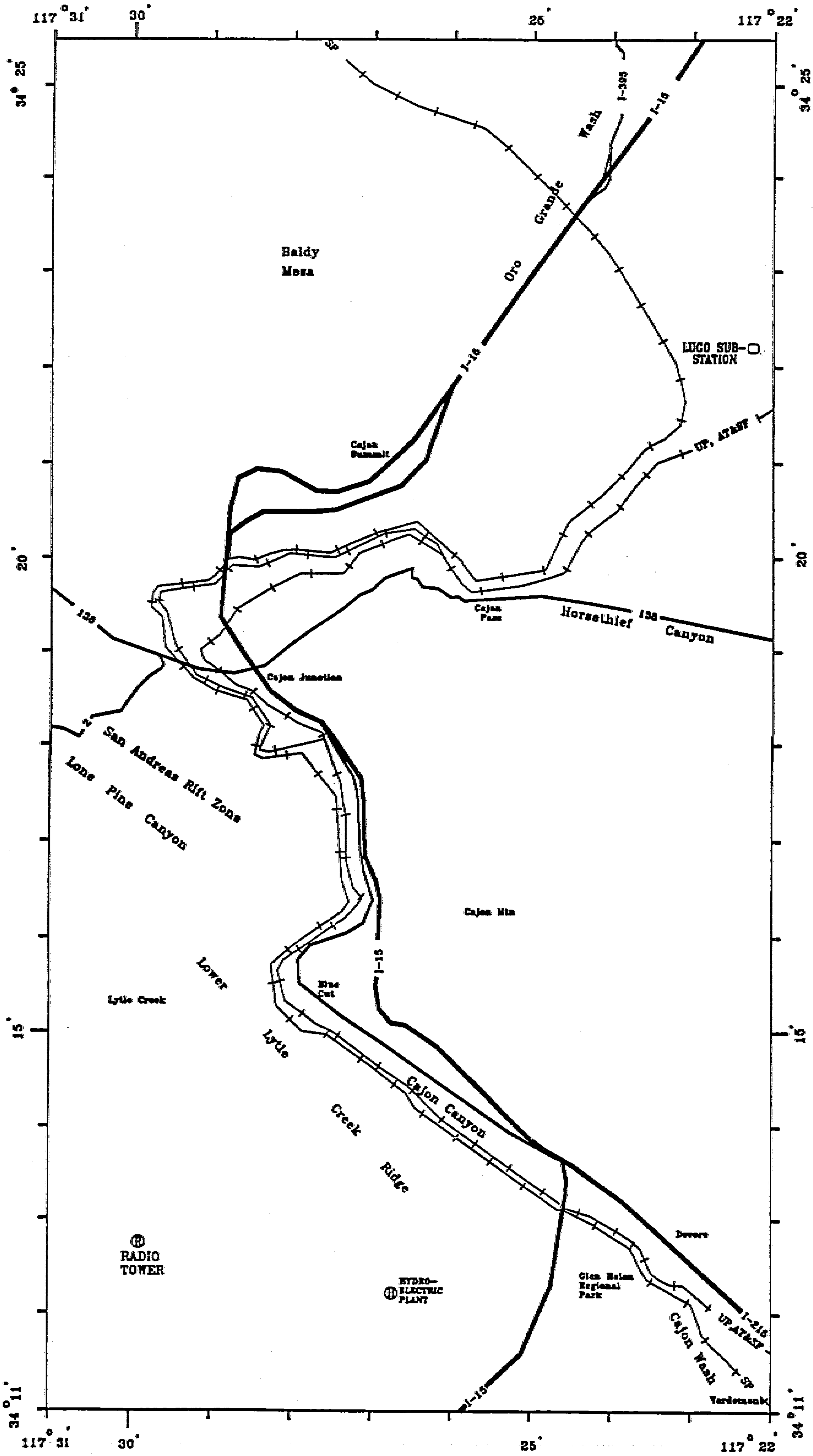


Figure 3.5-1 Map of the Transportation Lifelines