4.0 GEOLOGIC HAZARDS RESPONSES

4.1 Appendix B (g)(17)(B)

Comment

Please provide a 1:24,000 scale map showing geology and geomorphic features.

Response

A map at a scale of 1:24,000 showing the geology and geomorphic features within a two-mile radius of the project site is provided in Figure 4-1.

In a discussion with the CEC staff on January 17, 2002, CEC staff recommended that the City should review the recently published results of the earthquake studies. These studies may indicate the presence of new seismic faults that were probably not considered in the MGS design basis. CEC staff suggested that the locations of these new faults with respect to the project site should be considered in estimating the design ground acceleration. The CEC staff further recommended that the City should explain how the project design would meet the revised seismic requirements. The City's response based on the seismic analysis performed by Kenneth L. Wilson, C.E.G. (Wilson Geosciences, Inc.) is provided below.

Based on discussions with Mr. Hunter, representing the CEC, it was determined that the "new faults" reference was non-specific to any one fault, but referred generally to research being done or reported by the Southern California Earthquake Center (SCEC) based at the University of Southern California. SCEC has focused a substantial portion of their research on blind (buried) thrust faults responsible for numerous earthquakes in the southern portion of California. We believe this research suggests that the most significant "new fault" affecting the site is known as the Puente Hills blind thrust (PHT). Published reports and Internet research data were obtained for this fault zone, which is composed of three distinct segments and has an overall length of about 40 miles. It was first described in 1999 by Shaw and Shearer, and more recently discussed by others. The northwestern Los Angeles segment underlies the MGS site as shown in Figure 4-2. The fault properties and locations were estimated based on these two readily available sources.

EQFAULT (Blake, 1989-2000), a software program designed to allow estimation of site-specific earthquake affects, is described by Kleinfelder (2001). EQFAULT, while relatively simple to use, has certain limitations that can be overcome with careful application and some modification by the user of the fault-source data file. Thirty (30) earthquake ground motion attenuation relationships are part of the program and can be applied to site peak horizontal ground acceleration (PHGA) determinations, deterministic and probabilistic evaluations. Puente Hills blind thrust information was measured from maps and determined from reports, then entered into the basic fault-source data file. Ten (10) of the 30 attenuation relationships were used to estimate the site PHGA for Elysian Park, Puente Hills and Compton blind thrusts, and the Newport-Inglewood fault (please refer to Figure 4-3). The results of these studies are presented below.

Blind Thrust Faults Underlying the Los Angeles Basin

Based on data from past earthquakes and geophysical investigations, it was postulated, and later demonstrated, that a complex system of buried, low angle reverse (thrust) faults underlie the greater Los Angeles metropolitan region. Figure 4-3 presents the regional fault map as represented in Blake (1989, 2000). These buried thrust faults have not caused past surface rupture, and therefore, are referred to as "blind" thrust faults. These blind thrusts have caused several historic earthquakes, including the 1987 Whittier Narrows magnitude (M) 5.9 originally ascribed to the Elysian Park Thrust System (more recently associated with the Puente Hills blind-thrust according to Shaw and Shearer, 1999; Dolan et al, 2001) and the 1994 M6.7 Northridge on the Northridge thrust, possibly a buried on-shore extension of the Oak Ridge fault. Because of these earthquakes, blind thrusts have been the focus of several studies.

Blind or buried thrust faults typically do not offset, by definition, the surface deposits. However, they do generate co-seismic uplift and very likely cause co-seismic (sympathetic) movement on fault traces that may be linked to these blind thrusts at substantial depth. Few published maps exist (please see Figure 4-3) which attempt to delineate the precise subsurface boundaries of these blind thrusts (Blake, 1989-2000). Some investigators (Shaw and Suppe, 1996) have postulated that some form of near horizontal or shallow dipping blind thrust may underlie all or part of the Los Angeles Basin. Shaw and Suppe (1993) associated such a thrust with the Newport-Inglewood fault zone at substantial depth. Others suggest that such a *decollment* may connect to the San Andreas fault zone.

These blind thrusts may be divisible into segments, each of which may behave independently, or may break along their entire length on one event. Three of these north dipping blind thrusts that may have the most impact on the site are the Elysian Park, Compton, and Puente Hills. Their existence was inferred, and most believe now proven, from the clustering of deep earthquakes, from oil well log data, and from deep seismic data. It has been postulated that both the Elysian Park and Compton faults are capable of generating earthquakes of M6.7 to 6.8 (Blake, 2000), and the Puente Hills an M6.5 to 6.6 (one segment rupture) to M7.1 (multi-segment rupture) based on Dolan et al (2001).

Elysian Park Thrust Fault: The Elysian Park zone follows a line of hills extending approximately from Whittier through Montebello, Elysian Park, the Cahuenga and Sepulveda Passes (please see Figure 4-3). It was postulated that both the M 5.9 Whittier Narrows earthquake of October 1, 1987 and the M 4.5 Montebello earthquake of June 12, 1989 resulted from movement on this fault. Most recent studies place the 1987 earthquake on the Puente Hills blind thrust fault. Based on the location and magnitude of parasitic folds over the Elysian Park anticline, Oskin et al (1999) estimate a time-averaged slip rate of 0.8 to 2.3 mm/yr and a return period of 500 to 1300 years for a nominal M_w 6.2 to 6.7 earthquake.

The shallowest extent of the Elysian Park fault appears, from some references, to be 10 to 10.5 kilometers (Blake, 1989-2000), although balanced cross-sections by Namson and Davis (1994; Figure 15) show the fault to within about 5 kilometers of the surface (please see Figure 4-4). Oskin et al (1999) model the Elysian Park fault indicating three possible configurations, one with a variable dip (45- and 30-degrees), and two with constant dips (50- and 60-degrees). The models depict fault plane depths as shallow as 3 to 5 kilometers.

It is clear that substantial uncertainty still surrounds the characteristics of blind thrust faults in the Los Angeles Basin. Blake provides two fault-data files with his program UBCSEIS (Blake, 1998). In one file (Cdmgubc.dat) he includes the Elysian Park fault as a Type B fault. When the ICBO issued the Near-Source Zone maps in February 1998, they excluded blind thrust faults; therefore, Blake provides a second file (Cdmgubcr.dat) for the program to conform to these maps. The program can be run using either file. It would seem inappropriate, based on the nominal earthquake of M6.7 and the estimated slip rate up to 2.3 mm/yr, to ignore the Elysian Park fault as a Type B source for the seismic hazard assessment. In addition, the recent data on the Puente Hills thrust fault (see discussion below) suggests that it could be classed as a Type B fault if formally recognized by the California Geological Survey (formerly California Division of Mines and Geology—CDMG). With that consideration, it appears prudent to keep the Elysian Park fault in the UBC analysis process as a Type B fault, and to consider the Puente Hill blind thrust fault to the degree that it controls the analysis results.

Compton Thrust Fault: The Compton Thrust fault is a zone about 12 to 14 miles wide and extends from western Santa Monica Bay, through Torrance, at least to offshore of Seal Beach (please see Figure 4-3). Because of its distance from the site (6.0 km.), it would not be a controlling fault in the seismic hazard analysis, even though it would be classified as a Type B fault based on the M6.8 expected maximum magnitude. Little additional data are available for the fault. The State has indicated (Peterson, et al, 1996) that the slip rate is approximately 1.5 mm/yr and the return interval for the M6.8 event is approximately 676 years.

Puente Hills Blind Thrust: The Puente Hills blind thrust (Shaw and Shearer, 1999; Dolan et al, 2001) lies beneath the site. To the east of the site, it is under the Santa Fe Springs anticline and beneath the Coyote Hills (please see Figure 4-2). The shallowest expression of the fault is about 2 to 2.5 kilometers deep and the fault plane dips about 27 degrees north. Total length of the structure is about 40 kilometers from the downtown Los Angeles to northern Orange County. It has been divided into three segments with the site overlying the Los Angeles segment. Shaw and Shearer (1999) believe that the Puente Hills blind thrust lies above the Elysian Park thrust fault and is distinct from it. They propose relocation of the 1987 Whittier earthquake to the Puente Hills blind thrust. Additional discussion of this fault is found below in the *New Faults* section.

New Faults

EQFAULT was updated in 1998 to incorporate as a uniform standard the information developed by the CDMG (Peterson, et al, 1996) for California earthquake faults, which included the Elysian Park and Compton blind thrusts. Evolution of science related to blind thrust identification and characterization is ongoing. In 1999, Shaw and Shearer published a *Science* article describing in limited detail the Puente Hills blind thrust. More study has since been published or is currently in press. As far as can be determined for this study, the Landsat-based figure in the *Science* article and the figure in the Dolan et al (2001) summary (please see Figure 4-3) is the best representation for the subsurface location of the three segments of the Puente Hills blind thrust. Studies (SCEC, 2000) have hypothesized that the Puente Hills blind thrust is an important part of a master fault system connecting to the San Andreas Fault zone in the deep subsurface.

The Puente Hills blind thrust as shown by Shaw and Shearer (1999) strikes at roughly north 58 degrees west where its leading edge projects to the surface just southwest of the site at a depth of about 2.5 to 3 kilometers. In the Santa Fe Springs area, Shaw and Shearer (their Figure 1, a nearly north-south seismic section along the San Gabriel River) show a “growth triangle” bounded by secondary faults that propagate upward/south at an approximately 65-degree angle from the leading edge of the thrust plane. Shaw and Shearer (1999) show the fault to within about 800 feet of the surface in this area, although there is no indication that these features pose a fault rupture hazard.

Dolan et al (2001) performed additional detailed high-resolution seismic profiling at two sites (please see Figure 4-2) east of the proposed generating station site that demonstrates folding above the PHT, which extends into the shallow sediments (<200 m) as discrete kink bands, consistent with the late Quaternary activity. The shallow fold scarps were not associated with observable surface deformation during the 1987 Whittier Narrows (M6.0) earthquake. Using these data, the return interval for earthquakes on the Puente Hills blind thrust are estimated by Dolan et al (2001) as follows:

Puente Hills thrust (Los Angeles segment) = M6.5 to 6.6 = 400 to 1320 years
Puente Hill thrust (all three segments) = M7.1 = 780 to 2600 years

They suggest that the slip rates on the ramp segments range from 0.44 millimeters per year (mm/yr) to 1.7 mm/yr, with the preferred rates of 0.62 mm/yr to 1.28 mm/yr. The highest value is similar to the value used in FRISKSP (Blake, 1989-2000) for the Elysian Park of 1.5 mm/yr. Earthquakes of these magnitudes would generate very strong and intense ground motions at the site. Little is published about the Puente Hills blind thrust fault (Shaw and Shearer, 1999; Dolan et al, 2001), but many of its earthquake parameters should be similar to the Compton and Elysian Park faults. This fault is a Type B category based on UBC criteria.

Blake (1989-2000) does not include the Puente Hills blind thrust in his database (because it is not yet recognized formally be the California Geological Survey) so it was added for this study using the format described in the EQFAULT User's Manual. Based on the Puente Hills blind thrust fault plane depiction and description by Shaw and Shearer (1999), the necessary surface and subsurface location points (within the upper 4-kilometers), fault category, and class were determined for the Los Angeles segment, the northwestern-most of the three mapped segments. The results of the EQFAULT runs considering the Puente Hills blind thrust provides output for the fault-to-site-distance that is reasonable, therefore it appears that the location parameters are adequate for the analysis.

A magnitude 6.6 was selected for the Puente Hills blind thrust segment based on Dolan et al (2001). For the deterministic analysis, it was concluded that the multi-segment break (M7.1) was too unlikely versus a single segment break, in particular since the 1987 Whittier event already occurred on the adjacent Santa Fe Springs segment. Therefore, the M6.6 was selected as a reasonable maximum magnitude.

EQFAULT contains 30 attenuation relationships that may be applied to a site earthquake analysis. We reviewed ten (10) relationships, five (5) considering a 50 percent increase in ground motion for blind thrust faults and five (5) that do not consider this increase. The attenuation relationships are by authors whose work is widely used in southern California. Based on discussions with Lowney Associates a site soil condition of S_D was selected. The design related calculations by Lowney Associates considered both the UBC and a probabilistic method for determining the design level ground motion parameters for the site (Lowney, 2002).

The deterministic analysis results in Table 4-1 indicate that the Los Angeles segment of the Puente Hills blind thrust is the most critical of the four nearby faults considered. The average PGHA for the site is 0.53g to 0.78g for the Puente Hills blind thrust (without and with the 50 percent increase suggested by Campbell in Blake, 1989-2000). The high range of values for the Puente Hills thrust is 0.62g to 0.96g and low range is 0.41g to 0.64g.

Expected Depth of the Los Angeles Basin at the Site

The Southern California Earthquake Center (SCEC) research provides a consistent method to determine the depth of the sedimentary basin [defined as the depth to the 2.5-kilometer per second (km/sec) shear-wave velocity isosurface] based on Magistrale, et al. (2000). Based on the site coordinates the minimum depth, the computed depth, and the maximum depth are:

Longitude	**Latitude**	**Minimum Depth**	**Computed Depth**	**Maximum Depth**
-118.2208	33.9989	4260 meters	4434 meters	4540 meters

The "new" Puente Hills blind thrust fault has been reported on over the past 3 years by SCEC and its related scientists. The Puente Hills blind thrust fault fits the classification of a Type B fault (magnitude greater than or equal to 6.5). The Los Angeles segment of this fault underlies the site and is considered capable of a M6.6 earthquake. The peak horizontal ground acceleration (PHGA) was estimated deterministically using EQFAULT and ten (10) attenuation relationships. For the five attenuation relationships that consider a 50 percent increase in ground motions for blind thrusts, the simple average of these PHGAs is approximately 0.78g. For the five attenuation relationships that do not consider a 50 percent increase in ground motions for blind thrusts, the simple average of these PHGAs is approximately 0.53g.

The Elysian Park fault fits the classification of a Type B fault (magnitude greater than or equal to 6.5 and a slip rate estimated by Oskin et al of greater than 2 mm/yr). Recent research papers indicate that the fault extends to within 3 to 7.5 kilometers of the surface in some areas.

Based on the results of these studies, the design seismic parameters for the MGS site have been revised. The revised design seismic parameters are provided below in Table 4-2. It should be noted that Ca and Cv values are higher than earlier used for the MGS design. The design of the MGS has now been changed to meet the revised seismic requirements.

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Table 4-1
Deterministic Estimate of Peak Horizontal Ground Acceleration for the City of Vernon Malburg Generating Station Site

Attenuation Relationships[1]	**Median Site Peak Horizontal Ground (g = gravity) Acceleration (PHGA) for Four Faults**			
	Elysian Park Blind Thrust [M = 6.7]	**Puente Hills Blind Thrust**[2] **[M = 6.6]**	**Compton Blind Thrust [M = 6.8]**	**Newport-Inglewood [M = 6.9]**
Considers Blind Thrust as a 50% Increase in Ground Motion[3]				
Boore, et al, 1993 and 1993a	.886	.798	.701	.326
Crouse and McGuire, 1994	.471	.621	.453	.357
Silva and Abrahamson, 1993	.491	.686	.488	.326
Sadigh, 1997	.557	.827	.526	.321
Campbell, 1997 (Revised)	.644	.961	.595	.377
Maximum = .961	Minimum = .321	PHT Average = .779		
Does Not Consider Blind Thrust as a 50% Increase in Ground Motion				
Boore, et al, 1997	.627	.565	.497	.346
Crouse and McGuire, 1994	.314	.414	.302	.357
Silva and Abrahamson, 1993	.327	.457	.325	.326
Sadigh, 1997	.372	.552	.351	.321
Campbell and Bozorgnia, 1994	.430	.641	.397	.377
Maximum = .641	Minimum = .302	PHT Average = .526		

NOTES: (1) EQFAULT (Blake, 1989-2000); (2) Fault parameters determined from Shaw and Shearer (1999) Dolan et al (2001) were entered into EQFAULT data file; (3) Blake (1989-2000) page 33.

Table 4-2
Revised Seismic Design Parameters

Fault Type	B
Seismic zone	4 (z = 0.4)
Soil Profile Factor	S_D
Near-Source Distance	<2.0 km
Na	1.3
Nv	1.6
Ca 0.44 (Na)	0.57
Cv 0.64 (Nv)	1.02

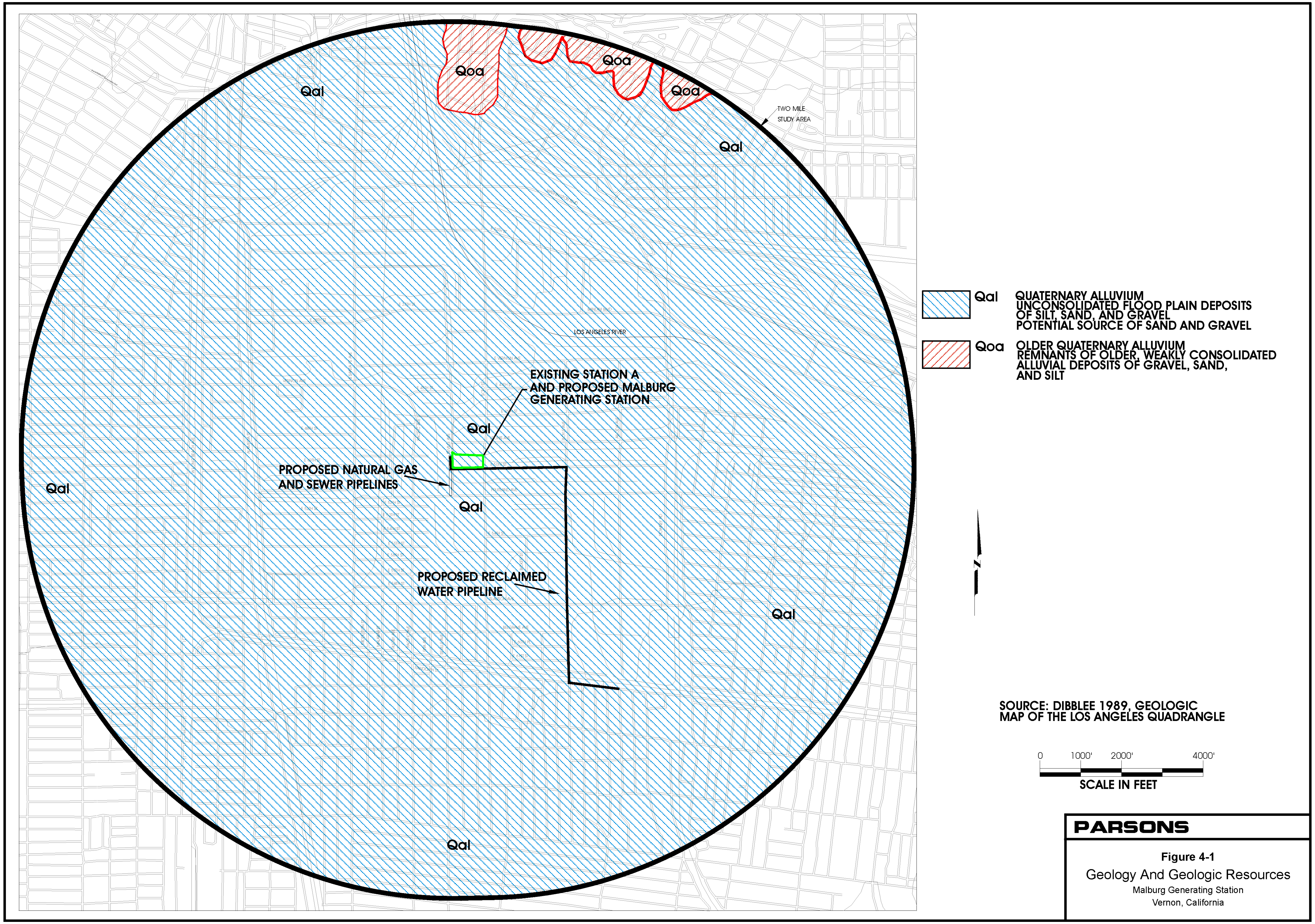

Figure 4-1
Geology And Geologic Resources
Malburg Generating Station
Vernon, California

Figure 4-2
Structure Contour Map of Segments of the Puente Hills Blind Thrust

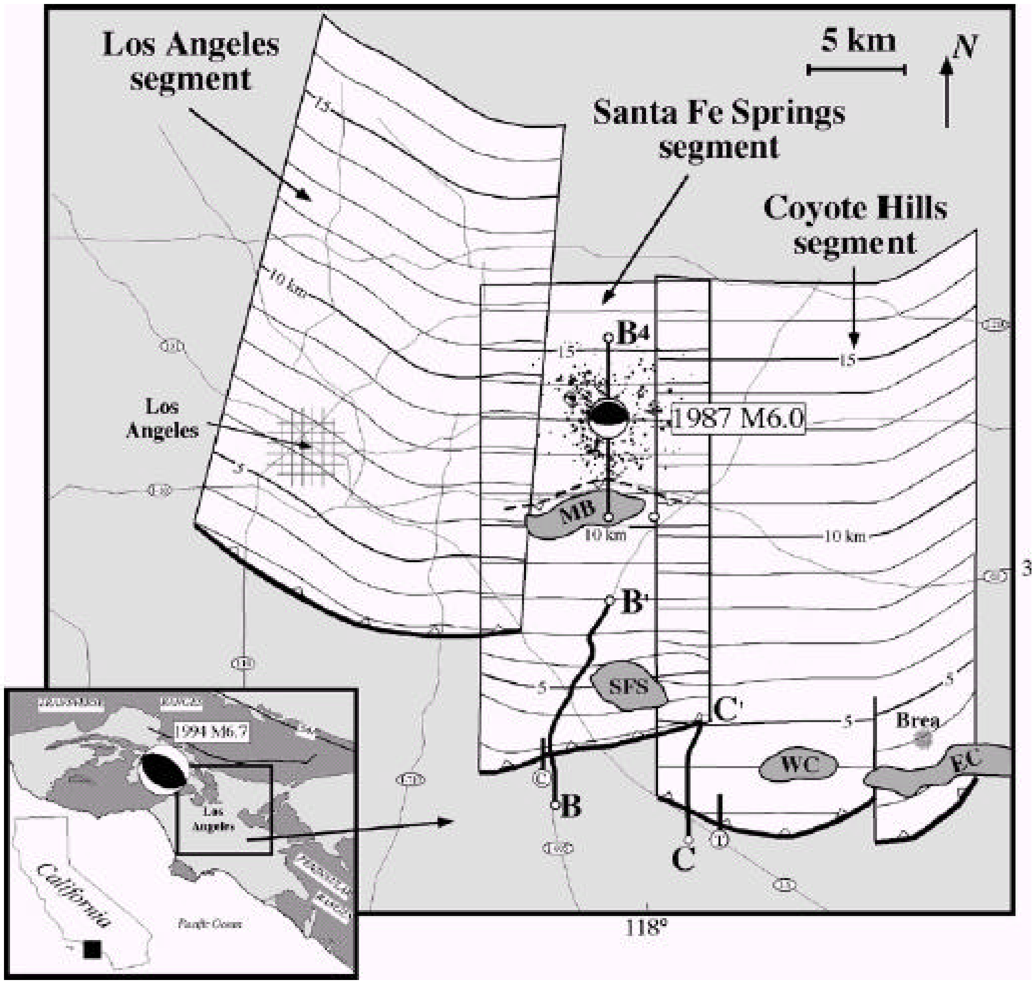

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Figure 4-3
Regional Fault Map Showing the Faults as Represented in Blake (1989-2000)

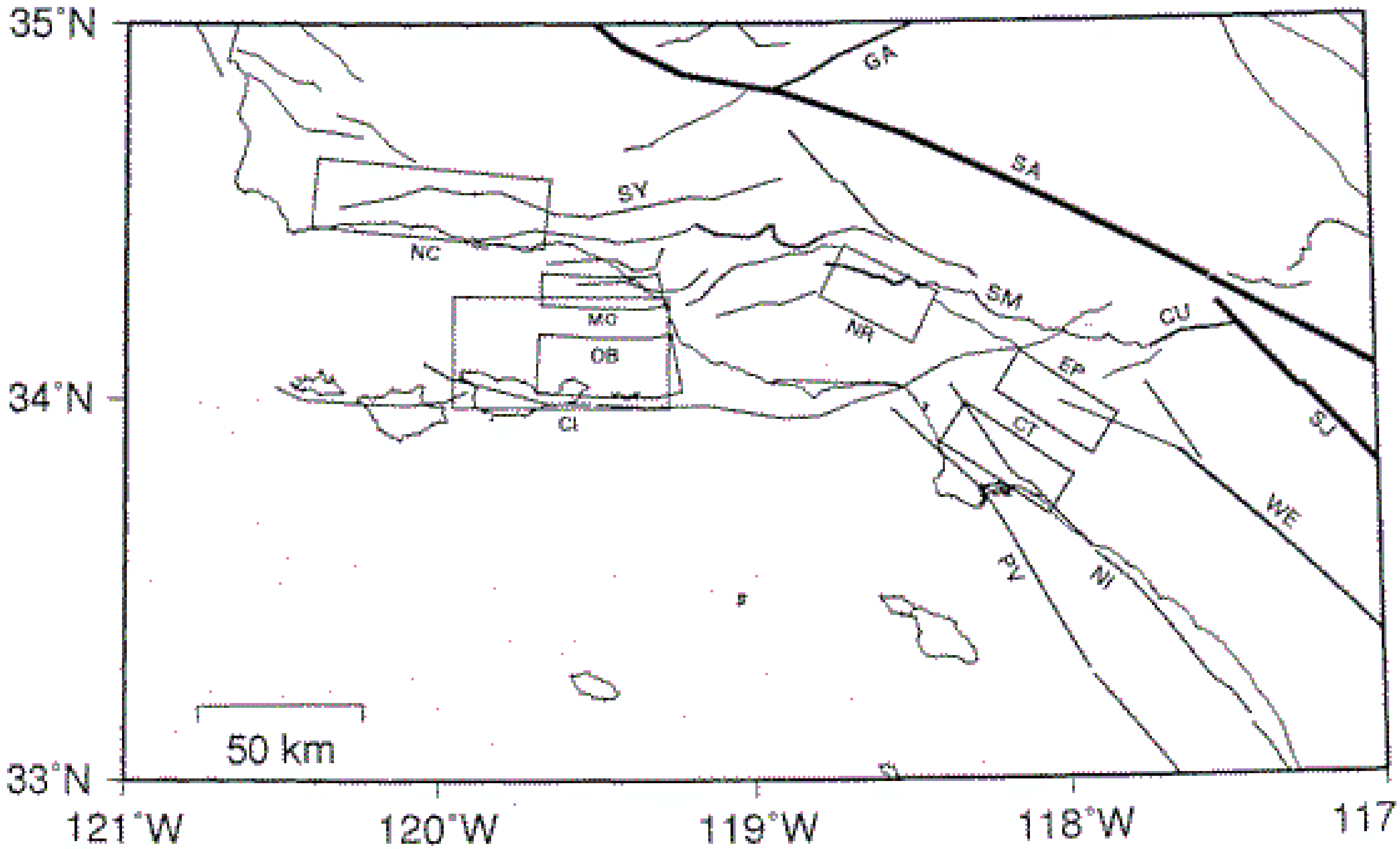

Figure 4-4
Model (south to north cross-section) from Namson and Davis (1994)

Approximately 5-kilometers as the Minimum Depth