MEMORANDUM

To: Julian Burke

Copies to: Habib Balian, Jim de la Loza, Carol Inge, Bob Cashin, David Meager, Diego Cardoso, Charles Stark, Joel Sandberg, John Adams, Girish Roy

From: MTA Tunnel Advisory Panel
Dan Eisenstein, Geoff Martin, Harvey Parker

Date: October 28, 1998

Re: RTAA - Technical Input and Comments on Red Line Subway Extension Alternatives

Please find enclosed a copy of our report on "Technical Input and Comments on Red Line Subway Extension Alternatives". Original of this report was forwarded to Booz Allen & Hamilton Inc. as a background information for their work on the RTAA.

MTA Tunnel Advisory Panel

REGIONAL TRANSIT ALTERNATIVES ANALYSIS

TECHNICAL INPUT AND COMMENTS ON RED LINE SUBWAY EXTENSION ALTERNATIVES

EXECUTIVE SUMMARY

This report provides technical input and background information on the Red Line subway extension alternatives for the Regional Transit Alternatives Analysis (RTAA).

Firstly, the report discusses possible modifications to the suspended Eastside Extension project and recommends modifications to achieve cost savings, should this alternative be reconsidered. The most significant modifications recommended are a change in alignment and changes in contracting and project management policies.

For the proposed Eastside and Westside Corridors the report focuses on those alternatives which involve subway options. For these, a brief discussion is provided about the geological and geotechnical conditions along the revised alignments with a special consideration for environmental aspects. Both Eastside and Westside alternative corridors involve some tunneling through contaminated ground. The report thus introduces in detail tunneling technologies suitable for contaminated ground. It is concluded that the newly developed closed face bentonite slurry tunnel boring machines can safely handle contaminated ground and, at the same time, can provide superior ground control with minimum settlement or other disturbance at the surface. For long term protection of the tunnels against gases (methane, hydrogen sulphide) it is recommended to use recently developed bolted precast concrete segmented liners with specially developed joints for gas tightness.

The report also deals with the unit costs of running tunnels and underground stations to be considered in calculations of total costs of various transit alternatives. These unit costs reflect costs of subway projects elsewhere in North America and worldwide as well as unit costs achieved at MTA projects.

Using these unit costs and adding the costs of electrical, mechanical and other systems as experienced by MTA, the total cost of subway alternatives comes to about $200 million per mile of subway, including underground stations, professional services and MTA staff. This cost compares closely with the average costs of similar subway projects in North America and worldwide.

1. INTRODUCTION AND TERMS OF REFERENCE

The MTA Tunnel Advisory Panel (TAP) has been requested to provide input to the Restructuring Plan and the Regional Transit Alternatives Analysis (RTAA). The input is focused on issues involving the feasibility of underground alternatives (running tunnels and stations), specifically geology, ground contamination, tunneling technology and cost aspects.

Brief comments on features of the suspended East Side Project amenable to change and cost savings and recommended modifications associated with proposed transit alternatives are summarized in Section 2.

Section 3 summarizes comments related to geologic and environmental conditions along Eastside alignment alternatives, together with tunneling technology and cost considerations.

Section 4 summarizes similar comments to those above for the Westside Corridor alternatives.

Section 5 summarizes unit costs of underground structures recommended for MTA evaluation.

2. MODIFICATIONS FOR EASTSIDE SUSPENDED ALIGNMENT

2.1 Features of the Suspended Project Amenable to Change

The existing (suspended) project involved several features which can be amended with resulting cost savings. These features include:

a) Changes in horizontal alignment.

b) Changes in vertical alignment.

c) Changes in contracting strategy.

d) Changes in project management.

2.2 Recommended Modifications Associated with Proposed Transit Alternatives

a) Shorten the alignment between Union Station and First/Boyle by eliminating Little Tokyo Station.

b) Locate the vertical alignment between Union Station and First/Boyle to such a depth that would not need ground conditioning (e.g. compensation grouting) to protect overlying structures.

c) Change contracting strategy to allow for the application of a "proactive" rather than "reactive" approach to construction of the tunnels and stations involving a consensus decision making process by the owner, designer and contractor.

d) Consider adopting the "design-build" concept as applied on a number of similar public projects, such as the Alameda Corridor Project.

e) Adopt "in-house" construction management, with only specialized services contracted out.

3. EASTSIDE CORRIDOR TRANSIT ALTERNATIVES

3.1 Geologic and Environmental Conditions along Alignment Alternatives

Two Red Line subway options are identified for the Eastside Corridor:

a) Existing Phase I Eastside Red Line Extension to First/Lorena

This option is the presently suspended project for which final design is essentially complete. The alignment is shown in Figure 1. The geologic and environmental conditions along this alignment have been the subject of thorough investigation and are reported in the Geotechnical Design Summary Report and the Environmental Summary Report referenced in the contract specification.

Planned tunnel and station excavations west of the First/Boyle station will primarily be in Young Alluvium comprising sands and gravels with local zones of cobbles and boulders. Excavation will be both above and below the groundwater levels. Of particular significance to construction west of First/Boyle is the presence of contaminated soil and groundwater and especially hydrogen sulfide in the groundwater over the region shown in Figure 2. To provide for a safe tunneling environment under these conditions, a closed face slurry tunneling machine has been specified (as described below) for the tunnels between the First/Boyle and Union Stations.

Planned tunnel and station excavations from First/Boyle to First/Lorena will be in Old Alluvium deposits (clays, silts, sands, and gravels) and bedrock units comprising siltsones and sandstones. Groundwater levels will be in most cases below tunnel invert Ground contamination is not a significant design concern over this section of the alignment.

b) Revised Eastside Red Line Extension from Union Station to Chavez/Soto

This option provides a direct alignment to First/Boyle, eliminates the Little Tokyo station and ends at Chavez/Soto, as shown in Figure 1. Although specific geotechnical investigations have not been performed over the new alignment between Union Station and First/Boyle, a review of available borehole logs (obtained from the City) in the near vicinity together with discussions with geologists, indicate that the geologic conditions likely to be encountered are similar to those west of First/Boyle described above. The extent of ground contamination would be considerably reduced in comparison with the suspended alignment.

The new alignment might require a slight rotation of the First/Boyle station and minor adjustments of the horizontal alignment between First/Boyle and Chavez/Soto stations. However, the geologic conditions would be similar to those defined for the existing alignment.

Environmental conditions between Union Station and First/Boyle are expected to be more favorable than those at the existing alignment, as the length of the alignment containing hydrogen sulfide is shorter, as shown in Figure 2 and discussed in more detail below.

3.2 Environmental Mitigation for Eastside Extension Tunnel Construction

The proposed alignment for the final design recently completed for the suspended Eastside Extension project traverses through heavily contaminated ground, particularly in the stretch immediately east of Union Station towards the Little Tokyo station and to the Los Angeles River. Contamination consists of soil and groundwater contaminated with chemical waste, methane, and very high concentrations of hydrogen sulfide. Numerous design measures were developed to mitigate and overcome all of this contamination during construction and operation.

Although, early studies reported high levels of methane and hydrogen sulfide, all measured in the headspace of monitoring wells. It has since been found that these high values are unreasonably high and unrealistic. More comprehensive investigations have determined that the industry-wide standard method of measurement of hazardous gases was giving improper results. New and improved methods of evaluation were developed for this project. The development of new, more reliable gas measurement techniques itself is a major achievement of MTA.

It has now been found that there is no evidence of hydrogen sulfide in the zone above the groundwater table in the Eastside Extension project. The hydrogen sulfide appears to be dissolved in the groundwater with average values of 50 to 65 ppmv with the highest concentration being 215 PPM with estimates that values as high as 250 ppmv are possible somewhere in the area. Even though the concentrations are not in the thousands of ppmv originally believed, considerable treatment will still be necessary and is essential. Fortunately, methods to minimize and control hydrogen sulfide during construction and during operation to the satisfaction of the MTA were developed and incorporated in the final design completed in 1998.

The proposed tunnel bypassing Little Tokyo Station will pass through similar hazardous soil, water, and gas contamination. Fortunately, the length of tunnel that will have to contend with such contamination will be much shorter for this alternative tunnel (see Figure 2). More importantly, many improved methods to contend with and overcome these hazards were developed by the Eastside Extension Design Team and can be applied to this bypass tunnel. It should be noted that groundwater containing hydrogen sulfide was successfully treated during construction of MOS-1 and the Gateway Center Building.

3.3 Tunneling Technology

Tunneling for the Eastside subway alternatives can be carried out using a slurry shield Tunnel Boring Machine (TBM). This fully mechanized technology uses a shield with a closed chamber at the front. This chamber is filled with bentonite suspension fluid maintained under pressure. The bentonite suspension, carrying particles of the excavated soil, is circulated through a separation plant located on surface, where soil particles are removed from the suspension, which is then pumped back to the tunnel face chamber. This technology offers two important advantages:

a) The tunnel face is permanently kept under positive pressure applied by the bentonite suspension. This pressure reduces stress relaxation and thus minimizes soil deformations and surface settlement. Also, the positive face pressure counteracts any soil failures or instabilities during excavation.

b) The excavated soil is transported through a closed system until it reaches the separation plant at surface. This is very important when excavating through zones of soils containing hazardous gasses such as methane and/or hydrogen sulfide. The excavated soil is never exposed to human contact until it reaches the separation plant, where special ventilation and mitigation measures can be incorporated and controlled.

The tunnel lining would be of the bolted concrete precast segmented type with continuous outside grouting. This is a one pass liner, which provides both the immediate and permanent support right behind the TBM. Previous studies carried out at The University of Illinois for the suspended Eastside Extension Project led to the development and testing of a segment joint, which is permanently resistant to penetration of gases under earthquake induced deformations.

It is envisaged that a single TBM would be needed to excavate the Eastside subway alternative with a separation plant located at one end of the tunnel. Tunneling would be thus carried out in the same direction for both tunnels.

3.4 Cost Consideration

Applying the unit costs discussed in Section 5 of this report, the revised Eastside Red Line Extension from Union Station to Chavez/Soto, including two underground stations (First/Boyle and Chavez/Soto) and one crossover, the total construction cost amounts to approximately $ 350 million. This corresponds to $ 200 million per mile of subway. Such an estimate is realistic when compared with subway costs elsewhere.

If the revised Eastside Red Line Extension is restricted from Union Station to First/Boyle only (one station without a crossover), the total construction cost would reduce to about $ 200 million.

4. WESTSIDE CORRIDOR TRANSIT ALTERNATIVES

4.1 Geologic and Environmental Conditions along Alignment Alternatives

Two Red Line subway options are identified for the Westside Corridor:

a) Existing Proposed Extension from Wilshire/Western to Pico/San Vicente via Wilton and Arlington

This option is the presently suspended project alignment shown in Figure 3, and is discussed in detail in the MTA draft EIS/EIR dated September, 1997. In discussion of the alignment, the above EIS/EIR notes—"The original LPA *(Locally Preferred Alternative)* for the Metro Red Line included an underground alignment along Wilshire Boulevard from the Los Angels Central Business District west to Fairfax Avenue (see Figure 4). MTA adopted this LPA after completion of the 1983 EIS/EIR. In 1985, a fire occurred at the Ross Dress-for Less Store on Third Street east of Fairfax Avenue. A City of Los Angeles Task Force determined the source of the fire to be naturally-occurring underground methane gas that seeped into a confined area of the building which had no ventilation. A spark caused the explosion and fire. In its report on the fire, the Task Force identified specific risk zones related to detection of methane gas.

In December 1985, the United States Congress passed Public Law No. 99-190, which stipulated that federal funds could not be used to tunnel into or through the area identified as potential "risk" or "high risk" in the June, 1985 City of Los Angeles report regarding the methane fire in the Fairfax area. *(See Figure 3)* Because of this prohibition and the need for federal funding for this project, the Underground Alternative along Wilshire Boulevard was rejected."

The proposed Wilshire/Western to Pico/San Vicente alignment via Wilton & Arlington shown in Figure 3 was adopted in 1996 after extensive studies of geologic and environmental conditions along alternate subway routes needed to by-pass the methane risk zones. The generalized geologic conditions along these routes (including the original Wilshire route) are shown in Figure 5. The existing Wilshire/Western station extends to a depth of 65 feet, and rests on the San Pedro Formation. Proposed tunnel inverts are primarily in the more shallow Lakewood Formation. Whereas the presence of methane was the primary concern for the Wilshire alignment, the presence of hydrogen sulfide is the primary tunneling concern along the Wilshire/Western-Pico/San Vicente alignment.

The nature and concentration of gas contamination along the alignment is fully documented in an EnviroRail report to MTA dated August, 1996. High concentrations of hydrogen sulfide are present in the unsaturated zones of the San Pedro Formation, particularly south of Country Club Drive and along Pico Blvd. However, safe tunneling and underground station construction is possible under these condition using present

tunneling and liner technology, provided appropriate mitigation measures are adopted, as discussed below.

b) Proposed "re-visited" alignment from Wilshire/Western to Wilshire/Fairfax

Although the alignment passes through the methane risk zone and was rejected in 1985 as described above, new developments in tunneling technology and improved mitigation methods warrants "re-visiting" the Wilshire subway alignment as a viable option, at least from a technical standpoint. Naturally, a parallel evaluation of the viability of rescinding the Federal Law would also be required. The generalized geology of the alignment is similar to that described above, and was the subject of geotechnical investigations in 1981 (Report to SCRTD by Converse Ward Davis Dixon, Earth Science Associates and Geo/Resource Consultants, Nov. 1981) and subsurface gas studies in 1984 (Engineering Science Report, January, 1984). Additional gas exploratory studies were conducted by EnviroRail in 1996.

The 1996 Enviro- Rail studies along Wilshire Boulevard from Crenshaw to La Brea Avenue, found no gas concentration within the San Pedro and Lakewood Formations, as these formations were saturated with groundwater. Minor concentrations of methane were detected in the Lakewood formation. Widely-dispersed hydrogen sulfide, methane and tar were found in the Fernando formation, at depths at about 60 to 100 ft.

From La Brea Avenue (the La Brea tar pits area) to Fairfax Avenue, dense oil saturated sands overly the soft rock of the Fernando Formation. Significant concentrations of methane gas have been found in this area, which is associated with the Salt Lake Oil Field.

4.2 Environmental Mitigation for Mid City Extension

General

The Tunnel Advisory Panel (TAP) strongly believes that the Mid City alignments, including an alignment straight down Wilshire are technically feasible and the congressional moratorium should be reconsidered in light of all the new technological developments in the last 20 years.

Abundant successful experience has been obtained in coping with methane and hydrogen sulfide in construction and in operating tunnels and stations. Essentially, substantially more ventilation and more detection monitoring are provided both during construction and operation to dispose of undesirable gasses. Such is the case for the Wilshire/Western station and adjoining tunnels. The technology to cope with methane and with oil has been proven on several tunnels in Los Angeles including MTA projects which are monitored continuously for any trace of hazardous gas.

Moreover, enormous strides were made in the development of the design for the Eastside Extension. New failsafe methods for constructing the tunnel in ground contaminated with chemical hazardous waste, methane, and even high levels of hydrogen sulfide were incorporated in the final design for the Eastside Extension. These were the result of extensive investigations and testing to adopt methods successfully demonstrated on other projects worldwide to the specific conditions of the Eastside Extension.

As previously described, the tunnel boring machine specified for the Eastside Extension was a special pressurized-face machine (Slurry TBM) which always maintains pressure on the ground being excavated to minimize any tendency for settlement and thus minimizing disturbance to the public. More importantly, the slurry TBM also removes all the excavated material, including any contaminants, which is pumped in a closed system up to a treatment plant where the contaminants can be safely, and more efficiently, handled. The methodology that was adopted for hydrogen sulfide, methane, and chemical hazardous waste can be applied to the Mid-City Extension.

A new tunnel lining system has been developed for the Eastside Extension, which can cope with hazardous fluids and gases even after an earthquake. The special precast concrete segment liner would be fully self-sustaining but a second line of defense could be provided by installing a gas membrane after which a cast-in-place lining would be placed. In the case of the Eastside Extension, the membrane and cast-in-place lining would be installed only if necessary and this may be the case for Option 1 of the Mid City Extension down Wilton/Arlington. For the Option 2 Wilshire alignment, the contamination is likely to be severe enough to warrant installation of the membrane and cast-in-place lining during initial construction. The lining through the tar pits area could also be made out of gasketed structural steel segments. Such is the case in the Eastside when the tunnel passes over an active blind thrust fault.

Finally, an extensive monitoring system has been developed and is in use today to continuously monitor existing tunnels and stations for any increase in gas concentration. Rarely does the system require increasing the ventilation but the system is set up to ensure the public is not in any danger at any time. Such monitoring and ventilation systems would naturally be an integral part of the design of any Mid City Extension.

Special Environmental Issues for Mid City, Option 1

A preliminary design has been fully developed for this Option 1 that accounts for all the known environmental issues. The design was developed to place the tunnel above the Lakewood Formation wherever possible since the Lakewood Formation appears to act as a barrier to very high measured concentrations of hydrogen sulfide in the groundwater in the San Pedro Formation.

Special Environmental Issues for Mid City, Option 2

Although Alignment Option 2 for Mid City (Wilshire Boulevard) has not been the subject of extensive geotechnical or environmental investigations, enough data has been obtained to identify the likely geo-environmental issues.

Naturally, the issues associated with the protection of the Tar Pits are extremely important. The depth of the tunnel can be selected to be below any expected paleontological artifacts. Some disruption may result if elevator or escalator shafts must be excavated through the deposits. At the same time, the shaft would provide a valuable resource for specimens to be retrieved from depths farther than ever before possible.

The existing data indicates that the principal hazard is methane gas, sometimes under pressure. This is confirmed even by a casual observation of the methane escaping under mild pressure in the Tar Pits. Other hazards include oil/tar and hydrogen sulfide. The data indicates that there may be more methane on the Wilshire alignment than the Option 1 alignment but much less hydrogen sulfide. Fortunately, the potential hazard of methane is lower than with hydrogen sulfide. The entire Wilshire alignment would be below the water table and thus the likely occurrence of hydrogen sulfide would be dissolved in the groundwater which is easier to handle than free gas in a vadose zone. Moreover, only a few of the borings and probes along Wilshire detected hydrogen sulfide. Finally, putting the Wilshire alignment at greater depth should avoid some of these environmental issues.

4.3 Tunneling Technology

Tunneling for the Westside alternatives involving subway segments would follow essentially the same principles as for the Eastside alternatives. It is proposed to use a slurry shield TBM with a closed system bentonite circulation in order to avoid exposure to contaminated ground. The lining would be again of the single pass, bolted, concrete precast segmented type with specially developed joints to resist earthquake deformations and to maintain tightness against gases under all conditions.

4.4 Cost Considerations

With the unit costs presented in Section 5. and by proportioning other costs from the more detailed Eastside estimate, it is believed that the total cost for the proposed "re-visited" alignment from Wilshire/Western to Wilshire/Fairfax should be in the order of $650 million for a total length of subway of 3.2 miles with three new stations.

5. UNIT COSTS

5.1 Basis for Unit Costs

The unit costs recommended in this document are derived from the following sources:

a) Costs of subway projects elsewhere in North America and worldwide obtained from published data or by personal communication and subsequently corrected for inflation.

b) Costs of tunnels and underground stations based on unit costs currently used by MTA.

c) Detailed cost analysis carried out for MTA on the suspended East Line Extension project.

The unit costs recommended below are of two types:

a) Unit costs per foot for construction of running tunnels and typical underground stations, which include the heavy civil construction, engineering design, construction management and oversight, but do not include electrical and mechanical systems and surface improvements.

b) Unit costs for a mile of finished subway, which include, in addition to the costs in a) above, the costs of electrical and mechanical systems, land aquisition and surface improvements.

5.2 Recommended Unit Costs for MTA Evaluation of Alternatives

The following recommendations are thus based on a synthesis of information from past MTA experience, the present state of MTA cost levels and the cost levels recorded at similar projects in North America and worldwide. As such, these recommendations are approximate only. However they could be used as guidance to evaluate and compare those alternatives which involve subway segments.

For the running tunnels excavated using the bentonite slurry TBM technology with a one pass segmented liner it is recommended to consider the construction cost as $7,500 per lineal foot of a single tunnel or $15,000 per lineal foot of the subway route. This cost considers the application of the bentonite slurry technology, including the separation plant providing that the tunnel length is at least 3,000 feet. As stated above, this cost is for heavy civil work and does not include electrical and mechanical systems.

For the underground stations excavated by the cut and cover method the costs can be considered as $ 40 - 45 million for a station without a crossover and $ 65 - 70 million for a station with a crossover. This cost is a complete cost for a finished station.

With the recommended costs as above the cost of a mile of subway, including one station per mile, comes to around $ 200 million. This compares very well with overall costs recorded at subway systems developed in similar geologic conditions in other parts of the world (e.g. Singapore, German cities, etc.).

East Side Alternatives Analysis

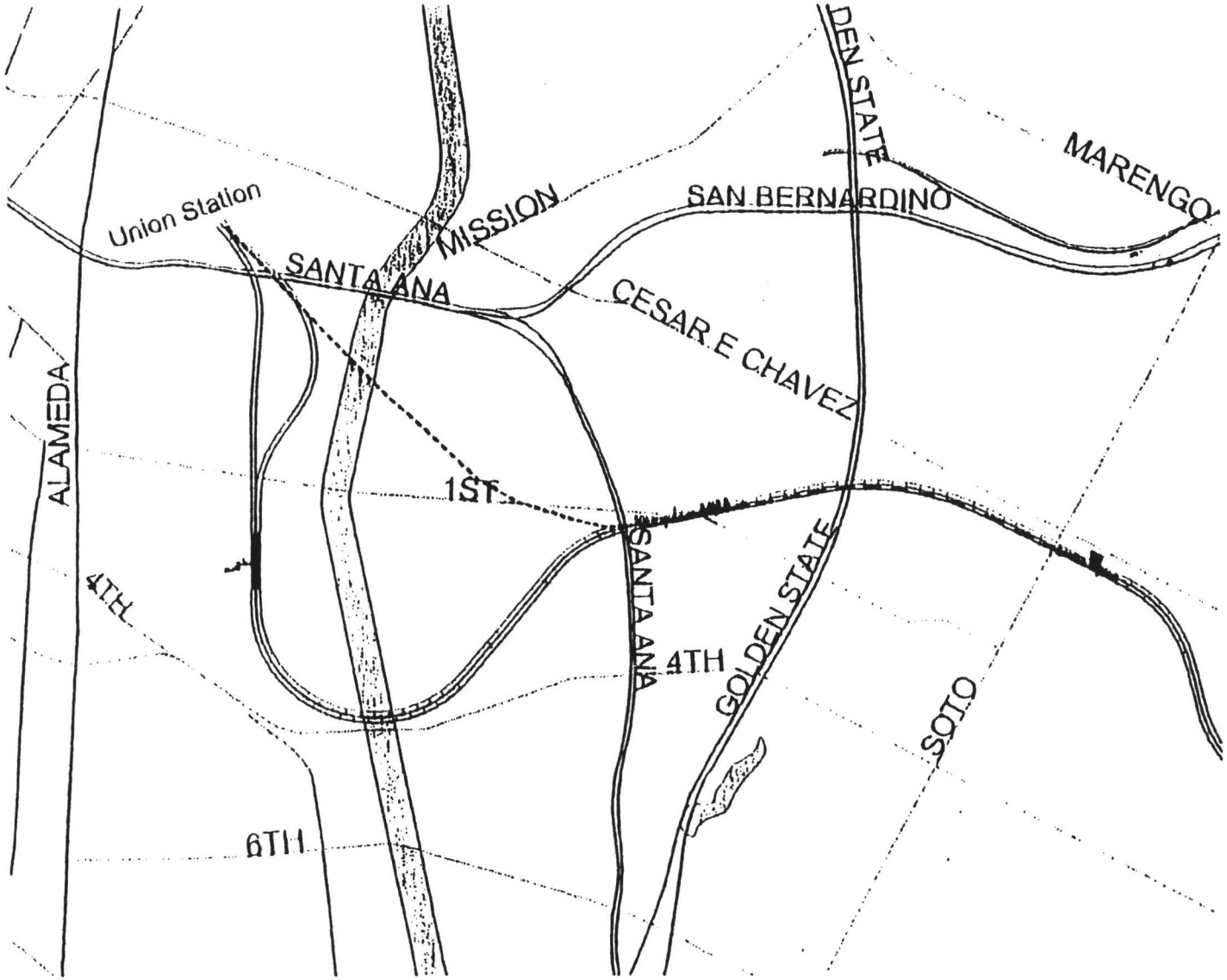

Figure 1 Eastside Corridor Alignment Alternatives

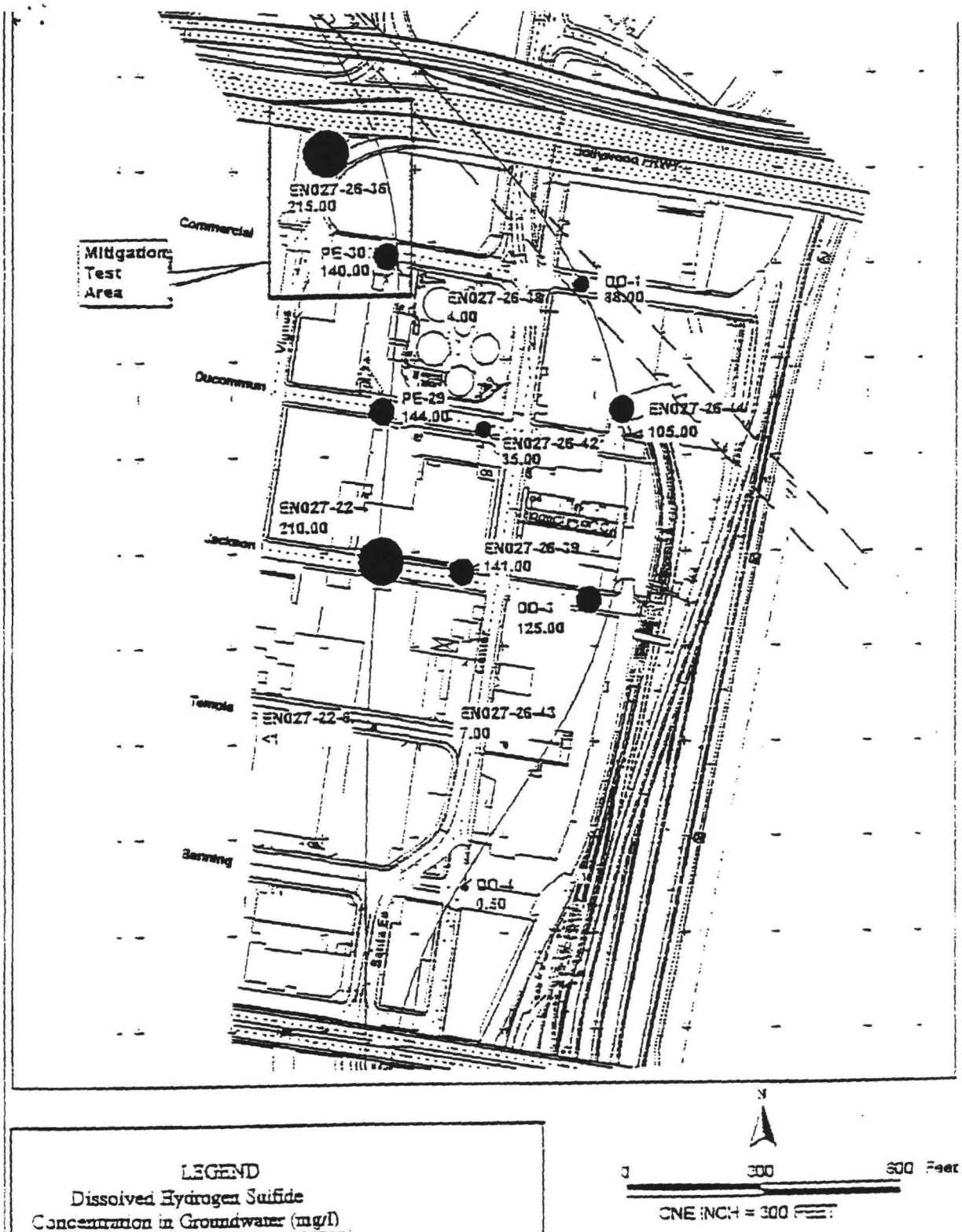

Figure 2 Alignment Alternatives in Relation to Hydrogen Sulfide Contamination Area

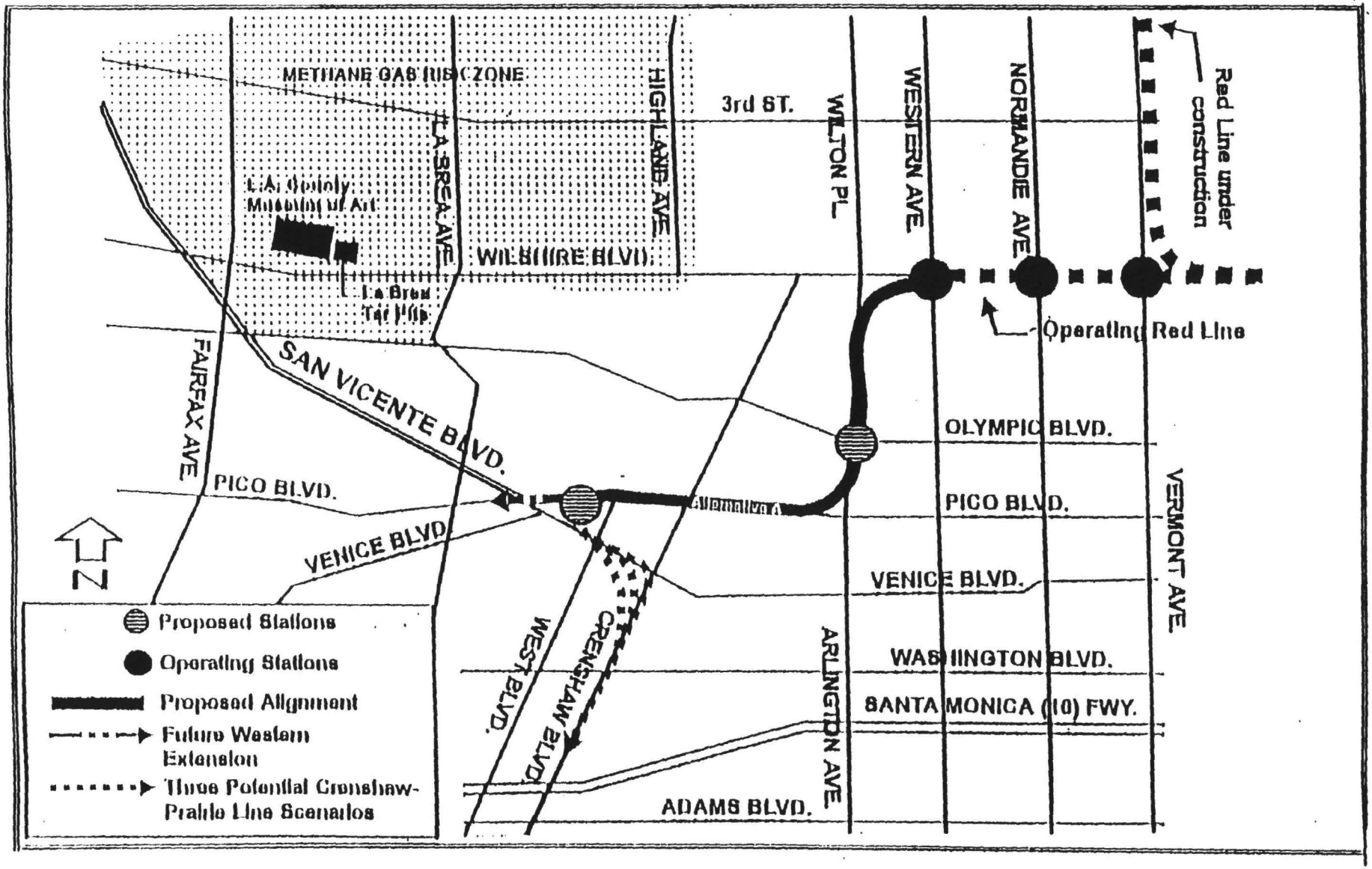

Figure 3 Suspended Mid-City Alignment

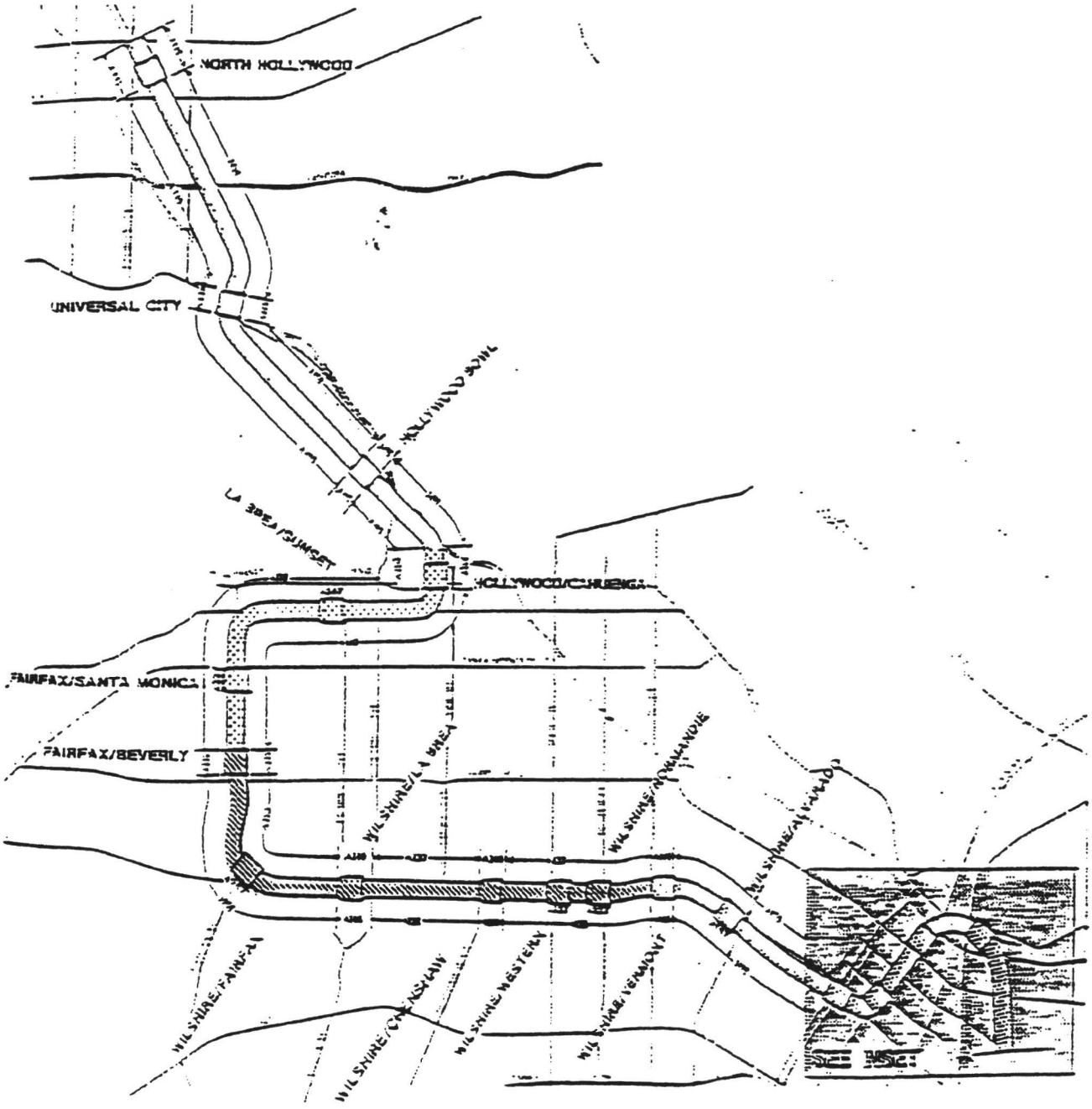

Figure 4 1985 Westside Corridor

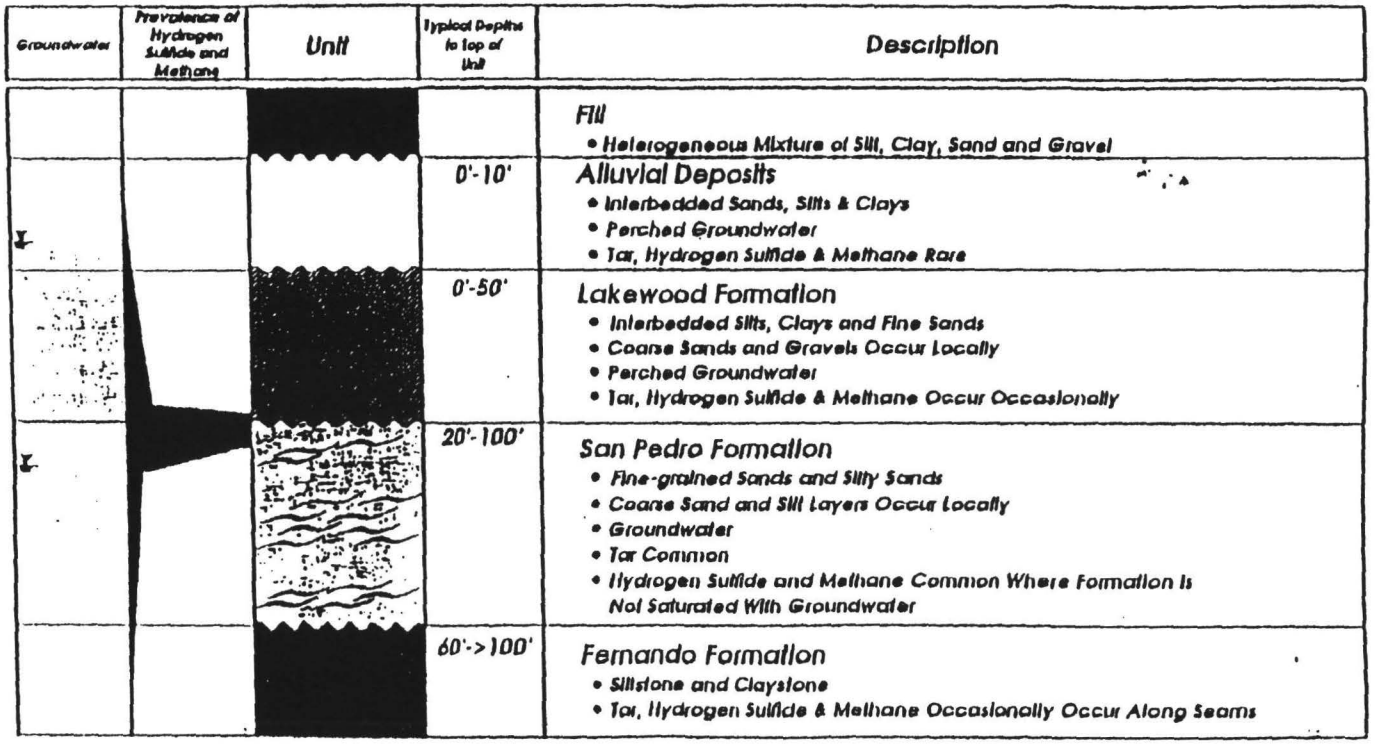

Figure 5 Generalized Stratigraphy along Mid-City Alternative Corridors