WESTSIDE SUBWAY EXTENSION

Construction and Mitigation Technical Report

Metro

August 2010

Table of Contents

List of Tables

List of Figures

1.0 INTRODUCTION

This Final Construction and Mitigation Technical Report describes the construction scenarios and techniques expected to be used for the Westside Subway Extension Project and their potential impacts. This description of construction is based on information known to date about construction of the proposed Project. Construction specifics are rarely known before design. For purposes of the Draft Environmental Impact Statement/Environmental Impact Report (DEIS/EIR), potential impact is analyzed using a reasonable worst-case approach to describe the potential impacts. For example, several possible construction staging areas may be analyzed, even though not all of them would be used. Analyzing potential "maximum impact," also allows the environmental process to identify potential constraints and mitigation.

In general, it is anticipated that tunneling of the subway will be performed with pressurized-face tunnel boring machines (TBMs) and the stations will be excavated using cut-and-cover techniques. Several construction sequences are under consideration, and many possibilities for tunneling strategies are described and evaluated. The most advantageous approaches will likely develop as the alignments, crossover locations, alternative station locations, and availability of long-term construction staging areas become defined better in future stages of this project.

Various types of contractor work and storage areas will be necessary for construction of the various elements of the project, such as tunnels, station box excavations, station entrances, crossover boxes, pocket tracks, mid-line concrete pour locations, traction power substation (TPSS) locations, and ventilation shaft locations. However, the most off-street space is needed for entry areas from which mining operations and the insertion/extraction of TBMs would be conducted. This includes the handling of precast-concrete tunnel segment (lining) supply, spoil removal, tunnel water supply and wastewater removal, power supply and other tunnel utilities. The characteristics of these work and storage areas that are important for consideration in the DEIS/EIR are summarized in this report as they are identified at this time.

This report summarizes the potential impacts associated with the construction of the Westside Subway Extension Project. The impacts addressed in this section would occur only during the construction period and would therefore be temporary and relatively short-term. The impacts discussed include construction scenarios based on typical and anticipated subway construction techniques, equipment and timing, and the anticipated construction staging areas that would be used by the construction contractors. The construction scenarios are used to evaluate construction impacts and to identify/propose mitigation measures.

Section 2.0 of this report provides a summary of the project description. Section 3.0 summarizes the federal, state, and local environmental regulations and guidelines pertinent to construction of the proposed project. Section 4.0 describes construction methods, techniques, and equipment anticipated to be used for the Westside Subway Extension, based on Metro's extensive subway construction experience. Sections 5.0 through 8.0 describe the affected environment, environmental consequences of construction and potential mitigation that would lessen business disruption and impacts to traffic, parking and transit, air quality, noise and vibration, and utilities.

2.0 PROJECT DESCRIPTION

This chapter describes the alternatives that have been considered to best satisfy the Purpose and Need and have been carried forward for further study in the Draft Environmental Impact Statement/Environmental Impact Report (EIS/EIR). Details of the No Build, Transportation Systems Management (TSM), and the five Build Alternatives (including their station and alignment options and phasing options (or minimum operable segments [MOS]) are presented in this chapter.

2.1 No Build Alternative

The No Build Alternative provides a comparison of what future conditions would be like if the Project were not built. The No Build Alternative includes all existing highway and transit services and facilities, and the committed highway and transit projects in the Los Angeles County Metropolitan Transportation Authority (Metro) Long Range Transportation Plan (LRTP) and the Southern California Association of Governments (SCAG) Regional Transportation Plan (RTP). Under the No Build Alternative, no new transportation infrastructure would be built within the Study Area, aside from projects currently under construction or projects funded for construction, environmentally cleared, planned to be in operation by 2035, and identified in the adopted Metro LRTP.

2.2 TSM Alternative

The TSM Alternative emphasizes more frequent bus service than the No Build Alternative to reduce delay and enhance mobility. The TSM Alternative contains all elements of the highway, transit, Metro Rail, and bus service described under the No Build Alternative. In addition, the TSM Alternative increases the frequency of service for Metro Bus Line 720 (Santa Monica–Commerce via Wilshire Boulevard and Whittier Boulevard) to between three and four minutes during the peak period.

In the TSM Alternative, Metro Purple Line rail service to the Wilshire/Western Station would operate in each direction at 10-minute headways during peak and off-peak periods. The Metro Red Line service to Hollywood/Highland Station would operate in each direction at five-minute headways during peak periods and at 10-minute headways during midday and off-peak periods.

2.3 Build Alternatives

The Build Alternatives are considered to be the "base" alternatives with "base" stations. Alignment (or segment) and station options were developed in response to public comment, design refinement, and to avoid and minimize impacts to the environment.

The Build Alternatives extend heavy rail transit (HRT) service in subway from the existing Metro Purple Line Wilshire/Western Station. HRT systems provide high speed (maximum of 70 mph), high capacity (high passenger-carrying capacity of up to 1,000 passengers per train and multiple unit trains with up to six cars per train), and reliable service since they operate in an exclusive grade-separated right-of-way. The subway will operate in a tunnel at least 30 to 70 feet below ground and will be electric powered.

Furthermore, the Build Alternatives include changes to the future bus services. Metro Bus Line 920 would be eliminated and a portion of Line 20 in the City of Santa Monica would be eliminated since it would be duplicated by the Santa Monica Blue Bus Line 2. Metro Rapid Bus Line 720 would operate less frequently since its service route would be largely duplicated by the Westside Subway route. In the City of Los Angeles, headways (time between buses) for Line 720 are between 3 and 5 minutes under the existing network and will be between 5 and 11.5 minutes under the Build Alternatives, but no change in Line 720 would occur in the City of Santa Monica segment. Service frequencies on other Metro Rail lines and bus routes in the corridor would be the same as for the No Build Alternative.

2.3.1 Alternative 1 – Westwood/UCLA Extension

This alternative extends the existing Metro Purple Line from the Wilshire/Western Station to a Westwood/UCLA Station (Figure 2-1). From the Wilshire/Western Station, Alternative 1 travels westerly beneath Wilshire Boulevard to the Wilshire/Rodeo Station and then southwesterly toward a Century City Station. Alternative 1 then extends from Century City and terminates at a Westwood/UCLA Station. The alignment is approximately 8.60 miles in length.

Alternative 1 would operate in each direction at 3.3-minute headways during morning and evening peak periods and at 10-minute headways during midday. The estimated one-way running time is 12 minutes 39 seconds from the Wilshire/Western Station.

2.3.2 Alternative 2 – Westwood/Veterans Administration (VA) Hospital Extension

This alternative extends the existing Metro Purple Line from the Wilshire/Western Station to a Westwood/VA Hospital Station (Figure 2-2). Similar to Alternative 1, Alternative 2 extends the subway from the Wilshire/Western Station to a Westwood/UCLA Station. Alternative 2 then travels westerly under Veteran Avenue and continues west under the I-405 Freeway, terminating at a Westwood/VA Hospital Station. This alignment is 8.96 miles in length from the Wilshire/Western Station.

Alternative 2 would operate in each direction at 3.3-minute headways during the morning and evening peak periods and at 10-minute headways during the midday, off-peak period. The estimated one-way running time is 13 minutes 53 seconds from the Wilshire/Western Station.

2.3.3 Alternative 3 – Santa Monica Extension

This alternative extends the existing Metro Purple Line from the Wilshire/Western Station to the Wilshire/4th Station in Santa Monica (Figure 2-3). Similar to Alternative 2, Alternative 3 extends the subway from the Wilshire/Western Station to a Westwood/VA Hospital Station. Alternative 3 then continues westerly under Wilshire Boulevard and terminates at the Wilshire/4th Street Station between 4th and 5th Streets in Santa Monica. The alignment is 12.38 miles.

Alternative 3 would operate in each direction at 3.3-minute headways during the morning and evening peak periods and operate with 10-minute headways during the midday, off-peak period. The estimated one-way running time is 19 minutes 27 seconds from the Wilshire/Western Station.

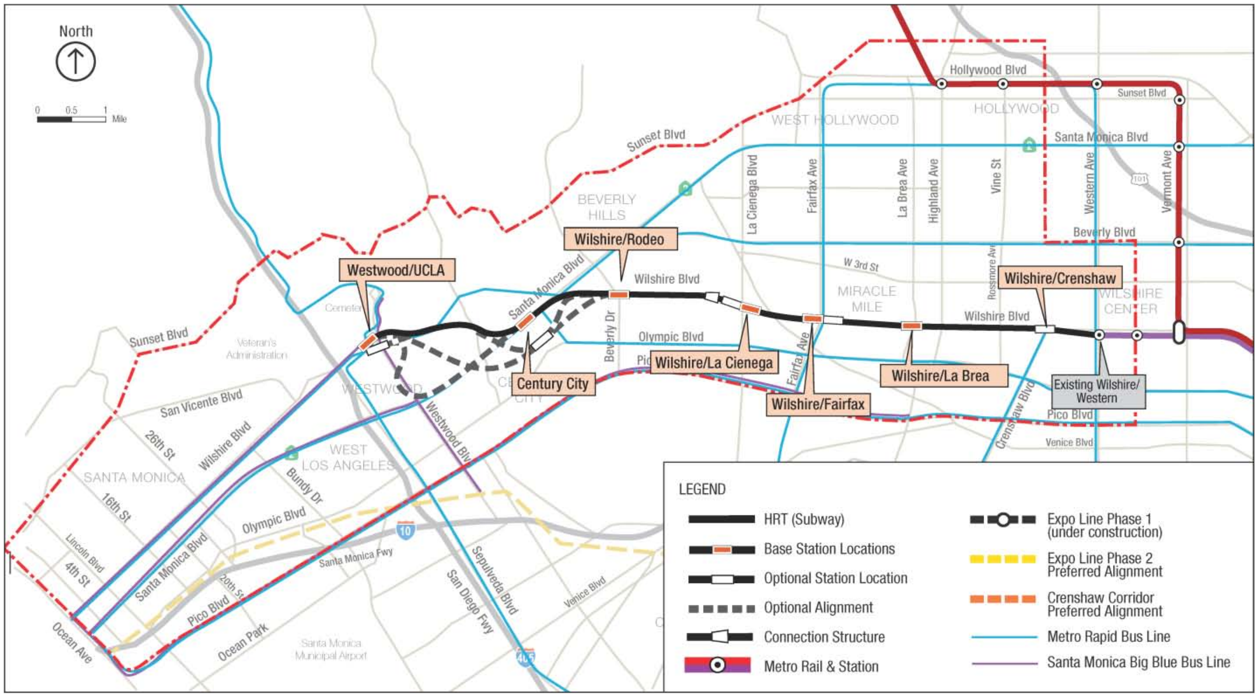


Figure 2-1. Alternative 1—Westwood/UCLA Extension

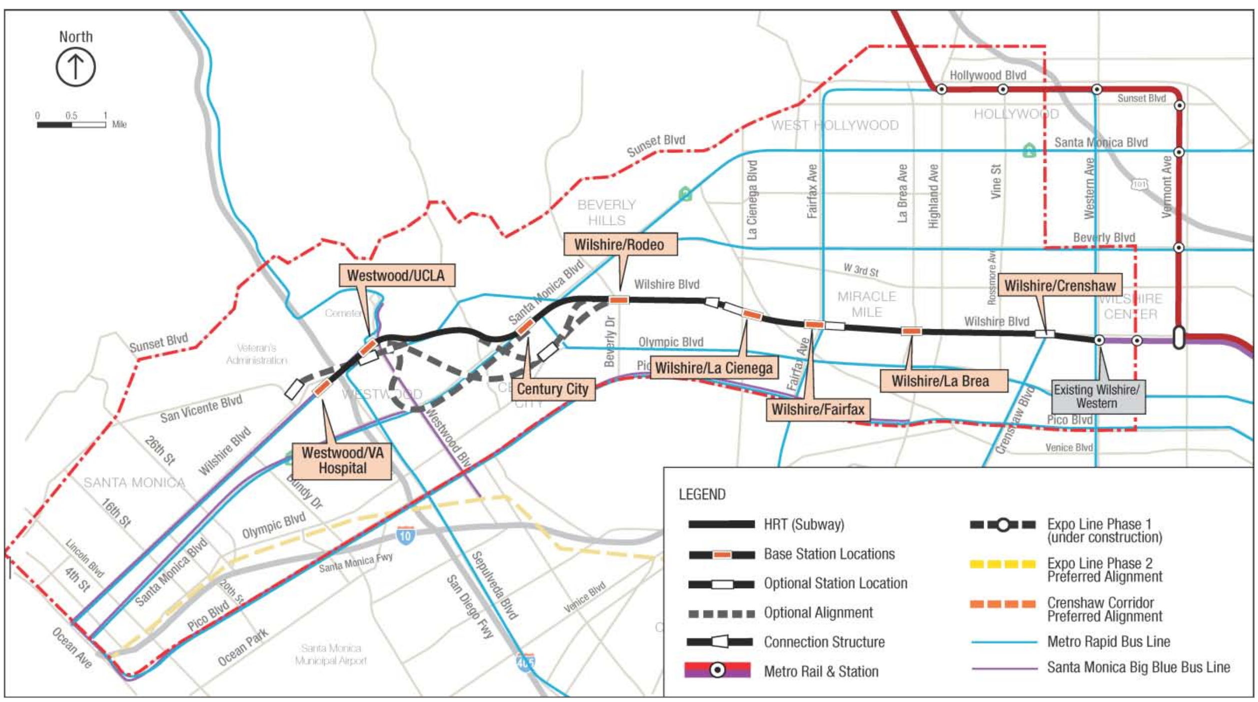


Figure 2-2: Alternative 2 – Westwood/Veterans Administration (VA) Hospital Extension

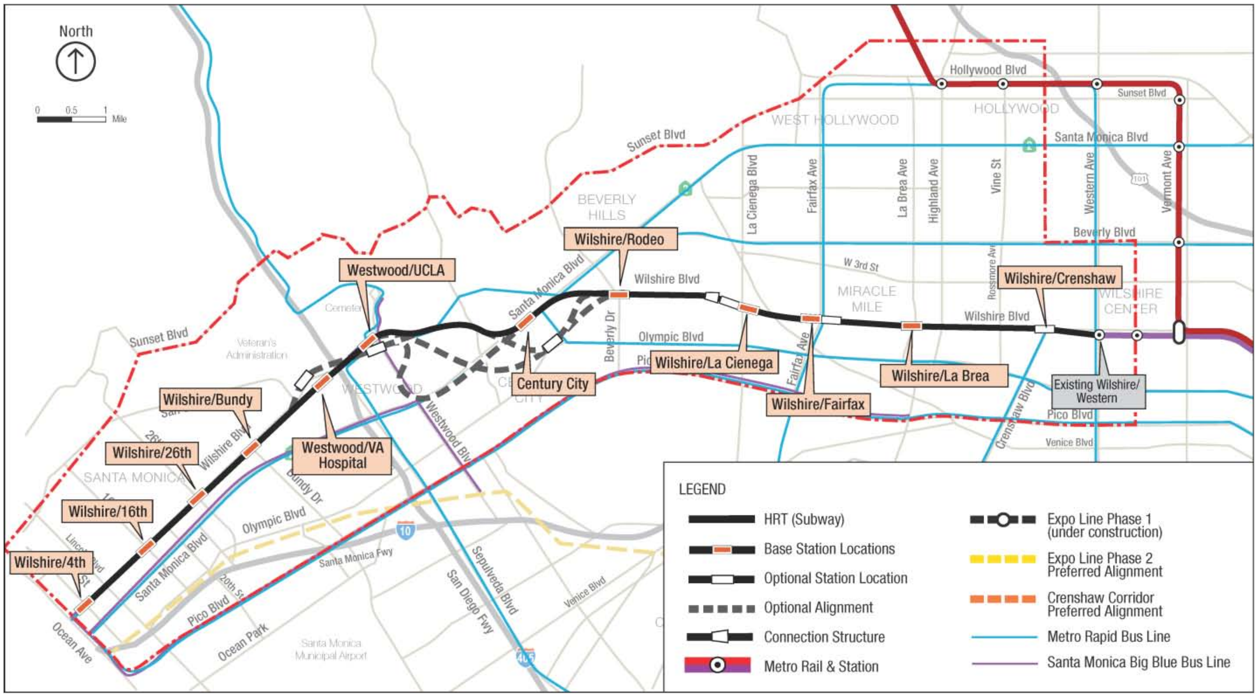


Figure 2-3: Alternative 3 – Santa Monica Extension

2.3.4 Alternative 4 – Westwood/VA Hospital Extension plus West Hollywood Extension

Similar to Alternative 2, Alternative 4 extends the existing Metro Purple Line from the Wilshire/Western Station to a Westwood/VA Hospital Station. Alternative 4 also includes a West Hollywood Extension that connects the existing Metro Red Line Hollywood/Highland Station to a track connection structure near Robertson and Wilshire Boulevards, west of the Wilshire/La Cienega Station (Figure 2-4). The alignment is 14.06 miles long.

Alternative 4 would operate from Wilshire/Western to a Westwood/VA Hospital Station in each direction at 3.3-minute headways during morning and evening peak periods and 10-minute headways during the midday off-peak period. The West Hollywood extension would operate at 5-minute headways during peak periods and 10-minute headways during the midday, off-peak period. The estimated one-way running time for the Metro Purple Line extension is 13 minutes 53 seconds, and the running time for the West Hollywood from Hollywood/Highland to Westwood/VA Hospital is 17 minutes and 2 seconds.

2.3.5 Alternative 5 – Santa Monica Extension plus West Hollywood Extension

Similar to Alternative 3, Alternative 5 extends the existing Metro Purple Line from the Wilshire/Western Station to the Wilshire/4th Station and also adds a West Hollywood Extension similar to the extension described in Alternative 4 (Figure 2-5). The alignment is 17.49 miles in length. Alternative 5 would operate the Metro Purple Line extension in each direction at 3.3-minute headways during the morning and evening peak periods and 10-minute headways during the midday, off-peak period. The West Hollywood extension would operate in each direction at 5-minute headways during peak periods and 10-minute headways during the midday, off-peak period. The estimated one-way running time for the

Metro Purple Line extension is 19 minutes 27 seconds, and the running time from the Hollywood/Highland Station to the Wilshire/4th Station is 22 minutes 36 seconds.

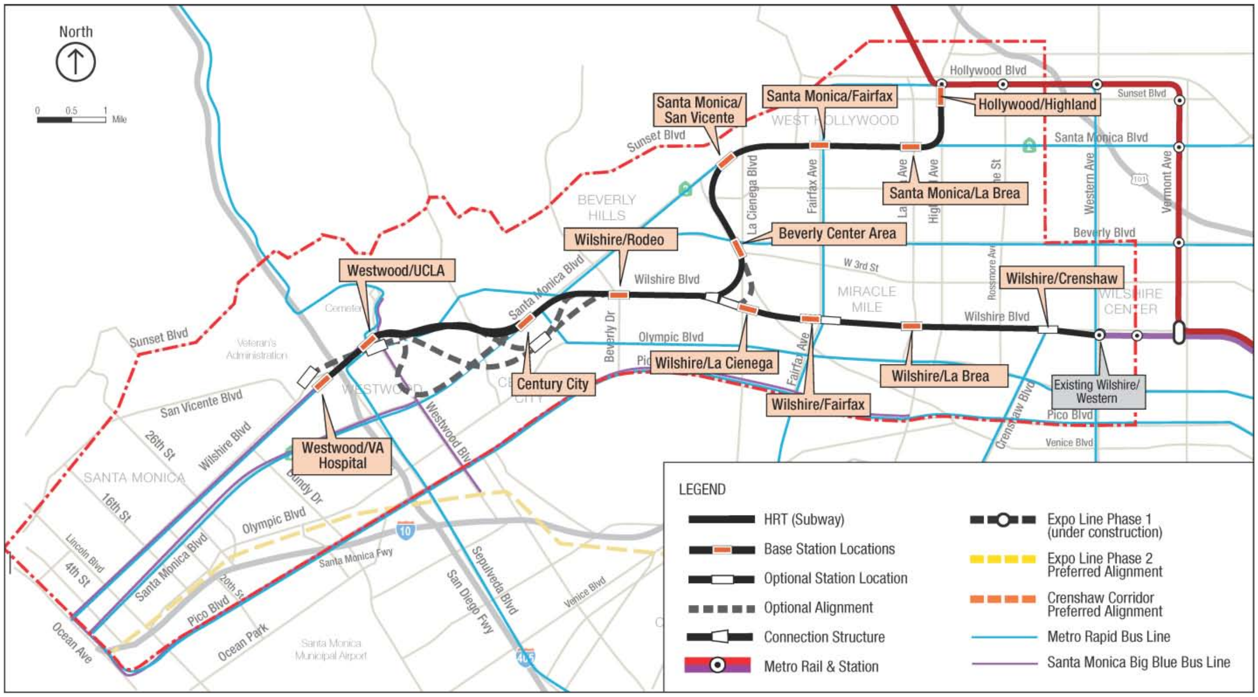


Figure 2-4: Alternative 4 – Westwood/VA Hospital Extension plus West Hollywood Extension

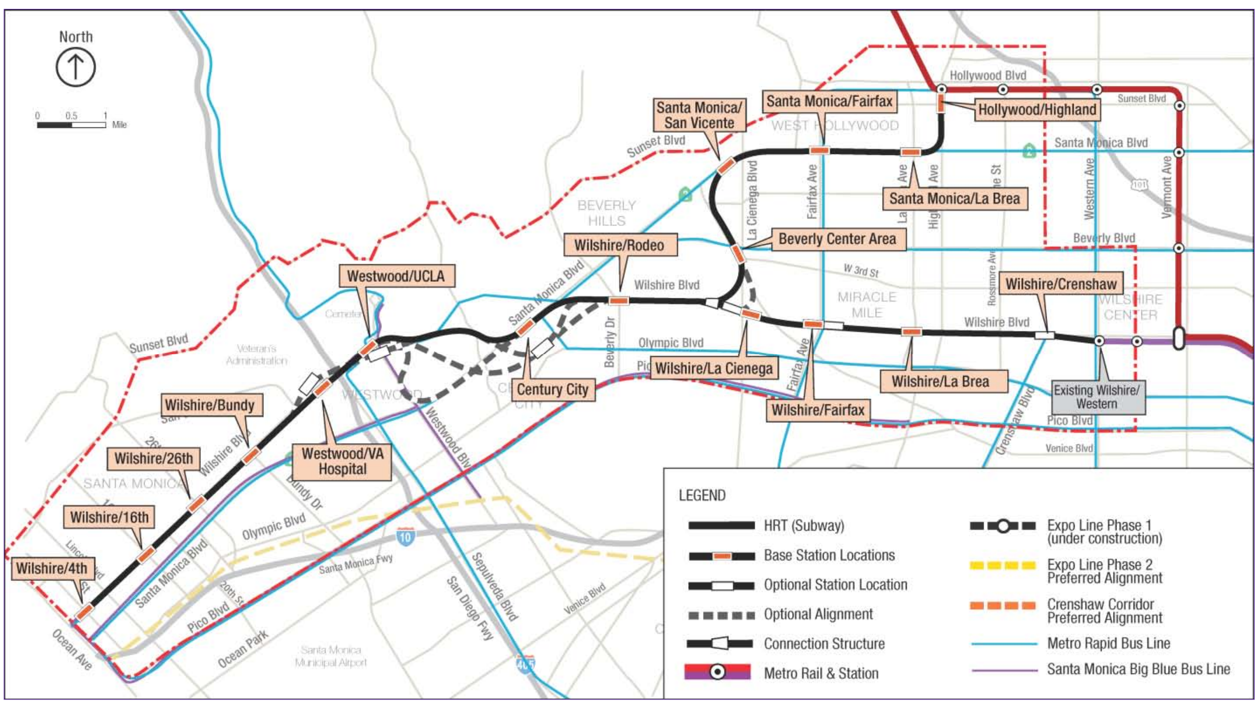


Figure 2-5: Alternative 5 – Santa Monica Extension plus West Hollywood Extension

2.4 Stations and Segment Options

HRT stations consist of a station "box," or area in which the basic components are located. The station box can be accessed from street-level entrances by stairs, escalators, and elevators that would bring patrons to a mezzanine level where the ticketing functions are located. The 450-foot platforms are one level below the mezzanine level and allow level boarding (i.e., the train car floor is at the same level as the platform). Stations consist of a center or side platform. Each station is equipped with under-platform exhaust shafts, over-track exhaust shafts, blast relief shafts, and fresh air intakes. In most stations, it is anticipated that only one portal would be constructed as part of the Project, but additional portals could be developed as a part of station area development (by others). Stations and station entrances would comply with the *Americans with Disabilities Act of 1990*, Title 24 of the California Code of Regulations, the California Building Code, and the Department of Transportation Subpart C of Section 49 CFR Part 37.

Platforms would be well-lighted and include seating, trash receptacles, artwork, signage, safety and security equipment (closed-circuit television, public announcement system, passenger assistance telephones), and a transit passenger information system. The fare collection area includes ticket vending machines, fare gates, and map cases.

Table 2-1 lists the stations and station options evaluated and the alternatives to which they are applicable. Figure 2-6 shows the proposed station and alignment options. These include:

- Option 1—Wilshire/Crenshaw Station Option
- Option 2—Fairfax Station Option
- Option 3—La Cienega Station Option
- Option 4—Century City Station and Alignment Options
- Option 5—Westwood/UCLA Station Option
- Option 6—Westwood/VA Hospital Station Option

Table 2-1: Alternatives and Stations Considered

Stations	Alternatives 1 Westwood/ UCLA Extension	2 Westwood/ VA Hospital Extension	3 Santa Monica Extension	4 Westwood/ VA Hospital Extension Plus West Hollywood Extension	5 Santa Monica Extension Plus West Hollywood Extension
Base Stations					
Wilshire/Crenshaw	●	●	●	●	●
Wilshire/La Brea	●	●	●	●	●
Wilshire/Fairfax	●	●	●	●	●
Wilshire/La Cienega	●	●	●	●	●
Wilshire/Rodeo	●	●	●	●	●
Century City (Santa Monica Blvd)	●	●	●	●	●
Westwood/UCLA (Off-street)	●	●	●	●	●
Westwood/VA Hospital		●	●	●	●
Wilshire/Bundy			●		●
Wilshire/26th			●		●
Wilshire/16th			●		●
Wilshire/4th			●		●
Hollywood/Highland				●	●
Santa Monica/La Brea				●	●
Santa Monica/Fairfax				●	●
Santa Monica/San Vicente				●	●
Beverly Center Area				●	●
Station Options					
1—No Wilshire/Crenshaw	●	●	●	●	●
2—Wilshire/Fairfax East	●	●	●	●	●
3—Wilshire/La Cienega (Transfer Station)	●	●	●	●	●
4—Century City (Constellation Blvd)	●	●	●	●	●
5—Westwood/UCLA (On-street)	●	●	●	●	●
6—Westwood/VA Hospital North		●	●	●	●

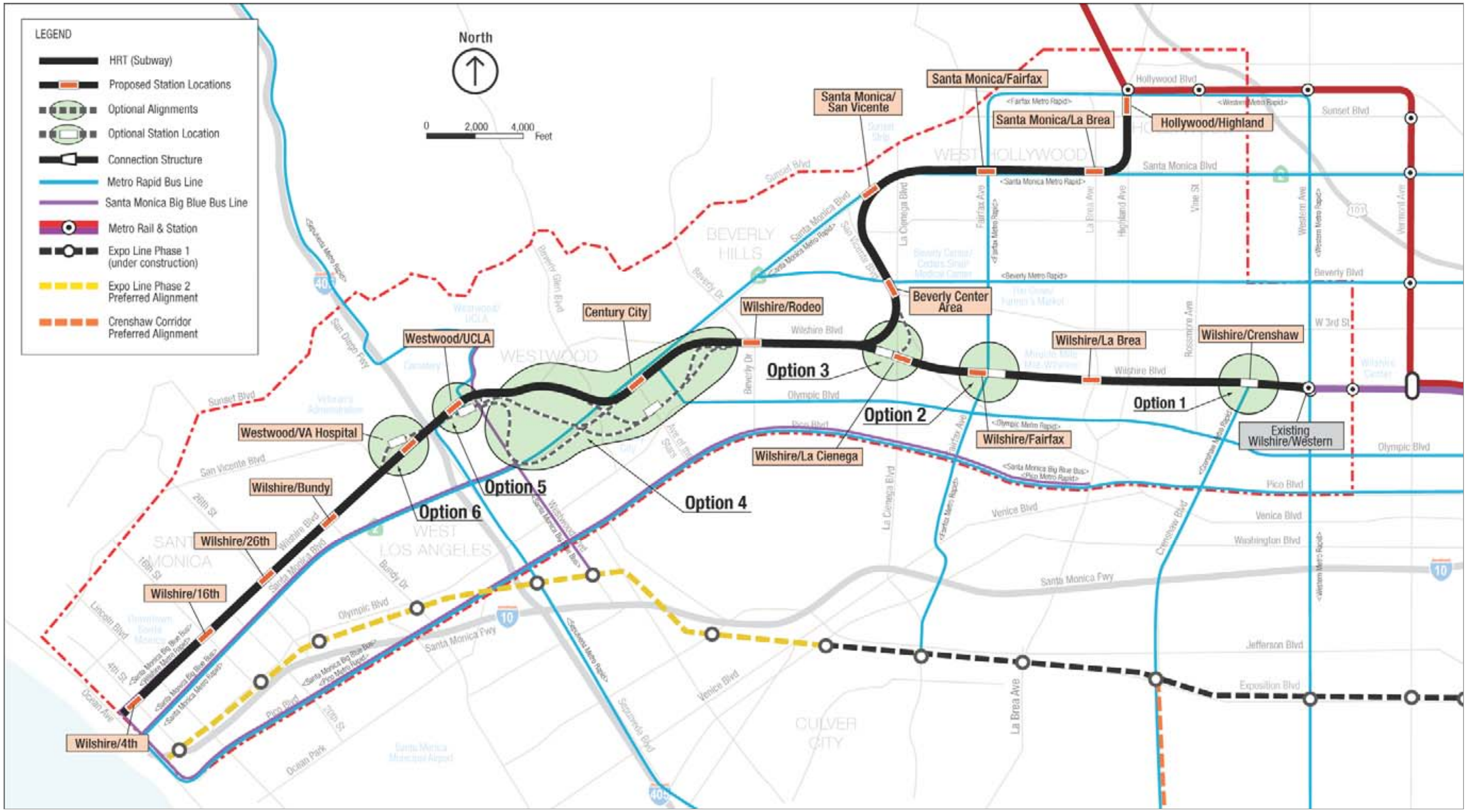


Figure 2-6: Station and Alignment Options

2.4.1 Option 1 – Wilshire/Crenshaw Station Option

- **Base Station: Wilshire/Crenshaw Station**—The base station straddles Crenshaw Boulevard, between Bronson Avenue and Lorraine Boulevard.
- **Station Option: Remove Wilshire/Crenshaw Station**—This station option would delete the Wilshire/Crenshaw Station. Trains would run from the Wilshire/Western Station to the Wilshire/La Brea Station without stopping at Crenshaw. A vent shaft would be constructed at the intersection of Western Avenue and Wilshire Boulevard (Figure 2-7).

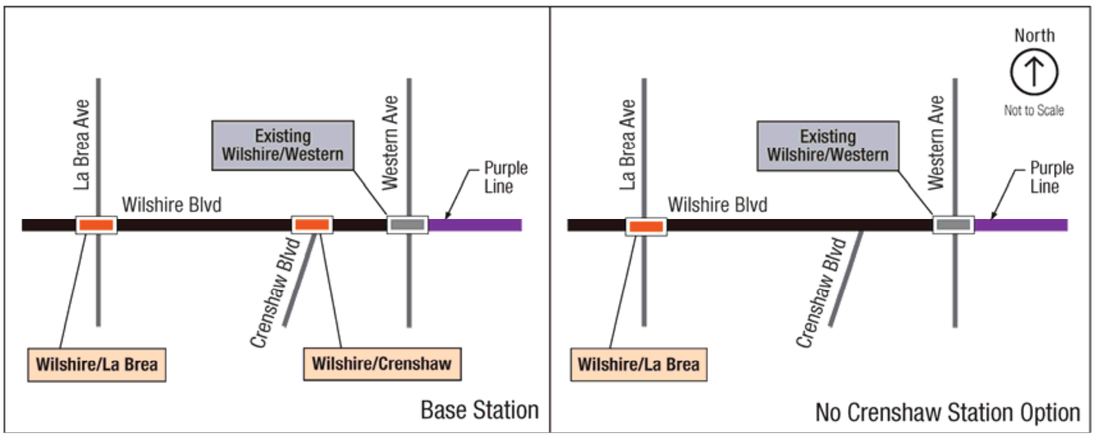


Figure 2-7: Option 1—No Wilshire/Crenshaw Station Option

2.4.2 Option 2 – Wilshire/Fairfax Station East Option

- **Base Station: Wilshire/Fairfax Station**—The base station is under the center of Wilshire Boulevard, immediately west of Fairfax Avenue.
- **Station Option: Wilshire/Fairfax Station East Station Option**—This station option would locate the Wilshire/Fairfax Station farther east, with the station underneath the Wilshire/Fairfax intersection (Figure 2-8). The east end of the station box would be east of Orange Grove Avenue in front of LACMA, and the west end would be west of Fairfax Avenue.

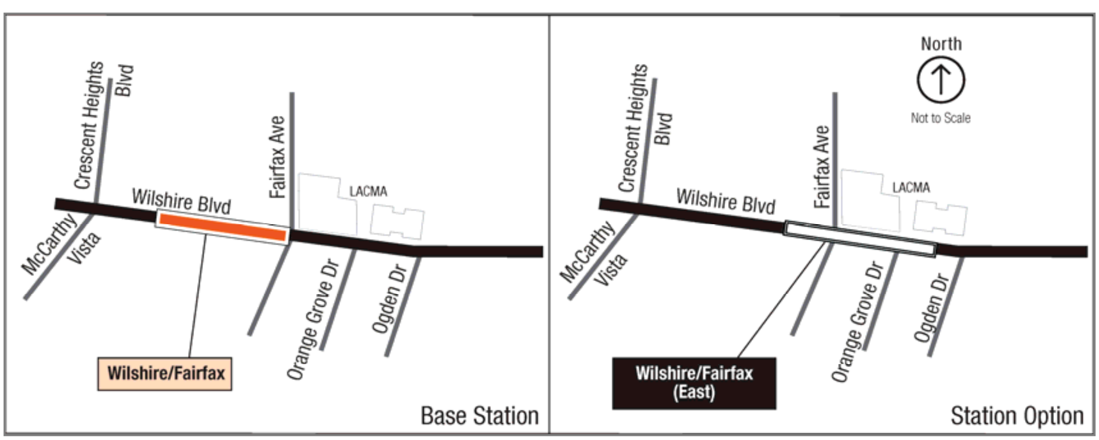


Figure 2-8: Option 2 – Fairfax Station Option

2.4.3 Option 3 – Wilshire/La Cienega Station Option

- **Base Station: Wilshire/La Cienega Station**—The base station would be under the center of Wilshire Boulevard, immediately east of La Cienega Boulevard. A direct transfer between the Metro Purple Line and the potential future West Hollywood Line is not provided with this station. Instead, a connection structure is proposed west of Robertson Boulevard as a means to provide a future HRT connection to the West Hollywood Line.
- **Station Option: Wilshire/La Cienega Station West with Connection Structure**—The station option would be located west of La Cienega Boulevard, with the station box extending from the Wilshire/Le Doux Road intersection to just west of the Wilshire/ Carson Road intersection (Figure 2-9). It also contains an alignment option that would provide an alternate HRT connection to the future West Hollywood Extension. This alignment portion of Option 3 is only applicable to Alternatives 4 and 5.

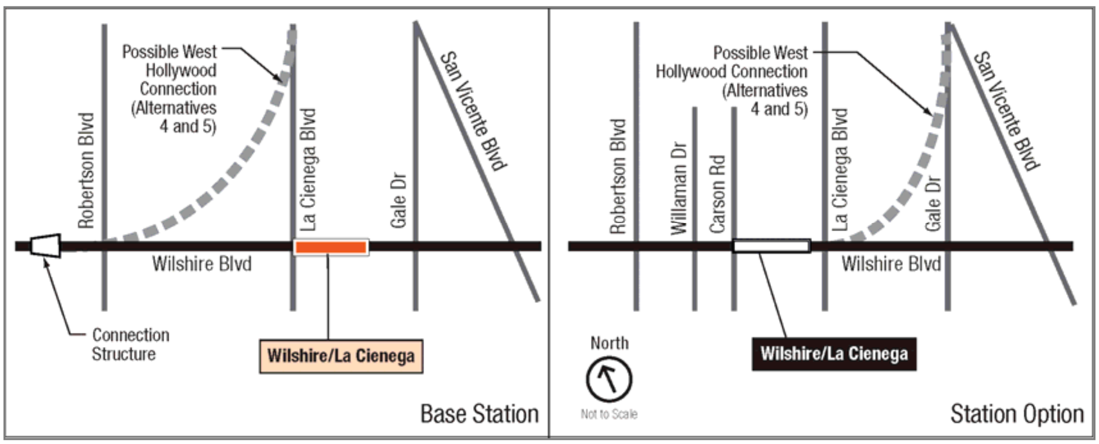


Figure 2-9: Option 3—La Cienega Station Option

2.4.4 Option 4 – Century City Station and Segment Options

2.4.4.1 Century City Station and Beverly Hills to Century City Segment Options

- **Base Station: Century City (Santa Monica) Station**—The base station would be under Santa Monica Boulevard, centered on Avenue of the Stars.
- **Station Option: Century City (Constellation) Station**—With Option 4, the Century City Station has a location option on Constellation Boulevard (Figure 2-10), straddling Avenue of the Stars and extending westward to east of MGM Drive.
- **Segment Options**: Two route options are proposed to connect the Wilshire/Rodeo Station to Century City (Constellation) Station: Constellation North and Constellation South. As shown in Figure 2-10, the base segment to the base Century City (Santa Monica) Station is shown in the solid black line and the segment options to Century City (Constellation) Station are shown in the dashed grey lines.

2.4.4.2 Century City to Westwood Segment Options

Three route options considered for connecting the Century City and Westwood stations include: East, Central, and West. As shown in Figure 2-10, each of these three segments would be accessed from both Century City Stations and both Westwood/UCLA Stations. The base segment is shown in the solid black line and the options are shown in the dashed grey lines.

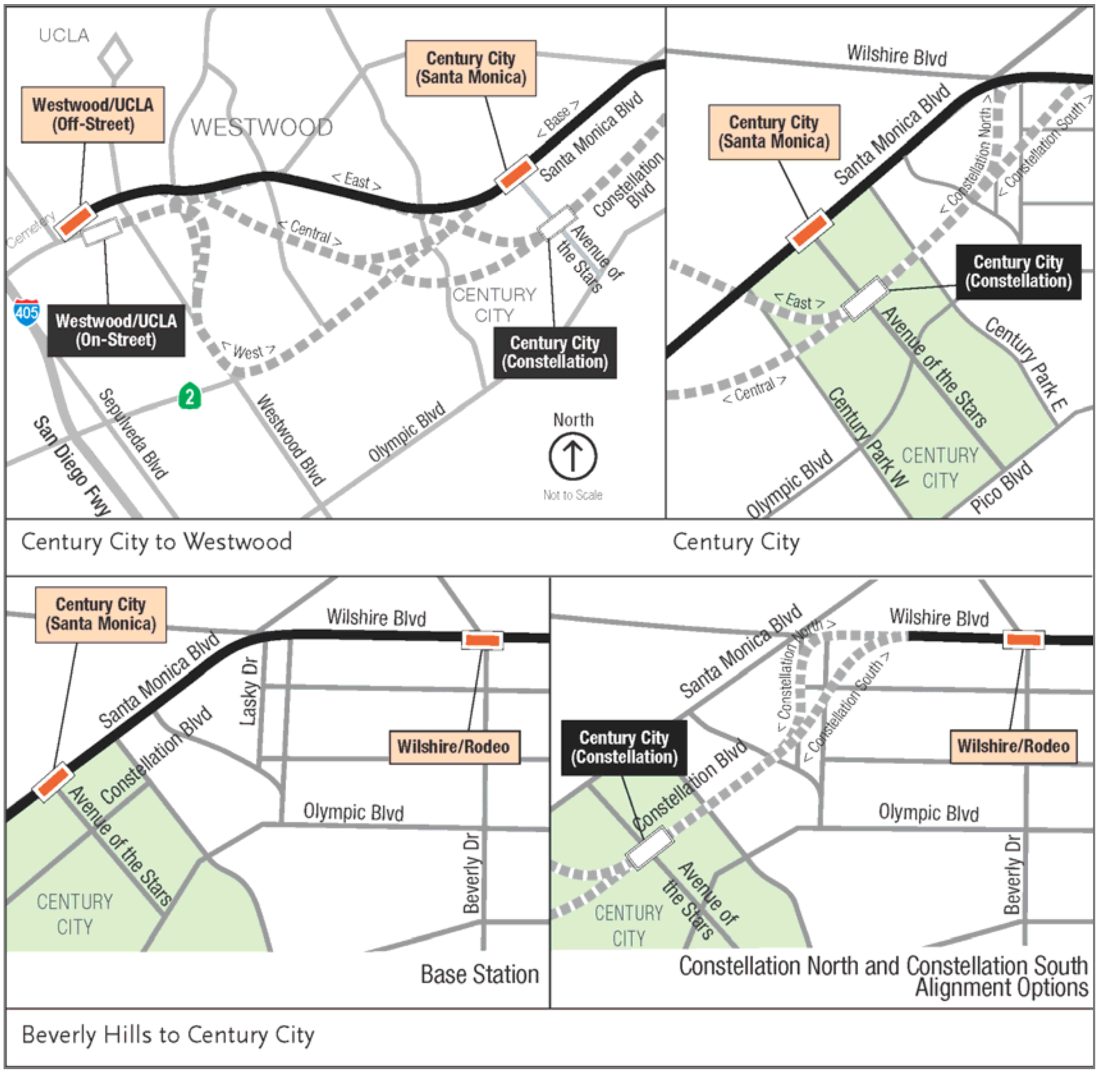


Figure 2-10: Century City Station Options

2.4.5 Option 5 – Westwood/UCLA Station Options

- **Base Station: Westwood/UCLA Station Off-Street Station Option**—The base station is located under the UCLA Lot 36 on the north side of Wilshire Boulevard between Gayley and Veteran Avenues.
- **Station Option: Westwood/UCLA On-Street Station Option**—This station option would be located under the center of Wilshire Boulevard, immediately west of Westwood Boulevard (Figure 2-11).

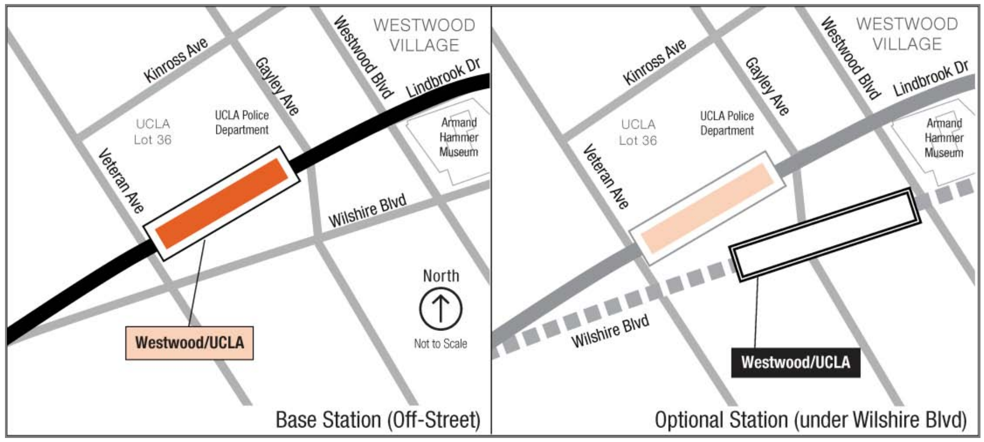


Figure 2-11: Option 5 – Westwood/UCLA Station Options

2.4.6 Option 6 – Westwood/VA Hospital Station Option

- **Base Station: Westwood/VA Hospital**—The base station would be below the VA Hospital parking lot on the south side of Wilshire Boulevard in between the I-405 exit ramp and Bonsall Avenue.
- **Station Option: Westwood/VA Hospital North Station**—This station option would locate the Westwood/VA Hospital Station on the north side of Wilshire Boulevard between Bonsall Avenue and Wadsworth Theater. (Shown in Figure 2-12)

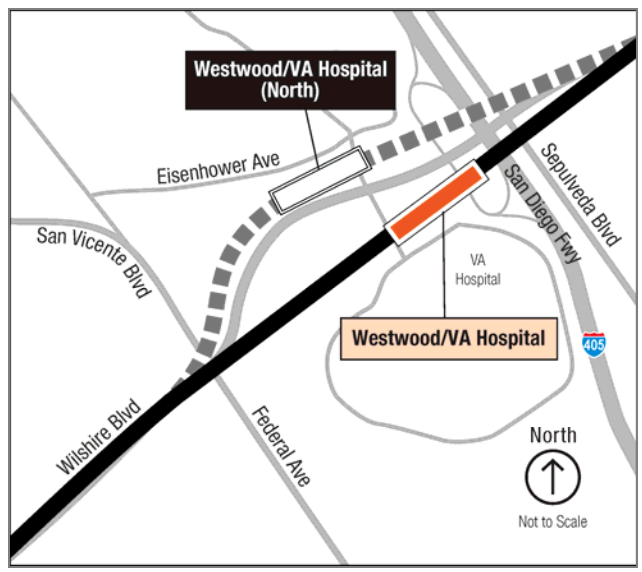


Figure 2-12: Option 6—Westwood/VA Hospital Station North

To access the Westwood/VA Hospital Station North, the alignment would extend westerly from the Westwood/UCLA Station under Veteran Avenue, the Federal Building property, the I-405 Freeway, and under the Veterans Administration property just east of Bonsall Avenue.

2.5 Base Stations

The remaining stations (those without options) are described below.

- **Wilshire/La Brea Station**—This station would be located between La Brea and Cloverdale Avenues.
- **Wilshire/Rodeo Station**—This station would be under the center of Wilshire Boulevard, beginning just west of South Canon Drive and extending to El Camino Drive.

- **Wilshire/Bundy Station**—This station would be under Wilshire Boulevard, east of Bundy Drive, extending just east of Saltair Avenue.
- **Wilshire/26th Station**—This station would be under Wilshire Boulevard, with the eastern end east of 26th Street and the western end west of 25th Street, midway between 25th Street and Chelsea Avenue.
- **Wilshire/16th Station**—This station would be under Wilshire Boulevard with the eastern end just west of 16th Street and the western end west of 15th Street.
- **Wilshire/4th Station**—This station would be under Wilshire Boulevard and 4th Street in Santa Monica.
- **Hollywood/Highland Station**—This station would be located under Highland Avenue and would provide a transfer option to the existing Metro Red Line Hollywood/Highland Station under Hollywood Boulevard.
- **Santa Monica/La Brea Station**—This station would be under Santa Monica Boulevard, just west of La Brea Avenue, and would extend westward to the center of the Santa Monica Boulevard/Formosa Avenue.
- **Santa Monica/Fairfax Station**—This station is under Santa Monica Boulevard and would extend from just east of Fairfax Avenue to just east of Ogden Drive.
- **Santa Monica/San Vicente Station**—This station would be under Santa Monica Boulevard and would extend from just west of Hancock Avenue on the west to just east of Westmount Drive on the east.
- **Beverly Center Area Station**—This station would be under San Vicente Boulevard, extending from just south of Gracie Allen Drive to south of 3rd Street.

2.6 Other Components of the Build Alternatives

2.6.1 Traction Power Substations

Traction power substations (TPSS) are required to provide traction power for the HRT system. Substations would be located in the station box or in a box located with the crossover tracks and would be located in a room that is about 50 feet by 100 feet in a below grade structure.

2.6.2 Emergency Generators

Stations at which the emergency generators would be located are Wilshire/La Brea, Wilshire/La Cienega, Westwood/UCLA, Westwood/VA Hospital, Wilshire/26th, Highland/Hollywood, Santa Monica/La Brea, and Santa Monica/San Vicente. The emergency generators would require approximately 50 feet by 100 feet of property in an off-street location. All would require property acquisition, except for the one at the Wilshire/La Brea Station which uses Metro’s property.

2.6.3 Mid-Tunnel Vent Shaft

Each alternative would require mid-tunnel ventilation shafts. The vent shafts are emergency ventilation shafts with dampers, fans, and sound attenuators generally placed at both ends of a station box to exhaust smoke. In addition, emergency vent shafts could be used for station cooling and gas mitigation. The vent shafts are also required in tunnel segments with more than 6,000 feet between stations to meet fire/life safety requirements. There would be a connecting corridor between the two tunnels (one for each direction of train movement) to provide emergency egress and fire-fighting ingress. A vent shaft is approximately 150 square feet; with the opening of the shaft located in a sidewalk and covered with a grate about 200 square feet.

Table 2-2. Mid-Tunnel Vent Shaft Locations

Alternative/Option	Location
Alternatives 1 through 5, MOS 2	Part of the connection structure on Wilshire Boulevard, west of Robertson Boulevard
Alternatives 2 through 5	West of the Westwood/VA Hospital Station on Army Reserve property at Federal Avenue and Wilshire Boulevard
Option 4 via East route	At Wilshire Boulevard/Manning Avenue intersection
Option 4 to Westwood/UCLA Off-Street Station via Central route	On Santa Monica Boulevard just west of Beverly Glen Boulevard
Option 4 to Westwood/UCLA On-Street Station via Central route	At Santa Monica Boulevard/Beverly Glen Boulevard intersection
Options 4 via West route	At Santa Monica Boulevard/Glendon Avenue intersection
Options 4 from Constellation Station via Central route	On Santa Monica Boulevard between Thayer and Pandora Avenues
Option from Constellation Station via West route	On Santa Monica Boulevard just east of Glendon Avenue

2.6.4 Trackwork Options

Each Build Alternative requires special trackwork for operational efficiency and safety (Table 2-3):

- Tail tracks—a track, or tracks, that extends beyond a terminal station (the last station on a line)
- Pocket tracks—an additional track, or tracks, adjacent to the mainline tracks generally at terminal stations
- Crossovers—a pair of turnouts that connect two parallel rail tracks, allowing a train on one track to cross over to the other
- Double crossovers—when two sets of crossovers are installed with a diamond allowing trains to cross over to another track

Table 2-3. Special Trackwork Locations

Station	Alternative 1 Westwood/ UCLA Extension	Alternative 2 Westwood/ VA Hospital Extension	Alternative 3 Santa Monica Extension	Alternative 4 Westwood/VA Hospital Extension Plus West Hollywood Extension	Alternative 5 Santa Monica Extension Plus West Hollywood Extension
Special Trackwork Locations—Base Trackwork Alternatives					
Wilshire/Crenshaw	None	None	None	None	None
Wilshire/La Brea	Double Crossover	Double Crossover	Double Crossover	Double Crossover	Double Crossover
Wilshire/Fairfax	None *MOS 1 Only: Terminus Station with Tail tracks*	None *MOS 1 Only: Terminus Station with Tail tracks*	None *MOS 1 Only: Terminus Station with Tail tracks*	None *MOS 1 Only: Terminus Station with Tail tracks*	None *MOS 1 Only: Terminus Station with Tail tracks*
Wilshire/La Cienega	None	None	None	None	None
Station Option 3 - Wilshire/La Cienega West	Turnouts	Turnouts	Turnouts		
Wilshire/Robertson Connection Structure	Equilateral Turnouts—for future West Hollywood connection	Equilateral Turnouts—for future West Hollywood connection	Equilateral Turnouts—for future West Hollywood connection	Equilateral Turnouts	Equilateral Turnouts
Wilshire/Rodeo	None	None	None	None	None
Century City	Double Crossover *MOS 2 Only: Terminus Station with Double Crossover and tail tracks*	Double Crossover *MOS 2 Only: Terminus Station with Double Crossover and tail tracks*	Double Crossover *MOS 2 Only: Terminus Station with Double Crossover and tail tracks*	Double Crossover *MOS 2 Only: Terminus Station with Double Crossover and tail tracks*	Double Crossover *MOS 2 Only: Terminus Station with Double Crossover and tail tracks*
Westwood/UCLA	End Terminal with Double Crossover and tail tracks	Double Crossover	Double Crossover	Double Crossover	Double Crossover
Westwood/VA Hospital	N/A	End Terminal with Turnouts and tail tracks	Turnouts	End Terminal with Turnouts and tail tracks	Turnouts
Wilshire/Bundy	N/A	N/A	None	N/A	None
Wilshire/26th	N/A	N/A	None	N/A	None
Wilshire/16th	N/A	N/A	None	N/A	None
Wilshire/4th	N/A	N/A	End Terminal with Double Crossover. Pocket Track with Double Crossover, Equilateral Turnouts and tail tracks	N/A	End Terminal with Double Crossover, Pocket Track with Double Crossover, Equilateral Turnouts and tail tracks
Hollywood/ Highland	N/A	N/A	N/A	Double Crossover and tail tracks	Double Crossover and tail tracks
Santa Monica/La Brea	N/A	N/A	N/A	None	None
Santa Monica/Fairfax	N/A	N/A	N/A	None	None
Santa Monica/ San Vicente	N/A	N/A	N/A	Double Crossover	Double Crossover
Beverly Center	N/A	N/A	N/A	None	None
Additional Special Trackwork Location (Optional Trackwork)					
Wilshire/Fairfax	Double Crossover	Double Crossover	Double Crossover	Double Crossover	Double Crossover
Wilshire/La Cienega	Double Crossover	Double Crossover	Double Crossover	Double Crossover	Double Crossover
Wilshire/ Rodeo	Pocket Track	Pocket Track	Pocket Track	Pocket Track	Pocket Track
Wilshire/26th	N/A	N/A	Double Crossover	N/A	Double Crossover

2.6.5 Rail Operations Center

The existing Rail Operations Center (ROC), shown on Figure 2-13, located in Los Angeles near the intersection of Imperial Highway and the Metro Blue Line does not have sufficient room to accommodate the new transit corridors and line extensions in Metro's expansion program. The Build Alternatives assume an expanded ROC at this location.

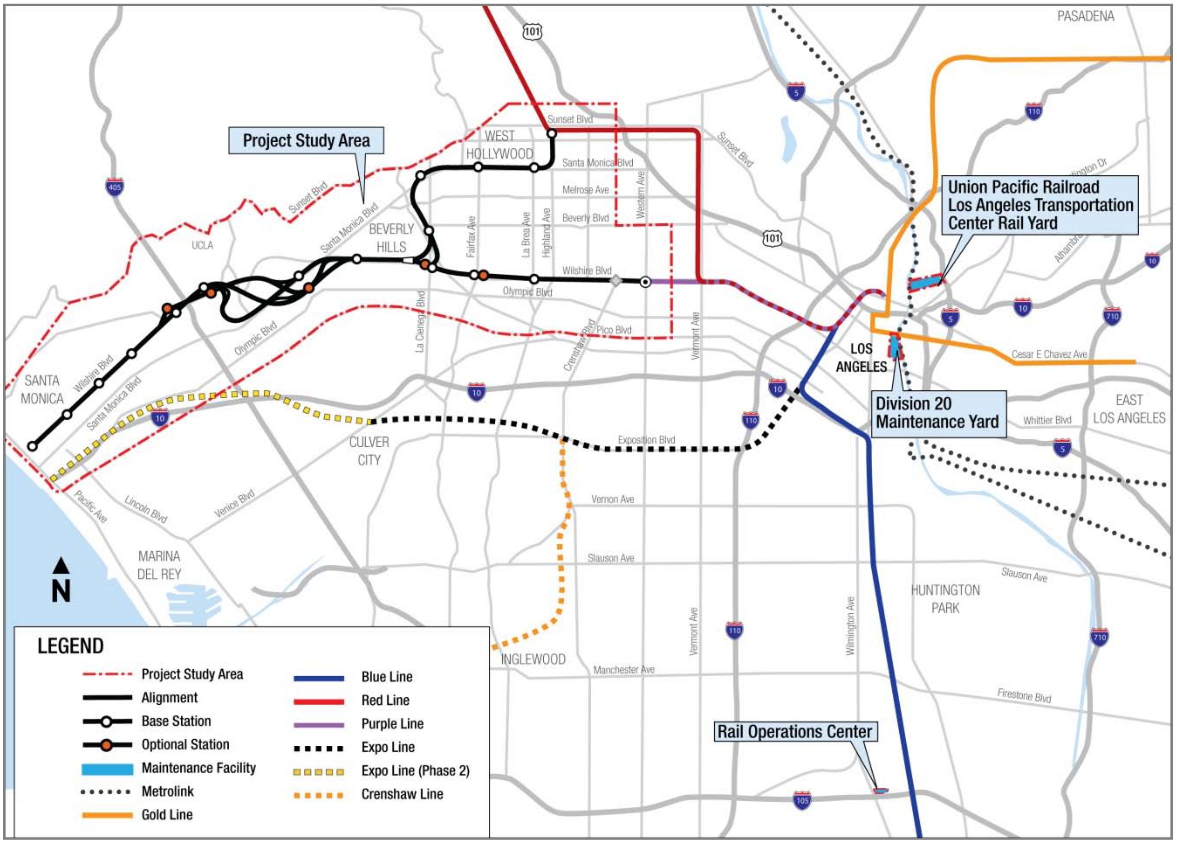


Figure 2-13: Location of the Rail Operations Center and Maintenance Yards

2.6.6 Maintenance Yards

If any of the Build Alternatives are chosen, additional storage capacity would be needed. Two options for providing this expanded capacity are as follows (Figure 2-14 and Figure 2-15):

- The first option requires purchasing 3.9 acres of vacant private property abutting the southern boundary of the Division 20 Maintenance and Storage Facility, which is located between the 4th and 6th Street Bridges. Additional maintenance and storage tracks would accommodate up to 102 vehicles, sufficient for Alternatives 1 and 2.
- The second option is a satellite facility at the Union Pacific (UP) Los Angeles Transportation Center Rail Yard. This site would be sufficient to accommodate the vehicle fleet for all five Build Alternatives. An additional 1.3 miles of yard lead tracks from the Division 20 Maintenance and Storage Facility and a new bridge over the Los Angeles River would be constructed to reach this yard.

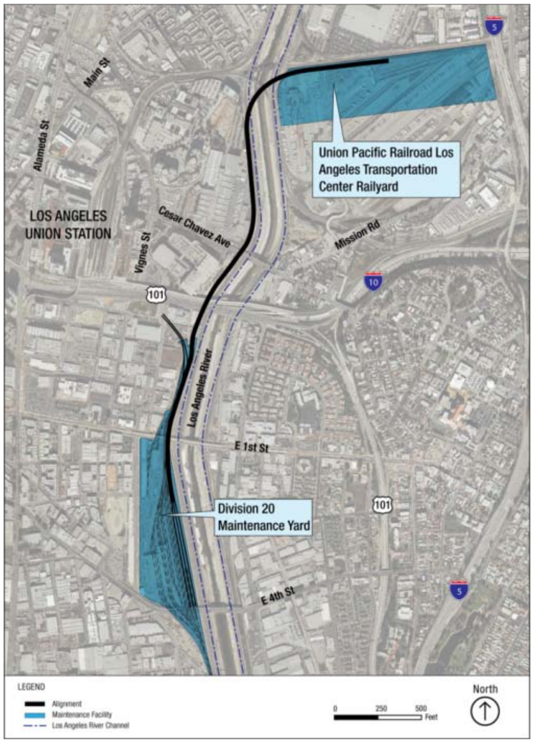


Figure 2-14: Maintenance Yard Options

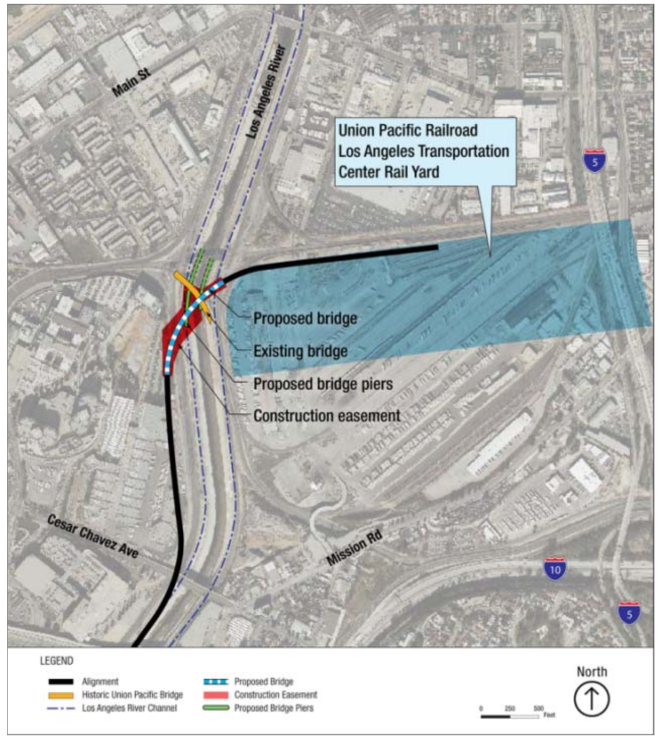


Figure 2-15: UP Railroad Rail Bridge

2.7 Minimum Operable Segments

Due to funding constraints, it may be necessary to construct the Westside Subway Extension in shorter segments. A Minimum Operable Segment (MOS) is a phasing option that could be applied to any of the Build Alternatives.

2.7.1 MOS 1 – Fairfax Extension

MOS 1 follows the same alignment as Alternative 1, but terminates at the Wilshire/Fairfax Station rather than extending to a Westwood/UCLA Station. A double crossover for MOS 1 is located on the west end of the Wilshire/La Brea Station box, west of Cloverdale Avenue. The alignment is 3.10 miles in length.

2.7.2 MOS 2 – Century City Extension

MOS 2 follows the same alignment as Alternative 1, but terminates at a Century City Station rather than extending to a Westwood/UCLA Station. The alignment is 6.61 miles from the Wilshire/Western Station.

3.0 REGULATORY SETTING

This section summarizes federal, state, and local environmental regulations and guidelines pertinent to construction of the proposed project.

3.1 Federal Regulations

Construction of the project would require compliance with the following federal regulations:

3.1.1 Transit Noise and Vibration Impact Assessment.

The Office of Planning and Environment in the Federal Transit Administration (FTA) has established guidelines to assess noise and vibration impacts from construction of proposed mass transit projects.[1]

- Federal Clean Air Act (42 USC 7401 et seq.)—The Clean Air Act (CAA), amended in 1990, is the comprehensive federal law that regulates air emissions from stationary and mobile sources, including construction equipment. The CAA authorizes the Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to protect public health and public welfare and to regulate emissions of hazardous air pollutants.[2]
- Federal Clean Air Act Conformity Requirement (42 USC 7506 Section 176(c))—The Federal Clean Air Act Conformity Requirement (42 USC 7507 Section 176(c)) sets limits by the federal government on financial assistance for, license or permit, approve, any activity that does not conform to approved implementation plan performed the lead agency.[3] Long term construction projects such as the proposed project may be affected by this requirement.
- National Ambient Air Quality Standards (NAAQS)—The Clean Air Act requires EPA to set the NAAQS for wide-spread pollutants with numerous and diverse sources considered to be harmful to public health and the environment. The EPA has promulgated NAAQS for six air pollutants: sulfur dioxide (SO_2), particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), and lead. The Act requires EPA to review the scientific data upon which the standards are based, and revise the standards, if necessary, every five years.[4] Effects of construction emissions on ambient air quality are evaluated using these standards.
- Clean Water Act—The United States Army Corps of Engineers (COE) under Section 404 of the Clean Water Act is responsible for a permit program for the discharges of dredged or fill material into waters of the U.S. The current plans for the Westside Subway Extension Corridor does not call for discharge of any dredged or fill material into the Los Angeles River or any other waters of the U.S.

---

[1] United States Department of Transportation Federal Transit Administration. 2006. Transit Noise and Vibration Impact Assessment (FTA-VA-90-1003-06) Chapter 12, Noise and Vibration During Construction: http://www.slocog.org/Library/PDF/Reports_Publications/4_Regional%20Trans%20Plan/5_References.pdf.
[2] United States Environmental Protection Agency Website: http://www.epa.gov/regulations/laws/caa.html.
[3] Cornell University Law School Website: http://www.law.cornell.edu/uscode/42/usc_sec_42_00007506----000-.html.
[4] United States Environmental Protection Agency Website: http://www.epa.gov/ttn/naaqs/.

- Federal Noise Control Act—The Noise Control Act of 1972 gives the U.S. Environmental Protection Agency (EPA) the authority to establish noise regulations to control major sources of noise, including transportation vehicles and construction equipment.[5]
- Resource Conservation and Recovery Act—The Resource Conservation and Recovery Act (RCRA) under Title 40, Protection of the Environment of the CFR, regulates hazardous wastes that may be encountered during construction activities. This statute provides for proper handling and disposal of any encountered hazardous materials.
- Toxics Substances Control Act—The Toxics Substances Control Act regulates handling of polychlorinated biphenyl wastes encountered during construction or demolition.
- Comprehensive Environmental Response, Compensation, and Liability Act—The Comprehensive Environmental Response, Compensation, and Liability Act regulates the handling and removal of underground storage tanks that may be encountered during construction.

3.2 State Regulations

Construction of the project would require compliance with the following state regulations, standards, and guidelines:

- California Clean Air Act—The California Clean Air Act, Chapter 1568, Statues of 1988; AB 2595 (1) established a legal mandate to achieve California's ambient air quality standards by the earliest practicable date; (2) prescribes a number of emission reduction strategies and requires annual progress in cleaning up the air; and (3) grants authority to the state's local air pollution control districts to adopt and enforce transportation control measures (TCMs).[6]
- California Ambient Air Quality Standards—California Ambient Air Quality Standards (CAAQS) define air quality standards and the maximum amount of pollutants that can be present in outdoor air without harm to public health. California law authorizes the California Air Resources Board (CARB) to set ambient (outdoor) air pollution standards (California Health & Safety Code Section 39606) in consideration of public health, safety, and welfare.[7]
- State Water Resources Control Board/Regional Water Quality Control Board—The State Water Resources Control Board, under Section 402 of the Clean Water Act, establishes a permitting system for the discharge of any pollutant (except for dredge or fill) into the waters of the United States. The permit is also called the National Pollution Discharge Elimination System (NPDES) permit. In California, the Regional Water Quality Control Board (RWQCB) oversees the permitting process. The jurisdiction of the RWQCB relative to the NPDES permits extends to "waters of the U.S." which is defined as: (1) navigable waters, (2) tributaries of navigable waters, and (3) wetlands. The project does not contain any potential impacts on the Los Angeles River or any other "waters of the U.S." resulting from construction activities (including discharge from dewatering activities related to structures or below ground rail construction).
- California Global Warming Solutions Act (AB 32)—The California Global Warming Solutions Act (AB 32), enacted in 2006, set the 2020 greenhouse gas emissions reduction

[5] United States Department of Transportation Federal Transit Administration: http://www.fhwa.dot.gov/environment/polguid.pdf.
[6] Chapter 1568, Statutes of 1988; AB 2595.
[7] California Environmental Protection Agency Air Resources Board Website: http://www.arb.ca.gov/research/aaqs/caaqs/caaqs.htm.

goal into law. It directed the California Air Resources Board (CARB) to begin developing discrete early actions to reduce greenhouse gases while also preparing a Scoping Plan to identify how best to reach the 2020 limit.[8]

- Senate Bill No. 375, Chapter 728 (SB 375)—California state law (Senate Bill No. 375 (SB 375) requires the CARB to set regional targets for the purpose of reducing greenhouse gas emissions from passenger vehicles, for 2020 and 2035. If regions developed integrated land use, housing and transportation plans that meet the SB 375 target, new projects in these regions can be relieved of certain review requirements of the California Environmental Quality Act (CEQA).[9]
- Governor's Executive Order S-13-08—Governor Executive Order S-13-08, enacted November 14, 2008, Executive Order S-13-08 enhances the state's management of climate impacts from sea level rise, increased temperatures, shifting precipitation and extreme weather events.[10]
- California Administrative Code, Title 24—California Administrative Code, Title 24, known as the California Building Standards Code or just "Title 24," contains the regulations that govern the construction of buildings in California.[11]
- Noise Element of the General Plan—The California Department of Health Services (CDHS) has studied the correlation of noise levels and their effects on various land uses and has established guidelines for evaluating the compatibility of various land uses as a function of community noise exposure. Section 65302(f) of the California Government Code requires each community to prepare and adopt a comprehensive long-range general plan for its physical development containing seven mandatory elements, including a noise element. The noise element must (1) identify and appraise noise problems in the community, (2) recognize Office of Noise Control guidelines, and (3) analyze and quantify current and projected noise levels, including noise from construction activities.
- California State CEQA Guidelines (CCR §§ 15000-15387)—The California State CEQA Guidelines (CCR §§ 15000-15387) are the regulations that explain and interpret the law for both public agencies required to administer CEQA and for the public agency. The guidelines further provide objectives, criteria and procedures for the overly evaluation of projects and preparation of environmental impact reports, negative declarations, and mitigated negative declarations by public agencies.[12]

3.3 Local Regulations

Construction of the project would require compliance with the following regional regulations and guidelines, well as city policies and ordinances:

- South Coast Air Quality Management District Guidelines and Criteria—SCAQMD reports to the CARB at the state level and is therefore responsible for reducing air pollution and attaining the State of CAAQS, and the NAAQS set forth by the EPA. SCAQMD provides guidelines (such as construction and operational criteria pollutant thresholds) used for determining the significance of air quality impacts from the

[8] California Environmental Protection Agency Air Resources Board Website: http://www.arb.ca.gov/cc/ab32/ab32.htm.
[9] California Environmental Protection Agency Air Resources Board Website: http://www.arb.ca.gov/cc/sb375/sb375.htm.
[10] California Climate Change Portal Website: http://www.climatechange.ca.gov/adaptation/.
[11] California Department of General Services Website: http://www.dsa.dgs.ca.gov/Code/title24.htm.
[12] California Environmental Resources Evaluation System Website: http://ceres.ca.gov/ceqa/.

implementation of a proposed project. Thresholds have been established by SCAQMD for six criteria pollutants: carbon monoxide (CO), reactive organic gases (ROG), nitrogen oxides (NO_X), sulfur dioxide (SO_2), coarse particulate matter (PM_{10}), and fine particulate matter ($PM_{2.5}$).[13]

Local jurisdiction General Plan Noise and Land Use policies and ordinances

- City of Los Angeles General Plan Framework.[14] This plan is used to determine compatibility of proposed construction activities.
  - **LU 3.15.1** Prepare detailed plans for land use and development of transit-oriented districts consistent with the provisions of the General Plan Framework Element and the Land Use/Transportation Policy.
  - **LU 3.15.2** Work with developers and Metropolitan Transportation Authority to incorporate public-and neighborhood-serving uses and services in structures located in proximity to transit stations, as appropriate.
  - **LU 3.15.3** Increase density generally within one quarter mile of transit stations, determining appropriate locations based on consideration of the surrounding land use characteristics to improve their viability as new transit routes and stations are funded in accordance with Policy.
  - **LU 3.15.6** Establish standards for the inclusion of bicycle and vehicular parking at and in the vicinity of transit stations; differentiating these to reflect the intended uses and character of the area in which they are located.

Applicable policies from the City of Los Angeles General Plan include policies from the Wilshire Community Plan and Westwood Community Plan.[15]

- Wilshire Community Plan:
  - **LU 12-1.1** Encourage non-related developments to provide employee incentives for using alternatives to the automobile (car pools, van pools, buses, shuttles, subways, bicycles, walking) and provide flexible work schedules.
  - **LU 15-1.3** Manage the supply of on-street parking to provide convenient parking for customers of commercial land uses and to encourage employees to park in off-street lots or garages or use alternate modes of transportation.
  - **N - Los Angeles Municipal Code Section 111 et seq.** Noise ordinance establishes sound measurement and criteria, minimum ambient noise levels for different land uses zoning classifications, sound emission levels for specific uses (radio, television sets, vehicle repairs and amplified equipment, etc.), hours of operation for certain uses (construction activity, rubbish collections, etc.), standards for determining noise deemed a disturbance of the peace, and legal remedies for violations. Its ambient noise standards are consistent with current state and federal noise standards.[16]
  - **N – 2.2** Enforce and/or implement applicable city, state, and federal regulations intended to mitigate proposed noise producing activities, reduce intrusive noise, and alleviate noise that is deemed a public nuisance.

[13] http://www.aqmd.gov/search/runsearch.asp.
[14] http://cityplanning.lacity.org/cwd/framwk/chapters/00/00.htm.
[15] http://cityplanning.lacity.org/complan/pdf/wilcptxt.pdf.
[16] http://cityplanning.lacity.org/cwd/gnlpln/noiseElt.pdf/

- ► **N – 3.1** Develop land use policies and programs that will reduce or eliminate potential existing noise impacts.

- Westwood Community Plan:
  - ► **LU 1-2.1** Locate higher-density residential within designated multiple family and near commercial centers and major bus routes where public services facilities and infrastructure will support this development.
  - ► **LU 9-2.1** Develop an intermodal mass transportation plan to implement linkages to future mass transit service.
  - ► **LU 10-1.1** Encourage non-residential developers and schools to provide employee incentives for utilizing alternatives to the automobile (i.e., carpools, vanpools, buses, flex time, bicycles, and walking).
- City of Los Angeles Noise Element—The City of Los Angeles has adopted local guidelines based on the community noise compatibility guidelines established by the CDHS for use in assessing the compatibility of various land use types with a range of noise levels. These guidelines are set forth in the City General Plan Noise Element and are expressed in terms of Community Noise Equivalent Levels (CNEL). CNEL guidelines for specific land uses are classified into four categories: (1) "normally acceptable," (2) "conditionally acceptable," (3) "normally unacceptable," and (4) "clearly unacceptable." A CNEL value of 70 dBA is considered the dividing line between a "conditionally acceptable" and "normally unacceptable" noise environment for noise sensitive land uses, including single-family and multi-family residences and schools. The primary objective and policy contained in this element that relates to construction noise is:
  - ► **Objective 2** Reduce or eliminate non-airport related intrusive noise, especially relative to noise sensitive uses.
  - ► **Policy 2.2** Enforce and/or implement applicable city, state and federal regulations intended to mitigate proposed noise producing activities, reduce intrusive noise and alleviate noise that is deemed a public nuisance.
- City of Beverly Hills[17]—Policies that can be used in evaluating impacts of construction activities include:
  - ► **LU 1.1** Conserve existing residential neighborhoods and accommodate growth and change in non-residential areas where development builds on and enhances the viability of existing business sectors that are Beverly Hills' strengths, promotes transit accessibility, is phased to coincide with infrastructure funding and construction, and designed to assure transitions and compatibility with adjoining residential neighborhoods.
  - ► **LU 1.2** Prioritize growth and accommodate the highest development densities in proximity to major transit corridors and rail transit stations as developed in the future.
  - ► **LU 3.1** City Form. Accommodate a balance of mix of land uses and require that development be located and designed to enable residents access by walking, bicycle,

[17] http://www.beverlyhills.org/services/planning/plan/draft_general_plan.asp

or public transit to jobs, commerce, entertainment, services, and recreation, thereby reducing automobile use, energy consumption, air pollution, and greenhouse gases.

- **LU 3.2** Allow the greatest development density on properties in proximity of public transit stops, stations, and corridors to facilitate its access and use in lieu of the automobile.
- **LU 6.2** Regional Coordination. Cooperate with adjoining and regional agencies to jointly plan land uses, transportation, and infrastructure that provide a cohesive and integrated strategy to accommodate growth that is environmentally, economically, and socially sustainable.
- **LU 8.4** Senior Housing. Encourage the development of senior housing neighborhoods that is accessible to commercial services, health and community facilities, and public transit.
- **LU 21.1** (Wilshire Boulevard Transit Oriented Development Center (Generally between La Cienega Boulevard and San Vicente Boulevard). Accommodate office, retail, residential, mixed use, live/work and live work development that facilitates access to and by public transit and reduce automobile trips, pollution, and energy consumption.
- **N 4.1** Enforce Hours of Construction Activity. Enforces restrictions on hours of construction activity to minimize the impacts of noise and vibration from the use of trucks, heavy drilling equipment, and other heavy machinery to adjacent uses, particularly in residential areas.

- City of West Hollywood[18]—Policies that can be used in evaluating impacts of construction activities include:
  - **LU – 1.9.1** Allow the continuation of existing and development of new public streets, parking facilities, storm drainage, and other infrastructure in locations which serve and are integrated with the city's land uses.
  - **LU – 1.19.30** Require that all uses and buildings enhance pedestrian activity along Santa Monica Boulevard with the land use urban design polices and standards specified for Issue 6.
  - **N - 17.1.1** Require development in areas where the ambient noise level exceeds 65 dB (A) to incorporate special treatment measures into project design to reduce interior noise levels. In addition to measures called out in the Uniform Building Code and State Noise Insulation Standards (California Administrative Code, Title 24), the following standards should be required of new development in these areas: (a.) use sufficient glazing for all sliding glass doors and all windows; (b.) use insulation between walls and other appropriate measures adequately reduce noise to acceptable levels (l17.1 and l17.5).
  - **N - 17.1.6** Require new equipment and vehicles purchased by the City of West Hollywood to comply with noise performance standards consistent with the best available noise reduction technology (l17.20).
  - **N - 17.1.8** Work with local agencies to provide public transit services which reduce traffic and noise (l17.20).

[18] City of West Hollywood. 2004. General Plan, Section 1.0 Land use and Urban Design; Section 17.0 Noise.

- ► **N - 17.1.9** Work with public transit agencies to ensure that the equipment they use does not generate excessive noise levels (l17.20).
- ► **N - 17.5.1** Require that construction activities which may impact adjacent residential units be limited to 8 a.m. to 7 p.m. during weekdays, except under special circumstances approved by the City; limited to interior construction between 8 a.m. and 7 p.m. on Saturdays; and prohibited on Sundays (l17.4).
- ► **N - 17.5.2** Require that construction activities incorporate feasible and practical techniques which minimize the noise impacts on adjacent uses (l17.4. and l17.17).
- ► **N - 17.6.1** Monitor and update data regarding the City's current and project noise levels (l17.26).
- ► **N - 17.6.2** Employ state-of-the-art advances in noise impact mitigation as they become available (l17.28).
- ► **N - 17.8.2** Encourage public agencies and institutions located in the City to incorporate appropriate measures to contain noise generated by their activities on-site (l17.25).

- City of Santa Monica[19]—Policies that can be used in evaluating impacts of construction activities include:
  - ► **LU – 1.3.4** Downtown Core area requires that a majority of ground floor street frontage on a block by block basis be active pedestrian-oriented use (shop-fronts, cultural activities, cafes, and other uses catering to walk-in traffic) in order to promote pedestrian activity at the ground floor. In the Downtown Frame area, require pedestrian-oriented design features for all ground street frontage.
  - ► **N – 1** Provide for measures to reduce noise impacts from transportation noise sources.
  - ► **N – 4** The City shall develop measures to control construction noise impacts.
- County of Los Angeles[20]—Policies that can be used in evaluating impacts of construction activities include:
  - ► **LU – 1.2** Promote and develop transit oriented districts along major transit corridors.
  - ► **LU – 1.4** Promote land use practices that encourage housing to be developed in proximity to employment opportunities.
  - ► **LU – 2.8** Promote compact, walkable, well-designed development.
  - ► **N - 1.1** Ensure the compatibility of land uses throughout the County to minimize the exposure to excessive noise levels.
  - ► **N – 1.2** Employ effective noise abatement measure to achieve acceptable levels of noise as defined by the Los Angeles County Exterior Noise Standards.
  - ► **N – 1.3** Ensure cumulative impacts related to noise do not exceed excessive levels.

[19] http://www.shapethefuture2025.net/links.html.
[20] http://planning.lacounty.gov/assets/upl/project/gp_web-ch03.pdf; City of Santa Monica.1992. Noise Element of the General Plan Goals, Policies, and Implementation.

Local jurisdiction noise ordinances and codes (and their requirements) that apply to construction activities include:

- City of Los Angeles[21]
  - Chapter 9 Noise Regulation
  - Article 1 General Provisions
  - Article 2 Special Noise Sources
  - - 113.03 Construction Noise
  - - 112.05 Maximum Noise Level of Powered Equipment or Powered Hand Tools
  - Article 6 General Noise
- City of Beverly Hills[22]
  - 5-1-102: Definitions
  - 5-1-104: General Standards Relative to Disturbance of Peace
  - 5-1-202: Machinery, Equipment, Fans, and Air Conditioning
- City of West Hollywood[23]
  - 19.28.70 Noise Mitigation
  - 9.09.040 Prohibited Noises – General Standard
  - Chapter 9.08 Noise
  - 9.09.050 Prohibited Noise – Specific Examples (c)(f)
- City of Santa Monica[24]
  - 4.12.010 Declaration of policy.
  - 4.12.020 Definitions.
  - 4.12.030 Exemptions.
  - 4.12.040 Exterior equivalent noise level measurement methodology.
  - 4.12.050 Designated noise zones.
  - 4.12.060 Exterior noise standards.
  - 4.12.070 Vibration.
  - 4.12.110 Restrictions on demolition, excavation, grading, spray painting, construction, maintenance, or repair of buildings.
  - 4.12.120 Posting of construction signs.
  - 4.12.130 Location, screening, and noise measurement of mechanical equipment.
  - 4.12.170 Noise reduction in project siting and design.

[21] http://www.amlegal.com/nxt/gateway.dll?f=templates&fn=default.htm&vid=amlegal:lamc_ca.
[22] http://www.sterlingcodifiers.com/codebook/index.php?book_id=466.
[23] http://qcode.us/codes/westhollywood/.
[24] http://www.qcode.us/codes/santamonica/.

- County of Los Angeles[25]
  - Chapter 12.08 Part 2 General Provisions
  - 12.08.030 Terminology—Conformity with ANSI standards
  - 12.08.090 Construction period.
  - 12.08.100 Cumulative Period.
  - 12.08.110 Decibel.
  - 12.08.130 Emergency machinery, vehicle of alarm
  - 12.08.140 Emergency work.
  - 12.08.160 Grading
  - 12.08.240 Noise histogram
  - 12.08.250 Noise Level (LN)
  - 12.08.260 Noise-sensitive zone
  - 12.08.350 Vibration
  - Part 3 Community Noise Criteria
  - 12.08.380 Noise zones designated
  - 12.08.390 Exterior noise standards
  - Part 4 Specific Noise Restrictions
  - 12.08.440 Construction noise
  - 12.08.470 Noise disturbance in noise-sensitive zones
  - 12.08.560 Vibration
  - Chapter 12.12 Building Construction Noise

[25] http://search.municode.com/html/16274/index.htm

4.0 SUMMARY OF CONSTRUCTION METHODS, TECHNIQUES, AND EQUIPMENT

4.1 Introduction

This section summarizes construction methods, techniques, and equipment anticipated to be used for the Westside Subway Extension, and based on Metro's extensive subway construction experience. In general, conventional construction techniques and equipment will be used, as typically performed in the Southern California region. This will include the use of specialized pressurized-face Tunnel Boring Machines (TBMs), which will be discussed further below. Although competitive bidding has the potential to bring about other, more innovative methods of construction, the following is a description of the major construction methods and techniques that are considered likely to be used for the Westside Subway Extension construction.

Major project elements include underground stations, tunnels, station-related facilities, maintenance and yard facilities, trackwork, ventilation equipment, and the installation of specialty systems work such as traction power, communication, and signaling equipment.

4.1.1 General Construction Scenario

Construction activities would begin simultaneously at several locations along the selected routes to accommodate areas of work requiring lengthy construction times, such as for the tunnels and underground stations, and to bring the different segments of the project to completion to meet the project completion schedule.

Many contractors specializing in various methods of construction would be working on the project during the construction period. Construction of the project would follow all applicable local, state, and federal laws for building and safety. Working hours would be varied to meet special circumstances and restrictions. Standard construction methods would be used for traffic, noise, vibrations and dust control, consistent with all applicable laws, and as described in the following sections.

The subsequent sections of this report discuss the alternatives proposed for the project, including the tunnel alignment and station locations. The expected construction schedules are summarized at the end of each of these sections. Generally, construction will be divided into a series of activities, which are often overlapping to minimize the duration of construction and the associated impacts. Table 4-1 depicts a typical sequence of construction activities for a tunnel segment of approximately 2 miles. In general, the duration of tunnel excavation (mining) would range from 10 to 18 months. This does not include the time for TBM procurement/mobilization, which is the time to prepare the work area for the equipment and to assemble the machine and its support components. Depending on the ground conditions encountered, site and work area constraints and the number of TBMs used for tunnel excavation, these durations can vary.

Table 4-1: Typical Sequence and Average Time Required for Construction

Activity	Tasks	Average Time Required (months)1
Preconstruction	Locate utilities; establish ROW and project control points and centerlines; and establish/relocate survey monuments.	4 – 6
Site Preparation	Relocate utilities and clear and grub ROW (demolition); widen streets; establish detours and haul routes; erect safety devices and mobilize special construction equipment; prepare construction equipment yards and stockpile materials.	12 – 18
Heavy Construction	Construction of stations and entrances, tunnels and associated structures; major systems facilities; disposal of excess material; backfilling of stations and portal, and refinish roadways and sidewalks.	24 – 36
Medium Construction	Lay track; construct surface facilities (including above-ground structures), drainage, and backfill; and pave streets.	12 – 24
Light Construction	Install all system elements (electrical, mechanical, signals, and communication), traffic signals, street lighting where applicable, landscaping, signing and striping; close detours; clean-up and test system.	6 – 12
Pre-Revenue Service	Testing of power, communications, signaling, and ventilation systems; training of operators and maintenance personnel.	5 – 6
Project Ready for Revenue Service		

[1]Some of these activities will be conducted in parallel.

During the construction period, the number of workers on the various construction sites at any one time will vary depending on the activities being performed. During the peak construction periods, work will be underway at several station sites and tunnel excavation will be concurrently progressing. During subsequent sections of this report, the anticipated numbers of construction workers will be presented for the alternatives discussed.

In general, excavated materials will be loaded onto trucks and removed from the site, or stored within the work areas for subsequent re-use as backfill. Excavated materials that are contaminated would be handled in accordance with the appropriate regulatory requirements. Typically, such materials would be separated, loaded onto trucks, and removed to an appropriate and regulated disposal site; although, on-site storage and re-use as contained fill may be possible if the level of contamination permits.

Based on the full build-out of the Westside Subway Extension (Alternative 5), the total volume of material to be excavated for all tunnel and station construction is expected to be approximately 7 million loose cubic-yards (CY). Using a truck load volume of 20 CY per truck, total tunnel and station excavations would require approximately 350,000 truckloads of material to be removed from the construction sites during the entire construction period. This number will be reduced to the extent that excavated materials can be stored and re-used. Further details on excavation and truck volumes are included in subsequent sections.

In addition to the tunnels and underground stations other Elements Common to All Build Alternatives include:

- Use of building protection measures such as underpinning or ground improvement (including grouting), combined with a geotechnical monitoring program as required to monitor and protect structures identified for such measures.
- Relocation, modification, or protection in-place of existing utilities in the path of the planned excavations.
- Removal or relocation of structures at construction staging sites and area around station entrances, where necessary.
- Construction of entrances to the underground stations.
- Construction of urban design enhancements around station entrances.
- Construction of surface and subsurface drainage systems.
- Construction of traction power substations with electrical power feeds.
- Construction of trackwork, ventilation, traction power, communications and signaling systems for train operations.
- Construction of emergency (backup) power systems.
- Construction of station finishes including fare vending equipment, elevators, escalators, landscaping, signage, and other amenities necessary for a functional station.
- Conducting system integration testing, simulated revenue operation test runs, and final commissioning of the system.

4.1.1.1 Preconstruction

Pre-construction evaluations would be completed during design phases to determine the condition of existing buildings, (including utilities and other structures or features) which are in proximity to the stations, tunnels and other underground structures. Analysis of adjacent buildings and property with respect to the excavation for underground stations and tunnels is necessary to determine whether additional protection work such as special excavation support systems, underpinning, or grouting is considered necessary to mitigate settlement. Geologic information is also considered when determining the need and methods for building protection. Concern for the integrity of the adjacent structures would also influence the method of excavation and type of support systems.

Prior to physical construction, buildings and facilities that could be affected (impacted) by the construction work will be surveyed to document their preconstruction condition. These preconstruction surveys are recorded and archived in case of disputes or claims associated with construction impacts. Immediately prior to the commencement of actual construction the essential results of these surveys will be confirmed, or corrected.

Preconstruction activities will also include the preparation of worksite traffic control plans, which will require regulatory agency approvals.

Local Business Surveys

Community relations and construction staff from Metro would contact and interview individual businesses, allowing for knowledge and understanding of how these businesses carry out their work. This survey identifies business usage, delivery, and shipping patterns and critical times of the day or year for business activities. This information will be used by Metro to develop construction requirements and Worksite Traffic Control plans, identify alternative access routes, and make efforts during construction to maintain critical business activities.

Geotechnical and Environment Investigations

During preliminary and final design of the project, subsurface (geotechnical) investigations would be undertaken to further evaluate geology, groundwater, seismic, and environmental conditions along the alignment. The geologic conditions will influence design and construction methods specified for stations, tunnels and other underground structures, as well as foundations. These investigations would be spaced along the alignment at tunnels, stations, and ancillary facilities to evaluate soil, rock, groundwater, seismic, and geo-environmental conditions, particularly to note locations where hydrocarbon or other contaminant deposits may be encountered.

Cultural Resource Investigations

The Cultural Resources Technical Report (Metro, 2010) provides details on historic, archeological and paleontological investigations and potential impacts. Areas known to have tar deposits and/or tar sands with potential paleontological features may require preliminary preparation and excavation is likely to take place early on and possibly as separate contracts in order to orderly and carefully remove the resources (i.e., fossils, artifacts, etc.) and prepare the ground for the coming excavations. In-street work will typically necessitate on-going lane closures.

In specific cases where paleontological or other significant cultural resources are found, it may be possible to alter the cut-and-cover construction methods to allow for sufficient time to evaluate and recover the resources while not requiring the complete suspension of construction activities. One such method could be to employ raised decking, which would allow for traffic to be restored as originally planned without disturbing the encountered resources. The decking system would be elevated above the existing street level, which would also require ramps for traffic to transition on-to and off-of the decking. Although raised decking may temporarily increase the visual impacts to adjacent properties, as well as present some access restrictions, this method would significantly reduce traffic impacts during any period of cultural resource investigation and/or recovery.

Historic Properties

There are existing historic resources adjacent to the proposed alternative alignments. Such properties could include structures located above tunnels that deviate outside street limits, as well as structures directly adjacent to tunnels, stations, or cut-and-cover construction areas, or areas proposed for acquisition. Specific impacted historic properties will be identified in the later stages of design as station entrances and design options are selected.

Other Preconstruction Work

Other preconstruction work will include surveys of site conditions, structures and other notable features. Sites for additional construction yards and staging will be acquired and noted in contract documents for bidding contractors. Public and environmental concerns will be noted and also incorporated into the construction documents as required by the project's mitigation and monitoring plans. Preparatory planning and community/stakeholder meetings will take place to make the public aware of what is to take place.

Construction Staging Areas

Temporary easements, typically a portion of the sidewalk, traffic lanes, and/or parking areas would be required at various locations for construction staging. Construction within the streets is also envisioned where no off-street areas can be identified for work-sites and/or access to underground excavations.

Construction Site Setup and Mobilization

Prior to construction activities, contractors will prepare the site to accept workers, equipment, and materials. This setup will include site preparations (including clearing, grubbing and grading), following by mobilization of initial equipment and materials. Prior to construction, work sites may require clearing and building demolition (see below) in some areas.

Construction Field Offices

In the earliest stages of construction, contractors and construction managers will establish field offices for personnel use during construction activities. In some cases, the field offices will be established in existing office space in the vicinity of the work areas. Where space allows, temporary jobsite trailers will be established for field offices. These offices will typically include power, environmental controls, offices, conference rooms, bathrooms, data/communications, and associated infrastructure. In some cases, on-site parking spaces are included adjacent to the offices. Often these offices are operational on a 24-hour basis to match the construction operations.

Building Demolition

As part of providing the space needed for construction, or preparing the necessary work areas, building demolition is often required. Such building demolition is performed by the main construction contractors or by specialty contractors in advance of the major contracts. In either case, demolition operations necessitate strict controls to ensure that adjacent buildings and infrastructure are not damaged or otherwise impacted by the demolition operations. These controls include construction fencing and barricades, environmental monitoring, and limits on the types of equipment and demolition procedures. Demolition equipment typically includes bulldozers and front-end loaders, which are often specially developed or modified to allow for precise and controlled dismantling (demolition). Prior to demolition, contractors may salvage items such as fixtures, mechanical equipment, and lumber. Where economical, materials such as steel and concrete may be recycled.

Utilities

Underground utilities must be thoroughly researched and locations noted on contract drawings. Handling of utilities is a time consuming and potentially delaying operation and will require that, as much as possible, notification and locations be contained in construction contract documents. During preconstruction, existing utilities may be more closely inspected and evaluated, including depth, condition, and exact location. An operation called "potholing" is typically done to physically locate certain utilities, which can then be appropriately marked or protected prior to main construction. Where in-place protection is not sufficient, relocation of utilities is required (see below). Utility relocations can be done prior to or during main construction operations, depending on the sensitivity of the utility.

4.1.1.2 Underground Utilities

Prior to beginning construction it would be necessary to relocate, modify or protect in place all utilities and underground structures that would conflict with excavations. The contractor will verify locations through potholing methods and where feasible, the utility will be relocated so as to stay out of station or other surface structure excavation. Where the utility cannot be relocated outside the excavation footprint, it will be exposed and hung from the supporting structure (deck beams) for the roadway decking over the cut-and-cover structure.

Shallow utilities, such as maintenance holes or pull boxes, which would interfere with excavation work, will require relocation. The utilities alignments will be modified and moved away from the proposed facilities. Utility relocation takes place ahead of station and other underground structure excavation. During this time, it may be necessary to close additional traffic lanes at one time.

It is possible that in some instances, block-long sections of streets would be closed temporarily for utility relocation and related construction operations. Pedestrian access (sidewalks) would remain open and vehicular traffic would be re-routed. Temporary night sidewalk closures may be necessary in some locations for the delivery of oversized materials. Special facilities, such as handrails, fences, and walkways will be provided for the safety of pedestrians.

Minor cross streets and alleyways may also be temporarily closed but access to adjacent properties will be maintained. Major cross streets would require partial closure, half of the street at a time, while relocating utilities.

Subject to other constraints, the underground stations have been located to avoid to the extent possible conflicts with the space occupied by utilities. Impacted utilities are expected to include storm drains, sanitary sewers, water lines, power lines, gas pipelines, oil pipelines, electrical ductbanks and transmission lines, lighting, irrigation lines, and types of communications, including phone (fiber optic), data, cable TV, etc.

Utilities, such as high-pressure water mains and gas lines, which could represent a potential hazard during cut-and-cover and open-cut station construction and that are not to be permanently relocated away from the work site, would be removed from the cut-and-cover or open-cut area temporarily to prevent accidental damage to the utilities, to construction personnel and to the adjoining community. These utilities would be relocated temporarily by the contractor at the early stages of the operations and reset in essentially their original locations during the final backfilling above the constructed station.

Utilities that need not be relocated, either permanently or temporarily, are uncovered during the early stages of excavation. These buried utilities, with the possible exception of sewers, are generally found within several feet of the street surface. They can be reinforced, if necessary, and supported in-place by hanging from deck beams.

All utility relocations will be coordinated with the utility owner. Relocation and protection of underground utilities will require excavation to the depth of the existing utility line and installation of a replacement utility in a new location, followed by backfilling and reconstruction of the pavement or surface improvements. This will occur within the affected ROW and on nearby streets as required.

Utility relocations often entail some form of temporary service interruptions, which are typically limited to short periods during the cut-over from the existing to the relocated service. Such service interruptions are typically planned to occur at periods of minimum use (such as nights or weekends for businesses), so that outages have the least impact on users.

Relocation of utilities would generally be performed before construction of the stations, tunnels or related facilities. Construction equipment typically required for relocation and restoration includes shovels, spaders, backhoes, excavators, trenchers, trucks, small cranes, and generators/compressors. Concrete trucks, asphalt trucks, pavers, rollers and compactors are typically required for street restoration.

In addition to utility relocations, various new utilities will be installed as required. These new installations can be expected to include communications cables (including fiber optic lines), electrical duct-banks, drainage facilities (pipelines, catch basins, etc.), water supply lines, and lighting.

4.1.2 Station/Cut-and-Cover Construction

All stations would be designed to accommodate Metro Heavy Rail six-car trains (i.e., approximately 450-ft long platforms). Each station will be designed somewhat differently, but all stations have similar dimensions: approximately 680-ft long, 70-ft wide (to fit considering two tracks, a middle column and side room) and 60-ft to 70-ft below street level. Side entrances would typically be about 60-ft long, 20-ft wide, and 25-ft deep.

For stations, cut-and-cover construction methods are anticipated. In an urban area, this construction technique generally begins by opening the ground surface to an adequate depth to permit support of existing utility lines and to install soldier piles, or other means of retaining the excavation. After the surface opening is covered with a temporary decking so traffic and pedestrian movement can continue, excavation proceeds to the necessary depth from beneath the decking. A concrete station box structure is then built within the excavated space, backfilled up to street level, and the surface is restored. The temporary excavation will be retained by an approved excavation support system, also known as a shoring system. In addition, adjacent building foundations will also be supported as necessary.

In addition to stations, excavations will also be needed for various ancillary structures such as crossovers, pocket tracks, vent shafts, emergency exits, and systems facilities. Typically, cut-and-cover techniques would also be used for these ancillary structures. On this project, cut-and-cover construction is minimized to structures connecting to the surface, with the majority of the alignment constructed below ground in tunnels.

A typical station excavation would occur over an approximately 12-month period and would result in approximately 120,000 CY of excavated soil. A bulk factor adds about 30 percent to the soil volume. Assuming approximately eight months for each station excavation, it would take approximately 25 to 50 haul truck trips per day to remove the excavated soils. However, the frequency of truck haul trips will depend on the contractor's equipment methods and rate of excavation. Further information is providing in subsequent sections.

It is estimated that approximately 12 to 18 months will be needed to establish the surface work area, install the support of excavation, and to complete excavation so as to be able to turn the station over for tunnel operations or for station concrete work. The total sequences described for underground station construction could be up to 48 months. Based on the anticipated volume of excavation for the tunnel and cut-and-cover stations, it is estimated that an average of 25 to 80 dump trucks per day would be required to haul and dispose of the excavated soils during excavation cycles.

4.1.2.1 Excavations in Potentially Gassy Ground

Methane is a hazard in confined spaces. As such, it is essential that tunnel workers be sufficiently protected, and thus detection and monitoring equipment would be required (see section 3.1). Fans similar to those used to dilute hydrogen sulfide concentrations would also dilute methane concentrations in the tunnel. Once above-ground, methane dissipates rapidly in the atmosphere and would not be a health hazard.

Station design would also include gas monitoring and detection systems, as well as ventilation equipment to dissipate gas. For stations, the use of relatively impermeable diaphragm or slurry walls may be required to reduce gas inflows, as well as requirements for additional ventilation, monitoring, and worker training for exposure to hazardous gases. In extreme cases, some work may require worker use of personal protective equipment (PPE), such as fitted breathing apparatus. Stations constructed in gas zones would have similar interior dimensions as other stations. Details concerning the special requirements for the permanent structure design of stations are included in the geologic hazard section of the Geotechnical and Hazardous Materials Technical Report (Metro, 2010).

Excavation equipment used below the decking may be required to be sealed and/or be of explosion-proof design. In areas of potential H_2S exposure, there are a number of techniques that can be used to lower the risk of H_2S release or exposure. Because station excavations are less confined than tunnels, gas exposure issues are anticipated to be less significant. Although pre-treatment of the ground/water prior to excavation, such as with hydrogen peroxide, is an option, it is not expected to be required.

Previous projects in the Methane Risk Zone have been successfully and safely excavated. Multiple underground parking garages have been constructed in this area. For example, the Los Angeles County Museum of Art built a two-level subterranean parking structure in a Methane Risk Zone. During excavation, hydrogen sulfide (above safe working levels) was encountered on several occasions. Workers donned PPE to protect against exposure during these events. Further investigation of operating underground structures will be undertaken during future design phases to assess effectiveness of barrier systems and detection equipment used.

4.1.2.2 Excavation Support System

The support of excavation is an important factor in the construction of deep excavations and there are various suitable methods that a contractor might construct. These methods could include soldier piles with lagging, slurry walls, or other similar techniques. It should be noted that the initial or temporary support system for the station excavation is typically designed and constructed by the station contractor. However, the final support for the station excavation is provided by the concrete station box structure, which is a permanent work element, designed by Metro's designers and built by the station contractor.

If the pre-construction building assessments indicate the necessity to protect nearby existing structures, the first step in construction of an underground station is to support the foundations of buildings adjacent to the station excavation. This is typically done by underpinning, which involves the placement of additional foundation elements under the building to support the structure well below the area to be excavated. Alternatively, the ground below the existing foundations can be improved by other means such as grouting. In lieu of underpinning or grouting, or in combination with grouting, the support of adjacent structures is commonly accomplished by use of more rigid excavation support systems, which in conjunction with proper excavation and bracing procedures, serves as building protection. **Figure** 4-1**Error! Reference source not found.** illustrates a typical cut-and-cover construction sequence.

Figure 4-2**Error! Reference source not found.** illustrates the initial excavation of Metro's Gold Line Eastside Extension's (MGLEE) 1st/Soto Station. The excavation's initial support system(s) is typically comprised of braced soldier piles and lagging, although alternative systems could include reinforced concrete drilled-in-place piles, tangent pile walls, diaphragm walls (slurry walls), and tied-back excavations. Initial support allows support of the ground while soil is removed from the excavation. This support remains in place for the duration of tunneling and other temporary work. Final support includes the concrete slabs, walls, and walkways for the stations entrances.

Some lateral movement of the excavation walls may occur during removal of soil. The amount of movement will depend on the contractor's excavation methods, wall design, and the height of the wall. Project specifications will call for monitoring of walls and adjacent ground for lateral movements and surface settlement. Acceptable movements, such that adjacent buildings can be protected, will be determined during final design. Specifications will call for the contractor to take appropriate action if limiting movements are approached.

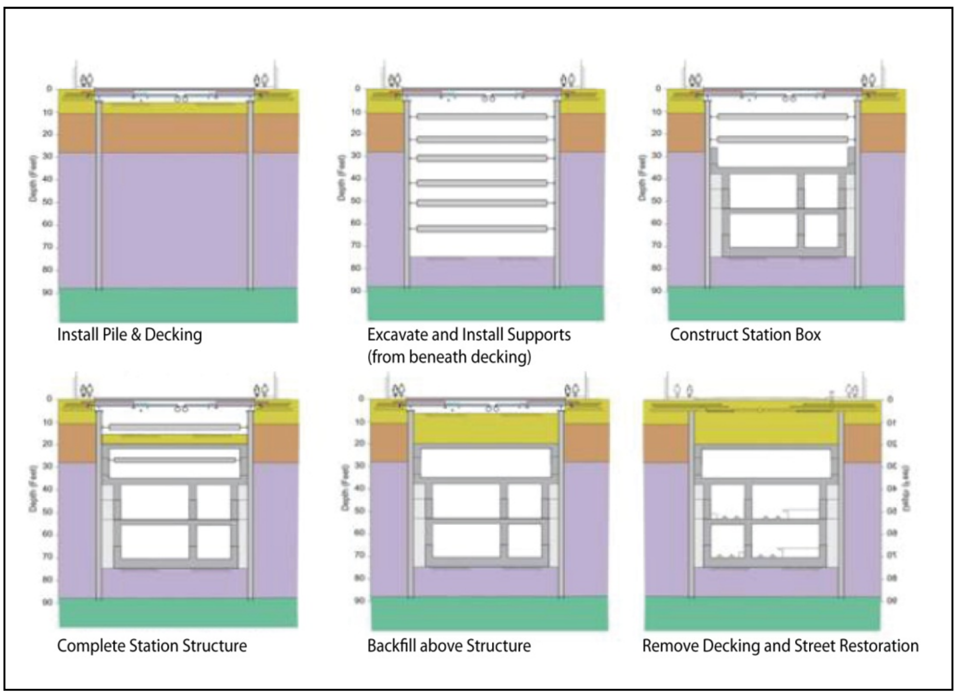


Figure 4-1: Typical Cut-and-Cover Construction Sequence

Figure 4-2: Typical Cut-and-Cover Construction Activities from the Metro Gold Line Eastside Extension

4.1.2.3 Soldier Pile and Lagging

Soldier pile and lagging walls are a type of shoring system typically constructed along the perimeter of excavation areas to hold back the soil around the excavation. This support system consists of installing soldier piles (vertical steel beams) at regular intervals and placing lagging in between the piles to form the retaining structure. Pre-auguring will be necessary for installation of the soldier piles. Pre-auguring involves drilling holes for each pile from the street surface (Figure 4-3**Error! Reference source not found.**) to eliminate the need for pile driving equipment and thereby reduce project noise and vibration levels that would otherwise occur while pile driving. The lagging, which spans and retains the soil between the piles, is typically timber or shotcrete (sprayed-on concrete).

Figure 4-3: Drilling for Soldier Pile Installation

A soldier pile and lagging excavation and support system is shown in Figure 4-4. To install the piles, the contractor would first occupy one side of the street to install one line of soldier piles. The soldier pile installation will require partial closures of traffic lanes on the side of the street where the equipment would be staged. The equipment required for installation of the soldier piles includes drill rigs, concrete trucks, cranes, and dump trucks.

Figure 4-4: Typical Soldier Pile and Lagging System (Metro Gold Line Eastside Extension)

After installation of soldier piles on both sides of the street at the station excavations, soldier piles would then be installed across the street at the station ends. This operation would also require lane closures, and is often done during night-time or weekend periods. The contractor would then proceed with installation of deck beams, installation of the deck panels and excavation and bracing. Deck panels (decking) allow continued traffic and pedestrian circulation since they will typically be installed flush with the existing street or sidewalk levels. However, deck installation would require night-time street closures on weekdays or full road closures on weekends with traffic detours. The decking would be installed in progressive stages.

A soldier pile and lagging system is generally used where groundwater is not a hazard or where grouting, or lowering of the groundwater level (dewatering) can be used to mitigate water leakage between piles. Dewatering is discussed in more detail below.

Alternatives to soldier pile and lagging walls include slurry walls and secant or tangent pile walls (see next section below). Use of slurry wall construction can provide a nearly water-tight excavation, eliminating the need to dewater.

4.1.2.4 Special Shoring Designs

In general, the shoring design along the alignment falls into one of three categories:

- Areas of no ground water;
- Areas of shallow ground water; and
- Areas with asphaltic sands, subsurface gases, and groundwater.

For station and other excavations where water is not anticipated, conventional soldier piles and lagging is expected, which is discussed above. This is also the most common shoring system used in the Los Angeles area.

The groundwater along the alignment varies in depth and expected inflow rate. Along most of the Segment 1 alignment, experience indicates that underground excavations on the order of 50- to 60-ft deep were successfully performed with minimum dewatering effort due to the presence of less permeable soils. Depending on the situation, this dewatering has been accomplished with a few strategically located wells supplemented by gravel-filled trenches and sumps as the excavation proceeded. In such cases, conventional soldier piles with lagging have been adequate.

However, there are some locations along Wilshire where the groundwater is near the ground surface, potentially under artesian pressure. In such cases, the use of dewatering through multiple wells is often necessary. Also, the use of soldier piles with lagging may be inadequate and a slurry (diaphragm) wall, secant pile, or similar system may be implemented. Slurry walls have been used along the Wilshire Boulevard corridor for a building basement/foundation at the intersection of Wilshire and Veteran Boulevard.

4.1.2.5 Tangent Pile or Secant Pile Walls

Tangent pile walls consist of contiguous drilled piles that touch each other. The contiguous wall generally provides a better groundwater seal than the soldier pile and lagging system, but some grouting or dewatering could still be needed to control leakage between piles. Similar to the soldier pile installation described above, the contractor would occupy one side of the street and drill the piles sequentially to form the retaining wall.

A secant pile wall system is similar to the tangent pile wall but the piles have some overlap, facilitating better water tightness and rigidity. The method consists of boring and concreting the primary piles at centers slightly less than twice the pile diameter. Secondary piles are then bored in between the primary piles, prior to the concrete achieving much of its strength. The completed secant pile wall for the Barnsdall Shaft in Hollywood for the Metro Red Line project is shown on Figure 4-5. Because of the close spacing of tangent piles, utilities crossing the wall often require relocation. The equipment required for installation of the tangent pile or secant pile walls includes drill rigs, concrete trucks, cranes, and dump trucks.

Figure 4-5: Secant Pile Wall Used at the Barnsdall Park Shaft

4.1.2.6 Diaphragm/Slurry Walls

Diaphragm walls (commonly known as slurry walls) are structural elements used for retention systems and permanent foundation walls. Slurry walls are constructed using deep trenches or panels which are kept open by filling them with a thick bentonite slurry mixture. After the slurry-filled trench is excavated to the required depth, structural elements (typically a steel reinforcement cage) are lowered into the trench and concrete is pumped from the bottom of the trench, displacing the slurry. Figure 4-6 and Figure 4-7 illustrate slurry wall excavation equipment.

Figure 4-6: Typical Slurry Wall Panel Excavation

Figure 4-7: Rebar Cage for Typical Slurry Wall Panel

Tremie concrete is placed in one continuous operation through one or more pipes that extend to the bottom of the trench. The concrete placement pipes are extracted as the concrete fills the trench. Once all the concrete is placed and has cured, the result is a structural concrete panel. Grout pipes can be placed within slurry wall panels to be used later in the event that leakage through wall sections, particularly at panel joints, is observed. The slurry that is displaced by the concrete is saved and reused for subsequent panel excavations.

Slurry wall construction advances in discontinuous sections such that no two adjacent panels are constructed simultaneously. Stop-end steel members are placed vertically at each end of the primary panel to form joints for adjacent secondary panels. In some cases, these members are withdrawn as the concrete sets. Secondary panels are constructed between the primary panels to create a continuous wall. Panels are usually 8- to 20-ft long, with widths varying from 2 to 5 feet.

Slurry wall construction would occur in stages, working on one side of the street at a time. These walls have been constructed in virtually all soil types to provide a watertight support system in addition to greater wall stiffness to control ground movement. Because slurry walls are thicker and more rigid than many other shoring methods, the walls may in some cases be used as the permanent structural wall, although this application is not anticipated for this project. Where slurry walls are used, the thickness of the permanent structural walls can sometimes be reduced, i.e., when compared to wall thicknesses used with a conventional soldier pile and lagging system.

Slurry walls are generally not adaptable to utility crossings and all utilities crossed by the wall would require temporary or permanent relocation. The equipment required for installation of the slurry walls includes clamshell or rotary head excavators, concrete trucks, slurry mixing equipment, cranes, slurry treatment plant, and dump trucks. The bentonite slurry would require disposal after a number of re-use cycles.

4.1.3 Station Construction in Potentially Gassy Ground

As discussed above, the use of slurry walls may be required for station excavation in potential gas areas. In addition, the final structure may include additional sealing from gas intrusion, such as with special gas-resistant membranes and/or joint sealants, which will increase resistance to leakage. Station design would also include gas monitoring and detection systems, as well as ventilation equipment to dissipate gas. Details concerning the special requirements for the permanent structure design of stations are included in the geologic hazard section of the Geotechnical and Hazardous Materials Technical Report (Metro, 2010).

4.1.3.1 Excavation and Decking

After installation of the temporary shoring (support) system and initial excavation, the contractor would proceed with installation of the deck beams, followed by multiple sequences of excavation and installation of cross bracing. In special situations, such as where cross-bracing impedes access from above, tie-back systems may be used. Tie-backs are strong cable strands that are installed and grouted into pre-drilled holes extending out and downward from the excavation support wall. After the grout sets and the cables are firmly anchored into competent ground, the tie-backs are tensioned to provide lateral support to the wall. The use of tie-backs may require temporary underground easements.

Deck panels (decking) are placed on the deck beams to allow traffic and pedestrian circulation to resume after the initial excavation. These deck panels are typically constructed of precast reinforced concrete. The decking is typically installed flush with the existing street or sidewalk level. Deck panel installation would require temporary street closures at the cut-and-cover areas and would be installed in progressive stages.

Entrances for TBM operations (i.e., tunnel portal locations) would follow similar construction methods as for the station excavations. Because the TBM entrances are typically in street locations, side entrances are often required in adjacent off-street locations. In such cases, the excavation in adjacent off-street locations may remain open to ground surface level and thus no decking would be used during construction.

4.1.3.2 Dewatering

Prior to installation of the ground support system, dewatering is likely to be required at the underground station sites to temporarily lower the groundwater level (if groundwater is present) below the station excavation depth or to an impermeable soil layer. This facilitates installation of the piles, improves soil stability, and allows excavation in dry conditions. Groundwater is pumped from wells installed around the perimeter of the excavation. If contaminated water is encountered, it is typically treated at the site prior to discharge. At the completion of the stations, pumping is discontinued and groundwater levels return to their natural level.

If dewatering methods are used, and depending on the site soil conditions and groundwater level at the time of construction, some surface settlement could be experienced due to groundwater lowering. Dewatering and groundwater pumping rates will be estimated during final geotechnical investigations and pump tests.

In general, water will be pumped out of sump pits as the excavation proceeds downward. Ditches and gravity flow will be used to drain the water into the low-lying sumps. Water will be passed through a settling basin to remove solids before being pumped into the local storm drain or sanitary sewer system. Based on prior experience along Wilshire corridor, deep basement excavation dewatering has been accomplished by pumping from limited number of deep wells strategically located within the site and augmented by gravel-filled trenches and sumps throughout the excavation area. It is anticipated that dewatering flows will be processed on site to remove oils and solids. Depending on the anticipated discharge flows at each excavation location, the excess flow capacity in the sewer systems will be checked to determine the optimal discharge point(s).

4.1.4 Station Drainage

It is anticipated that the majority of stations will not be provided with subdrain systems or permanent dewatering wells. On this basis, the station structures where shallow groundwater exists will have to be thoroughly waterproofed. Even in such cases, an internal sump pump system may be required at some stations. Within the gassy areas, a special waterproofing system will be required to also provide a barrier against gas intrusion.

4.1.4.1 Settlement Protection Measures

Underground excavation for stations using the cut-and-cover technique can result in some ground relaxation and deformation of the retained soils. The magnitude of ground movement depends on the strength of the surrounding ground and the rigidity of the shoring system. For cut-and-cover excavation, the zone potentially susceptible to ground movement generally extends a lateral distance approximately equal to the depth of the excavation. Buildings within this zone will be evaluated for susceptibility to settlement and the need for additional protection measures. Typical building protection measures are discussed below.

Presence of Existing Tie-backs

At proposed station locations planned adjacent to the existing deep basements, there may be existing abandoned tie-backs projecting into the space of the planned station. These tie-backs, although no longer in service, will interfere with the construction of shoring and station walls. In many cases, the locations of these tie-backs can be reasonably well established. Accordingly, if soldier piles and lagging are used, the soldier piles can be spaced to avoid the tie-backs during drilling and these tie-backs can later be de-tensioned and cut off as the excavation and lagging proceeds. The presence of abandoned tiebacks can be significantly more problematic if tangent or secant piles are installed or if slurry wall systems are used. Specialized methods and equipment to de-tension and cut the tiebacks have been used, but it is often preferred to adopt a soldier pile and lagging system where tie-backs are known to exist.

Existing Foundations

Many of the station excavations will be within close proximity of existing foundations. Careful planning and execution will be required to protect these existing foundations. Depending on specific situations, foundations may have to be underpinned. If feasible, a preferred approach is to design a more rigid excavation support system that can resist the additional loads imposed by the adjacent foundations. In such cases, a stiffer tangent pile, secant pile or slurry wall shoring system may be required. Pre-loading of excavation support bracing may also be implemented.

For buildings adjacent to cut-and-cover construction, it is anticipated that the shoring system, in conjunction with internal bracing, will provide a relatively rigid temporary support for the proposed excavation that would result in deformation within the tolerable limits of the structures. Evaluations during future phases, along with previous Metro experiences, will help determine the appropriate levels of monitoring, protection, and mitigation measures required during construction.

Asphaltic Sands

When excavating in asphaltic sands (tar sands) (see Geotechnical and Hazardous Materials Technical Report. Metro, 2010)), efforts will be undertaken to avoid excessive disturbance. Excavation methods will be closely controlled to minimize over-excavation or vibrations. In some cases, a layer of gravel may have to be placed over the asphaltic sands to permit construction traffic. Also, when grade is achieved within these soils, a mud slab will be required to minimize disturbance. Asphaltic sands are present along the alignment between about La Brea Avenue and Fairfax Avenue; with heavier concentrations near Wilshire Boulevard and Fairfax Avenue. Groundwater is also present in this reach.

The asphaltic sands have unique properties and the engineering characteristics are not as well documented as compared to other soils. However, contrary to common expectations, it is proven that these sands possess shear strength. Design parameters for excavation support systems in asphaltic sands will need to consider some additional pressure due to these soils. There are numerous cases of successful experience in construction of deep basements and underground parking structures in the Wilshire/Fairfax area soils, such as construction of underground structures at the Los Angeles County Museum of Art. Similar designs elements, construction techniques and operating methods and procedures can be applied to the planned excavations.

4.1.5 Backfilling

Excavation at the station will require backfilling over the top (roof) of the station structure to fill the area between the structure and street surface. This backfilling is typically done with imported soils, which are delivered by truck. Backfilling will be primarily carried out in the last three or four months as the station is completed. Depending on the station configuration, this operation will be done in stages. Each station will require approximately 20,000 CY of imported backfill deliveries, or roughly 1,000 truck-loads (depending on the type of trucks used). During peak backfill periods, approximately 50-100 trucks per day would be expected to bring backfill into the site.

The number of backfill deliveries can be reduced by stockpiling excavated materials on site for re-use. It will not be feasible to re-use tunnel excavated materials for backfill because of the conditioning agents and/or slurry added to the excavated soils. Soils excavated from station sites may be suitable for re-use. However, given the urban area, sites suitable for soil stockpiling will be very limited.

4.1.5.1 Disposal of Excavated Materials

With the decking installed and the utilities supported, the major excavation work for the station box can proceed. Spoils from station sites would be moved out from under the deck onto an off-street work site or closed parking/traffic lane and loaded from there into haul trucks. Occasionally spoils loading in the street during excavation and the initial drilling of soldier piles and deck installation could be required.

Assuming each station to be approximately 680-ft long by 70-ft wide by 60-ft deep, the average volume of material from the cut-and-cover station excavation for each station is approximately 135,000 CY, which is based on the soils expanding by approximately 30 percent through the excavation and loading process. For deeper or longer stations, this volume would increase. For instance, for a 70-ft deep station, the average volume of material is approximately 160,000 CY.

This excavated material would be brought to the surface and loaded into trucks for disposal. Assuming and the use of 20 CY haul trucks, the total number of excavation truck trips required would be approximately 5,000 to 7,000 trucks. For a typical station configuration, this would equate to a maximum of approximately 50-60 truck trips per day.

The distance to the various landfill sites will vary. A special study examining excavated materials disposal reviewed existing state approved landfills within 20 miles of the project sites and indicated an available capacity for all waste generated by the project alternatives. Also, demand for fill by other construction projects in the Los Angeles area may facilitate the re-use of excavated materials on other projects. For further details on the analysis, an identification of the landfills and their capacities, and haul routes that would minimize impacts, see Transportation Impacts Technical Report (Metro, 2010).

Contaminated spoils are separated as soon as they are identified during the excavation cycle. Personnel qualified in identification and handling of these materials is on-site during the excavation operations. These spoils would be temporarily stockpiled separately on-site and handled in accordance with applicable regulations for handling and transporting contaminated materials. All trucking of materials to landfills would be timed to correspond with hours of operation.

4.1.5.2 Traffic

Traffic flow can be affected during the entire period of construction of at any given location, which is typically anticipated to be approximately 4-5 years. Depending on the traffic flow and location, a variety of mechanisms are available to control and maintain traffic in constricted intersections, including decking to temporarily replace street pavement and sidewalks, and temporary bridges. Decking will typically contain hatches or removable panels to facilitate lowering equipment or materials (such as odd-shaped and outsize items) down into the station excavation with minimal traffic disruption.

Cross streets, if used, will typically be carried through intersections on similar decked structures. Pedestrian access (sidewalks) would remain open, although in some instances, portions of the sidewalks may be closed temporarily for decking construction. Where sidewalks must be temporarily removed, pedestrian access will be maintained by bridges, temporary walkways, and other means. Some streets may also have to be temporarily closed under certain special circumstances, such as deck beam installation.

Trucking for supplies brought into the site is estimated to be approximately 5-10 trucks per work-day for the duration of station construction. For example, during a one-year period, assuming 5-6 work-days per week, this equate to approximately 1,800 truck trips. This does not include delivery of tunnel segments, concrete trucks, or imported backfill deliveries, which are addressed later in this report.

This estimate also does not include worker/employee commutes. The number of workers will vary depending on the operation needs, but for a typical station location, the estimated number of workers is approximately 85 personnel daily. This assumes two shifts of approximately 35 workers each plus approximately 15 office employees (counting both the contractor and the construction manager).

4.1.6 Ventilation Shafts and Emergency Exits

A number of ventilation structures and, for some options, emergency exit structures will be required. The station structures will generally house emergency ventilation fan shafts as well as separate emergency exit shafts at both ends of the stations. Ventilation fans are used for extracting smoke from tunnels and stairs for evacuation in the event of an emergency, such as a fire in the underground areas. The exact location of these facilities would be determined during the final design. These shafts are typically constructed as extensions of the station excavation, using cut-and-cover construction methods.

Mid-line ventilation structures will also be required where long tunnel reaches exist between stations. The construction of mid-line ventilation structures will be similar to Stations (cut-and-cover), only much shorter in length, generally less than 200-ft. Mid-line ventilation structures will be positioned based on the ventilation design of the overall system.

In addition, to ventilation and emergency exit structures, stations will usually include some above-ground structures that will be completed near the end of the station construction cycle. These above-ground structures may be limited to entrance features, stairways, and elevator/escalator entry points. In some case, Metro operations and maintenance spaces, including power equipment, communications facilities and/or control rooms, may be housed in above-ground structures.

4.1.7 Pocket Tracks and Crossovers

The rail system will require crossovers and pocket tracks for proper operation. Crossovers allow trains to move from one track to the other. A pocket track is a third track set between the existing two running tracks for temporary storage of out-of-service trains and for use as an emergency crossover. Pocket tracks and crossovers will be constructed using cut-and-cover construction.

Each crossover will be approximately 450-ft long, 60-ft wide, and 60-ft below ground (depending upon the distances between track centers). Pocket tracks will be approximately 1100-ft long, 60-ft wide, and 60-ft below ground.

4.1.8 Tunnel Construction

Figure 4-8: Typical Transit Tunnel

Whereas stations, crossovers, and ventilation structures will generally be constructed by cut-and-cover methods, the running tunnels will be constructed by mechanized tunneling methods. The use of pressurized-face TBMs (**Figure** 4-10**Error! Reference source not found.**) is planned to optimize control of the ground and to minimize settlement overlying and surrounding the tunnels. TBMs are large-diameter horizontal "drills" that continuously excavate circular tunnel sections. There are two types of pressurized-face TBMs, Earth-Pressure Balance (EPB), or Slurry-Face TBM.

Figure 4-9: Typical Pressurized-Face TBM

It is expected that the TBM used for different reaches of the tunnels will be subject to varying, site-specific requirements, including geologic conditions. For instance, where hydrocarbons and/or gases are expected to be encountered it is likely that a specialized Slurry-Face TBMs will be required. Where there is no known deposit of hydrocarbons, it is expected that the contractor will have the option of using either a Slurry-Face or EPB TBM. Each TBM operation has its own advantages and disadvantages that will be weighed by the bidding contractors. The characteristics of these machines are discussed further below.

4.1.8.1 Earth Pressure Balance (EPB) TBMs

In North America, EPB TBMs are the most common. These TBMs rely on balancing the thrust pressure of the machine against the soil and water pressures from the ground being excavated. EPB TBMs are generally well suited for mining in soft ground, which is expected along the Westside Subway Extension alignment. Gassy tunneling conditions are also anticipated and are discussed further below. These TBMs can also mine through variable soils, groundwater, and methane conditions and may also be adapted for harder materials. On the Metro Gold Line Eastside Extension project, EPB TBMs were successfully used to mine about 1.4 miles of tunnel. The excavation method for an EPB TBM is based on the principle that tunnel face support is provided by the excavated soil itself.

The excavated soil in an EPB TBM is contained in a chamber behind the cutting wheel by a bulkhead as shown in **Figure** 4-10. The "earth pressure" in this chamber balances the external soil and groundwater load which in turn minimizes movement of the ground in front of the TBM. The screw conveyor and rate of TBM advance restrict the rate of soil removed from the chamber to maintain the earth pressure.

Typically, EPB TBMs require that the soil at the excavation face is "conditioned" to help provide a more fluid and cohesive material and improve material flow and handling characteristics. This conditioning, which includes the use of non-toxic, biodegradable polymers, surfactants, bentonite and similar agents, aids in ensuring consistency of the excavated soils, maintaining the appropriate face pressures, and in reducing wear on the TBM components.

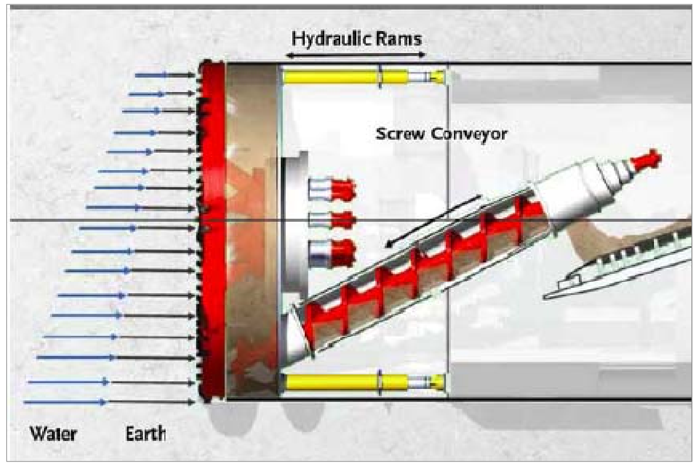


Figure 4-10: Schematic of Earth-Pressure Balance TBM

When the conditioned excavated spoils are transported through the tunnel to the ground surface, it is still wet. This often requires drying of the spoils prior to transport off-site and/or lining of spoil hauling trucks to prevent water from leaking onto roadways. An example of TBM spoils removed from a tunnel at a construction staging site is depicted in **Figure** 4-11.


Figure 4-11: Wet Soil at Surface EPB TBM

4.1.8.2 Slurry-Face TBMs

Slurry-Face TBMs will likely be required for tunneling in the elevated gas zones, where the addition of the slurry and the relatively closed spoil removal system provides additional protection against gas intrusion into the tunnel environment. Where lower gas concentrations are expected, EPB TBMs may also be suitable.

With Slurry-Face TBMs, a bentonite (clay) mixture or "slurry" is injected in a pressurized environment at the tunnel excavation face. This combination of pressure and slurry stabilizes supports the soils during excavation. Depending on the ground encountered, conditioners may be added to the slurry. Excavated soil is mixed with the slurry fluid and then pumped out of the tunnel through large (approximately 18" diameter) pipelines with in-line booster pumps, depending on the length of the tunnel.

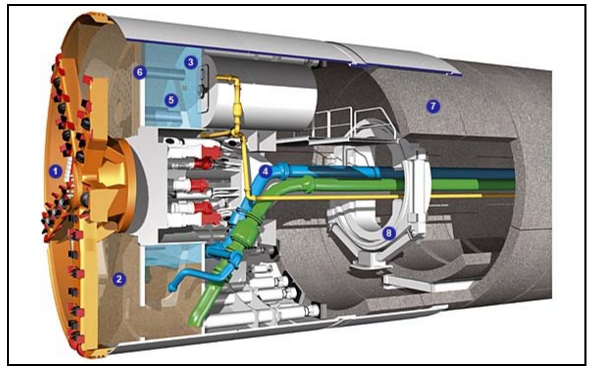


Figure 4-12: Typical Slurry-Face TBM with Precast Segment Lining

With a Slurry-Face TBM, excavated materials are transported from the tunnel face to an above-ground separation plant via pipelines. The excavated materials are treated at the plant, where they are separated from the slurry mixture. This process would also allow for the safe dispersion of any potentially gaseous components above ground without endangering tunnel personnel.

One of the effects of slurry excavation methods involves handling clean-up from spills, such as from leaky joints and worn pipe lines. Because the pipelines are often buried, slurry leakage is typically limited to the slurry mixing facility or slurry treatment plant. Slurry clean-up and removal will meet the strict standards of governing agencies and the needs of the surrounding community.

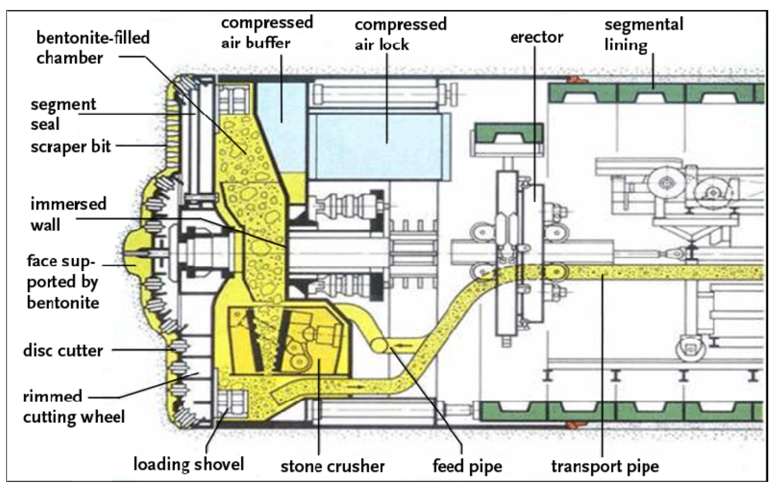


Figure 4-13: Slurry-Face TBM Tunnel with Slurry Pipeline in Foreground

Figure 4-14: Schematic of Slurry-Face TBM

As an alternative to on-site spoil/slurry separation, it may be possible to transport the slurry to an alternate location for treatment. This would likely entail additional lengths of slurry pipelines along streets or sidewalks, although such pipelines would probably need to be buried in shallow trenches to reduce potential community impacts. Depending on the distance to be pumped for treatment/separation and subsequent off-site disposal, this alternative may not be economical based on the time and cost to install, operate, and remove the additional pipelines and related infrastructure. There are also community and public safety concerns about the potential for slurry leakage and associated hazards. The processed water used in the slurry is also a potential source of concern and will require proper containment, treatment, and disposal. Slurry treatment is discussed in further detail in subsequent sections.

Figure 4-15: Typical Slurry Mixing Plant

4.1.9 Contractor Work and Storage Areas

Contractor work and storage areas would be necessary for construction of the tunnels, similar to that required for stations and ancillary facilities. Construction staging areas are required for assembly, setup, materials storage, and operation. Typically, these staging areas will be at station excavations to facilitate access to the tunnel. Off-street space will be needed for setup, insertion, operation, and extraction of TBMs. Work areas are also required to support tunnel excavation operations, including processing and removal of tunnel spoils, handling of precast concrete tunnel lining segments, and tunnel utilities (including ventilation, water supply, wastewater removal, power supply, etc.). Use of in-street work areas will only be utilized when no off-street alternative exists.

Typically, a tunnel staging site of roughly 1-2 acres in area (200-ft by 300-ft or equivalent) is required at the starting point of each tunnel drive. In addition to direct TBM support, such as storage for tunnel precast concrete segments, this space is needed for loading/unloading facilities, construction equipment, worker facilities, and offices.

4.1.10 Tunnel Excavation

Tunneling generally has less visible effect on surrounding areas than cut-and-cover methods since the street surface and utilities are not appreciably disturbed and there is less traffic disruption. The specific tunneling technique used will depend largely on the geologic conditions. The tunnels for this project are expected to be excavated in soft ground (i.e., clays, sands and silts), using TBMs. This soft-ground can also consist of gravels, cobbles, and sometimes boulders. Two circular tunnels, bored side-by-side separated by a pillar of ground between, are proposed. An alternative is an "over-under" configuration in which one tunnel is bored directly above the other. This stacked arrangement is recommended only where right-of-way area above is constrained or where special design circumstances come into play, such as at transfer/interchange structures between separate rail lines.

Figure 4-16: Typical TBM-excavated Tunnel with Precast Concrete Segmental Liner

The TBMs will require launching area to start each tunneling operation. Following tunnel excavation, the TBM would be dismantled and retrieved at the designated exit point (construction shaft). The TBM can then be transported back to the launching area, reassembled, and repeat its journey for the second twin tunnel. As in prior Metro subway construction, two TBMs could be launched at the same time.

Tunnel driving operations consist of a series of activities. The TBM is advanced a small distance (typically 4 to 5 feet) by means of hydraulic jacks, which push against the previously installed tunnel lining ring. Following a complete "push" to advance the TBM, the hydraulic jacks are retracted and the next lining ring is installed. This process is repeated as the tunnel advances from one station to the next.

When initially starting a tunnel drive from a shaft or station excavation, a heavy steel frame is typically erected to allow a rigid structure for the TBM to push from so that it can start to move forward and excavate through the ground outside the station or shaft (see **Figure** 4-17). Often, the soils that the TBM will initially mine through are treated to improve their strength and reduce susceptibility to settlement.

Temporary precast concrete segmental liners are erected behind the TBM, which allow for continued advanced. The initial tunnel lining segments erected within the shaft are later removed once the TBM is fully "buried" and is mining continuously.

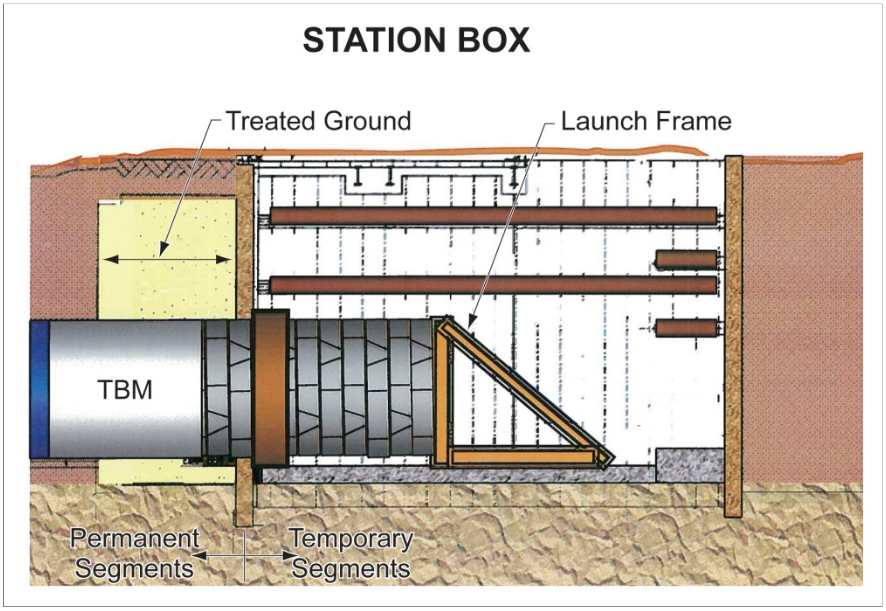


Figure 4-17: Launching a TBM from the Station Excavation

Excavated materials would be removed through isolated construction shafts or at cut-and-cover station excavations. With a conventional TBM, the excavated materials (spoils) are taken to the rear of the TBM by a screw conveyor and deposited on a conveyor belt. The conveyor belt drops the spoils into mine cars, which are then transported back to the launching area by a locomotive operating on temporary rail tracks fastened to the bottom of the tunnel. At the shaft, the mine cars are lifted out by a crane or hoist and the material is loaded into trucks for off-site disposal or temporarily stockpiled at the site for later disposal. Alternatively, belt conveyor systems could be used to transport spoils, through the tunnel and/or from the shaft to the surface.

Spoils would be disposed off-site at locations which are usually selected by the construction contractor with appropriate regulatory approvals, depending on the specific conditions of the spoils. With the expected use of pressurized-face TBMs, the spoils must generally undergo at least partial treatment on-site before being loaded on trucks for off-site disposal.

Figure 4-18: Typical TBM Tunnel Shown During Construction

4.1.10.1 Settlement Resulting from Tunnel Excavation

During the TBM tunnel excavation operations, the machine excavates slightly more soil than is taken up by the final lining. This is often referred to as "ground loss," which is the term for the small excavated volume that is greater than that defined by the permanent tunnel structure. These ground losses can produce surface settlement. The settlement can occur during mining or, depending on ground conditions, the time between the actual ground losses and the manifestation of the settlement could be days or weeks after the mining. Pressurized-face TBMs have become the leading soft ground tunnel excavation technology worldwide. A principal reason for this is the reduction in ground loss and settlement versus non-pressurized methods.

The amount of ground surface settlement will be a function of the tunnel depth, tunnel size, proximity of adjacent tunnels, ground conditions, TBM characteristics, and the contractor's excavation techniques. In addition to ensuring adequate face pressures through the use of pressurized-face TBMs, the requirement for precast segmental linings, grouted as the TBM advances, also minimizes settlement potential. The grouting operation is performed within the tunnel behind the TBM to promptly fill the annular space between the segmental lining and the surrounding ground.

In addition, at specific locations based on ground conditions or sensitive facilities above the tunnel, additional methods can be used to improve the ground prior to tunnel excavation and further minimize settlement potential. Such methods include permeation or chemical grouting, jet grouting, ground freezing and structural underpinning.

The width of the potential settlement zone is approximately two times the depth of the tunnel. Accordingly, structures located within these settlement/deformation zones would be further evaluated for potential impact and required mitigation measures.

As discussed above, pressure is maintained at the face of the TBM tunnel excavation to reduce the potential for ground loss, soil instability or surface settlement. In addition, a rigid, precast, bolted, gasketed lining system would be employed. In combination with the face pressure, grout would be injected immediately behind the TBM, in the annular space between the installed precast concrete liners (tunnel rings) and the excavated ground. The pressurized-face TBM can excavate below the groundwater table without requiring dewatering or lowering of the groundwater table. Metro recently completed the Gold Line Eastside Extension tunnels using EPB TBMs with no discernable settlements.

4.1.10.2 Settlement Protection Measures for Tunnels

For shallow tunnels below sensitive structures or utilities, additional methods can be employed to further reduce settlement. Such methods would depend on the ground conditions and structure details at specific areas. Some of the protective methods that could be employed along the alignment are discussed below.

Permeation Grouting

Permeation grouting is a method used to improve the ground prior to tunneling. Chemical (sodium silicate) or cement-based grouts are injected into the ground to fill voids between soil particles and provide greater strength and stand-up time for the soils. This grout can be placed through pipes from the surface before the tunnel reaches the grouted area, from pits or shafts adjacent to the grouted area, or in some instances from the tunnel face. In this latter case, the tunneling machine must be stopped for a period of time to drill ahead, install grout pipes, pump grout, and allow the grout to solidify. Permeation grouting is typically used in sandy soils, which are common along the Westside Subway Extension alignment. The permeation grouting method has been used successfully for the Metro Red Line in instances where the tunnel passed under potentially sensitive structures such as the US 101 freeway (downtown, Hollywood and at Universal City), and the Metro Gold Line Eastside Extension at its crossing of the I-5 freeway.

Compaction Grouting

Compaction grouting involves consolidating the ground prior to or following tunnel excavation. Compaction grouting entails the controlled injection of a stiff grout (typically sand with a small amount of cement) into the soils at and above the planned tunnel excavation. Grout pipes are installed in advance of tunneling and grout is injected to pre-consolidate the ground prior to the tunnel passing or to replace ground lost after the tunnel excavation. In either case, the grout improves the soil integrity and makes the ground more resistant to deformation. Compaction grouting methods were used successfully on the Metro Gold Line Eastside Extension.

Compensation Grouting

Compensation grouting is an alternate method in which grout is injected as the tunnel is excavated. Compensation grouting involves carefully controlled injection of grout between underground excavations and structures requiring protection from settlement. For tunnel applications, the grout pipes are installed above the intended tunnel position, in advance of tunneling. Grout is injected above the tunnel crown as the TBM excavation advances. The grout densifies the soil above the tunnel crown and replaces some of the ground that may be lost during the mining operations. This method prevents ground loss from propagating to the surface, thus mitigating settlement. A key component in controlling compensation grouting is careful monitoring of both structure and ground movements to allow the timing and quantities of grout injected to be optimized. Similar methods were used in several instances for the Metro Red Line project in the Downtown Los Angeles area and along portions of Hollywood Boulevard.

For grouting methods, surface preparation would likely be required (traffic controls, removal of landscaping, etc.) to allow space for drilling equipment, installation of grout pipes, and injection of grout. In cases where large structures are above the tunnel, access into the building or basements (where basements exist) could be required for grouting operations. In such cases, the use of the building could be limited during the grouting operations. After grouting is completed, the area would be restored to its existing condition.

The potential community impacts associated with these grouting methods, which are often performed from streets and sidewalks, can in some cases be mitigated by using directional drilling methods. Directional drilling can be done from off-street locations and can allow for horizontal orientation of grout holes along the tunnel alignment. This method, which was employed on the Metro Gold Line Eastside Extension, can provide an efficient grouting system with less community impact.

Underpinning

Underpinning involves supporting the foundations of an existing building by carrying its load bearing element to deeper levels than its previous configuration. This helps protect the building from settlement that may be caused by construction work in the soils near that foundation. It permanently extends the foundations of a structure to an appropriate level beyond the range of influence of the construction activity. This can be accomplished by providing deeper piles adjacent to or directly under the existing foundation and transferring the building foundation loads onto the new system. Underpinning may not be appropriate if the building is directly above the tunnel.

Existing Foundations

Some limited sections of tunnels may be within close proximity of existing foundations. Careful planning and execution will be required to protect such existing foundations. Depending on specific situations, such footings may need to be underpinned. Similar to potential situations in the cut-and-cover excavation, specific conditions may exist where building foundations above the tunnel could impart additional loads on the tunnel lining. In such cases, the tunnel lining would have to be designed for the additional loads, such as those imposed by adjacent building foundations where the tunnel alignment crosses beneath or near high-rise structures.

Presence of Existing Tie-backs

It is possible that abandoned tie-backs could project into the planned tunnel excavation area. Such situations are problematic because the TBMs cannot excavate through such tie-backs. The tie-back cables must be cut and removed from the area to be mined by the TBM so that the TBM cutter-head is not damaged. Tiebacks are anticipated, at areas adjacent to deep basements and/or parking garages in buildings generally constructed after 1965. Specific locations will be studied in detail in subsequent stages of design.

Where the locations of the tie-backs can be reasonably well established, it is possible to mine up to the tie-back and stop. Then the forward chamber of the TBM can be pressurized with compressed air and workers can enter ahead of the machine to cut and remove the tie-back(s). In such situations, workers operating in a compressed air environment are subject to strict safety protocols including time limitations and the need to decompress follow any such compressed air work periods. Tiebacks are anticipated in locations, for example, that are adjacent to deep basements or underground parking garages in buildings constructed after 1965. However, it is usually not preferred to stop a pressurized-face TBM during mining and to avoid such situations a small-diameter shaft would need to be excavated from the ground surface so that the tie-back(s) can be cut prior to the TBM mining through the area.

Depending on the number of tie-backs intruding into the tunnel envelope and the depth of the tunnel, a short section of cut-and-cover excavation may be required in the tie-back zone. Such an excavation would likely be decked over similar to the methods used for station excavations. However, rather than constructing a concrete tunnel structure inside the excavation, the TBM would still be used to “walk-through” the open excavation and would still erect the precast tunnel segments. Once the TBM had progressed completely through the area, backfill would be placed and compacted around the precast segments and up to the ground surface, which would then be restored.

In any of the situations above, the ground in the tie-back areas may need to be improved or strengthened prior to cutting the tie-back to minimize ground losses and associated settlement. This ground improvement can be accomplished through various grouting methods or, when below the groundwater table, by using ground freezing.

Tunneling in Gassy Ground

Gassy conditions likely to be experienced during construction are described in the Geotechnical and Hazardous Materials Technical Report (Metro, 2010). Tunneling in gassy and/or tar-laden ground presents additional challenges for the safe execution of the construction work and for the integrity of the equipment and facilities. The primary line of defense against encountering gas involves adequate ventilation, which dilutes and transports encountered gases out of the tunnel. In addition, gas monitoring devices will be utilized to automatically shut-down electric power to the TBM, excluding backup safety lighting. In the event of a machine shut- down, personnel will be trained in what procedure they are to take, generally to retreat to the rear of the TBM equipment while gas monitoring personnel, with proper protective equipment, check the source and cause of the power shut off. TBMs and associated equipment used in the tunnel will be sealed and be of explosion-proof design for use in a gassy environment.

As referenced earlier, a fully enclosed system, such as a pressurized-face Slurry-Face TBM is expected to be used for tunneling in known gassy or potentially gassy areas. This technology is considered an improvement over the methods used during construction of Metro's initial operating segments. Tunneling using a Slurry-Face TBM minimizes exposure of workers to elevated gas concentrations underground, since the excavated soil is removed in a fully enclosed slurry pipeline to an above-ground, enclosed treatment plant. Where an EPB TBM can be converted to operate similar to a Slurry-Face TBM, with a closed spoil transport system, it would afford similar benefits and would likely be acceptable for use.

In areas of potential H_2S exposure, there are a number of techniques that can be used to lower the risk of H_2S exposure. First, it has been studied that the mixing and dilution of the Slurry-Face TBM excavation process itself reduces the potential for gas generation.

In addition, areas that have been determined to be at risk of elevated H_2S levels can be treated by injecting hydrogen peroxide into the ground/water in advance of the tunnel excavation. This "in-situ oxidation" method reduces H_2S levels even before the ground is excavated. This pre-treatment method is unlikely to be necessary where a Slurry-Face TBM is used, but may be implemented in at tunnel-to-station connections or at cross-passage excavation areas, which are discussed further below. Injection wells may be required at close spacings so that hydrogen peroxide is injected throughout the targeted area. Also, because this treatment requires high hydrogen peroxide concentrations, there are worker health and safety issues. The oxidation process releases pure oxygen, which could be a flammability concern in the tunnel. This can be mitigated with increased monitoring and ventilation

In addition to pre-treatment of the ground/water prior to mining, additives can be injected into the bentonite slurry during the mining and/or prior to discharge into the slurry treatment plant. The use of sodium hydroxide as an additive to raise the pH of the slurry has been found to be effective to suppress H_2S gas releases or "off-gassing." However, because of health and safety issues associated with use of sodium hydroxide, Cal/OSHA has previously indicated that they would not support such an application in a tunnel environment. In the slurry treatment plant, which can be more tightly controlled and monitored, sodium hydroxide dosing may be possible.

A more promising technique is the addition of zinc oxide to the slurry, a method commonly used in oil-field operations. The zinc oxide precipitates out dissolved sulfides to similarly reduce any potential for H_2S release or exposure. The slurry pipelines can be equipped with H_2S sensors that can automatically start zinc oxide dosing when certain levels are reached. However, if zinc dosages are significant enough, the post-treatment solids could be considered contaminated, which could require disposal at special facilities.

These treatments can neutralize the presence of hydrogen sulfide, thus improving the safety of workers involved in the slurry and separation plant systems. Such treatments have the additional benefit of reducing the corrosive effects of H_2S when it is dissolved in the slurry or groundwater.

Further to the treatment methods discussed above, the above-ground slurry treatment plant can be designed and operated to minimizing off-gassing both within the plant and to the environment surrounding the plant. This can principally be done by segregating slurry treatment areas and providing separate ventilation systems for areas exposed to off-gassing. The ventilation systems can also be out-fitted with air monitoring and treatment systems, such as scrubbers, to ensure that air leaving the plant environment meets air quality standards, including odor controls.

Where warranted, continuous air quality monitoring can be employed in the areas around the slurry treatment plant. These systems can be remotely monitored and equipped with alarms for warning of elevated gas levels and, if necessary, shutting down the tunnel excavation until air quality improves. Data-logging systems may also be employed to check the safe limits of exposure over time. These systems are frequently employed in the wastewater treatment industry and can be adapted to this application.

Tunnel Safety Considerations

All underground construction will require reviews and consents from Cal/OSHA, the Metro Tunnel Advisory Panel, and the Metro Fire Life Safety Committee, which includes members from the Los Angeles City and County Fire Departments, as well as Metro safety specialists.

Prior to tunnel construction, designs will have been developed to minimize gas intrusion into the tunnel or station under construction and for the final structure. These designs may include some combination of continuous, sealed excavation support systems, pressurized-face TBMs with closed spoil transport systems, pre-treatment of potential gas areas, and special membranes and systems to seal tunnel linings and structural elements. These concepts will be further developed during preliminary design. Additional precautions involve a strict adherence to tunnel safety standards, including use of tunnel ventilation systems during construction, monitoring for gas, and use of specialized mechanical and electrical equipment.

In California, tunnel construction safety is governed by the California Occupational Safety and Health Administration (Cal/OSHA) Tunnel Safety Orders and worker safety training. California Electrical Safety Orders also will apply for use of electric equipment. California Tunnel Safety Orders are considered to be among the most comprehensive, structured, and most stringent in the world, and have been cited for use in other states.

Where methane and/or H_2S gases could be encountered, the regulations are specific and begin with the tunnel classification. The classifications range from "non-Gassy" where there is little likelihood of encountering gas during the construction of the tunnel, to "Gassy" which is applied when gas in the tunnel is likely to be encountered at a concentration greater than 5 percent of the Lower Explosive Limit (LEL) of the gas. More specific safety requirements of the Tunnel Safety Orders are described below:

Ventilation

The tunnel must have adequate ventilation to dilute gasses to safe levels. Methane is combustible when mixed with air in the range of between 5 percent and 15 percent by volume. Below 5 percent (the LEL), it is not explosive, however lower alarm levels are set at 10 percent of the LEL for a margin of safety. Similarly, hydrogen sulfide (H2S) levels must be maintained well below safe worker exposure limits, given by OSHA to be 10 parts per million (ppm). Project tunneling specifications will reference the Tunnel Safety Orders and require excess ventilation capacity. Gas levels are monitored continuously and recorded over time to ensure no exposure to maximum levels or sustained levels. The main ventilation systems must exhaust flammable gas or vapors from the tunnel, be provided with explosion-relief mechanisms, and be constructed of fire-resistant materials.

Because of the additional hazards associated with the potential presence of hydrogen sulfide gas, tunnel ventilation systems in gassy tunneling areas will need to be robust and capable of delivering large volumes of air to the tunnel environment. In addition, due to the corrosive nature of H_2S gas, the typically-used rolled steel vent ducting may have to be replaced with fiberglass ducts, which are less readily-available and more expensive.

Internal combustion engines and other equipment, such as lighting, must meet standards of the US Mine Safety and Health Administration (MSHA). These approvals require verification that equipment is safe with respect to not producing sparks or emitting gas into the tunnel.

Smoking is not allowed in the tunnel, nor is standard welding, cutting, or other spark-producing operations. Special permits and additional air monitoring are required if welding or cutting operations are essential for the work. In addition, welding is only allowed in stable atmospheres containing less than 10 percent of the LEL and under the direct supervision of qualified personnel.

A fixed system of continual automatic monitoring equipment is provided for the working areas of the tunnel. The monitors have sensors situated to detect gas and automatically signal the workers and shut down electric power in the tunnel (except for ventilation, lighting, and pumping equipment necessary to evacuate personnel) when 20 percent or more of LEL is encountered. In addition, a manual shut down control is required. Tests for flammable and hazardous gas and petroleum vapors are conducted in the return air and measured a short distance from the work areas.

A refuge chamber or alternate escape route must be maintained within 5,000 feet of the face of a tunnel classified as gassy or extra-hazardous. Workers must be provided with emergency rescue equipment and trained in its use. Refuge chambers are to be equipped with a compressed air supply, a telephone, and means of isolating the chamber from the tunnel atmosphere.

Health and safety training and procedures are required based on the hazards anticipated. A process that involves training, auditing, and monitoring is required to ensure that procedures are followed and that health and safety can be maintained during construction.

Environmental controls will also be required to dilute and control elevated methane and/or H_2S to protect workers underground, workers above-ground, and the areas surrounding tunnel excavation and ventilation sites. Issues associated with gaseous release during construction will be minimized based on the requirement for a pressurized-face TBM with a closed spoil transport system in the affected reaches. The use of these technologies in the potential gas areas will minimize exposure of workers to elevated gas concentrations, since the excavated soil is not exposed while in the tunnel environment. Vapor controls and monitoring, and possibly other safety design features to be determined during Preliminary Engineering, will be employed at the surface if gaseous contaminants are released as the slurry is treated at the separation plant and then circulated for reuse by the TBM.

In addition, special personal protective equipment, such as supplied-air respirators, will be readily available in key locations within the tunnel when operating in potential H_2S zones or when air monitoring warrants this step. In these cases, all tunnel personnel will receive special safety training associated on the use of this equipment as well as other safety-related precautions.

4.1.10.3 Surrounding Properties

By itself, there is no discernable difference with respect to surrounding properties or historic resources from tunneling in the potentially gassy areas versus tunneling in other zones. The ancillary ventilation and other facilities used in the elevated gas zones are not substantially different from those used for tunnels outside the gas zones, and are unlikely to result in a greater potential to affect these properties.

Slurry Treatment Plant

With the Slurry-Face TBM method of tunneling, a bentonite slurry is used to apply fluid (hydraulic) pressure to the tunnel face and to transport soil cuttings from the TBM to the surface. The slurry that is pumped from the TBM to the separation plant contains excavated soils, which are processed to separate the soil (solids) from the slurry (liquid). After processing, the soil is disposed of off-site and the “cleaned” bentonite slurry is pumped back to the TBM. The slurry is pumped in and out of the tunnel through a series of pipes. The result is that excavated material is kept enclosed and in a fluid state until it reaches the above-ground slurry treatment plant.

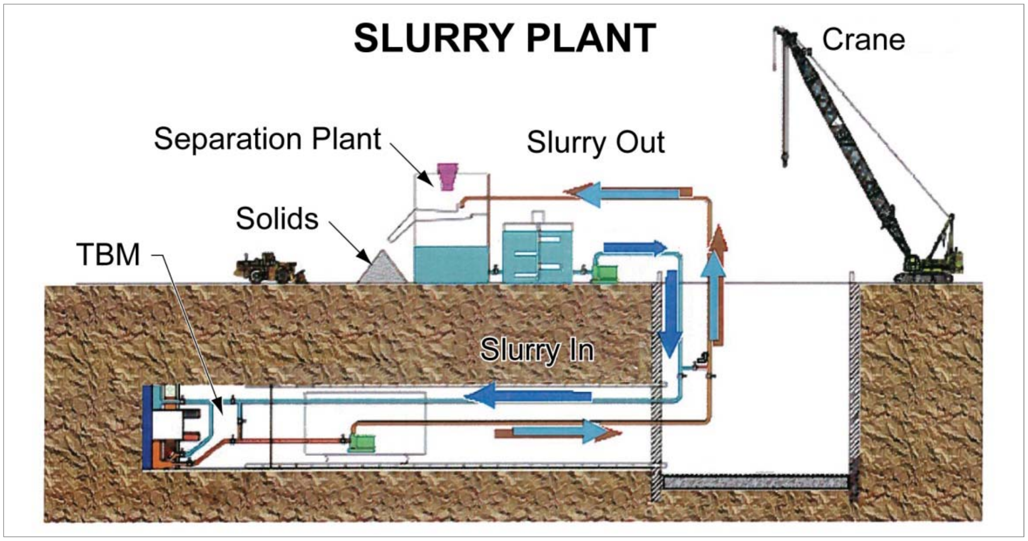


Figure 4-19: Schematic of Typical Slurry-Face TBM Operation

This method involves the setup of a temporary slurry treatment plant(s) at surface. The slurry treatment plant provides two basic functions: 1) to prepare the bentonite slurry by mixing the slurry for use in the tunneling process, and 2) to treat the used slurry, i.e., the slurry discharge coming from the TBM. The slurry discharge will be pumped out via pipeline to the ground surface where will undergo a separation process for soil (clay, sand, and gravel) removal. The removal process involves settling and the use of sieves for separation of large particles and centrifuges for small particles. Once the excavated material is separated from the slurry, the resulting soil can typically be stockpiled at the plant grounds or at off-site locations for approximately two to three days to dry before being hauled to a landfill or other disposal facility.

The slurry plant is anticipated to require an approximately one-half-acre site for the equipment and enclosure. The facility is anticipated to be approximately 50-ft tall (see figures below). Water removed from the discharge slurry would be recycled for further use in preparing the bentonite slurry.

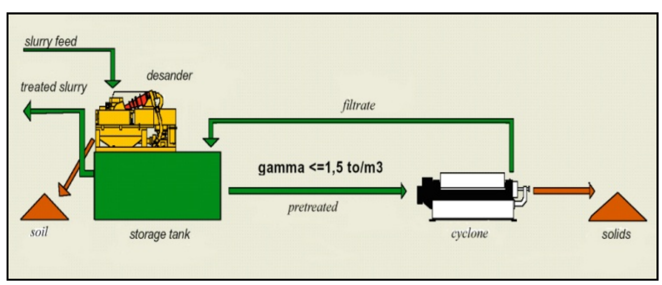


Figure 4-20: A Schematic Diagram of Slurry Treatment Process

Slurry treatment plants recently used are shown in Figure 4-21 and Figure 4-22. When space and noise restrictions are of concern, treatment plants may be containerized for size reduction and sound proofing.

Figure 4-21: Typical Slurry Treatment Facilities (Stacked Configuration)

Figure 4-22: Enclosed Slurry Plant with Materials Storage Silos

Excavated Materials (Spoil) Removal

Spoils would be disposed off-site at locations that are usually selected by the construction contractor, with the concurrence of applicable authorities. However, because all tunneling would be performed with pressurized-face TBMs, the spoils must undergo some treatment (drying of EPB-TBM spoil; or de-sanding and other processing of Slurry-TBM spoil) on-site before being loaded on to trucks for off-site disposal. For mostly sandy soils, drying can likely be accomplished on-site. For soils with higher water content (clays), and in the event that the volume of such soils is substantial, an additional temporary off-site storage/drying location may be needed. This can be avoided if a disposal facility that accepts wet soils can be identified. Additional separation processes may also be an option. Suitable disposal sites will be identified to ensure the excavated material can be removed and transported to the disposal area in a timely and efficient operation. Designated haul routes will be followed, as noted in the Task 10.12 Technical Report.

Environmental concerns are often encountered at the site areas where spoils are transported from the underground work locations to the ground surface and then loaded into trucks. These are typically work zones subject to noise and dust control restrictions. Noise and/or dust walls are typically required to mitigate these concerns. The impact of tunnel construction activities on storm water is a consideration as far as the potential for these excavated materials to come in contact with storm water or be discharged into storm water drainage facilities.

Disposal of Tunnel Spoils

For typical disposal of excavated materials, see the following sections on station construction and excavation. For a typical tunnel excavation operation, mining both tunnels at approximately 20-ft per 10-hour shift, the rate of spoil removal would be approximately 130 loose cubic-yards (CY) per hour to be hauled off-site. From any single construction staging site this material will be produced from two tunneling machines, which will often operate simultaneously. It would be expected that on better mining days the spoils to be removed could be doubled to be in the range of 250 loose CY per hour, or approximately 12 trucks per hour, which would equate to one truck every 4-5 minutes. With temporary stockpiling of spoils on the site, the hauling could be partially deferred to off-shifts (night-time periods) and to weekends. For a typical mining day, approximately 75 to 100 truck-loads of spoil would leave the site, although the truck traffic can be controlled by the contractor and can be distributed throughout the day-time and/or night-time periods, if allowed by local regulatory agencies.

Excavated soils and excess material would be transported off-site to approved disposal sites along designated routes. If materials are suspected to be contaminated, testing would be required prior to transportation. Soils containing contaminants will be characterized, excavated, loaded onto trucks, and transported off-site to a treatment or disposal facility. Waste disposal profiles will be generated from soil sampling and site characterization data. Based on the site characterization data, soils excavated at the site will be classified as non-hazardous or hazardous depending on the concentration of the impacted soil. Depending on the test results of the soils, disposal options could include the following sites:

For hazardous materials: [see also Geotechnical and Hazardous Materials Technical Report (Metro, 2010).

- Waste Management Inc., Kettleman City, CA
- Clean Harbors Environmental Services, Buttonwillow, CA
- Veolia Environmental Services, Azusa, CA
- US Ecology Nevada, Inc., Beatty, NV

For non-hazardous, petroleum hydrocarbon-containing wastes:

- Thermal Processing Systems Treatment, Adelanto, CA
- Waste Management, Palmdale Landfill, Palmdale, California;
- Waste Management, McKittrick Waste Disposal Facility, McKittrick, California;
- Thermal Remediation Solutions, Azusa, California

For contaminated, non-hazardous soils:

- Philadelphia Recycling, Mira Loma, CA
- Municipal landfills, or other locations identified by the contractor.

Disposal of Contaminated Soils during Construction

The issue of disposal of soils and other waste from construction in the potentially gassy areas, which may also contain tar and other potential contaminants, is preliminarily addressed through records-database searches and other available information. The focus is on identifying any special handling and/or safety issues associated with these materials and identifying existing disposal facilities with available capacity.

This segment would likely encounter soils impacted with petroleum hydrocarbons, volatile organic compounds (VOCs), and hydrogen sulfide (H_2S) from natural sources. In addition, sites impacted by underground storage tanks, dry cleaners, and other potential waste generators may also be encountered.

Tunnel Lining Construction

Precast concrete segments with gaskets will furnish the initial and final support of the tunnel and along, with ventilation and utility piping, is the major logistical component of the tunnel excavation operation.

Single-pass, double-gasketed, precast concrete segments are considered the lining system of choice to limit infiltration of water and gas through the final lining. These systems are well-proven worldwide and provide a high-quality tunnel lining very close behind the TBM excavation. Based on the groundwater regime anticipated, this type of lining system is optimal. However, in areas of gassy ground, additional steps may be required to provide greater protection against gas leakage into the tunnel environment, either during the tunnel excavation period or subsequently. Further details on segment design and testing is included in the Geotechnical and Hazardous Materials Technical Report (Metro, 2010).

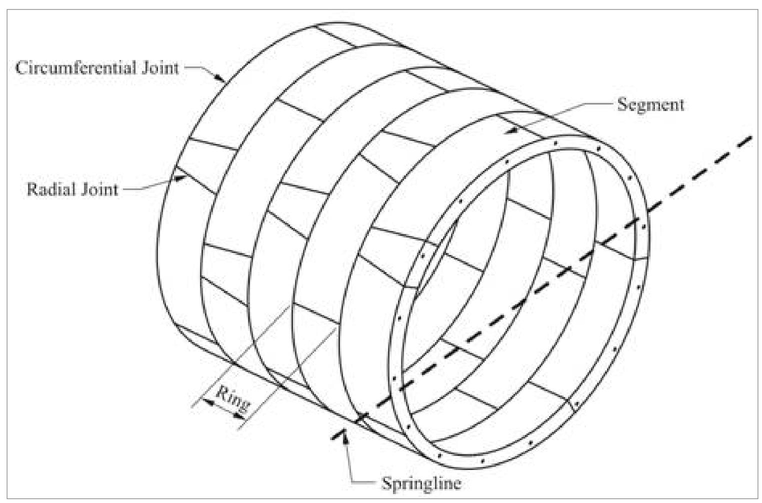


Figure 4-23: Typical Precast Concrete Segmental Tunnel Lining

These steps may include some combination of the following:

- Separate application of barrier seal to be installed on surface joints.
- Additional segment thickness to allow for wider gaskets, with more surface area and thus an improved seal for prevention of water/gas migration.
- Special high-performance concrete, which is less permeable, with or without additional reinforcement.
- Application of surface-applied grout or mortar seal to joints between segments.
- Addition of hydrophilic (swelling) seals to one of the gaskets.

- Supplemental injection of a self-sealing, water- and gas-proof product between gaskets.
- Coatings on segments to reduce concrete permeability.
- Addition of a secondary high-density polyethylene (HDPE) membrane and protective concrete on the inside surface of the finished tunnel.
- A membrane applied in the base of the tunnel only, prior to placement of the trackbed and walkway concrete, with tunnel diameter space provisions to permit subsequent installation of a full-perimeter membrane or similar product with protective concrete (i.e., should it be determined to be necessary in the future).

As mentioned earlier, the tunnel lining may need to be designed for additional loads imposed by existing building foundations above the tunnel.

The precast concrete segments are fabricated off-site and delivered by truck to the site. Several days or weeks of segments may be stored at the work site to ensure and uninterrupted supply to the tunnel excavation operations. A typical precast segment storage area is shown in. Care is required to ensure that the segment gaskets are not damaged during transport, shipment, or due to prolong exposure to sunlight. Depending on the gasket composition and the typical storage period, the segment gaskets may need to be installed onto the segments at the site, as opposed to at the off-site pre-fabrication facility. If this is necessary, a small enclosure is required to install the gaskets under controlled conditions.

Figure 4-24: Precast Concrete Segments Storage

Cross-passage Construction
Cross-passages between adjacent tunnels are to be constructed at intervals along the running tunnels. These openings will be almost entirely hand-excavated (mined with small excavators as opposed to TBMs) and concreted. Before exposing the ground, particularly where water or gas will be encountered, it is good practice to install a tight seal of improved soils (using grout or other soil improvement methods) around the perimeter of the area to be excavated. Because excavation and construction of these structures is particularly

sensitive to ground, water and gas conditions, cross-passage locations may be shifted to some extent to take advantage of favorable ground conditions.

Individually, ground conditions will dictate the method and detail of preparing the cross-passage site for excavation. It is contemplated that after ground treatment, a tight ring with grouted holes will be drilled from within the tunnel and then grouted with chemical or cement grout designed for the ground encountered. Steel spiling bars (pre-reinforcement) may also be employed, which will be drilled or driven from the tunnel above the cross-passage envelope.

Alternately, depending on the availability of access at the surface, drilling and grouting might take place from above the tunnels. Although surface drilling is often more disruptive to traffic and the surrounding community, it may provide for a greater control and quality of grouted ground and minimize impacts to tunnel excavation operations. In areas of weaker soils or higher groundwater, jet grouting from the surface may be utilized to provide a higher-strength and more consistent area of improved ground for cross-passage excavation. When below the water table, ground freezing is another method that could be considered.

Cross-passages will be excavated by non-mechanized, sequential excavation methods. Sequential excavation and support methods call for the ground to be excavated incrementally in small areas and stabilized or supported prior to advancing the next increment. The ground can be stabilized with an array of different methods including steel supports, spiling pre-reinforcement, and shotcrete (sprayed concrete). Excavated soils would be removed through the TBM tunnels. The sequence of excavation would be determined during design stage and controlled and modified as needed during construction based on actual conditions encountered. This construction technique is considered in special instances where the planned depth, shape, or length of the tunnel may not be cost effective using more traditional methods.

Ground movements, possibly resulting in surface settlement, could also occur during excavation for cross-passages between tunnels. The amount of settlement would be a function of the sequence of excavation and the amount of ground support (including thickness of shotcrete applied), each of which are adjusted during mining to minimize ground settlement.

Because it is difficult to construct cross-passages at the same time as excavating the running tunnels, cross-passage construction typically is done when the excavation of the main tunnel is not proceeding. Therefore, the construction of cross-passages is often on the critical path for tunnel construction.

In areas with potential exposure to gas, special monitoring will be as required for each cross-passage location. At the breakouts from the main tunnel, grouting and other aspects of the construction will not vary substantially from the normal (less gassy) procedure. However, as mentioned earlier, pre-treatment of the ground to reduce the potential for gas exposure is an option. Also, probe holes extending into the cross-passage area from the main tunnel will likely be drilled prior to starting the cross-passage excavation. Such probe holes would be beneficial for detecting water and/or gas and can allow for excavation plans to be adjusted based on this new information.

Because the environment for the cross-passage excavation is not as well sealed as that for the main TBM tunnels, additional requirements for gas monitoring, detection, ventilation, and worker protection systems will likely be required.

The permanent lining for cross-passages will likely be constructed of cast-in-place concrete. However, in potential gas areas, special gas-resistant membranes and/or joint sealants may be required. These measures would be similar to those used for stations constructed in potential gas areas. The completed cross-passages may also be equipped with gas monitoring and detection systems, as well as special ventilation equipment to dissipate gas. The requirements for these systems will be determined during Preliminary Engineering.

4.2 Alternative 1 – Westwood/UCLA Extension

This section describes the likely sequence of construction activities necessary to construct the tunnel, stations, and operations/maintenance facilities of Alternative 1. Generally, Alternative 1 (from Wilshire/Western to Westwood/UCLA) would likely be designed and constructed in the following three segments or reaches:

- Segment 1 – Construction of the alignment from the existing Wilshire/Wilshire/Western Station to the Wilshire/Wilshire/Fairfax Station. This segment is the same as MOS 1.
- Segment 2 – Construction of the alignment from Wilshire/Fairfax Station to the Century City Station. Tunnel construction would be largely dependent on the Century City Station option chosen, which is being evaluated at this time. The terminus of Segment 2 is the same as MOS 2.
- Segment 3 – Construction of the alignment between the Century City Station and Westwood/UCLA Station.

Depending on available funding, more than one segment could be constructed concurrently.

4.2.1 Construction Scenario - Segment 1 – Wilshire/Western to Wilshire/Fairfax

4.2.1.1 Preconstruction

In addition to the preconstruction activities outlined in Section 4.1.1.1, the areas surrounding the Fairfax and La Brea stations are known to have tar deposits and or tar sands with potential paleontological features. Preliminary preparation and excavation is likely to take place early on and possibly as separate contracts in order to orderly and carefully remove the resources (i.e., fossils, artifacts, etc.) and prepare the ground for the coming excavations. In-street work will typically necessitate on-going lane closures.

4.2.1.2 Stations

Within the Wilshire/Western to Wilshire/Fairfax reach, there are two or three new stations to construct (Wilshire/Crenshaw, Wilshire/La Brea, and Wilshire/Fairfax Stations) and an existing station (Wilshire/Western) to tie in to. Under Option 1, the Wilshire/Crenshaw would be deleted and a vent would be constructed between Crenshaw and Lorraine Boulevard. These new stations, in addition to modifications required to the existing Wilshire/Western Station are described in Table 4-2 below.

Table 4-2: Alternative 1, Segment 1 Station Descriptions

Station Notes	
Wilshire/Western	Wilshire/Western Station currently exists and is in operation. The west wall of the existing station will need to be removed to allow for the rail and systems to be extended into the new segment.
Wilshire/Crenshaw	Option 1 includes a design option to not construct this station and a vent shaft would be constructed at this location.
Wilshire/La Brea	Wilshire/La Brea Station is near the midpoint of Segment 1.
Wilshire/Fairfax	Asphalt (tar) impregnated soil is located in the lower reaches of the Wilshire/Fairfax Station (Paleontological issues to be discussed in subsequent chapters).

At the existing Wilshire/Western Station, a west-end TBM retrieval shaft is a consideration in comparing the "gutting or stripping" of two TBMs versus the need for relatively small retrieval shafts. In addition, the site is potentially reasonable for use in supporting tunnel excavation operations.

The Wilshire/La Brea Station is a viable site for tunnel mining. Potential construction work area appears to be a half-block width and a block long at the east end of the station, which could be used for receiving TBMs entering from the west and for the entry of TBMs to excavating to the east.

The Wilshire/Fairfax Station has a reasonable potential construction work area and is the likely preferred location to launch two TBMs for tunnel excavation, particularly considering the major access point for tunneling to the west of Fairfax. After the tunnels are excavated, the ensuing work would include concrete placing, cross-passage construction, vent shafts, intermediate access shaft construction (if required), and all finishing and utility installation operations. The site of this station has known hydrocarbon and subsurface gas deposits) that will potentially slow the construction and special controls will be required.

Given this consideration, tunnel excavation operations could alternatively be staged from an access shaft just west of the existing Wilshire/Western, with the tunnels proceeding westward to Wilshire/Fairfax. Although space is more constrained at this location, and construction could create more impacts on Metro customers using the station, it would be also be advantageous to launch the TBMs from a non-gassy zone.

In order to maintain traffic, all but two of the station excavations (Westwood/UCLA Station—Off Street Station and Westwood/VA Hospital Station) are to be decked over to support traffic. Depending upon site constraints a station deck and support of excavation may be installed in stages over the street using several street closures. Partial street closures would typically occur during night-time periods, while full road closures, if necessary, would occur over extended weekends. The local community will be consulted concerning the road closure periods. Removal of decking after construction of the station and tunnels will be similarly staged.

After the station or track structure has been completed, backfilling operations atop the structure will commence. Street and site restoration activities are discussed in a subsequent section.

In the section between Wilshire/Western and Wilshire/Fairfax, a crossover structure is planned west of the Wilshire/La Brea Station. An optional location for the crossover would be at the Wilshire/Fairfax Station, west of the station.

4.2.1.3 Station Excavation

It is anticipated that all station excavations along this segment would encounter variable amounts of subsurface gas and groundwater. Therefore, the use of more impermeable excavation support walls and/or dewatering systems will be the likely methods of station initial support.

Table 4-3 shows the estimated volume of material from the cut-and-cover station excavation and the associated daily truck trips and truck loads for each station in Segment 1 from Wilshire/Western to Wilshire/Fairfax.

Table 4-3: Estimated Amounts of Excavated Materials for Station Construction for Segment 1

Station	Estimated Total CY Excavated	Estimated Daily Haul Truck Trips	Estimated Total Haul Truck Loads
Wilshire/Western*	12,000	25	600
Wilshire/Crenshaw	160,000	25-50	8,000
Wilshire/La Brea	200,000	25-50	10,000
Wilshire/Fairfax	135,000	25-50	7,000

* TBM Access Shaft adjacent to existing station

Contractor Work and Storage Areas

Contractors work and storage areas will be necessary for construction of station excavations, tunneling, station entrances, crossover boxes, pocket tracks, mid-line structures, TPSS locations, and ventilation or emergency exit shaft locations. Several potential construction staging sites have been identified; however, not all of these potential construction staging sites would be selected for use.

Wilshire/Crenshaw

potential construction site is proposed for the Metro-owned property between Crenshaw and Lorraine Boulevards.

Wilshire/La Brea

A potential construction site is proposed for the Metro-owned property, on the north side of Wilshire Boulevard, between La Brea Avenue and Detroit Street. Another potential site is just west of La Brea Avenue, on the south side of Wilshire Boulevard. A double crossover is currently planned on the west side of the station.

Wilshire/Fairfax

A potential construction site is proposed for the entire parcel immediately north of Wilshire Boulevard, south of the apartments, between Fairfax and Crescent Heights and also on the south side of Wilsire, west of Fairfax. An alternative location for a double crossover is on the west side of the station. The Johnnies restaurant building is to remain. A potential construction site is proposed at South Ogden Drive.

In order to mine east along this segment, the Wilshire/Fairfax Station excavation would be the first item of construction, after demolition of existing buildings designated to be removed. Several options are available for staging this construction. A side entry to the station excavation of approximately 40-ft in length, would afford access of the TBM and construction machinery to the tunnel headings at the east end of the station excavation. A construction staging area of about 150-ft by 1000-ft to the north side of the station is envisioned, and all material delivery and removal of excavated materials could take place within these confines.

The lot south of the LACMA between Orange Grove Aveune and Ogden Drive has potential for use as an additional construction staging area. Another potential construction staging site has been identified on the south side of the station west of Fairfax. While these logically would not work well as a TBM launch site, it could be beneficially used for staging TBM equipment components and be used as an interim storage area for precast segments, ventilation line, utility lines, and for ease of transfer to the main mining location at the Fairfax site.

Two TBMs could be assembled at the Wilshire/Fairfax Station construction staging area, located between South Crescent Heights Boulevard and Fairfax Avenue to the north side of Wilshire Boulevard. Components would be lowered to tunnel grade at the side access and then moved into position for use at the tunnel faces or headings. Utilities, air, water, disposal, electricity, sanitation, and communication equipment could be positioned near the east end of the 150-ft by 1000-ft construction yard.

This construction yard, besides being used for the normal staging of precast concrete segments, fan or ventilation line, temporary spoil storage, shaft support (air, water, electricity, spoil hoisting), offices and shops, would also be used for the mixing and processing of slurry that could be used in the slurry wall excavation support or tunnel excavation operations. If used, the slurry TBM support facilities would likely be confined to an area of approximately 100-ft by 75-ft. In many cases, an additional area of approximately 100-ft by 200-ft would be required for the slurry treatment (separation) facility, which would include filters, centrifuges, and vibrator equipment. Often this equipment can be stacked to save space. Additional description of the slurry separation process is in the tunnel construction section below.

4.2.1.4 Station Construction

The cut-and-cover stations will be constructed with poured-in-place concrete, which will differ substantially depending on the length and the design configuration for the structure. Access for the concrete forming and placing is limited and the construction will be slow and difficult to precisely determine. The duration for completing the concrete and architectural work is expected to be approximately 24-32 months. The amount of concrete being placed will likely be upward of 30,000 CY, which will take approximately 3,000 transit mix truck loads for each station. Reinforcement steel will average a total of 3,500 tons per station.

The construction sequence for the station structures would include construction of the foundation base slab, followed by the installation of exterior walls and any interior column elements. Slabs are typically poured as the columns and intermediate floor and roof wall pours progress. Station entrance locations are generally used as access points to the underground station during the construction process. Exterior entrances would be constructed after the station structure has been completed.

During station construction, approximately 5 to 10 concrete trucks per day can be anticipated for normal operation. Occasional large pours would be needed at the stations, depending on the construction sequencing and schedule. These large pours could potentially require 30 to 40 trucks per day. The larger pours are expected to be performed at night to ensure supply and delivery of concrete and to minimize traffic impacts. Other support and delivery trucks, approximately up to 10 to 20 trucks per day, would also be anticipated during the peak station construction periods to bring materials such as rails, structural steel, and mechanical and electrical equipment.

Station concrete construction and architectural finish work will take place after tunnel operations are completed. Once the tunnel construction operation is past, the station work will have free access. This work may commence to some degree from one end of the station as long as interference with the tunneling operations is controlled. Once station structure work is complete, the station excavation will be backfilled and the permanent roadway will be constructed.

4.2.1.5 Tunnel Construction

The tunnels could be excavated eastward from the Wilshire/Fairfax Station to the existing Wilshire/Western Station. The route of advance of the tunnels would be from the below-grade Wilshire/Fairfax Station, through the Wilshire/La Brea Station and on to Wilshire/Western Station.

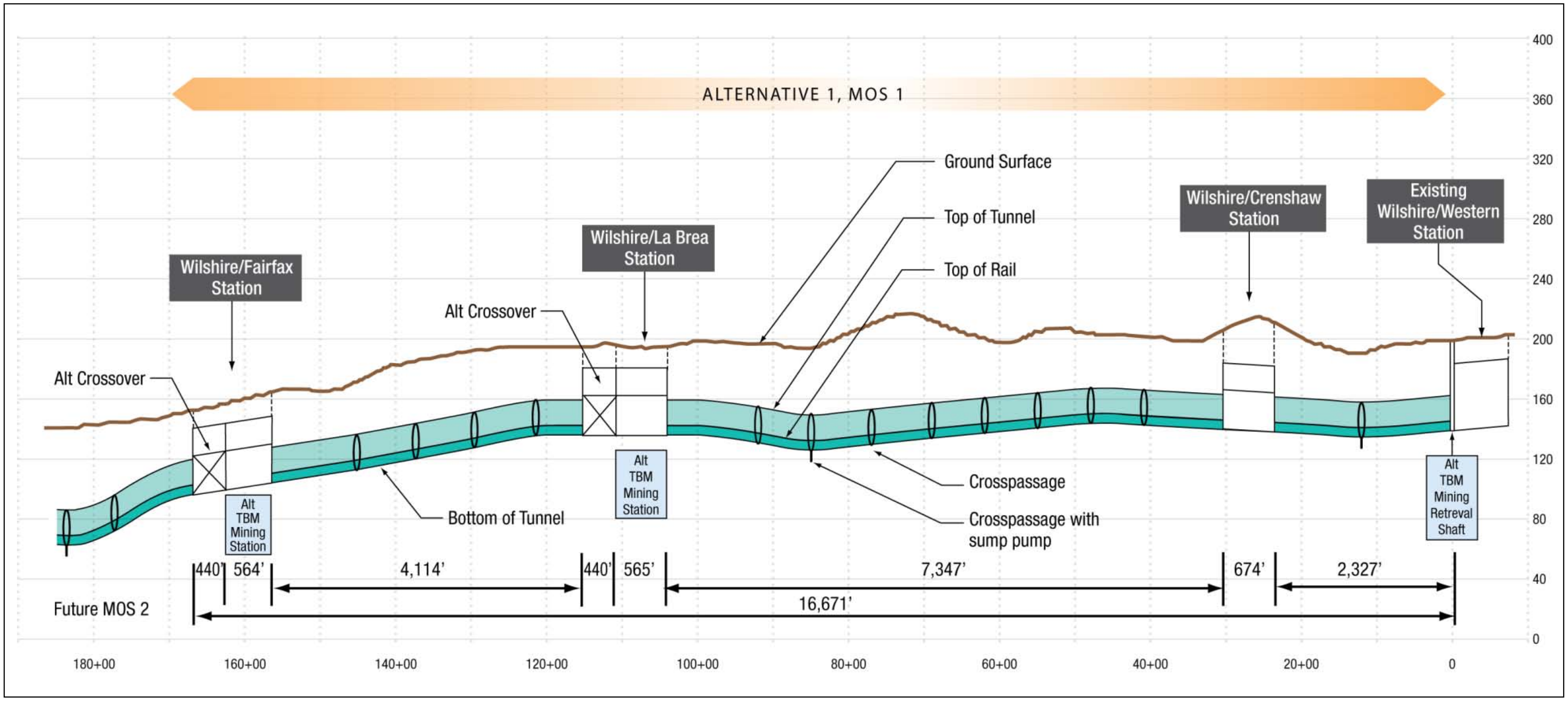
Whereas stations, crossovers, and ventilation structures will generally be constructed by cut-and-cover methods, the running tunnels will be constructed by mechanized tunneling methods. TBM components will be shipped to the tunnel construction sites by trucks. Several oversize deliveries will be required, some of which will be done during nights and weekends. However, these large component deliveries are limited to initial setup period for the, as well as during the removal period after excavation work is complete. If a TBM is to be re-used to excavate a subsequent adjacent tunnel, the entire machine may be transported by road from one site to the next. This is a rare event, which often requires full or partial road closures and is typically done during night-time periods.

The pre-cast concrete liners are pre-fabricated off-site and delivered by truck to the site. Segment loads are estimated to be 6 to 10 truck loads per day for the duration of tunneling based on an estimated overall excavation rate of 30- to 50-ft per day. Segments needed for at least several days' production are generally stored at the work-site to allow continuous tunneling as the rates of advance may vary between 0- and 100-ft per day. Tunneling operations are typically continuous, occurring six or seven days a week, usually with two 10-hour shifts per day.

The pre-cast concrete liners are pre-fabricated off-site and delivered by truck to the site. Segment loads are estimated to be 6 to 10 truck loads per day for the duration of tunneling based on an estimated overall excavation rate of 30- to 50-ft per day. Segments needed for at least several days' production are generally stored at the work-site to allow continuous tunneling as the rates of advance may vary between 0- and 100-ft per day. Tunneling operations are typically continuous, occurring six or seven days a week, usually with two 10-hour shifts per day.

Table 4-4: Tunnel and Construction Lengths for Alternative 1, Segment 1

Station	Length (feet)	Description
0+00		From Wilshire/Western Station proceeding west under Wilshire Boulevard
23+90	2,390	Enter Wilshire/Crenshaw Station (Option)
30+40	650	Exit Wilshire/Crenshaw Station proceeding west under Wilshire Boulevard
103+60	7,320	Enter Wilshire/La Brea Station
112+00	840	Exit Wilshire/La Brea Station proceeding west under Wilshire Boulevard
156+40	4,440	Enter Wilshire/Fairfax Station
165+60	920	Exit Wilshire/Fairfax Station proceeding west under Wilshire Boulevard
	16,560 (3.13 miles)	Total Length
	2,410	Total Station Length
	14,150 (2.7 miles)	Total Twin Tunnel Length
Scenarios to Consider		
A	Mine with TBMs from Fairfax and remove them from the new retrieval shaft at Wilshire/Western Station. Alternate plan, to leave TBM shields in the ground at Wilshire/Western and remove remaining equipment from Wilshire/Crenshaw shaft.	
B	Mine with TBMs from Fairfax, retrieving them at La Brea and with two TBMs from La Brea removing them from the new retrieval shaft at Wilshire/Western Station, or stripping the TBMs, leaving the steel shield in place.	
C	Mine east from La Brea to Western and west from La Brea to Fairfax.	
D	Mine from east to west, from Wilshire/Western. Remove TBMs at Wilshire/Fairfax. This scenario would allow for tunnel excavation to continue to the west.	



Note: Alternative 1, Segment 1 is the same as MOS 1.

Figure 4-25: Alternative 1, Segment 1- Wilshire/Western Station to Wilshire/Fairfax Station

Anticipated Ground Conditions

Geologic conditions for the Westside Subway Extension are described in the Geotechnical and Hazardous Materials Technical Report (Metro, 2010). In tunnel terminology, the tunnels will be excavated through soft ground, as opposed to rock. Much of the tunnel will be excavated below the groundwater table. In addition, some of the alignment will be in gassy ground conditions, including methane and hydrogen sulfide. In limited areas, naturally-occurring tar sands will be encountered.

It should be noted that some weak rock is anticipated to be encountered in far easterly reaches near Wilshire/Western station. However, the presence of this rock will have no appreciable effect on the rate of advance or operation of the pressurized-face TBMs.

The tunnel will also be excavated through the Santa Monica Fault zone. In general, the tunnel advance rate is not expected to be significantly affected. However, in specific sections where displacements along fault traces are probable, the tunnel construction methodology may be altered to better account for the potential for displacement in a seismic event. Specific measures to be studied further could include the following:

- Cut-and-cover construction methods could be used at the fault zone in advance of the TBM mining through the area. In this case, the cut-and-cover excavation would be done first, the TBM would “walked-through” the excavation (and then continue mining normally), and an over-sized cast-in-place concrete tunnel structure would be built within the excavation. This tunnel structure would then be backfilled above and the surface restored, similar to methods used at stations.
- Alternatively, the TBM mining could proceed normally through the area, and then subsequently the tunnel lining could be enlarged. The process to enlarge the tunnel would be done following mining in this segment and would likely be done concurrent with nearby cross-passage excavations. Construction methods would be similar to cross-passages as ground improvement would be required before any tunnel lining segments could be removed. Where feasible, dewatering of this area may also be done. Once the segments are removed in the area to be enlarged, and new over-sized cast-in-place concrete tunnel lining would be constructed, including transition structures at the interface with the segmental tunnel lining.
- With either of the above option, it may be possible to shift a cross-passage or a mid-line vent structure location to be closely coincident with the fault zone. Because special construction methods will be necessary anyway for these structures, this would avoid the need to significantly alter the typical TBM tunnel excavation.
- If the fault zone occurs in a relatively short tunnel drive, another option would be to use a larger diameter TBM to excavate that particular reach of tunnel. However, the required over-size is anticipated to be significant enough that this large diameter TBM would not be used in other tunnel sections. For this reason, this alternative may be the least practical.

In addition to above, the tunnel alignment may be adjusted based on the fault orientation and/or surface conditions above the tunnel. This step would mitigate some of the impacts from the above alternatives.

Potentially Impacted Soils

Potentially impacted soils may be encountered during construction of the selected alignment near existing and historic underground storage tank sites (UST) including gasoline stations, dry cleaners, and industrial facilities. Soils may be impacted with petroleum hydrocarbons, VOCs, and H_2S. Many soils along the Wilshire Boulevard Corridor are impacted with tar and crude oil due to presence of oil producing formations, evidenced by existing and abandoned oil fields.

TBM Operations

It is anticipated that all tunneling and station excavations along this segment from the existing Wilshire/Western Station to the proposed Wilshire/Fairfax Station would encounter subsurface gas and groundwater. Therefore, it is recommended to use TBMs that can be equipped to mine with closed spoil transport systems, i.e. pipelines or similar systems where the excavated materials are not exposed to the tunnel environment.

Selection of an EPB or Slurry-Face TBM may be a contractor's preference based on the machines expected performance in the anticipated ground conditions. To some extent, EPB TBMs are better suited to less permeable soils (clays), while Slurry-Face TBMs are better suited to more permeable soils (sands and gravels). With modern and evolving TBM designs, it may be possible to use "dual-mode" machines to convert from a slurry excavation operation into an EPB operation and still have the potential to covert the operation back to slurry mode.

Following tunnel excavation, the TBMs may then be dismantled underground with the shield (outer shell) left in place, such as at the Wilshire/Western Station if the TBM mines from west to east. An alternative to dismantling the TBM would be to excavate a separate retrieval shaft. However, from a traffic management standpoint due to traffic impacts at the retrieval shaft, retrieving the TBM is less desirable than dismantling the TBM. An exception is if the TBMs could be re-used immediately or in a reasonable timeframe for constructing the next reach of tunnel (i.e., Segment 2); the disruption caused by retrieval from the street may be justified.

The Metro-owned parcel on the north side of Wilshire between S. La Brea and S. Detroit has potential for use as an additional interim construction staging area. The nearby site at S. Ogden is less workable as a TBM launch site, but could be used for staging TBM equipment components. The S. Odgen site may also be used as an interim storage area for precast segments, ventilation line, utility lines, etc. in support of the main mining operation.

Estimated Volume of Excavated Materials from Tunnel Construction

For this segment, the total volume of excavated materials for the tunnel excavation from Wilshire/Western to Wilshire/Fairfax is estimated to be approximately 450,000 CY. Based on this volume and the anticipated sequence of construction, the maximum truck counts for tunnel spoil removal is estimated to be from 40-80 daily truck trips.

The tunnel spoils will be loaded onto trucks for removal to the disposal sites. The loading and hauling of tunnel spoils will be restricted to minimize disturbance to residences and other noise-sensitive areas.

Considering the complete and full length of the tunnels, approximately 13-14 miles, the total volume of material excavated from all the tunnels will be approximately 2.0 million loose CY.

Construction Personnel and Parking

The estimated number of construction personnel for different activities are as summarized in Table 4-5.

Table 4-5: Construction Activity Summary for Alternative 1, Segment 1 Construction

Activity	Duration (months)	Construction Equipment							Soil (CY)	Concrete (CY)	Haul Truck Trips per Day	Workers per Day
		Haul Truck	Concrete Truck	Dozer	Excavator	Crane	Drill Rig	Flatbed				
Pre-Construction	4-6						X	X	N/A	N/A	5	10-20
Site Preparation	12-18	X	X	X	X				1,000	1,000	10-20	20-30
Access Point at Wilshire/Western Station	18-30	X	X	X	X	X	X	X	12,000	4,000	20-30	20-30
TBM Tunnel from Wilshire/Western to Wilshire/La Brea	12-24	X	X	X	X	X		X	300,000	Precast Segments	40-80	50-80
Wilshire/Crenshaw Station (Option)	24-48	X	X	X	X	X	X	X	160,000	17,250	25-50	20-30
Wilshire/La Brea Station (Cut-and-Cover)	24-48	X	X	X	X	X	X	X	200,000	17,250	25-50	20-30
TBM Tunnel from Wilshire/La Brea to Wilshire/Fairfax	6-10	X	X	X	X	X		X	150,000	Precast Segments	40-80	50-80
Wilshire/Fairfax Station (Cut-and-Cover)	24-48	X	X	X	X	X	X	X	135,000	20,000	25-50	20-30
Operating Systems Installation	5-6					X		X	N/A	N/A	2	20-30

In most situations, there will be several concurrent construction operations and many crews of workers at each site. When concurrent work sites are considered, it can be expected that there will be approximately 150 field workers during day shift, another 60 for swing shift and approximately 30 office personnel, for a total of approximately 240 daily personnel.

Workers will be encouraged to use public transportation for commutation to the work sites. In addition, the contractors will make arrangement for nearby off-site parking locations that can be used by the construction workers. However, all such parking areas will require Metro approval. If necessary, transportation to and from public transit stops and/or parking areas will also be provided at the beginning and end of work shifts.

Street/Site Restorations

This work restores the street or ground surface to its original condition, or better. The site restoration operations will closely follow the previous work of building the station structures. One half of a street will be restored at a time in order to maintain the surface traffic flow. Or alternately, depending on regulatory agency and community approvals, the restoration work may take place over weekend periods when the entire street might be temporarily closed to through traffic. Backfill material will be trucked in, placed, and compacted.

During the backfilling above station structures and other cut-and-cover structures, final utility installations would be performed to establish the utilities in their permanent locations. New sewer manholes and cable/duct vaults are built. Sidewalks that have been removed to allow for station excavations would then be restored to their original configurations. Following the completion of backfilling, the permanent street would be constructed, including required paving, striping, and signage. Street and sidewalks would be restored in accordance with City standards, including landscaping required.

4.2.1.6 Vent Shafts and Emergency Exits

Construction of ventilation shafts, include mid-line ventilation structures, and emergency exits and construction of cross-passages will generally take place following the completion of the tunnel excavation. To an extent though, shaft and exit work might be done in advance and only the connection to the tunnel liner be necessary upon completion of the tunnel mining. Shafts and exits will connect to surface streets or surrounding areas and be subject to all the requirements of public interface. Cross-passages though take place solely below the surface and will be subject to detailed coordination with on-going tunnel construction. Vent shafts, emergency exits, and cross-passage work will be exposed to conditions of encountering hydrocarbons and will be subject to strict ventilation and ground support requirements.

In general, ventilation fans and noise-producing equipment will be housed in below-grade spaces to minimize noise to the extent possible and to minimize the amount of above-ground space needed. Ventilation Shafts have not been designated at this early stage, but they would be expected to be located between stations approximately one mile from a given station. These shafts can be considered to be mini versions of station structures in that generally the identical structural support of excavation and concrete construction methods will be utilized. Whereas a station may extend some 600 feet or more in length, the vent structure will likely not exceed one hundred feet in length and traffic and public interfacing will be much simpler to perform. Construction duration for building these ventilation structures will be basically the same length as for the stations due to the need for tunneling operations, excavation, and concrete lining, to be able to continue through the vent shaft. Alternatively though, the lower track level chambers might be isolated which would allow the upper structure to be completed.

4.2.1.7 Summary

All work will conform to project specifications and industry standards. The equipment used in construction would include graders, dozers, cranes, concrete trucks, pumping equipment, flat bed trucks, dump trucks to haul dirt, tunnel boring machines, and rail mounted cars to transport materials within the tunnel. Spoils would be hauled away from the work sites by trucks to approved disposal sites. Table 4-6 summarizes the sequence of construction activities anticipated for Segment 1.

Table 4-6: Sequence of Construction Activities – Alternative 1, Segment 1

Activity	Duration	Description	Equipment Required
Pre-construction	Up to a year	Limited excavation. Preliminary preparation and excavation for paleontological deposits.	Largely hand tools and small equipment
Tunnel Construction	Approx. 3 years or more, counting TBM fabrication and mobilization	Excavation and tunnel lining	TBM, slurry pumping and separation equipment, concrete equipment
Underground Utilities	Half a year or so	Locate, move and support utilities	Hand tools and small excavation equipment
Station Excavation	Approx. 1-year	Support of excavation and cut-and-cover excavation	Various excavation equipment and a crane
Station Construction	Approx. 2-½years	Form and place concrete structure, finish work, architectural and mechanical	Concrete form and placing equipment
Street/Site Restorations	Approx. 4 months	Paving and sidewalks	Paving equipment
Vent Shafts and Emergency Exits	Concurrent - approx. 12 months	Shafts and cross-passages	Crane and tunnel equipment

4.2.2 Construction Scenario –Segment 2 – Century City Extension

Table 4-7 shows tunnel and construction lengths for each station included in Segment 2. There are several scenarios that may be used for the tunnel mining and related construction of Segment 2:

- **Wilshire/Fairfax Tunneling West to Century City (Santa Monica Boulevard Station):** If sufficient work site area and a mining shaft remain at Wilshire/Fairfax concurrent with or following completion of Segment 1, TBMs could proceed from the Wilshire/Fairfax Station west to the Century City Station. In this scenario, the TBMs would be removed at the Century City Station area located along Santa Monica Boulevard.
- **Century City (Santa Monica) Station Tunneling East to Wilshire/Fairfax:** This option is a “skewed” station from the middle of Santa Monica Boulevard at the west end to a tie-in at the east end, with a reasonably good construction work area. Using this station, an alternative would be to mine east from Century City Station to the Wilshire/Fairfax Station. If the Century City Station is located along Santa Monica Boulevard, there is sufficient area that could be made available within the Santa Monica Boulevard right of way. But this site is isolated in that it is located in the middle of active roads and the isolation and shape makes utilization in the street center largely prohibitive. To this end, the Wilshire/Fairfax crossover (which may be eliminated based on operations planning simulations) or other shaft excavation would be left with temporary decking for removal of the TBMs during Segment 1 construction, and then

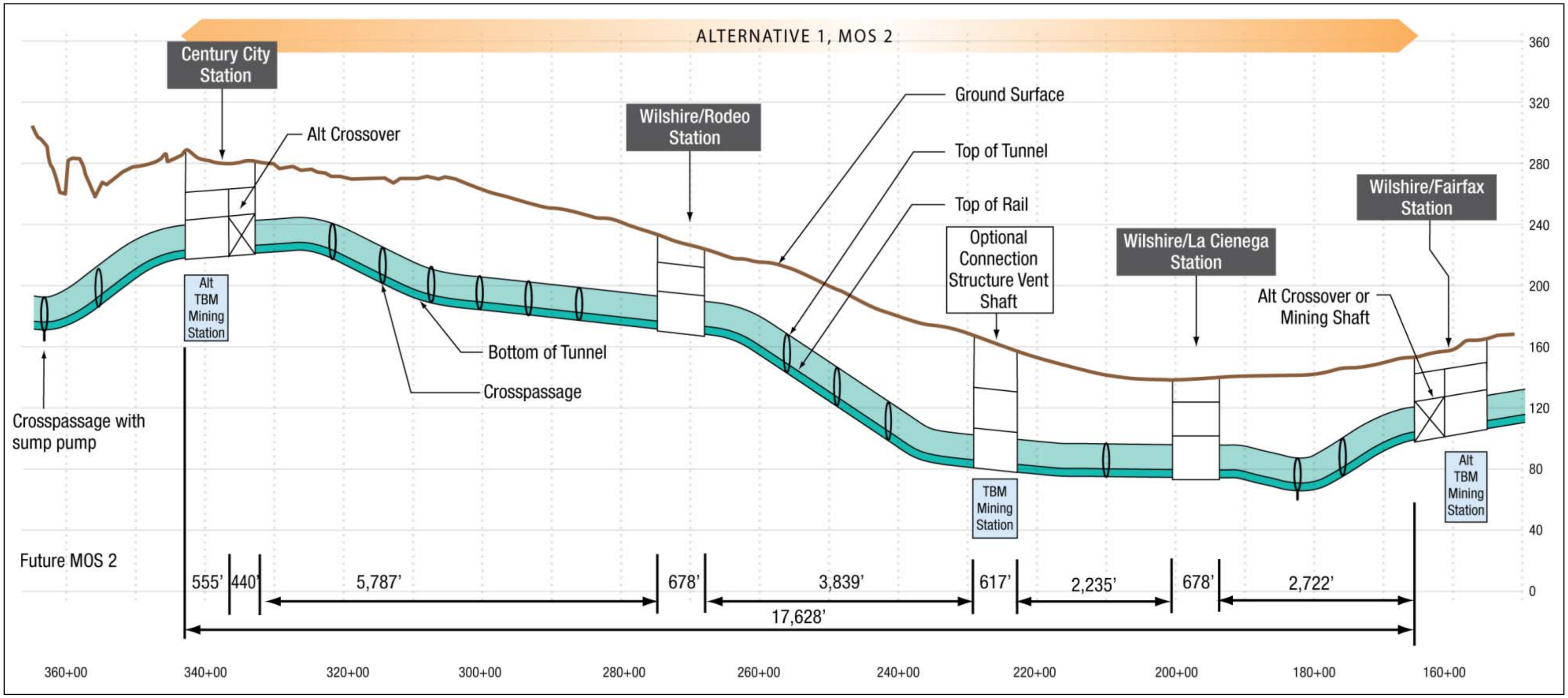
permanently covered as part of Segment 2. Dependent on the length of time that the Segment 1 segment has to operate prior to work on Segment 2, this may or may not be a feasible option.

- **Century City (Constellation) Station Tunneling East to Wilshire/Fairfax:** Again, this alternative would be to mine east from Century City (Constellation) Station to the Wilshire/Fairfax Station. To this end, the Wilshire/Fairfax crossover (which may be eliminated based on operations planning simulations) or other shaft excavation would be left with temporary decking for removal of the TBMs during Segment-1 construction, and then permanently covered as part of Segment 2. Dependent on the length of time that the Segment 1 portion is in operation prior to work starting on Segment 2, this may or may not be a feasible option.
- **Wilshire/Fairfax Tunneling West to Century City (Constellation) Station:** If the Century City Station is located on Constellation Boulevard at Avenue of the Stars, work space may be limited to station construction and TBM retrieval only. Hence, mining would need to proceed west from the Wilshire/Fairfax Station. However, if construction work area can be made available when needed for tunnel construction, TBM mining could proceed from Century City (Constellation Boulevard) Station to the Wilshire/Fairfax Station.
- **Wilshire/La Cienega Station Tunneling:** This station could be used for tunnel excavation (mining) to both east and west, retrieving the machines at Wilshire/Fairfax and at Century City. This site is also close to the West Hollywood tunnel connection to the main Wilshire line. However, the work areas currently available are limited, which severely constrains this scenario. Given the constraints at Century City and the potential interference at Wilshire/Fairfax, the Wilshire/La Cienega site may be considered in the future if additional construction work area can be made available.

Table 4-7: Tunnel and Construction Lengths for Alternative 1, Segment 2

Station	Length (feet)	Description
165+60	0	Exit Wilshire/Fairfax Station
202+60	3,700	Enter Wilshire/La Cienega Station
213+80	1,120	Exit Wilshire/La Cienega Station
269+30	5,550	Enter Wilshire/Rodeo Station
275+80	650	Exit Wilshire/Rodeo Station continuing westerly under Wilshire
333+00	5,720	Enter Century City Station (varies depending on Century City Station location)
342+80	980	Exit Century City station.
	17,720 (3.4 miles)	Total Length
	2,750	Station Length
	14,970 (2.8 miles)	Twin Tunnel Length
Scenarios to Consider		
A	Mine from Century City (Santa Monica Boulevard) Station toward the east with two TBMs retrieving them from Wilshire/Fairfax.	
B	Mine from Century City (Constellation Boulevard) Station toward the east with two TBMs retrieving them from Wilshire/Fairfax.	

C	Mine from Wilshire/Fairfax toward the west using the existing mining site and retrieve TBMs from Century City.



Note: The terminus for Alternative 1, Segment 2 is the same as MOS 2.

Figure 4-26: Alternative 1, Segment 2- Wilshire/Fairfax Station to Century City Station

Segment 2 may be constructed using the one of the Century City stations proceeding east. The alternatives are to excavate the tunnel east from either of the two viable Century City sites, both from which excavation would proceed east to Wilshire/Fairfax. Considering construction viability, either of the Century City Stations (at Santa Monica Boulevard or Constellation Boulevard), could be selected.

Alternatively, Segment 2 might potentially be constructed using the Wilshire/Fairfax Station work areas, proceeding west. However, the use of this station depends on the timing of the Segment 1 construction, which may have used the Wilshire/Fairfax Station to excavate east. In this scenario, if the Wilshire/Fairfax Station concrete work is delayed, or if a west extension of the station is provided to allow excavation of Segment 2, then the concept is viable.

4.2.2.1 Preconstruction

The La Brea tar pit area in the vicinity of the Wilshire/Fairfax Station is known to have tar and/or tar sands with paleontological features that must be protected and otherwise removed intact. However, since the excavation of this station will already be complete, this will not be a concern unless the station excavation (construction shaft) is extended west. If an extension is used, preliminary preparation and excavation is to take place early on in Segment 2, or even in Segment 1. In this case, separate "advanced work" contracts may be utilized in order to orderly and carefully excavate through and prepare the ground for the coming station excavation. This early work may necessitate on-going lane closures.

Other preconstruction work in Segment 2 will be as outlined in the general construction scenario.

4.2.2.2 Underground Utilities

The handling of underground utilities in this segment will be similar to that described in the general construction scenario.

4.2.2.3 Stations

The end of the line for Segment 2, at Century City, either at Santa Monica Boulevard or at Constellation Avenue would likely be the location of a tunnel portal entry/exit point, due to its confined conditions. If Fairfax is used as the station for tunnel excavation mining would have to proceed from the Wilshire/Fairfax Station west to the Century City Station. To this end, the Fairfax tail tracks, beyond the end of the station platform (if required for operations), would have to be left with temporary decking during Segment 1 construction, and then permanently covered as part of Segment 2. Dependent on the length of time that the Segment 1 portion has to operate prior to work on Segment 2, this may or may not be a feasible option.

If tunneling commences at the Wilshire/Fairfax Station, the mining entry locations are the same as Segment 1, except from the west end of the station. If the Century City (Santa Monica) Station location is used as an entrance, TBMs would be assembled at the Century City Station construction staging area and would be moved vertically to tunnel grade or horizontally from established side access points and then slid into position for use at the tunnel faces or headings. Utilities, air, water, disposal, electricity, sanitation, and communication would be positioned near the working entries to the tunnels for the mining operations. Wilshire/Rodeo Station, though potentially workable for staging tunnel excavation, is too near the western reach and is not considered a good mining station.

Table 4-8: Alternative 1, Segment 2 Station Descriptions

Station Notes	
Wilshire/La Cienega	Wilshire/La Cienega Station would likely be utilized only for station construction and transporting TBMs through the excavation. Using the site as a TBM launch/retrieval station would break the mining reaches into disproportionate lengths so as to be economically less viable.
Wilshire/Rodeo	No construction staging areas have been identified. The station would likely have to be built by closing down lanes in Wilshire Boulevard and/or side streets.
Century City (Santa Monica Blvd)	This station has alternatives on Santa Monica and Constellation, with the station running essentially east and west on Santa Monica Blvd., but skewed to the southern side on the east. This layout ties the station into a sizeable construction work area, rendering it a feasible station location.
Century City (Constellation Blvd) (Option 4)	Segment Option-Constellation North provides for tunnel realignment through the Constellation Boulevard Station. This site has what appears to be a large and workable construction work area at the northeast end. Either of these two station options on Santa Monica and Constellation Boulevards appears to be workable and the choice of selection perhaps will be from other than construction.

Station Excavation

This is largely described in the previous sections as far as it pertains to support of excavation, support of utilities and construction of roadway decking, including general sequencing of the work.

Segment 2 would contain 6 total stations: 3 stations from Segment 1 - Wilshire/Crenshaw, Wilshire/La Brea, and Wilshire/Fairfax, and 3 new stations - Wilshire/La Cienega, Wilshire/Rodeo, and Century City. Station options are at Wilshire/Crenshaw, Wilshire/La Cienega, and Century City. Depending upon selected tunnel alignment there might also be an open cut connection structure west of La Cienega.

Table 4-9: Estimated Amounts of Excavated Materials for Station Construction for Segment 2

Station	Estimated Total CY Excavated	Estimated Daily Haul Truck Trips	Estimated Total Haul Truck Loads
Wilshire/La Cienega	140,000	25-50	7,000
Wilshire/Rodeo	140,000	25-50	7,000
Century City (with crossover)	200,000	25-50	10,000

Wilshire/La Cienega - A potential construction site is proposed for the northeast corner of Wilshire and La Cienega Boulevards, extending northward on La Cienega Boulevard.

Wilshire/Rodeo Station - A potential construction site is proposed for the property on the southwest corner of Wilshire Boulevard and Canon.

Century City Station - A potential construction site is proposed for the alternate Constellation Boulevard site, where sufficient space is available for a tunnel excavation operation. This potential work area appears to have minimally 500-ft by 300-ft available, three and a half acres or more. This station has two potential options. The base station is on Santa Monica Boulevard and the station option is on Constellation Boulevard. Undated drawing A-006.2.1 depicts the station running essentially east and west on Santa Monica, but skewed to the southern side on the east. This depiction ties the station into a very sizeable construction lay down and work area rendering it a feasible station location. Segment Option-Constellation North provides for tunnel realignment through the Constellation Boulevard Station. This site too has what appears to be a large and workable construction lay down and work area at the northeast end as depicted on undated drawing A-006.3. Either of these two station options appears to be workable and the choice of selection perhaps will be from other than construction criterion

Station Construction

With regard to the new stations on this segment, Wilshire/La Cienega, Wilshire/Rodeo, and Century City, the general construction approach is largely as has been described previously as far as it pertains to support of excavation, support of utilities and construction of roadway decking, including the general sequencing of the work.

In general, station concrete construction and architectural finish work will take place after tunnel operations are completed and when the station work will have free access. Some work may commence concurrent with the tunneling, as long as it is limited to the station area farthest away from the tunnel. In this way, any interference with the tunneling operations is limited.

4.2.2.4 Tunnel Construction

The tunnel is to be excavated using approved pressurized-face TBMs, with or without slurry, since hydrocarbon deposits or potential gas areas are not expected to be significant in this reach.

It is expected that groundwater (and perhaps limited gassy conditions) may be encountered along some portions, such as the west end near the Wilshire/Fairfax station, and in the Century City area. Therefore, consideration may be given to use of Slurry-Face TBMs to mine this portion of the alignment as well as Segment 1. If slurry mining is used from the Fairfax station it is expected that separation will take place on-site and the processed materials disposed of through conventional methods.

Estimated Volume of Excavated Materials from Tunnel Construction

The total volume of excavated materials for the tunnel excavation from Wilshire/Fairfax to Century City is estimated to be approximately 525,000 CY. Based on this volume and the anticipated sequence of construction, the maximum truck counts for tunnel spoil removal is estimated to be from 40-80 daily truck trips.

4.2.2.5 Street/Site Restorations

This work is largely described above and is the reverse of the previous work of building any of the stations. The stations will have the top or roof concrete completed followed by earthen backfill, road deck removal, removal of the top 8' or so of the structure utilized for support of excavation, roadway paving, pedestrian sidewalk construction including full restoration of access to the businesses. The final condition of the street and sidewalk upon restoration will be critical to attaining final acceptance of the construction contract.

4.2.2.6 Vent Shafts and Emergency Exits

Construction of ventilation shafts, emergency exits and construction of cross-passages will be as generally described in the preceding section.

This segment also includes the connection structure for the West Hollywood Extension.

4.2.2.7 Summary

Table 4-10: Sequence of Construction Activities – Segment 2

Activity	Duration	Description	Equipment Required
Pre-construction	None is expected	Controlled excavation	Largely hand tools and small equipment
Tunnel Construction	Approx. 3 or more years, counting TBM purchase	Excavation and tunnel lining	TBM, potentially slurry pumping and separation equipment, concrete equipment
Underground Utilities	Approx. 6 months	Locate, move and support utilities	Hand tools and small excavation equipment
Station Excavation	Approx. 1 year	Support of excavation and cut-and-cover excavation	Various excavation equipment and a crane
Station Construction	Approx. 2-½ years	Form and place concrete structure, finish work, architectural and mechanical	Concrete form and placing equipment
Street/Site Restorations	Approx. 4 months	Paving and sidewalks	Paving equipment
Vent Shafts and Emergency Exits	Concurrent, approx. 6 months	Shafts and cross-passages	Crane and tunnel equipment

4.2.3 Construction Scenario - Segment 3 – Century City to Westwood/UCLA

4.2.3.1 Stations

Westwood/UCLA Station - Potential construction sites are proposed on UCLA Lot 36 between Gayley Avenue and Veteran Avenue and north of Wilshire Boulevard. This off-street site would allow a separation of Segment 3 construction activities from adjacent Segment 2 activities (if concurrent), which would be advantageous. There would be no need for covering or decking the station since there would be no traffic. The open excavation would provide economic and schedule benefits.

Table 4-11: Estimated Amounts of Excavated Materials for Station Construction

Station	Estimated Total CY Excavated	Estimated Daily Haul Truck Trips	Estimated Total Haul Truck Loads
Westwood/UCLA	120,000	25-50	6,000

The main work area is around 350-ft by 300-ft and there are additional areas to both the east and west that are suitable for staging, parking, storage, and work areas.

Special Shoring Design

Similar to previous discussions, some areas of Westwood have shallow groundwater, potentially under artesian pressure. This has necessitated the use of dewatering operations through multiple wells. In such cases the use of soldier piles with lagging may be inadequate and a slurry wall, secant pile, or similar excavation support system may be necessary.

4.2.3.2 Tunnel Construction

For Segment 3 ending at the Westwood/UCLA Station, a crossover would be located west of the station, east of Sepulveda Boulevard to allow for trains to "switch" tracks to change direction. Tail tracks would be located on the west side of the I-405 Freeway with a vent shaft just on the VA Hospital property that will not preclude a future station location. Trains would enter the crossover from the east, extend along one of the tail/pocket tracks, and head back to the Westwood/UCLA Station to travel eastward.

The segment of the alignment connecting the Century City Station and the Westwood/UCLA Station is not as likely to be classified highly gassy and, hence may be mined with EPB TBMs. Other construction elements will be as described in the preceding sections.

Due to the over 2-mile length between the Century City and Westwood stations, it is likely that one to two mid-line vent shafts will be required. Similar mid-line ventilation structures were discussed in earlier sections. As was the process for the Metro Red Line North Hollywood Tunnels, vent shafts may be constructed ahead of tunneling, with TBMs transported through (walked-through) the vent shaft excavations.

This segment of Alternative 1 would likely be mined with two TBMs driven eastbound from the Westwood/UCLA Station towards the Century City Station.

Estimated Volume of Excavated Materials from Tunnel Construction

The total volume of excavated materials for the tunnel excavation from Century City to Westwood/UCLA is estimated to be approximately 300,000 CY. Based on this volume and the anticipated sequence of construction, the maximum truck counts for tunnel spoil removal is estimated to be from 40-80 daily truck trips.

The TBMs would be dismantled underground with the shell left in place. Alternatively, the TBMs could be removed at the Century City Station if the excavation from the Segment 2 construction is left with temporary decking.

4.2.4 Construction Schedule

Alternative 1 (from Wilshire/Western to Westwood/UCLA Extension) would be constructed in three segments.

Design and construction of Segment 1 (from Wilshire/Western to Wilshire/Fairfax) is expected to take about 7-½ years. Final design (including bid process) for Segment 1 is expected to take approximately two years. Following design, construction would start at the primary tunnel mining location (possibly at Wilshire/Western or at Wilshire/Fairfax). Construction (not considering pre-construction) is expected to take about 5-½ years.

Design and construction of Segment 2 (from Wilshire/Fairfax to Century City) would be largely dependent on the options chosen. However the schedule is anticipated to be approximately a year less than for Segment 1, due to the pre-construction activities connected with the tar deposits for Segment 1. On this basis, a total design and construction duration of about 6-½ years is a reasonable expectation. This is based on the concept that pre-construction would start a year earlier than construction on Segment 1. These early activities would focus in the tar pit areas at Fairfax and La Brea.

It has not been determined if Segment 2 will have sufficient funding to start up before Segment 1 is completed. Further, it is not determined what station will be used to excavate the tunnel. There are advantages in excavating tunnel from the Wilshire/Fairfax Station, but this has the drawback that to do so may delay the start up of Segment 2, as well as possibly delay the completion of the Wilshire/Fairfax station. In order to define start and finish dates for Segment 2 the various options need to be evaluated in more detail.

Design and construction of Segment 3 of Alternative 1 (located between Century City and Westwood/UCLA extension) is expected to take approximately 5-½ years. Currently there are no significant pre-construction activities envisioned for this segment. By staging the tunnel excavation operation from the Westwood/UCLA Station (or some other more westerly station) to excavate east to the Century City Station, this reach of tunnel and station would be able to proceed independently of any effect of work timing for Segment 1 and Segment 2.

Together Segments 1, 2 and 3 constitute Alternative 1, which would be constructed within a time-span of approximately 7-½ years if all work is concurrently scheduled. However, given the space limitations and other constraints, it would be difficult to advance all three segments at the same time. It is possible that one or more of the segment reaches will be advanced further ahead of the adjacent reaches, thus reducing the amount of concurrent work in the same proximity. Under this scenario, Alternative 1 construction would take from 9 to 15 years for completion.

4.2.5 Options

This section describes the variations to construction techniques and schedule that the station and alignment Options may cause for Alternative 1. Except for the initial establishment of station excavation to the point where tunnel excavation operations can commence, station construction will generally not affect tunnel excavation.

Tunnel concreting operations might be affected, depending on how the contracts where tunnel and station interface are set up. Some stations are of larger size (length) than others and some concrete work is more complex than others so durations of station construction will vary. In general, it will be the station used in staging tunnel excavation operations that will get finished last, and will be on the critical path.

4.2.5.1 Station Options

Option 1 - Remove Wilshire/Crenshaw Station

Option A is an option to not include the Wilshire/Crenshaw Station. A vent shaft would need to be constructed in this location if the station is deleted. The vent shaft would be located mid-way between Crenshaw Boulevard and Lorraine Boulevard. This option involves an elimination of what would otherwise be concurrent work and therefore would not materially affect the Segment 1 tunnel operations or overall schedule. The construction of a smaller ventilation shaft though will invoke similar concerns as a station, only the structure would be smaller and less involved.

Wilshire/Crenshaw Station is considered too close to Wilshire/Western Station and the eastern terminus of Segment1 to be an effective mining station, even though it may have the potential for having a large construction work area.

Option 2 - Wilshire/Fairfax Station– East

For this option, a potential construction staging area is on the south side of Wilshire Boulevard between Orange Grove Avenue and Ogden Drive. A double crossover is planned as an option on the west side of the station. This is potentially additional work space for the tunnel and station construction. However, this added area is merely a supplement to the main construction yard to the north and west of the Wilshire/Fairfax intersection.

Option 3 - Wilshire/La Cienega Station with Transfer Station

This station is multi-level (or stacked vertically), with one track below the other and vertical circulation connecting the two. The station needs to be stacked to stay within the Wilshire Boulevard right-of-way and not extend below adjacent structures. With the stacked tunnel configuration, vertical cross-passages will be needed. The vertical cross-passages consist of stairwells connecting the upper and lower tracks. The cross-passage would be constructed by cut-and-cover methods as a small extension out from the main cut-and-cover excavation and structure. However, there is limited space for this work and innovative construction techniques may be required to allow construction with minimal right-of-way and construction impacts. A potential construction site is proposed for the property on the north side of Wilshire Boulevard, between Le Doux Road and Stanley Drive.

Option 4 – Century City (Constellation) Station

While the station location does not shift, the cut-and-cover construction will extend to Century Park East, due to tie-backs from an existing building foundation on the southwest corner of Constellation Boulevard and Century Park East. A potential construction site is proposed for the property on the east corner of Constellation Boulevard and Century Park East. There is a potential construction staging area at the southeast corner of Constellation Boulevard and Century Park West at the existing bus layover area.

This option furnishes an acceptable and perhaps more desirable station location for tunnel construction, although this depends on available construction staging area at time of construction.

Option 5 - Westwood/UCLA Station - On Street

The potential construction site is proposed for the UCLA Lot 36 property on the northwest corner of Wilshire Boulevard and Gayley Avenue. This option, if selected, would reverse the positive effects of having the station off the street, and therefore is not a preference for use as a tunneling site.

Option 6 – Westwood/ VA Hospital – North of Wilshire

Option 6 appears viable but does not indicate any particular benefit over the base Westwood/VA Hospital Station.

4.2.5.2 Alignment Options

Option 4: Beverly Hills to Century City Segment Options

These variations are essentially tunnel alignment alternates and do not affect public access. Tunneling under private property should not pose a greater physical problem, however liability exposure must be considered. Option 4 has three options for traveling between the

Wilshire/Rodeo Station and the Century City Station. These include the base alignment, which travels from the Wilshire/Rodeo Station, along Santa Monica Boulevard to the Century City (Santa Monica) Station; and North Constellation alignment and Constellation alignment that are described below; that traverse one of two routes to the optional Century City (Constellation) Station. The variation in construction schedules for these options are described below.

There is no significant change to the overall construction and schedule scenario for the Constellation alignment option assuming tunnels are aligned clear of subsurface building supports or lowered below them. This option will require further study and geotechnical exploration.

The North Constellation option has a potentially undesirable affect in that it involves an "S" curve for tunnel mining operations which can become problematic in holding tunnel alignment. Additionally, the curves appear to be tight, or of rather small radius. In general, any curve is more difficult to hold than a straight line and any curve means that the tunnel precast segments have to be "different" and installed in the right place at the right point in the mining operation. This option may not be as viable as the base alignment or the Constellation alignment option.

Option 4 – Century City to Westwood UCLA Segment Options

The East, Central and West Segment Options connect either Century City Station (Santa Monica Boulevard Station or Constellation Station) to either Westwood/UCLA Station (On-Street or Off-Street Station). The West Segment Option would add approximately 4,000 LF of additional tunnel compared to the base alignment.

Once the tunnel alignment has been determined, it is expected that any of these options are suitable for implementation and will have little effect on the construction scenario or schedule.

4.2.5.3 Trackwork Options

Locations for the additional track work for each alternative were identified, and then evaluated through a rail operations simulation. The evaluation, done in conjunction with Metro, considered location and size of crossovers, pocket tracks and tail tracks. The work involving these options is essentially only an extension of the work of excavating and concreting a station except that it is not as complicated. Cut-and-cover construction methods would be used, similar to that described in the previous sections.

The excavated structure can generally be "narrowed" from that needed for construction of the passenger portion of the station and the concrete work will be simplified, i.e., less deep, less wide, and less complicated. The schedule would be only nominally affected and potentially not affected at all, assuming additional manpower is added to the construction work crews so that the work is concurrent with other activities.