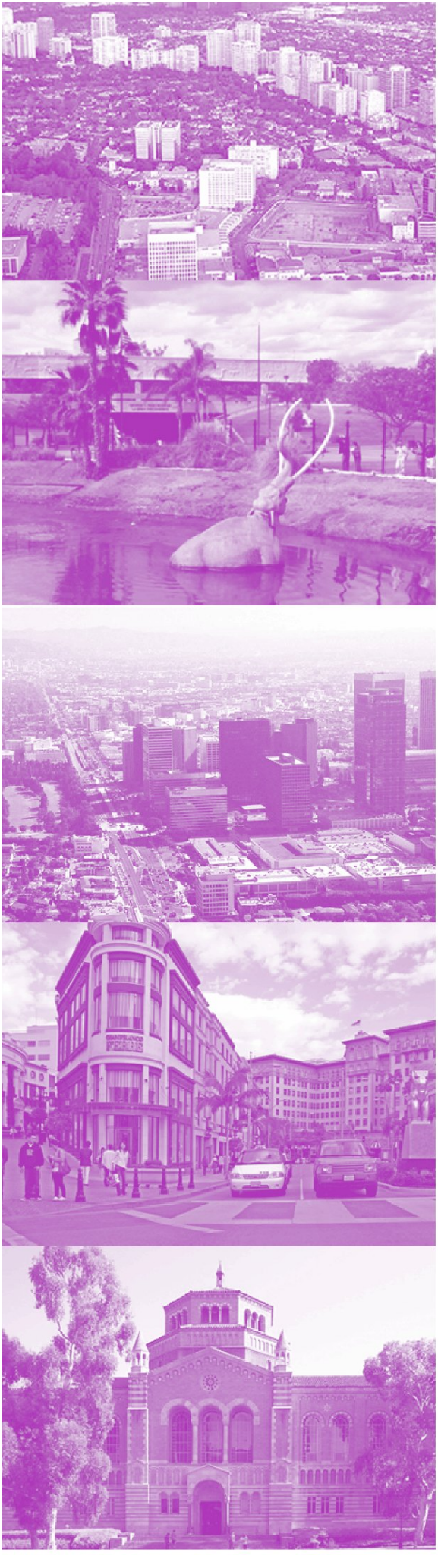

WESTSIDE SUBWAY EXTENSION PROJECT

Executive Summaries

for the

Century City Area

Tunneling Safety Report

and

Fault Investigation Report

Prepared for:

Metro

Prepared by:

PARSONS BRINCKERHOFF

October 19, 2011

089513

Tunneling Safety Report

EXECUTIVE SUMMARY

On October 28, 2010, the Metro Board approved the Draft Environmental Impact Statement/ Environmental Impact Report (EIS/EIR) for the Westside Subway Extension Project (the Project), which included two tunnel alignment options through the Century City area. The proposed station locations would be on either Constellation Boulevard or Santa Monica Boulevard, but both would be centered on the Avenue of the Stars. During the October 28 meeting, Metro staff expressed concerns related to the potential impact of the Santa Monica fault zone on the proposed Santa Monica Boulevard Station. (Additional investigations were being planned to locate the fault zone near the station.) Concerns were also expressed at the meeting regarding the safety of tunneling under Beverly Hills High School (BHHS), which would be required for the proposed Constellation Boulevard Station.

To address the tunneling safety concerns, the Metro Board approved the following motion from Supervisor Yaroslavsky to be undertaken during preparation of the Final EIS/EIR. Specific items in the Board motion included the following:

> *... that in the West Beverly Hills to Westwood area:*
>
> - *Staff fully explore the risks associated with tunneling under the [Beverly Hills] High School, including but not limited to the following: risk of settlement, noise, vibration, risks from oil wells on the property, impact to use of the school as an emergency evacuation center, and overall risk to student faculty and community;*
> - *"Staff analyze the possibility of moving the subway tunnel in order to avoid all school buildings and avoid any future plans to remodel BHHS.*

In addition, Metro staff was directed to fully investigate the nature and location of faults in the Century City area and their potential impact on the proposed station locations. The resulting conclusions from both the tunnel safety and fault studies would provide a basis for the Board to make a decision on which station option to adopt. The resulting studies have been completed and presented in two separate reports: the *Century City Area Fault Investigation Report*—addresses the issues surrounding the safety of tunneling under and near BBHS, West Beverly Hills, Century City, and Westwood—and this report, the *Century City Area Tunneling Safety Report*.

Risk of Settlement

Pressurized closed-face tunnel boring machines (TBMs) will be used to excavate the tunnels for the Project. These machines provide immediate support of the ground and use proven systems for monitoring and controlling machine functions. These machines were successfully used on the Metro Gold Line Eastside Extension (MGLEE) where ground movements were always held to very small values. Along most of the alignment there was no measureable settlement.

The alignment under BHHS would pass under portions of a structure consisting of masonry walls and concrete floor beams and columns. Analysis of these structures, as well as experience gained from other tunnel excavations in the U.S. and worldwide where tunneling occurred under similar structures, show that building distortions from tunneling will not result in structural or functional impairment of the buildings. A comprehensive monitoring program will be implemented to ensure that ground movements ```from tunnel excavation are controlled below a level that could cause structural or functional damage and are in a range where cracking of finishes does not occur or is very minor.

Noise and Vibration

Metro constructed and now operates 18 miles of Red and Purple Line tunnels through downtown Los Angeles, Hollywood, and North Hollywood. The tunnels run directly under a number of buildings. Metro reports that, to date, no complaints about noise or vibration during service operations have required mitigation. Vibration and noise tests were recently performed in boreholes during the environmental studies. On the campus of BHHS, study results predict that ground-borne vibration from the trains would be no greater than 64 decibels, which is less than the vibration criterion of 72 to 75 decibels established by the Federal Transit Administration (FTA) for residential and institutional uses respectively. The predicted noise level would be no greater than 33 decibels, which is also lower than the FTA criteria of 35 and 40 decibels for residential and institutional use. Monitoring of noise and vibration above existing Metro tunnels has shown no detectible noise or vibration above normal background levels.

During construction low levels of noise and vibration may be experienced for a day or two as each of the two TBMs pass under a given location. In addition, as the tunnels are driven, construction trains bring supplies to and from the tunnel heading. These underground sources of will also be controlled to be within Metro criteria. Metro construction specifications also provide requirements to monitor and limit construction noise at the surface worksites, such as at Century City Station. Metro will address and mitigate any substantiated complaints related to noise and vibration, however there were no substantiated noise-level complaints made during MGLEE tunneling.

Risk from Gassy Ground and Oil Wells

Century City and much of Beverly Hills are located within the Methane Zone identified by the City of Los Angeles in 2003. In fact, almost the entire Project corridor lies within the current Methane Zone. However, the Century City Project area is not within the former Potential or High Potential (methane) Risk Zone created in 1986, which is centered in the Wilshire/Fairfax area. For the Project, methane and hydrogen sulfide gas sampling and monitoring were conducted in the Century City and Beverly Hills areas, including the BHHS campus. The results of this testing in the ground indicate that these gases are present in the area of Constellation Boulevard. In some areas, the concentrations were at or above levels that could be explosive under unfavorable conditions, but the measured concentrations were less than those encountered along the Red Line in downtown Los Angeles. The hydrogen sulfide levels in the Century City area (for both alignment options) area were either low (measured in parts per billion) or not detectable.

The State of California has pioneered the development and implementation of regulations for safe tunneling in gassy ground. Moreover, the tunneling industry in Los Angeles has much experience successfully driving miles of tunnels in gassy ground. These tunnels were constructed using the strict state tunnel safety regulations, as would the tunnels constructed under West Beverly Hills, Century City, and Westwood. Accordingly, it has been demonstrated many times that tunnels can safely be constructed and operated in soils containing subsurface gases.

The hazard or risk during tunneling depends on the volume, concentration, and pressure in the surrounding soil, and can vary between borings. Conditions in the tunnel are not directly related to those in the soil because the presence of the tunnel lining limits the flow into the tunnel and because ventilation is provided to dilute and remove gases that enter the tunnel. During tunneling, the pressurized closed-face TBM can be thought of as a submarine. The volume of gas (or water containing dissolved gas) released from the soil during TBM tunneling is confined to the excavated material chamber because of the closed-face and gas-tight lining that is installed immediately behind the TBM.

There are a number of oil wells (active and abandoned) on the BHHS campus and in the vicinity. A comprehensive study of all available information found that there was one mapped abandoned oil well within the proposed tunnel alignment. According to the state's records, the location of this well is beneath a parking structure on Century Park East and does not lie within the BHHS campus. The magnetic survey program indicated that the mapped locations of abandoned oil wells could be inaccurate by 50 to 200 feet.

A geophysical (magnetic) survey was performed on the BHHS campus to detect metal, which would indicate the presence of an abandoned oil well casing. The survey identified only one anomaly on the BHHS campus that is close to the alignment. It is on the west edge of the lacrosse field and is located 5 to 10 feet north of the tunnel envelope. The anomaly may or may not be a well casing, but it will be further investigated and addressed appropriately as described below.

For exploration beneath the BHHS buildings during the next phases of design, horizontal directional drilling (HDD) investigation will be conducted along the alignment at tunnel level. A magnetometer probe survey will be conducted in the drilled hole to detect metal casings so that if found, they can be re-abandoned properly below the tunnel depth prior to tunneling. Moreover, during tunnel construction in Los Angeles, magnetometer surveys have been conducted in probe borings extending in front of the TBM to ensure that obstructions, such as well casings, are detected before they are reached by the TBM. In suspected oil field areas, probing of the tunnel zone will be carried out by HDD either before tunneling or ahead of the face during tunneling.

Abandoned oil wells have been encountered in the past during tunneling in Los Angeles. Procedures have been developed to evaluate the well conditions and safely re-abandon them. Metro has experienced no gas incidents related to encounters with oil well casings during tunnel excavation.

Tunneling through Fault Zones

To construct the Project, it will be necessary to pass through at least two active fault zones. There are numerous proven designs and construction means and methods to safely build a tunnel through fault zones. Design methods include building a larger diameter tunnel and/or a very strong but flexible lining to withstand several feet of movement without collapse and still be repairable. As for tunneling in unfaulted ground, there are construction techniques to assure safe tunneling through faults while minimizing ground settlement. Additionally, there are proven procedures to monitor and control ground movements and protect overlying structures as the tunnels are advanced through the fault zones. These construction techniques could include closed-face TBM tunneling and special water- and gas-tight lining segments made with steel and compressible concrete. Additional investigations will be needed to more accurately define the extent and nature of the fault zones.

Since the tunnels will be designed to not collapse during an earthquake, the tunnels will affect neither the threat to buildings above active faults during an earthquake nor the severity of shaking.

Impact to Use of School as Emergency Evacuation Center

The tunnel will be designed so that it will not collapse even during the Maximum Design Earthquake (MDE). Accordingly, the Project will not reduce the availability of BHHS for use as an emergency shelter or impact the operations of its use as an emergency shelter.

Potential of Shifting Tunnel Alignment to Avoid All School Buildings and Any Future Plans to Remodel BHHS

Many considerations are analyzed in determining a tunnel alignment and station location for a project such as this. To minimize impacts to BHHS structures as well as to achieve maximum safe train speeds between stations (by minimizing curves and grade differentials), several alignments were studied for the Century City—Constellation Boulevard alignment. The current alignment minimizes tunneling under buildings to the east and west of the Century City—Constellation Boulevard Station. The station position on Constellation Boulevard requires the tunnel alignment to be under the south portion of BHHS Building B in order to reach the station location. There is no reasonable tunnel alignment that does not pass under structures within the school campus.

The vertical alignment of the tunnel would be 55 to 70 feet below the ground surface (to the top of the tunnel), which would allow for construction of an underground structure over the tunnel at a later date. Foundations for a future structure, including deep underground parking, could be safely set above the tunnel, while deep foundations, if necessary, could extend down so they are adjacent to or between the tunnels. Coordination would be required between Metro and BHHS to ensure compatible designs.

Overall Risk to Students, Faculty, and Community

On most transit tunnel projects, significant portions of the alignment are constructed adjacent to or beneath buildings. The capability of tunneling beneath structures without damage has resulted in large part from the use of pressurized closed-face TBMs, with systems and protocols to monitor and control their operation. The American Public Transportation Association (APTA) prepared a report in 2006 that concluded that tunnels could be safely constructed and operated in the Wilshire Corridor. Furthermore, Metro has followed up and built on the recommendations of the APTA report through analysis of more detailed geotechnical information and their experience gained in successfully completing the tunnels for the MGLEE that was constructed through the former Boyle Heights oil field. The construction and operational safety measures used for that project will be incorporated into the Project's designs and specifications. The Project is not expected to pose new threats to the students, faculty, or community as a result of its construction and operation.

Fault Investigation Report

EXECUTIVE SUMMARY

On October 28, 2010, the Metro Board approved the Draft Environmental Impact Statement/ Environmental Impact Report (EIS/EIR) for the Westside Subway Extension Project (the Project), which included two tunnel alignment options through the Century City area. The proposed station locations would be on either Constellation Boulevard or Santa Monica Boulevard, but both would be centered on the Avenue of the Stars. During the October 28 meeting, Metro staff expressed concerns related to the potential impact of the Santa Monica fault zone on the proposed Santa Monica Boulevard Station. (Additional investigations were being planned to locate the fault zone near the station.) Concerns were also expressed at the meeting regarding the safety of tunneling under Beverly Hills High School (BHHS), which would be required for the proposed Constellation Boulevard Station.

To address the tunneling safety concerns, the Metro Board approved the following motion from Supervisor Yaroslavsky to be undertaken during preparation of the Final EIS/EIR. Specific items in the Board motion included the following:

> *... that in the West Beverly Hills to Westwood area:*
>
> - *Staff fully explore the risks associated with tunneling under the [Beverly Hills] High School, including but not limited to the following: risk of settlement, noise, vibration, risks from oil wells on the property, impact to use of the school as an emergency evacuation center, and overall risk to student faculty and community;*
> - *"Staff analyze the possibility of moving the subway tunnel in order to avoid all school buildings and avoid any future plans to remodel BHHS.*

In addition, Metro staff was directed to fully investigate the nature and location of faults in the Century City area and their potential impact on the proposed station locations. The resulting conclusions from both the tunnel safety and fault studies would provide a basis for the Board to make a decision on which proposed station to adopt. The resulting studies have been completed and presented in two separate reports: the *Century City Area Tunneling Safety Report*—which addresses the issues surrounding the safety of tunneling under and near BHHS, West Beverly Hills, Century City, and Westwood—and this report, the *Century City Area Fault Investigation Report*.

Purpose of Investigation

The purpose of this fault investigation was to determine the location of active faults in the vicinity of the Century City station options and tunnel alignments. The tunnel alignment options in the Century City/West Beverly Hills area cross two mapped fault zones—the Santa Monica fault zone and the West Beverly Hills Lineament (WBHL) fault zone. The Santa Monica fault zone is known to have had zones of ground rupture within the last 11,000 years (Holocene age). A prominent scarp (step in the topography) can be traced continuously from Century City to Pacific Palisades. It marks the active strand of the Santa Monica fault zone, and provides the most definitive evidence of the fault's Holocene activity. However, until this study was undertaken, the location of the active strand(s) of the Santa Monica fault zone in the Century City/West Beverly Hills area had not been specifically evaluated through subsurface geologic investigations. The WBHL, a linear topographic feature to the east of Century City, was suspected to be a fault and to be the northern extension of the Newport-Inglewood fault zone. Until this study was undertaken, no subsurface investigation had been conducted to determine its precise location or existence as an active fault.

Because the alignments for the Project will necessarily cross active fault zones, the tunnels will be designed to accommodate fault deformation. Neither the Santa Monica fault zone nor the WBHL have been mapped as active Fault Zones under the Alquist-Priolo Earthquake Fault Zoning Act. Since subway stations are structures for human occupancy, they should not be built on active fault/deformation zones because of life/safety concerns expressed in state regulations and in Metro design criteria.

Field Investigations

Geotechnical studies conducted during the Final EIS/EIR in 2011 consisted of 56 core boreholes and 192 Cone Penetrometer Test (CPT) soundings along 7 transects (study lines), and 5 seismic reflection profiles along the same 7 transects in the Century City area. This fieldwork focused on the two fault zones (the Santa Monica and the WBHL) that would potentially be intersected by the tunnel alignment options and would impact the proposed station locations.

Analysis

Detailed analyses of the newly acquired geotechnical data (specifically, the CPTs and seismic reflection profiles that show displacements in the youngest strata present in the area) determined that the active traces of the Santa Monica fault zone (Figure 1) would pass through the proposed station location on Santa Monica Boulevard at Avenue of the Stars. For this reason, it was recommended that this station location no longer be considered an option. In contrast, no faulting was found passing through or in close proximity to the proposed Constellation Boulevard Station.

A subsequent station option was proposed to shift the station along Santa Monica Boulevard farther east, centered between about Century Park East and Moreno Drive. A section of a prominent scarp on the grounds of the Los Angeles Country Club suggested that the active traces of the Santa Monica fault zone might pass to the north of this proposed east-shifted station. However, the active strands could also be somewhat south of the scarp and closer to the proposed station location if erosion (by drainages emanating from Benedict Canyon) has modified the location of the scarp relative to the active traces.

Of more specific concern to the proposed Santa Monica Boulevard (east) Station is the WBHL. The new CPT and seismic data show clear evidence that the WBHL is a wide zone of faulting (Figure 1) that displaces the youngest (late Pleistocene) strata that are present in this area. The proposed Santa Monica Boulevard (east) Station would straddle the zone of faulting along the WBHL. In addition, the Santa Monica fault zone must intersect the WBHL in the vicinity of Santa Monica Boulevard near Moreno Drive or within the Los Angeles Country Club to the north. Zones of fault intersection are likely to be areas of significant structural complexity, including the likelihood of secondary faulting, folding, and distributed off-fault deformation. For these reasons, it is recommended that the proposed Santa Monica Boulevard (east) Station no longer be considered.

Figure 1: Fault Zone

With respect to the activity of the faults, both the Santa Monica fault zone and WBHL show clear evidence of post-middle to late-Pleistocene activity in the study area. Moreover, the topographic scarp associated with Holocene activity and characterizing the surface traces of the active strands of the Santa Monica fault zone has been studied west of the I-405 freeway, where trenching revealed evidence for a 300-foot-wide zone of faulting. There, geologists found definitive evidence of folding associated with slip on the main strand from 1,000 to 3,000 years ago, and surface slip on other strands of the fault from 10,000 to 17,000 years ago. If the WBHL is considered the northern extension of the Newport-Inglewood fault zone, then, by virtue of the Newport-Inglewood fault zone being Holocene active, it is also considered active.

Based on a regression analysis of maximum magnitude versus fault length for past earthquakes, the Santa Monica fault zone is capable of generating earthquakes in the magnitude range M6.9 to M7.2, with average surface displacements of approximately 3 to 6 feet. A major event on the WBHL might be between M6.4 (generally the lower end of the magnitude range for surface rupture) and M7.2, also with average surface displacements of up to 3 to 6 feet, depending on the length of rupture on the northern-most portion of the Newport Inglewood-WBHL fault zone.

Conclusions

Analysis of borings, CPT data, and seismic reflection profiles along 7 transects, in conjunction with mapped topographic landforms, have identified two active fault zones in the Century City area: the northeast-southwest trending Santa Monica fault zone and the northwest-southeast trending WBHL. Santa Monica Boulevard effectively lies within the Santa Monica fault zone from west of Century Park West to east of Avenue of the Stars. The originally proposed Santa Monica Boulevard Station at Avenue of the Stars would be directly within the fault zone.

The WBHL is a wide fault zone with several well-defined strands situated along the eastern margin of Century City. It is the inferred northern extension of the active Newport-Inglewood fault zone. The WBHL terminates the active Santa Monica fault to the east. The location of the proposed Santa Monica (east) Station would straddle the WBHL.

No evidence of faulting was found on the proposed Constellation Boulevard Station site. Based on the results of these fault investigations, there is clear evidence that the proposed station locations on Santa Monica Boulevard (both east and west) would be in active fault zones, and are not viable options for station locations. The proposed station on Constellation Boulevard would not be within an active fault zone and is a viable option for a station location.