Preliminary Review Comments of Century City Area Fault Investigation Report Westside Subway Extension Project Century City and Beverly Hills, CA

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1.0 EXECUTIVE SUMMARY

This report presents the results of our review of the Century City Area Fault Investigation (Fault Report) and Century City Area Tunneling Safety Report (Tunnel Report) for the Westside Subway Extension (WSE) project. The reports were prepared by Parsons Brinkerhoff (PB) in October 2011 for the Los Angeles County Metropolitan Transportation Authority (Metro). The report also includes our observations of fault tunneling on the campus of the Beverly Hills High School (BHHS) completed by BHHS geotechnical consultant. The following summarizes our review opinions of PB's studies as requested by the City of Beverly Hills (City). Details of our report reviews used to develop our opinions are provided in the following sections.

Constellation Station Studies –When compared with the studies completed at the Santa Monica Station, the relatively sparse exploration data presented for the Constellation Station does not indicate, nor fully negate, the presence of faulting. It is our opinion that the current studies for this station are not as thorough as for the Santa Monica Station. Therefore, we recommend that comparable geological and geotechnical explorations be carried out for the Constellation Station.

Santa Monica Station Relocation – Relocating the station further south or east along Santa Monica Boulevard, including the gap (see Figure 2) between the Santa Monica Fault Zone (SMFZ) and West Beverly Hills Lineament/Newport Inglewood Fault Zone (WBHL), has risks similar to the current proposed Santa Monica Station owing to high probability of ground deformation stemming from earthquakes originating from the SMFZ or by previously unmapped fault splays. Data collected at the recent fault trenching performed at BHHS, does not appear to indicate that the WBHL is an active fault. Relocating the Santa Monica Station further east as shown in Figure 2 could be feasible if the WBHL is also shown to be inactive where it crosses Santa Monica Boulevard, and if the SMFZ terminates west of the Beverly Hills City Limits. We recommended fault trenching occur at the station location.

Tunneling Beneath Beverly Hills High School – The proposed tunnel crown is approximately 50 to 70 feet below the existing ground surface along the BHHS campus. The tunnel is therefore not likely to directly impact the campus facilities (as we understand their current use). The proposed BHHS underground parking garage could be constructed above the tunnel to a maximum depth of about 30 to 50 feet below grade, leaving at least 20 feet of undisturbed soil above the tunnels. Risks associated with ground loss during construction, vibrations during construction and operation, and hazards from methane and other gasses should be mitigated by the design and plans and specifications for the project.

Precedents for Stations on Fault Zones – While there are case histories of tunnels surviving earthquakes in relatively good condition, damage has been noted in references we reviewed for stations subjected to strong ground shaking. The California Geological Survey could designate the SMFZ as "active," and thus place it into the category of an Alquist-Priolo Earthquake Hazard Fault Zone (AP Act). Since enactment of the AP Act in 1972, no underground transit stations in California have been knowingly sited across regulatory-defined active faults. Accordingly, if the SMFZ is defined as active the Santa Monica Station should not be located underground where the SMFZ is mapped. The WBHL does not appear to be active based on the trenching completed at BHHS, but as discussed above, should be confirmed with additional trenching along Santa Monica Boulevard.

2.0 INTRODUCTION

The proposed WSE will be a heavy-rail subway connecting to the existing Wilshire/Western station at the Purple Line. The proposed alignment travels west along Wilshire Boulevard through Beverly Hills and westward into the Century City and Westwood areas of Los Angeles. The proposed subway alignment in the study area is shown in Figure 1. A proposed station is located on Santa Monica Boulevard (Santa Monica Station) with an alternate at Constellation Boulevard (Constellation Station). The tunnel alignment for the Constellation Station passes beneath residential and commercial buildings, including the BHHS campus. The draft environmental impact report (DEIR) cites that one of the reasons to consider the Constellation Station as an alternative site is the possibility that active faults might cross the Santa Monica Station. The active SMFZ and the likely inactive WBHL, are shown in Figure 2.

We previously prepared a DEIR Summary Letter dated October 14, 2010 for the City of Beverly Hills (City). In our DEIR Summary Letter, we provided the following recommendation to the City about faults potentially impacting the proposed WSE in Century City:

> “Given the uncertainty of the Santa Monica Fault and West Beverly Hills Lineament, further evaluation to identify fault traces should be completed prior to final location of the Santa Monica base station. The Santa Monica Fault could have one or more distinct fault traces that could impact the station location. The trace(s) would be identified during the geotechnical investigation of the project using a combination of geophysical

techniques, subsurface explorations, and/or trenching (where possible). If a trace is discovered passing through the proposed station, then the station would likely need to be relocated."

The WSE project owner (Metro) commissioned the Fault and Tunnel Reports to address selection of the Century City area station location. The Fault Report presents conclusions regarding the potential for fault rupture at the station locations. The Tunnel Report presents safety concerns regarding tunneling below occupied structures, specifically the BHHS.

3.0 SCOPE OF SERVICES

The primary purpose of our services is to evaluate the geotechnical reports produced for the Final Environmental Impact Report (FEIR) in order to form an opinion on the potential impacts to the City from project construction. A secondary purpose was to provide observation of the fault trenches completed at BHHS. The City authorized our services on September 27, 2011.

4.0 PROJECT TEAM

To provide opinions to the questions above, we have retained a paleoseismologist or fault specialist as part of our team to evaluate the Fault and Tunnel Reports. Dr. Roy Shlemon is a recognized expert for evaluating activity on Quaternary-age faults in southern California and his qualifications are attached to this letter as Appendix A. Dr. Shlemon's report is attached as Appendix B. In addition to Dr. Shlemon, our team consists of our Director of Underground Services, Robert Robinson; engineering geologist, Dean Francuch; and geotechnical engineer, Travis Deane. Resumes of the project team are also provided in Appendix A. Note that Dr. Shlemon was invited by BHHS representatives to view the fault trenching completed at BHHS by their geotechnical consultant, Leighton & Associates. His observations are included in his report.

5.0 CONSTELLATION STATION STUDIES

5.1 General

We reviewed the fault studies performed at the proposed Constellation Station and compared them to fault studies completed at the Santa Monica Station. The intent of our review was to assess that a reasonable investigation had been undertaken to confirm that fault strands were not present in the proposed Constellation Station site, nor that the possible presence of faults in the vicinity do not impact the Constellation Station. The next section references the relevant pages in the Constellation Station studies in the Fault and Tunnel Reports followed by our review and opinion.

5.2 Century City Reports

5.2.1 Fault Report

The following pages of the Fault Report discuss or depict the studies completed for the Constellation Station:

- Pages 1 and 2
- Figure 8
- Page 23
- Page 28

5.2.2 Tunnel Report

The focus of the Tunnel Report is on the safety of tunneling for the Constellation Boulevard alignment and refers to the Fault Report for the fault studies. Therefore, the Tunnel Report does not comment on active faults crossing the Constellation Station.

5.3 Technical Review

Based on the findings near the Santa Monica Station alternative location, the proposed location of the Constellation Station alternative appears to show less probability of active faulting. Page 2 of the Fault Report states that *"…no faulting was found passing through or in close proximity to the proposed Constellation Boulevard Station*." This assertion that Constellation Station is not within a fault zone and that it is a viable option is premature based on the level of study presented in the Fault Report. Note that the WBHL fault trenching completed on the BHHS campus is east of the Fault Report studies.

In our opinion, the study at Constellation Station was not as thorough as that completed for the Santa Monica Station. Transects in the vicinity of the SMFZ and WBHL generally included closely-spaced CPTs and borings as well as seismic reflection profiles. However, along the Constellation Boulevard alignment, the evaluation was limited to a northeast-southwest oriented subsurface profile drawn using existing explorations of variable quality, age, and marginal depth, and a few widely-spaced new CPTs and borings performed for the Fault Report. One transect was also drawn perpendicular to the station (northwest-southeast); this transect was fairly well studied to a similar level of effort to the SMFZ and WBHL areas.

The profile provided along the Constellation Boulevard alignment in the Fault Report interprets lateral continuity of strata, and therefore no obvious signs of faulting. We reviewed the boring logs along the Constellation Boulevard alignment and generally agree with their interpretations with the following exceptions. The interpretation of lateral continuity relies on the identification of marker beds (e.g., discrete gravel beds). Since their interpretation is based largely on existing logs from several different sources, those marker beds are potentially more difficult to correlate than if they were identified in a series of explorations performed in a new, single study, such as that completed for the Santa Monica Station.

Furthermore, the soil profiles shown on Figures 4 and 5 of the Tunnel Report interpreted three fault strands, with the western-most strand based on only two borings, spaced about 500 feet apart. As a result of the wide borehole spacing, the strand is interpreted to lie midway between two borings (69-036-1 and G-168B), about 350 feet east of the station/crossover (see Figure 2). This fault strand could occur anywhere within this 500-foot interval, and consequently might be located as close as 100 feet from the east end of the station/crossover. Also to the west of this western-most fault strand, the boundaries between the San Pedro Formation (Qsp) and the overlying Lakewood Formation (Qlw), and between the Qlw and the overlying older alluvium (Qalo) are shown inclined upward, rather than horizontal, as interpreted within the fault strand-bounded block to the east that show uplifted and depressed blocks along interpreted fault strands. An alternate interpretation, in the absence of available data from additional borings, might be to interpret yet another fault strand within the east end of the station/crossover structure. The report states that the fault line locations are also interpreted from seismic reflection surveys, but this particular strand does not appear to be crossed by a seismic reflection line performed for the fault study. Additional borings and possibly trench explorations, and geophysical studies should be completed in this area to determine the absence or presence and locations of potential fault strands crossing the proposed station.

Several shallow borings were drilled at the Constellation Station, but their primary purpose appears to have been for gas testing, as identified on Figure 5 of the Tunnel Report. It is not clear if soil samples were obtained that might be used for age-dating. Detailed logs of these borings were not provided in the Fault and Tunnel Reports. Groundwater levels are not noted on these borings (M-19, B-1, B-2, B-3, B-4, and B-7). These borings also do not extend down to the station invert, and none extend to 40 or 50 feet below station bottom, as might normally be required for design. We believe that a seismic profile and deeper borings with piezometers should be considered for the station. The deeper borings would be required for station design in order to analyze the station excavation bottom stability, dewatering requirements, presence of methane and hydrogen sulfide gas, temporary shoring depths and support, and other design elements.

It is our opinion that the Fault Report authors should provide justification that the profile drawn from the existing explorations along the Constellation Boulevard alignment is sufficient, or label it as preliminary, warranting a much greater level of study as was undertaken in other areas (even in some areas where faults were not previously mapped).

In summary, we agree with the conclusions of the Fault Report that the Constellation Station location appears to be more favorable than the Santa Monica Boulevard location based on the exploration data that is interpreted to show no faulting in the station area. However, in our opinion, additional explorations at Constellation Station are warranted based on the questions we discussed above regarding the Fault Report studies, coupled with the directive for these studies. The directive on Page 1 of the Fault Report states that "…*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*." Based on this directive, we do not believe the WBHL and the Constellation Station were fully investigated particularly when compared with the studies performed at the Santa Monica Station.

6.0 RELOCATION OF SANTA MONICA STATION

6.1 General

We reviewed the potential for relocating the Santa Monica Station along Santa Monica Boulevard to avoid the SMFZ and WBHL. The next section highlights possible relocation of the Santa Monica Station in the Fault and Tunnel Reports followed by our review and opinion.

6.2 Century City Reports

6.2.1 Fault Report

The following pages of the Fault Report discuss relocation of the Santa Monica Station:

- Pages 1 through 5
- Page 8
- Page 10 Pages 12 through 14
- Page 28

6.2.2 Tunnel Report

The focus of the Tunnel Report is on the Constellation Boulevard alignment. Therefore, this report does not comment on relocating the Santa Monica Station.

6.3 Technical Review

6.3.1 General

We generally agree that placing a station along the Santa Monica Boulevard alignment will be more risky than at Constellation Boulevard due to increasing likelihood of faults to the north, along the SMFZ. Based on the results of the fault trenches recently completed at the BHHS, it is our opinion that the WBHL may not be considered active, contrary to what was asserted in the Fault Report. Specifically, we recommend trenching be performed within the WBHL zone in the median of Santa Monica Boulevard near Moreno Drive to confirm the findings of the BHHS studies. If it is confirmed that the SMFZ and WBHL are not present, or determined to be inactive, if present, then a station could be considered feasible at this location from a fault hazards perspective.

From our review of the Fault Report and from our knowledge of regional and site-specific tectonics, we recognize that many more faults may underlie the upper plate (north side) of the SMFZ. The most recent and highest rate of slip is topographically expressed by a generally east-west, pre-urbanization en-echelon series of escarpments along Santa Monica Blvd. and within the Los Angeles Country Club. South of this alignment, fault presence and relative activity is likely less, but additional studies are warranted. The SMFZ is more active towards the north side with more recent topographic expression, but less active towards the south with less topographic expression, though fault traces are identified to the south.

There are three possible adjustments or modifications to the proposed Santa Monica Station location that should be assessed: 1) moving the station to the “gap” between the SMFZ and WBHL, or eastward over the WBHL if it is demonstrated to be inactive, 2) moving the station to the southern margin of Santa Monica Boulevard, and 3) placing this section of the alignment at grade.

6.3.2 Station in the “Gap”

As shown in Figure 2, traces of the SMFZ are interpreted to curve northeast near the intersection with the WBHL, leaving a gap between the two faults along Santa Monica Boulevard. However, the apparent curves of the fault traces may be due to topographic variations and could be misleading. Also, fault rupture is not the only potential issue associated with displacement of the SMFZ. Ground deformation due to complex fault movements could increase stresses on the buried walls at the station. However, based on the recent BHHS trench investigations, the WBHL may not be present or active in this area. Consequently additional studies may be warranted to assess if moving the station into this apparent “gap”, or even further to the east, is a viable alternative.

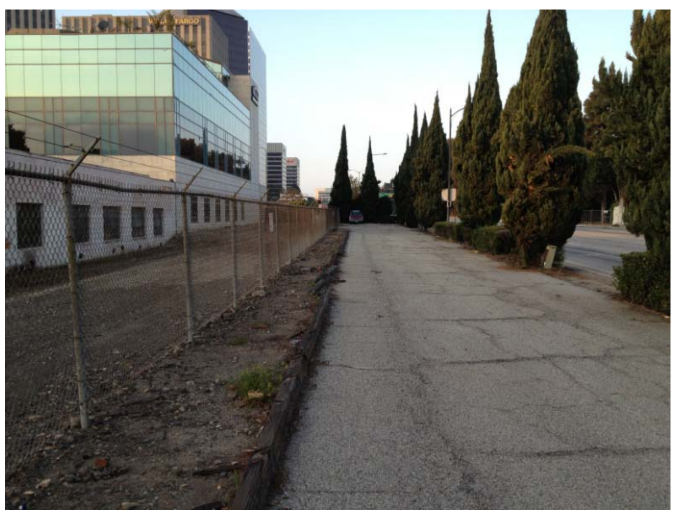
It is uncertain if the main trace of the SMFZ, or a fault splay, lies within the gap, even though maps presented in the Fault Report indicate otherwise. The Fault Report notes that the portion of the SMFZ that bends away from Santa Monica Boulevard is within an area that may have been modified by stream activity. The erosion could have modified the topographic expression of the SMFZ to make it appear that the fault curves to the north, when in actuality it could follow Santa Monica Boulevard in a more straight-line fashion until it intersects with the WBHL. As a result, there is a reasonable chance that the SMFZ crosses the gap.

Moving the station further northeast into the WBHL could be a feasible option based on our interpretation of the Fault Report data and trenching at BHHS. The Fault Report concludes that the WBHL is structurally connected to the active Newport-Inglewood Fault zone to the southeast, and therefore is also considered active. However, the recent trench mapping at the BHHS contradicts this conclusion. Also, the Fault Report geologic sections showing displacements of geologic units by the WBHL (Plate 4 of Fault Report) terminate in the Older Alluvium Sand Deposits (geologic symbol: Qfo). The unit is identified as late Pleistocene (Table 1 of Fault Report), which makes it too old to be an indicator of Holocene fault activity. This is an important issue in deciding if a fault is “active”, which relies on movement within the recent Holocene Epoch (the last 10,000 to 12,000 years).

The BHHS excavated several fault trenches on campus which are detailed in Dr. Shlemon’s report (Appendix B). Based on the observations presented in Dr. Shlemon’s report and our discussions with him, the probability of the WBHL being active at the BHHS study area is low (see Section 8.0 below for discussion on defining faults as “active”). Therefore, we recommend that considerations should be given to excavating a confirming trench along Santa Monica Blvd, across the WBHL. If similar conclusions are derived regarding the absence of active faults along the WBHL, or that the ages of any such offset precede the state’s cutoff date for active faulting, then the potentially active fault zones shown in Figure 2 from the Fault Report that pass through the BHHS study area should be deleted.

With tentative reclassification of the WBHL fault splays and zone through the BHHS study area as “in-active”, the extrapolated WBHL features crossing Santa Monica Boulevard to the northwest of the BHHS campus should be further explored to confirm absence or inactivity of fault splays at this location. While the faulting observed at the BHHS trenches is now considered inactive, this does not negate activity in the area of Santa Monica Boulevard due to the presence of the SMFZ. The possible intersection of the likely active SMFZ at Santa Monica Boulevard complicates WHBL activity at this location. Furthermore, fault traces east of the Beverly Hills city limits could be present and/or active as they are further east of the BHHS campus (and thus unexplored by the BHHS fault trenches).

As discussed above, we recommend that additional studies be considered to determine fault activity of the WBHL in the vicinity of Santa Monica Boulevard. An east-west fault trench could be excavated in the old railroad right-of-way on the south side of “Big” Santa Monica Boulevard as shown in Figure 2 and Photograph 1 below, to confirm the WBHL findings at the BHHS. A north-south fault trench perpendicular to the trace of the SMFZ should also be considered at the west end of the proposed station in this area to confirm the termination of the SMFZ at the WBHL. Depending on the results of these additional studies, locating the station within the currently denoted WBHL may be feasible.



Photograph 1 – South Side of “Big” Santa Monica Boulevard looking southwest along the old railroad right-of-way.

6.3.3 Santa Monica Boulevard Right-of-Way (ROW)

One option could be to locate the station on the south edge of Santa Monica Boulevard rather than at the current center of the ROW. Santa Monica Boulevard is approximately 300 feet wide from the edge of the golf course to the buildings of Century City. However, while fault activity could be less along the south side of Santa Monica Boulevard, the Fault Report (p. 12) indicates that the SMFZ may be up to 300 feet wide.

We also suggest consideration be given to placing the Santa Monica Station at grade. While the WSE is proposed underground throughout the alignment using an electrified third rail, an above-grade, third rail "subway" has precedence on several transit systems both domestic and international. Examples include Long Island (Photograph 2 below), New York, Chicago, Tokyo, and Berlin transit systems.

Photograph 2 – Long Island Railroad Third Rail

An at-grade platform for the Santa Monica Station would still be subject to the potential of fault rupture; however, it is our opinion that the threat to life safety would be significantly less than a below grade station. Such a station location would likely require reassessment by Metro of federal and state regulations regarding above ground transit station locations relative to active faults. An at-grade alignment could run along the existing busway along Santa Monica Boulevard as shown in Photograph 3 below.

Photograph 3 – Santa Monica Boulevard Busway looking northeast

An at-grade station would require approaches of the track out of the tunnels that could be constructed using cut-and-cover excavations. Traffic access along lanes of Santa Monica Boulevard would require modifications, including the possibility of at-grade crossings such as shown in Photograph 4 below. However, these challenges should be weighed against cost savings from elimination of a below grade station and potential impacts to project schedule and budget from potential conflicts with the BHHS and other parties along the proposed Constellation Boulevard alignment.

Photograph 4 – Third Rail Grade Crossing in Tokyo

7.0 TUNNELING BENEATH BHHS

7.1 General

We reviewed the Tunnel Report regarding the safety of constructing the Constellation Boulevard alignment below the BHHS and other occupied structures. The intent of our review was to comment on assertions made in the Tunnel Report regarding the practicality and safety of tunneling and present our opinions regarding stated and unstated tunneling risks based on our experience on several similar tunneling projects. The next section highlights tunneling studies in the Fault and Tunnel Reports followed by our review and opinion.

7.2 Century City Reports

7.2.1 Fault Report

The focus of the Fault Report is on the fault studies for Santa Monica and Constellation Stations while the safety of tunneling for the Constellation Boulevard alignment is described in the Tunnel Report. Therefore, this report does not comment on safety of tunneling below structures such as BHHS, and consequently is not relevant to this section of our report.

7.2.2 Tunnel Report

The following pages of the Tunnel Report discuss risks associated with tunneling below the BHHS campus:

- Pages ES-1 through ES-3
- Pages 2-7 and 2-8
- Page 3-4
- Page 4-1
- Pages 4-4 and 4-5
- Page 5-4
- Page 8-1
- Page 8-4
- Page 8-6
- Page 8-10

7.3 Technical Review

7.3.1 General

The Tunnel Report provides a generalized review of relevant case history data and an optimistic perspective on likely behavior and approaches to construction of the WSE in the

Beverly Hills and Century City areas. Nevertheless, the conclusions that construction of tunnels, using state-of-the-practice closed-face Tunnel Boring Machines (TBMs) can result in negligible to minor settlements, and little to no impacts from gas, groundwater, and soil variability is a generally realistic assessment. The details of the specifications developed by Metro, the procurement of the appropriate TBMs, and construction implemented by an experienced contractor will be essential to complete a quality tunnel project with little or no impacts on overlying and adjacent buildings.

The information provided in the Tunnel Report does not provide detailed information on the correct operation of a closed-face TBM to preclude or minimize surface settlement. Typically, TBM operational requirements are provided in the contract documents (plans and specifications) that guide the contractor's selection and design of the TBM, his operation of the TBM including allowable minimum face pressure, means of monitoring muck weights or volumes, maximum allowable settlements, and settlement monitoring instrumentation and surveying. Ground improvement techniques and settlement compensation techniques that might be used to minimize surface settlements and compensate for excessive ground losses (if they occur) should also be included in the Contract Documents.

7.3.2 Ground Settlement

We agree that closed-face TBMs provide the best means, methods and opportunities to achieve negligible ground losses and small to unmeasurable settlements (p. 4-4). Overall, our experience with closed-face TBMs has been good, although there has been much more experience with earth pressure balance machines (EPBM) than slurry-pressure balance machines (SPBM) in the United States. Ground losses of 0.5% or less and resulting settlements of fractions of an inch are typical of most closed-faced TBM projects. However, large ground losses and surface settlements have occurred on a small percentage of international projects, and over a small percentage of the length of these projects. Isolated large ground losses have more frequently occurred where the TBM exits and enters the stations or shafts, where mixed-face conditions occur (e.g., flowing cohesionless soils in contact with cohesive and hard soils or rock), or where face pressures have not been maintained equal to or greater than the ambient soil and groundwater pressures. Ground losses can occur due to excessive intake of soil into the cutterhead, an enclosed excavation cross section due to poor TBM alignment control (particularly on curves), inadequate grout filling behind the gasketed concrete segmental lining, and lowered face pressure during extended maintenance.

These settlement and ground control issues should be identified during the normal risk assessment process undertaken during preliminary and final design phases and mitigated through the specification of appropriate construction methods and safeguards in the Construction Documents and with the selection of an experienced contractor, who brings experienced staff to the project, a TBM with characteristics that promote a small overcut, continuous monitoring and real-time reporting and review of critical machine parameters (e.g., face pressures, conditioner usage, muck volumes or weights, and cutter tool wear), constant review of TBM operational data, frequent monitoring of deep ground movements around the advancing TBM and surface settlements, and daily collaboration between the construction management staff and contractor.

The Tunnel Report does not discuss ground improvement methods in any detail, but ground improvement techniques, appropriate to various soil conditions, are typically specified for most major tunneling projects to stabilize soils and compensate for tunneling induced ground losses before they progress up to ground surface to impact utilities and structures. Ground improvement methods such as jet grouting, soil/cement mixing, permeation grouting, compaction or compensation grouting, dewatering, and freezing, are commonly used on many major tunnel projects and all provide opportunities for stabilizing the soils and reducing ground losses, particularly beneath critical structures, at launching and retrieval pits, and at cross passages. Remedial grouting measures, such as compaction grouting or compensation grouting, and fracture grouting have been used successfully to compensate for known excessive ground losses and prevent adverse surface settlements in real-time as the TBM moves forward through the ground. All of the preventative and remedial measures should be handled in the specifications, and where possible, with incentives to the contractor to optimize the quality of his work product on this project.

From Metro's experiences on the Gold Line project (or MGLEE), where closed-face TBMs were very successful in minimizing settlements to about 0.3 inches (Robinson and Brogard, 2007) , there is a good discussion of "a comprehensive program of instrumentation and surveying conducted to monitor ground movement above the MGLEE tunnels…"(p. 4-4). Similar instrument and survey systems should be included throughout the WSE project, as well as settlement points on buried utilities and buildings, and tilt meters and crack gages on building components. Borehole extensometers should be installed to provide useful information on the location and source of ground losses immediately above the advancing TBM. The collected and plotted deformation data should be shared with BH staff and building owners.

The 0.5 percent ground loss that is noted in the Tunnel Report is a reasonable number particularly given that the MGLEE tunnels resulted in about 0.3 percent ground loss, and has been used on many recent projects in reasonably competent ground such as is present along the alignment (p. 4-5) as a starting point for developing settlement predictions. Actual surface settlements measured over most of the lengths of tunnel alignments constructed by closed-face TBMs in the United States in the last 15 years are generally equivalent less than 0.5 percent ground loss. Consequently, measured settlements along tunnel or project centerline are generally less than 1 inch, and are often less than 0.25 inch, which is about the level of accuracy of most standard surface surveying. Larger ground losses and resulting settlements typically relate to inappropriate operation of the closed-face TBMs, and can be detected with the instrument monitoring systems and corrected at the insistence of the owner, construction manager and contractor.

7.3.3 Noise and Vibration

Construction related vibrations are likely to be transitory, since the tunnel heading will be advancing at the average rate of about 50 to 100 feet per day beneath and beyond any one single property. Perceptible tunnel vibrations due to subway trains are more likely to occur in curves, at cross-overs or switches, and where track is misaligned due to poor construction and/or poor maintenance. However, a Metro test programs had indicated no adverse noise or vibration due to transit tunnel operations along both the Red and Gold Lines.

The Tunnel Report notes that noise and vibration tests have already been performed on the BHHS and indicate that construction and train operation noises and vibration will be below FTA limits. Measurements would be made under BHHS during construction (p. ES-2). However, there is no indication that these would be used as “not to exceed” baselines for construction. There should also be comments, and eventually specification requirements on using sound-damping noise walls, low noise fans, and minimizing trucks entering and leaving staging areas during hours that would disrupt local residents, businesses, and public facilities

Underground construction typically mutes most of the construction related noise and vibration. However, surface activities such as ventilation fans, cranes, muck removal and loading into dump trucks, and bringing construction materials on site could result in noise and vibration impacts to nearby and adjacent homes and businesses. Noise walls, 12 to 20 feet high, erected around the construction site have been effective on other recent tunnel projects in significantly reducing impacts such as noise and dust to neighbors.

7.3.4 Gassy Ground

For gassy ground, the Tunnel Report notes that "volume of 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" (p. 5-4). This would be the case if the contractor is required to utilize a SPBM, where the excavated muck and bentonite slurry is pumped to the ground surface for treatment. However, this would only be partially true if the contractor uses an EPBM, in which the excavated soil is brought out of the "chamber" or cutter-head via a cased screw auger and then dumped onto a conveyor belt for conveyance via any of several means (muck trains, extended conveyor or slurry pipeline) to the portal. When the excavated soil is expelled from the screw auger onto the conveyor belt, entrained gas may bleed off into the air. However, the volume of gas will be limited to that which is only entrained in the excavated soil and will be limited by the earth pressure maintained on the face. On many tunnel projects, high ventilation rates have been used effectively to dilute and expel this gas from the tunnel. If the muck is fluidized and carried out by slurry line, then the gas bleeds off from the slurry at the ground surface. There are also options for neutralizing hydrogen sulfide in the ground, or in transit through the tunneling machine, by injecting chemicals such as bleach, hydrogen peroxide and permanganate. We understand that on the Gold Line tunnel construction, a SPBM was required where methane and hydrogen sulfide gas concentrations were anticipated to be high by the designers.

The recent Metro Gold line specifications required the installation of double-gasketed segmental liners coupled with high ventilation rates for either an EPBM or SPBM along with continuous monitoring for gas concentrations. Similar specification requirements should be applied to the WSE to provide sufficient redundancy to prevent methane and hydrogen sulfide buildup in the tunnel during construction and operations. Most longer than 15-foot diameter TBM-excavated soil tunnels in the U.S. are supported with a bolted precast concrete segments with a gasket around each segment that mates with adjacent segments. Metro has implemented the use of double-gasketed, bolted concrete segments for tunnel lining in order to greatly reduce the potential for gas and groundwater entering the tunnels. This double-gasketed lining system was extensively tested for and is unique to Los Angeles tunnel projects. In addition, the double-gasketed, bolted, precast segmental liner will be fully encased in a 4- to 6-inch thick annulus of grout that is pressure injected around the lining as it is installed at the rear of the advancing TBM. The double gaskets and grouted annulus will virtually eliminate the potential for gas to enter the tunnel through the lining. Federal and state required active ventilation implemented during construction and operation of the tunnels will further dilute gas that enters the tunnel.

Lastly, the contractor is required, in potentially-gassy and gassy ground to install gas detection monitoring systems to continuously monitor the tunnel atmosphere for gas. On most tunneling projects the tunnel foreman or safety engineer also carries a portable gas detector to check the tunnel atmosphere for gas levels. This multiple redundancy of sealing, ventilation, and monitoring has precluded gas from being an issue in most tunnels during and following soil tunnel construction with precast concrete gasketed segmental linings during the last 30 to 40 years.

Based on review of the Tunnel Report, only boring C-119B involved gas testing at three elevations at the Santa Monica Station; whereas, six borings were tested for gas concentration at multiple elevations at the Constellation Station. Additional borings should be drilled and tested for gas concentrations, along with groundwater levels along the final tunnel alignment.

7.3.5 Groundwater

The Tunnel Report notes 500-foot spacing for the borings (p. 2-8). In our opinion, this spacing is too wide with regards to the complexity of the faulted geology and variable groundwater levels in the West Beverly Hills/Century City area. The borings do not appear to have been drilled through the faults, which are shown as steeply inclined to vertical features. Ideally borings, possibly angled, should be drilled through the faults to look for clay gouge, soil consistency, ground water levels changes, and other properties that could impact the tunnel construction. The presence of high groundwater levels to the north of the SMFZ and to the east of the WBHL, and substantially lower groundwater levels to the south and west of these features suggests the presence of clay gouge that is impeding groundwater flows.

Subsurface conditions at BHHS were explored with 14 borings; however, only four are deep enough to go below the tunnel horizon. Only three borings have monitoring wells installed, and water levels were measured in three of the borings during drilling. The three borings with monitoring wells show water levels 10 to 40 feet above the proposed tunnel crown, however, without information on screen locations and sealing methods, it is not possible to determine from which soil horizon(s) the water is originating. From our review, it is unclear if a perched water table is present for some of the upper soil units, or possibly a confined artesian condition for some of the lower soil units. Also, it is unclear how the groundwater levels change across the various postulated faults as water levels were measured in only three borings in the three fault strand bounded blocks.

The fault block furthest to the west apparently has no groundwater measurements. A complete discussion on a postulated groundwater barrier to the northwest of the Constellation Station site is lacking (p. 2-7). We recommend that additional borings with wells and piezometers be installed and a map of contoured groundwater levels be developed to help identify the location, orientation, and cause of the "groundwater barrier." Identification of this feature will be important for both the tunnels and stations.

7.3.6 Existing and Future Structures

Beneath the BHHS, the top or crown of the proposed tunnels are 50 to 70 feet below ground surface. This should provide adequate depth for future development of parking garage/basements down about three to four levels or 30 to 50 feet deep. Normally, construction is limited to no closer than one tunnel diameter above the crown or to the sides of a tunnel. However, closer excavation may be permitted by Metro with adequate design evaluation, lateral support, and protection of the transit tunnels.

The Constellation Boulevard alignment passes below significantly more house, commercial buildings and other structures (including the BHHS) than the Santa Monica Boulevard alignment. The number of structure directly above the tunnels increases the challenges of adequate exploration as well as the need for more careful construction methods and additional monitoring of settlements and ground behavior. Agreements with Metro on design and construction limitations and requirements for any new structures built over the tunnels would be needed from at-grade property owners above the tunnels. These agreements would likely include a maximum basement depth, any special tall building support constraints, such as proximity of piers or pile tips, and basements adjacent to the tunnels.

8.0 PRECEDENCE FOR STRUCTURES ON FAULT TRACES

8.1 General

We reviewed the Fault and Tunnel Reports for comments on locating transit structures on or adjacent to fault traces. The intent of our review was to evaluate case histories of transit structures placed along fault zones, and structures that were impacted by fault displacements. The next section highlights similar structures along fault zones in the Fault and Tunnel Reports followed by our review and opinion.

8.2 Century City Reports

8.2.1 Fault Report

The following pages of the Fault Report discuss structures placed on or near fault traces:

- Page 16
- Page 30

8.2.2 Tunnel Report

The following pages of the Tunnel Report discuss structures placed on or near fault traces:

- Page ES-3
- Pages 7-1 and 7-2

8.3 Technical Review

8.3.1 Overview of the Alquist-Priolo Act

This section provides additional history of and use of the AP Act than is discussed in the Fault Report (p. 16). The authors of the Fault Report note that the assumed likely inclusion of the SMFZ and WBHL into the AP Act is a sufficient reason enough to select the Constellation Boulevard alignment. However, if the results of the recent trenching on the BHHS campus are to be believed, then the WBHL should not be classified as "active".

The original name of the AP Act was the Alquist-Priolo Geologic Hazards Zones Act established on December 22, 1972. The State Geologist delineated earthquake fault zones for active traces of the San Andreas, Calaveras, Hayward, and San Jacinto faults. Preliminary review of 175 quadrangle maps occurred between 1973 and 1974. Official maps were issued on July 1, 1974, and Earthquake Fault Zones became effective at that time. The cities and counties were required to implement programs to regulate development within mapped AP Act zones.

Faults were mapped as "active" if they had surface displacement in the last 11,000 years (Holocene). Faults were mapped as "potentially active" if they showed evidence of surface displacement during Quaternary time (last 1.6 million years). "Potentially active" faults are now referred to as "recently active" faults.

The AP Act was renamed the Alquist-Priolo Special Studies Zones Act on May 4, 1975. On January 1, 1976, 81 maps of new zones and five maps of revised zones were implemented.

Beginning in 1977, the State Geologist decided fault zones must meet the criteria of "sufficiently active and well defined." However, the term "potentially active" continued to be used as a descriptive term on map explanations until 1988.

Since 1977, an earthquake fault zone boundary (EFZ) is defined to extend 500 feet to either side of a "major" active fault and about 200 to 300 feet to either side of a well-defined, minor fault. Exceptions exist where faults are locally complex or where faults are not vertical. Within these zones owners of new or rebuilt structures may be required to complete subsurface investigation to delineate faulting on the project boundaries. EFZ maps are typically issued every year or two to delineate additional and revised zones.

The AP Act was again renamed the Alquist-Priolo Earthquake Fault Zoning Act on January 1, 1994. By August 16, 2007, a cumulative total of 547 official maps of active fault locations had been issued. Of these, 148 maps have been revised since their initial issue and four maps have been withdrawn. Additional faults will be zoned as "active" in the future and some will be revised.

Sufficiently Active-This is defined as evidence of Holocene surface displacement along one or more of a fault's segments or branches. Holocene surface displacement may be observable or inferred; it need not be present everywhere along a fault to qualify that fault for zoning. Note that the amount of fault displacement is not specified.

Well-Defined-This is defined as a fault trace that is clearly detectable by a trained geologist as a physical feature at or just below the ground surface. The fault may be identified by direct observation or by indirect methods. The critical consideration is that the fault (or some part of it) can be located in the field with sufficient precision and confidence as to indicate that the required site-specific investigations would meet with some success. Determining if a fault is sufficiently active and well defined is a matter of judgment. Certain faults considered to be active at depth are so poorly defined at the surface that zoning is impractical.

The AP Act is applicable to any project defined under Section 2621.6 of the AP Act. This includes:

- Any subdivision of land which is subject to the Subdivision Map Act, and which contemplates the eventual construction of structures for human occupancy.
- A structure for human occupancy is any structure used or intended for supporting or sheltering any use or occupancy, which is expected to have a human occupancy rate of more than 2,000 person-hours per year.

- Exemptions for structures with human occupancy include either of the following:
  - A single-family wood-frame or steel-frame dwelling to be build on parcels of land for which geologic reports have been approved
  - A single-family wood-frame or steel-frame dwelling not exceeding two stories when that dwelling is not part of a development of four or more dwellings.

In practice, the minimum setback distance from an active fault trace is typically 50 feet. With respect to building set back, the act simply states that: "No structure for human occupancy shall be permitted to be placed across the trace of an active fault. Furthermore, the area within 50 feet of such active faults shall be presumed to be underlain by active branches of that fault unless proven otherwise by an appropriate geologic investigation and report." (CGS, 2007).

All sections of the AP Act apply to proposed human occupancy structures. When a property pre-dating the AP Act is located within an EFZ, the transferor or agent acting for the transferor must disclose to the prospective transferee the fact that the property is located within a delineated EFZ. The disclosure must include proof and must be disclosed by an appropriate agent as defined by this section.

8.3.2 Stations and Tunnels Subjected to Fault Displacements

We reviewed case histories of fault displacement for several types of structures, including tunnels, subways, stations, buildings, and underground pipelines. We did not find references to stations knowingly placed across an active fault trace. The following discussion highlights tunnels and subways that had been directly subjected to earthquake shaking and fault displacements.

A study of tunnels affected by strong earthquakes revealed multiple cases of tunnels damaged by seismic fault offsets, including the Bolu twin tunnels (Turkey), Wrights Railway Tunnel (California), Kern County Tunnel (California), Balboa Inlet Tunnel (California), and several tunnels in Japan. Research indicates that tunnels may be vulnerable tectonic deformations. Very little or no evidence exists indicating that relatively recent concrete lined tunnels have experienced significant damage or collapse due to seismically induced shaking. There is some evidence that some underground stations have experienced minor damage, particularly at connections with tunnels, and in some of the associated utilities.

The Bolu Tunnels are 50 feet wide and 2 miles long and cross the North Anatolian Fault Zone (strike-slip), along a 500-1000 foot wide shear zone. After a 7.2 Moment Magnitude earthquake in 1999, deformation up to 30 inches was observed in the tunnel and a section of the tunnel, temporarily under construction, collapsed (Kontogianni, V. I. and Stiros, S. C., 2003).

In 1906, the Southern Pacific Railroad's Wrights Tunnel was damaged by a 7.7 Moment Magnitude earthquake occurring in the San Andreas Fault Zone (strike-slip). This 1.2 mile tunnel experienced offsets of between 5 to 6 feet. The tunnel, above which two parallel seismic surface ruptures were observed, collapsed along a 300 foot long section crossing the fault zone (Kontogianni, V. I. and Stiros, S. C., 2003). In this location, the tunnel was timber-supported and considerable crushing of timbers and upward heave of rails occurred (Brown et al., 1981).

The Kern County Tunnel, crossing the White Wolf Fault (reverse strike-slip), was damaged during a 7.5 Moment Magnitude earthquake in 1952. The tunnel, lined with timber and about 1 to 2 feet of reinforced concrete, was located in an area where fault displacements occurred during the earthquake. After the earthquake, both compressive and lateral displacements were detected along the ground surface. The liner was offset just over 4 feet (Kontogianni, V. I. and Stiros, S. C., 2003).

The partially completed Balboa Inlet Tunnel was affected by the San Fernando Magnitude 6.6 earthquake in 1971. The tunnel crossed the Santa Susana Thrust Fault, along which displacement occurred about 1,000 feet from the portal. The reinforced concrete liner was cracked and there was spalling along a 300-foot section at the fault crossing. On each side of the fault, there was also longitudinal cracking in the tunnel liner for about 1,000 feet (Brown et al., 1981).

The San Pablo Tunnel, used to transport water through the Berkley Hills from the San Pablo reservoir, was constructed between 1917 and 1920 and is about 2.5 miles long with a cross-section about 8 feet wide. The tunnel crosses two major fault zones, the Hayward Fault, and the Wildcat Fault, as well as several unnamed faults. In 1969, control points were set up for alignment checks after circumferential and longitudinal cracks were observed. It was not reported whether or not this occurred because of fault rupture or creep (Brown et al., 1981).

During the 7.6 Magnitude Chi-Chi Earthquake in 1999, a portal for water intake tunnels was ruptured for a distance of 30 feet as a result of thrust faulting in Taiwan (Aydan, O., 2003).

Japan has several instances where fault rupture crossed tunnels. The Tanna Railway tunnel on the main line between Tokyo and Kobe was under construction in 1930 when it was damaged by an earthquake with a magnitude estimated at 7.1. Tunneling conditions were very wet and required drainage drifts. Near one of the drainage drifts, a shear zone displaced about 9 feet left lateral and 2 feet vertical. This completely closed the drainage drift. At the surface, about 500 feet above the tunnel invert, fault displacement was less and measured 3 feet left lateral and 1.5 feet vertical (Brown et al., 1981).

The Inatori Tunnel in Japan experienced surface rupture along the Tanna Fault during the 1977 Izu earthquake. With a surface wave magnitude of 6.8, the earthquake caused damage to the 65-foot long railway tunnel with a relative displacement of 40 inches. The railway tunnel crossed the fault at right angles, with a cover of 300 feet. This movement caused extension of the tunnel (Brown et al., 1981).

Similar damages occurred due to the motions of the Rokko, Egeyama, and Koyo faults to the tunnels of Shinkansen and subway lines through the Rokko Mountains. The underground rapid transit subway line in Kobe experienced collapse of 3 of the 10 stations as a result of strong ground shaking during movement of the nearby Egeyama fault (strike-slip). In particular, the Daikai station collapsed after it was subject to torsional failure due to permanent ground displacement from nearby fault displacement (Aydan, O., 2003).

In addition, Shannon & Wilson had staff in San Francisco during and following the 1989 Loma Prieta Earthquake who observed several railroad tunnels immediately after the earthquake and observed no damage other than minor spalling of thin concrete, grout and gunite patches in brick- and concrete-lined tunnel crowns.

We also reviewed highway tunnels and transit tunnels in the Seattle area immediately after the 2001 Nisqually Earthquake in western Washington. None of the four tunnels that were reviewed showed any indications of shaking related damage; however, minor damage was observed in one of the cut and cover stations at the intersections with the running tunnels.

The Tunnel Report indicates that a special tunnel liner design may be required, such as a strong but flexible lining to withstand several feet of movement without collapse (p. 7-2 note above). The use of such a specialized liner would only be required where displacements might occur across an "active" fault, which at this point may only apply to the SMFZ. This could require a localized larger diameter liner, which means that the larger diameter TBM would be needed. The larger diameter tunnel might be on the order of 23 to 26 feet in diameter to accommodate fault offset. Alternately, a flexible lining and a lining backed with crushable grout could be used, but this could also require a larger diameter TBM. The larger diameter TBM might be accommodated with shafts to either side of the SMFZ. It appears that the design team and Metro have not yet settled on a design for the fault crossing.

9.0 LIMITATIONS

This report was prepared for the exclusive use of the City of Beverly Hills for specific application to this project. This report is a review of information provided in the Century City Reports.

The analyses, conclusions, and recommendations contained in this report are based on information provided in the Metro Reports and our experience in the project vicinity. We assume that the exploratory borings provided in the Metro Reports are representative of the subsurface conditions throughout the project alignment (i.e., the subsurface conditions everywhere are not significantly different from those disclosed by the explorations).

Within the limitations of the scope, schedule, and budget, the analyses, conclusions, and recommendations presented in this report were prepared in accordance with generally accepted professional geotechnical engineering principles and practices in this area at the time this report was prepared. We make no other warranty, either express or implied. These conclusions and recommendations were based on our understanding of the project as described in this report and the site conditions as interpreted from the Metro Reports.

Shannon & Wilson, Inc. has prepared the document, "Important Information About Your Geotechnical/Environmental Report," in Appendix C to assist you and others in understanding the use and limitations of this report.

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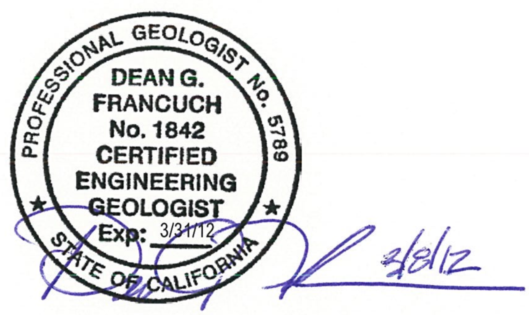

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10.0 REFERENCES

Aydan, O, 2003, Proceedings of the Eighth U.S.-Japan Workshop on Earthquake Resistant Design of Lifeline Facilities and Countermeasures against Liquefaction: held at the Edmont Hotel, Tokyo, Japan, December 16-18, 2002, p 227-237.

Brown, I. R.; Brekke, T. L.; and Korbin, G. E., 1981, Behavior of the Bay Area Rapid Transit tunnels through the Hayward fault: Washington, D. C., U. S. Department of Transportation, Report no. UMTA-CA-06-0120-81-1, 208 p.

California Geological Survey, 2007, Fault-Rupture Hazard Zones in California, Alquist-Priolo Earthquake Fault Zoning Act with Index to Earthquake Fault Zones Maps, Special Publication 42, Interim Revision.

Kontogianni, V. A. and Stiros, S. C., 2003, Earthquakes and Seismic Faulting: Effects on Tunnels: Turkish Journal of Earth Sciences, v. 12, p 153-156.

Parson Brinckerhoff, 2011, Century City Area Tunneling Safety Report, Westside Subway, Extension Project, report prepared by Parson Brinckerhoff, Los Angeles, CA, Contract No. PS-4350-2000, for Metro, October 14, 2011.

Parson Brinckerhoff, 2011, Century City Area Fault Investigation Report, Westside Subway, Extension Project, report prepared by Parson Brinckerhoff, Los Angeles, CA, Contract No. PS-4350-2000, for Metro, October 14, 2011.

Robinson, B. and Bragard, C., 2007, Los Angeles Metro gold Line Eastside Extension-Tunnel Construction Case History, Proceedings, Rapid Excavation and Tunneling Conference, Toronto, Canada, p. 472 – 494.

Shannon & Wilson, 2010, Geotechnical Engineering Report, Westside Subway Extension, Review of Draft Environmental Impact Report: report prepared by Shannon & Wilson, Inc., Glendale, CA, Project No. 51-1-10024-001, for the City of Beverly Hills, October 13, 2010.

Shannon & Wilson, 2010, Geotechnical Engineering Comments Letter, Westside Subway Extension, Review of Draft Environmental Impact Report: letter prepared by Shannon & Wilson, Inc., Glendale, CA., Project No. 51-1-10024-001, for the City of Beverly Hills, October 14, 2010.