TYPE SELECTION REPORT

Main Post Tunnel (34-0163 L/R)
Retaining Wall No. 8 (34-0162)
Battery Tunnel (34-0161 L/R)

I. INTRODUCTION

It is proposed to construct a new roadway to replace the existing six-lane Doyle Drive portion of Route 101 in order to improve the seismic, structural, and traffic safety of the roadway within the setting and context of the Presidio of San Francisco and its purpose as a National Park. As shown in Exhibit 1, the new facility will include a southbound auxiliary lane between the Park Presidio Interchange and the Girard Road exit ramp, landscaped medians, continuous shoulders, and direct access to and from the Presidio at Girard Road. The project limits are from Merchant Road, just south of the Golden Gate Bridge Toll Plaza, to the intersections of Richardson Avenue/Francisco Street and Marina Boulevard / Lyon Street.

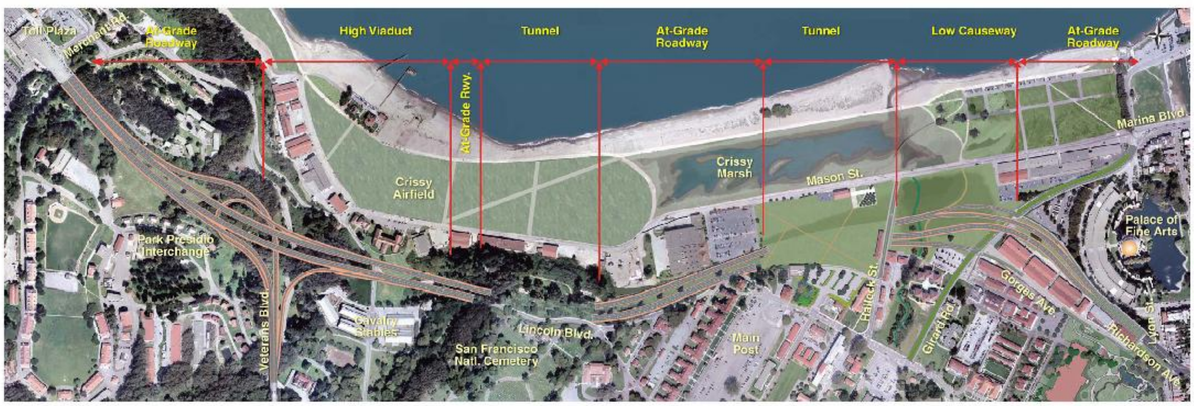

Exhibit 1 – Preferred Alternative

Doyle Drive, the southern approach of Route 101 to the Golden Gate Bridge, is 1.5 miles long with six traffic lanes. There are three San Francisco approach ramps which connect to Doyle Drive: one beginning at the intersection of Marina Boulevard and Lyon Street; one at the intersection of Richardson Avenue and Lyon Street; and one where Veterans Boulevard (Route 1) merges into Doyle Drive approximately 1 mile west of the Marina Boulevard approach. Doyle Drive passes through the Presidio on an elevated concrete viaduct (Marina Viaduct) and transitions to a high steel truss viaduct (Presidio Viaduct) as it approaches the Golden Gate Bridge Toll Plaza.

Doyle Drive was built in 1936 and it is approaching the end of its useful life, although regular maintenance, seismic retrofit, and partial rehabilitation activities are keeping the structure safe in the short term. However, further structural degradation caused by age and the effects of heavy traffic and exposure to salt air will require, in the long term, permanent improvements to bring Doyle Drive up to current design and safety standards.

The Arup/PB Joint Venture will deliver construction documents for the Main Post Tunnel, Retaining Wall No. 8 and the Battery Tunnel structures of the new alignment. The portal structures of the Main Post and Battery Tunnels have not been included as part of this type selection pending completion of the architectural design. Caltrans will deliver the construction documents for all roadways, elevated bridge structures and other standard retaining wall structures.

Main Post Tunnels

The Main Post Tunnels are proposed to replace the Marina Viaduct, an existing elevated concrete structure, with a cut-and-cover tunnel structure in nearly the same location. The proposed tunnel is a two cell structure with one cell accommodating northbound traffic, and the other southbound traffic. The northbound tunnel length is approximately 920 feet, and the southbound length approximately 1020 feet. The typical combined width of the tunnel structure is approximately 103 feet. The proposed structure will typically be 43 feet wider than the existing structure to accommodate the southbound auxiliary lane and shoulders. A six foot high crown at the roof slab will be maintained throughout the length of the tunnel as an architectural feature.

Imported and site excavation fill will be placed on top of the Main Post Tunnels with the intent of creating a "bluff" that architecturally evokes the historic Presidio Main Post bluff. Pedestrian trails and cultural landscaping will be featured as part of the bluff. Access to the bluff area by motorized vehicles will be primarily limited to maintenance vehicles.

The Main Post Tunnels will also pass beneath Halleck Street and the relocated upper story of the two-story historic Building 201. The tunnel roof slab will need to be designed and detailed to meet the profile requirements of Halleck Street. Building 201 will be temporarily moved prior to construction of the Main Post Tunnels. It is currently proposed that after completion of the tunnels, the upper story and roof of the building be reconstructed on top of the tunnel adjacent to Halleck Street.

Sag curves along the northbound and southbound Doyle Drive profiles are located near the beginning of the tunnel to accommodate Halleck Street. This will require that a drainage sump be constructed adjacent to the Main Post Tunnel to prevent the ponding of water.

The proposed tunnels will be designed in accordance with the project specific design criteria which is based on the AASHTO LRFD Design Specifications (4th Edition, with 2008 Interim Revisions) and applicable California Amendments and additional provisions for buried construction. Although vehicle access to the bluff on top of the tunnel will be limited, the tunnel roof slab will be designed for AASHTO LRFD HL-93 Live Loading to accommodate possible use by emergency vehicles.

Cast-in-place concrete structures are the preferred construction type for the Main Post Tunnels. Precast arched roof elements were considered but rejected due to the elliptical shape of the soffit provided by pre-casters rather than the circular arc of a vaulted ceiling. Also, the long spans and the change in soffit radius near the beginning of the tunnel will cause additional difficulties for construction. It is also believed that the seismic resistance of a composite precast and cast-in-place structure might be significantly less than that of a complete cast-in-place structure. In particular, there is concern with developing a connection between the precast roof elements and the cast-in-place walls that would sufficiently allow for a plastic hinge to form in the tunnel walls. Based on the estimated costs, strength, and durability, no other materials were considered.

Two alternatives were considered for the Main Post Tunnels:

1) A cast-in-place concrete structure with the invert slab maintaining a constant top of slab elevation over the transverse tunnel section, with the Doyle Drive profiles and superelevations achieved by constructing a roadway section within the tunnel.
2) A cast-in-place concrete structure with the top of the invert slab matching the Doyle Drive profiles and elevations. The invert slab will be thickened near the walls as required to allow plastic hinging in the walls under lateral seismic loading.

Alternative 1 will have a constant structure height across the transverse section. Structurally, this will produce uniform wall stiffnesses and, consequently, a more uniform distribution of loads throughout the tunnel section. This would be particularly beneficial during seismic loading where the ductility capacity of the structure can be better controlled. Additionally, the uniform wall heights should simplify construction of the invert slab and the tunnel walls. But this alternative requires more excavation and material to construct than Alternative 2. The General Plan estimate for Alternative 1 indicates the cost would be almost $9 million more than the cost of Alternative 2.

Alternative 2 will produce a tunnel structure with variable wall heights which may produce a less desirable structural system than Alternative 1, but would still meet project design criteria for static and seismic loading. The construction would most likely be more difficult than Alternative 1 because of the variable wall heights and also the variable invert slab elevations but the construction cost estimate shows the cost for Alternative 2 is $9 million or 9% less, than the cost for Alternative 1.

Retaining Wall No. 8

Retaining Wall No. 8 (RW8) is located along the southbound Doyle Drive between the southbound Main Post Tunnel and the southbound Battery Tunnel. The wall will support a cut into the existing bluff currently supporting Lincoln Boulevard. At the east end of the wall adjacent to the north-east corner of historic Building 106, near the southbound entrance to the Main Post Tunnel, RW8 will need to accommodate the existing alignment of Lincoln Boulevard, which extends beyond the wall layout line into the proposed Doyle Drive southbound alignment. At this location, the structural system of the wall will need to support a cantilever slab at the top of the wall that extends a maximum distance of 9 feet over the Doyle Drive at-grade roadway. Building 106 is approximately 18 feet from the layout line at its closest point. The Presidio Trust requires that construction of the wall not impact Building 106 and the design of the wall accommodate all loads imposed on the wall by the building. According to the Main Post Parkway landscape unit shown on page 27 of the Doyle Drive Project Architectural Criteria Report (August 2008), the single lane one-way curved segment of Lincoln Boulevard around Building 106 can be programmed for conversion into the multi-use trail system. If the Presidio Trust opts to implement this configuration, it would eliminate the cantilever section of Lincoln Boulevard over RW8.

Two alternatives were considered for Retaining Wall No. 8:

1) Alternative 1 is a retaining wall typically utilizing tangent piles, except at the Main Post Tunnel, where a Type 1 wall is specified to retain embankment fill. Over most of the wall length, tieback anchors are used with the tangent piles where excessive wall heights preclude the use of cantilevered piles. In some locations, the wall heights approach 40 feet. Where Lincoln Boulevard extends beyond the wall layout line, cantilevered tangent piles are specified because the basements for Building 106 and other adjacent building structures do not allow for tieback anchors. At this location, the wall height is approximately 20 feet. For this height, the wall can be satisfactorily designed using a cantilevered tangent pile system. To accommodate the cantilevered slab supporting Lincoln Boulevard, a structural concrete slab utilizing the tangent piles and CIDH tension piles is specified to resist overturning loads due to the cantilever.
2) Alternative 2 uses Caltrans' standard Type 1 walls, supported on CIDH piles, throughout most of the length of the wall. To accommodate the cantilevered slab supporting Lincoln Boulevard, a Type 1 wall is modified to support a similar structural concrete slab and CIDH tension pile system to that used in Alternative 1.

The geotechnical investigation indicates a sandy fill, approximately 35 feet thick, exists on the face of the bluff slope. This fill is loose, and subject to collapse during excavation. The tangent piles specified as part of Alternative 1 would preclude the need to excavate within this loose fill. At Building 106, the use of a cantilevered tangent pile wall system will not require temporary support, or permanent underpinning of the existing building, to achieve the Presidio Trust's requirement that Building 106 not be impacted by the retaining wall construction. The General Plan estimate for Alternative 1 is $11.8 million, which is almost $3 million less than Alternative 2. A negative aspect of Alternative 1 is that the tieback anchors permanently extend beneath the existing Lincoln Boulevard. Right-of-way issues related to these permanent anchors still require resolution with the Presidio Trust, and might preclude the use of this alternative if these issues can not be resolved.

The primary advantage of Alternative 2 is that it does not require resolution of permanent right-of-way issues with the Presidio Trust, although temporary tieback anchors extending beneath Lincoln Boulevard would be required for the temporary shoring. This alternative will require temporary support or underpinning of Building 106. It would also most likely require extensive relocation of utilities around the building to construct support for Building 106. The General Plan estimate for Alternative 2 is $14.8 million, $3 million greater than the estimated cost of Alternative 1.

Battery Tunnels

The Battery Tunnels are proposed to replace the existing at-grade roadway in approximately the same location. The underground structure is comprised of a 760 feet long northbound tunnel and an 860 feet long southbound tunnel. The two tunnels will be constructed separately at different stages in order to maintain normal traffic flow during construction. The southbound tunnel will be constructed first and will serve as part of a temporary detour. The buried depths of the structures vary from 33 feet at the northbound portals to 40 feet at the southbound portals.

These structures are considered as shallow tunnels and will be constructed with conventional cut-and-cover methods. Cast-in-place concrete boxes are proposed at the structure type because of the satisfactory serviceability and structural integrity under service and extreme loading conditions that cast-in-place concrete structures provide.

Two alternatives are considered for the tunnel construction:

1) Separation of temporary shoring and permanent walls: soldier piles with lagging or secant pile walls are used to provide temporary shoring during tunnel excavation. Permanent concrete tunnel walls will be cast against the temporary shoring.
2) Combination of temporary shoring and permanent walls: slurry/diaphragm walls are used as temporary shoring and as part of the permanent structure.

For Alternative 2, the connection between the permanent slurry/diaphragm wall and the base slab of the tunnel is traditionally difficult and expensive to construct, and may not perform well under seismic loading. Also, the General Plan estimate for Alternative 1 is $85.1 million and for Alternative 2 is $93.6 million. Based on the estimated cost for each of the alternatives and the questionable seismic behavior of the slurry/diaphragm wall, Alternative 1 is recommended for the tunnel construction.

The project site will be excavated using the proposed shoring method with bracing members installed at various elevations. Internal bracing is proposed for the southbound tunnel in order to eliminate any encroachment into the property of the adjacent Presidio National Cemetery. The excavation of the northbound tunnel can be either internally or externally braced at the option of contractor.

For simplicity, the same shoring method used for the southbound tunnel is also proposed for Retaining Wall No. 6 which is located in a cut condition at the west portal of the southbound tunnel. Standard Type 1 cantilever retaining walls are proposed for Retaining Walls No. 5 and No. 7 since they will be constructed in fill condition.

The proposed tunnel will be designed in accordance with the project specific design criteria which is based on the AASHTO LRFD Design Specifications (4th Edition, with 2008 Interim Revisions) and applicable California Amendments and additional provisions for buried construction.

II. BRIDGES & STRUCTURES

Bridge Name	Bridge Number	Width	Length	Comments
SB Main Post Tunnel	34-0163L	60'-6", 85'-0" & Varies	1016'-0"	CIP, Cut and Cover Tunnel
NB Main Post Tunnel	34-0163R	49'-6"	909'-0"	CIP, Cut and Cover Tunnel
Retaining Wall No. 8	34-0162	N/A	1219'-0"	Alt. 1 - Tangent Pile With Tiebacks Alt. 2 - Type 1 Wall
SB Battery Tunnel	34-0161L	66'-0" Min. & Varies	860'-0"	CIP, Cut and Cover Tunnel
NB Battery Tunnel	34-0161R	56'-0" Min. & Varies	762'-0"	CIP, Cut and Cover Tunnel

III. GEOLOGY

The Arup/PB Joint Venture prepared Preliminary Foundation Reports for the Main Post Tunnels and the Battery Tunnels. Caltrans prepared Preliminary Foundation Reports for the Retaining Walls including Retaining Wall No. 8. The subsurface profile was developed from the results of the field exploration program including over 30 rotary wash borings and five cone penetration test soundings within the structure limits.

Main Post Tunnels

The Main Post Tunnels are located in an area of reclaimed tidal marsh overlying a deep bedrock basin filled in with sediments. The surficial soil unit is Fill up to 12 feet thick. Because much of the Fill was placed hydraulically, the Fill is primarily comprised of very loose sand with some silt and clay. Below the Fill are the remains of a Tidal Marsh, consisting of Bay Mud/Marsh Deposit, which is typically soft, compressible and often contains plant material. Loose to medium dense Marine Sands are interbedded within the Bay Mud/Marsh Deposit. The Tidal Marsh layer is between 4 and 20 feet thick. Below the Tidal Marsh layer is a dense to very dense sand layer known locally as Colma Sand. The Colma Sand layer is typically 50 to 60 feet thick. The Colma Sand is underlain by between 30 to 140 feet of Old Bay Clay depending on the depth of the basin. The Old Bay Clay is a low to medium plasticity very stiff clay with infrequent dense marine sand lenses. Below the Old Bay Clay is a thin layer of Colluvium over Franciscan Bedrock. At the deepest point encountered, bedrock was found to be 245 feet below the ground surface.

Three groundwater zones exist in the area where the Main Post Tunnels are located. The first groundwater zone is perched and encountered in the Fill above the Bay Mud/Marsh Deposit. Typically the level of this zone is about 3 feet below the ground surface. The second groundwater zone is encountered in the Colma Sand and is under a slight artesian pressure. This groundwater zone water level stabilizes near or just above the ground surface. The third groundwater zone is encountered in the marine sand layers within the Old Bay Clay. This groundwater zone is under very strong artesian pressures with the water level stabilizing as high as 23 feet above the ground surface.

Retaining Wall No. 8

Retaining Wall No. 8 supports a cut into the bluff rising from the west portal of southbound Main Post Tunnel up to east portal of the southbound Battery Tunnel. The surficial soil unit is a medium dense Sandy Fill that ranges from not encountered up to 12 feet thick. A horizontal borehole drilled in the slope indicates that the fill is approximately 35 feet thick, horizontally. To the west end of the wall, the Fill is underlain by about 15 feet of Sandy Silt and Sandy Clay. Below the Sandy Silt and Sandy Clay layer at the west end of the wall and directly below the fill at the east end of the wall is medium dense to dense

Colma Sand. The Colma Sand layer increases from about 20 feet thick at the west end of the wall to over 100 feet thick at the east end. At the west end, the Colma Sand lies over serpentinite bedrock. To the east, the bedrock dips steeply and the Colma Sand overlies Old Bay Clay and Deep Marine Sands to a depth of approximately 150 feet. The depth to bedrock was not determined at the east end of the wall.

Groundwater is expected to be encountered only in the western portion of the proposed wall cut and a perched water table is anticipated above the Sandy Silt and Sandy Clay layer in the rainy season.

Battery Tunnels

The Battery Tunnels are located on a bluff above the reclaimed tidal marsh. The depth and nature of the bedrock changes along the alignment of the Battery Tunnels, ranging from approximately 59 feet of overburden soils on top of serpentinite bedrock at the east end to approximately 12 feet of soil over sandstone bedrock near the west end of the tunnels. The surficial soil unit is a medium dense sandy Fill that is present along the entire alignment of the tunnels. The sandy Fill ranges between 3 and 23 feet thick. Near the east portal, the Fill is underlain by a thin Buried Soil Horizon comprised of silts and sands with organics. At the east end, below the Buried Soil Horizon is a layer of medium stiff Sandy Silts and Sandy Clays ranging up to 12 feet thick. The Sandy Silts and Sandy Clay layer is underlain by up to 32 feet of dense Colma Sand. A second layer of Sandy Silts and Sandy Clay exists below the Colma Sand, which in turn is underlain by Colluvium, Residual Soil, or Franciscan Bedrock (serpentinite). At the west end, the sandy Fill is underlain directly by Residual Soil over a large block of hard sandstone bedrock.

To the west, as the bedrock surface rises in elevation, a seasonal groundwater layer is typically perched on the soil-rock interface. Groundwater elevation measured within the rock stabilizes near the top of the rock surface. At the east end, groundwater was encountered in the Colma Sand between elevations 40 feet and 50 feet. Overall, the groundwater elevation increases from east to west (and north to south) as the top of the bedrock increases in elevation.

IV. SEISMIC EVALUATION

The seismic loading criteria adopted for the evaluation of the Main Post Tunnel, Battery Tunnel, and the Retaining Wall No. 8 structures have been developed for a two-level design philosophy, with ground motions representative of the Safety Evaluation Earthquake (SEE) and Functionality Evaluation Earthquake (FEE). The design acceleration response spectra (ARS) and spectrum-compatible ground motions were developed by a site-specific seismic hazard assessment (SHA) conducted for the project, based on the following definitions of the SEE and FEE provided by Caltrans:

- SEE: envelope of the median (50th percentile) deterministic Maximum Credible Earthquake ARS and a probabilistic hazard ARS based on a 1,000-year mean return period (i.e., 5% probability of exceedance in 50 years).
- FEE: probabilistic hazard ARS based on a mean return period of 108 years (i.e., 50% probability of exceedance in 75 years).

The ARS have been developed based on the Next Generation Attenuation (NGA) seismic hazard model. Three independent sets of spectrum-compatible rock motions for each of the SEE and FEE events have been generated using actual earthquake ground motion records. Each set includes two horizontal components that simulate the Fault-Normal (FN) and Fault-Parallel (FP) motions and the “up-down” vertical component. Directivity and “fling” effects have been included in the FN and FP components. As required by design codes, the envelope of structural response computed using the three independent sets of motions as excitation will be used in the structural analyses.

The set of motions comprise acceleration, velocity, and displacement time histories at rock characterized by a ‘V_{s30}‘ shear wave velocities of 3,000 fps and 5,000 fps. For the evaluation of structural response, these motions have been used in site response analyses of representative soil profiles on the Main Post Tunnel and Battery Tunnel alignments.

The SEE and FEE performance requirements for the structural design of the Doyle Drive Project are based on the Caltrans classification criteria pertinent to Recovery Routes.

V. LIQUEFACTION POTENTIAL

Without mitigation, soil liquefaction is anticipated in some areas below the Main Post Tunnels. The saturated sandy Fill and the loose marine sands are susceptible to liquefaction. Post liquefaction settlements were estimated to range from 0 to 6.5 inches. The Colma Sand and the marine sand layers within the Old Bay Clay have a very low probability of liquefaction triggering.

Soil liquefaction is not anticipated directly below Retaining Wall No. 8 and the southbound roadway in front of the wall as it will be founded in the dense Colma Sand. Loose sandy Fill and Marine Sands are located just north of the northbound roadway in the reclaimed tidal basin; however the wall is embedded deep enough into the slope so that liquefaction is not expected to cause instability of the wall.

Soil liquefaction is not anticipated below the Battery Tunnels. The sandy Fill and Colma Sand are typically not saturated. Where it is below the groundwater table, the Colma Sand has a very low probability of liquefaction triggering.

VI. FOUNDATION TYPES

Main Post Tunnels

The Arup/PB Joint Venture considered the following four foundation types for the Main Post Tunnels:

1) Cast-in-Drilled-Hole (CIDH) piles
2) “Torquedown” piles
3) Mat foundation on improved soils
4) Mat foundation on unimproved soils

The potential use of CIDH piles were eliminated because the presence of high groundwater in soft/loose soils as well as the mild artesian pressures within the Colma Sand indicate that the CIDH will need to be installed using temporary casing along the full depth of the pile and also that a drilling polymer will be required. “Torquedown” piles (a 12¾-inch-diameter closed-end steel pile that is rotated into the ground) were eliminated because a large number of piles may be required to resist lateral seismic pressures. A mat foundation on unimproved soil was eliminated because of the expected large consolidation and liquefaction related deformations. Therefore, a mat foundation with appropriate ground improvement is proposed to support the Main Post Tunnels. Two types of ground improvements for the Main Post Tunnels are being considered:

1) Cement Deep Soil Mixing (CDSM)
2) Impact Piers

Both ground improvement options would extend down to the Colma Sand and serve to reduce the potential for liquefaction triggering, provide a competent bearing layer for the mat foundation, and reduce impacts due to consolidation settlements.

Installing CDSM columns into the Colma Sand is the preferred ground improvement method because it offers better performance with regard to liquefaction resistance and consolidation settlements and because it allows the reuse of the existing timber piles supporting the Marina Viaduct. Once the Marina Viaduct is removed, the groups of timber piles can be encapsulated with Soil-Cement columns where they are below the new tunnel alignments and new CDSM columns can be installed where the timber piles are not present to provide a consistent foundation bearing stiffness. It is anticipated that approximately 35% replacement with the CDSM will be required with the CDSM columns will be placed in a grid pattern. Numerical analyses will be required to determine the most efficient replacement and configuration scheme for the final design. This reuse of materials offers significant savings and retains the high performance of the ground improvement method.

The Impact Piers may be less expensive than CDSM, but given the difficulties of installing them under artesian conditions as well as through soft marsh deposits, they portend to be difficult to construct with high reliability. Impact Piers may not be able to be installed adjacent to the existing Low Viaduct timber piles without damaging them because of the ramming required and CDSM columns may be required around the existing piles. Impact Piers also have the disadvantage of causing noise and vibration while the aggregate is rammed into place.

Retaining Wall No. 8

The Arup/PB Joint Venture considered the following types of foundations for Retaining Wall 8:

1) Soldier Pile and Lagging with tiebacks
2) Soil Nailed Walls
3) Cement Deep Soil Mixing (CDSM)
4) Tangent Pile or Secant Pile

The Solider Pile and Lagging with tiebacks wall was eliminated because of the high cost associated with a large amount of tiebacks being installed and because Right of Way issues must be resolved. The Soil Nailed Wall was eliminated because the sandy fill on the face of the slope was deemed too loose to standup for drilling and installation of the soil nails and because of unresolved Right of Way issues. The CDSM column wall was eliminated because the walls are not typically structurally rigid enough for this application.

A permanent tangent pile or secant pile wall is proposed for Retaining Wall No. 8. The wall has the advantage of being installed prior to excavation and as such will not require any temporary work. Tiebacks may be required for the tangent pile or secant pile wall and will require the resolution of Right of Way issues, specifically whether tiebacks will be allowed under Lincoln Boulevard.

The construction of a Caltrans Type 1 Cantilever Concrete wall was also considered. This is typically a cost efficient design, however because in this situation the wall is being built into an existing slope, temporary support of the open excavation will be required. This temporary support is commonly a soil nail wall. Right of Way issues must be resolved before the temporary support with soil nails becomes a viable option.

Battery Tunnels

The Arup/PB Joint Venture considered the following two foundation types for the Battery Tunnels:

1) Mat foundation on unimproved soils
2) CIDH piles into bedrock where overburden soils exist below the tunnel

CIDH piles were eliminated because it was determined that installing the piers was not necessary and the tunnels could be supported on the native soil and rock. Therefore, a mat foundation is proposed to support the Battery Tunnels on the native soil and rock. The tunnels will be supported on Colma Sand at the east end of the project and on bedrock to the west. The tunnels will be designed to handle changes in the stiffness of the bearing material along the alignment and an aggregate base layer approximately 2 feet thick will be placed below the excavation to cushion varying stiffness between the soil and rock materials and to allow for the flow of groundwater to the face of the bluff.

VII. SEISMIC DESIGN

The seismic design of the Main Post Tunnel, Battery Tunnel, and Retaining Wall No. 8 has been carried out based on the principles of Performance Based Earthquake Engineering (PBEE), with the initiation of tunnel cross-section design guided by displacement (and curvature) ductility estimates required to resist transverse racking displacements. The performance requirements for the FEE and SEE established in the project-specific Design Criteria document (April 2008, Rev 3a) have been used in the design process.

The cross-section racking “capacity” design studies involved generation of parametric sets of moment-curvature analyses pertinent to the tunnel invert slab, walls, and vaulted roof structure. The analyses involved studying the deformation kinematics of several tunnel cross-section types and configurations subjected to racking distortions, to evaluate the strain-based performance measures compatible with the FEE and SEE performance criteria.

The seismic demand on the tunnel structures have been estimated by dynamic soil-structure-interaction (SSI) analyses. The site-response analyses sited in Section IV are used to develop strain-compatible model parameters (shear-wave velocity, compressional-wave velocity, and damping profiles) and free-field motions. For the time being the SSI analyses have been performed for 2D models of typical cross-sections of the Main Post and Battery Tunnels for the SEE loading criteria.

VIII. CONSTRUCTABILITY & TEMPORARY STRUCTURES

Main Post Tunnels

Construction of the Main Post Tunnels will require excavations up to approximately 13 feet deep. Treatment of the soils with a CDSM grid can provide temporary support required for shallow excavations (less than 8 feet). Sumps and pumps will be required to remove the perched water over the tidal marsh deposits. If the aquatard formed by the tidal marsh deposits begins to leak and pressurized water in the Colma Sand is no longer confined, dewatering wells and pumping are anticipated to be required.

After installation of the CDSM grid, the soils can be excavated to the required depth. An approximately 2 feet thick crushed aggregate mat over a geotextile or geogrids should be installed to create a solid working surface.

If Impact Piers are used, temporary soldier pile and lagging walls may be required to support the excavation. Tiebacks may be used as necessary. Dewatering with sumps and pumps should be adequate unless the groundwater from the pressurized Colma Sand leaks into the excavation at which point dewatering wells and pumping are anticipated to be required. Again, an approximately 2 feet thick crushed aggregate mat over a geotextile or geogrids should be installed to create a solid working surface.

Retaining Wall No. 8

Construction of Retaining Wall No. 8 will require the resolution of Right of Way issues, specifically whether tiebacks or soil nails will be allowed under Lincoln Boulevard. Tiebacks cannot be used from southbound Station 65+50 to 68+00 to avoid impacting the basement of Building No. 106. Building No. 106 may require underpinning depending on the chosen alternative.

Construction of a tangent pile or secant pile wall is much simpler in this application. If the Caltrans Type 1 Cantilever Reinforced Concrete Wall is chosen, temporary support of the open excavation (typically soil nail wall) will be required as well as dewatering. Whereas tangent pile or secant pile walls allow for installation prior to excavation of the slope and do not require dewatering. Once installed, the tangent pile or secant pile wall becomes a permanent structure.

Battery Tunnels

Construction of the Battery Tunnels will require excavations up to approximately 40 feet deep. In order to support these excavation depths, retaining walls will need to be constructed. As discussed previously, the preferred options to support the excavation are temporary retaining structures such as soldier pile and lagging or secant pile walls. Lagging will be taken down to the top of the bedrock and then rock bolts will be installed. Secant piles will be taken below the bottom of the excavation, including into the bedrock. Both temporary retaining structures would require internal bracing to limit deflections. Short portions of the excavation may be able to be cut at a 2:1 (H:V) slope and will not require retaining structures.

The contractor may choose between a soldier pile and lagging wall and a secant pile wall, but each wall type has advantages and disadvantages. Soldier pile and lagging walls are typically less expensive to install than secant pile walls. The choice of a soldier pile and lagging wall requires wells be installed to dewater to the top of the bedrock or the bottom of the excavation, whichever is shallower. Dewatering is not necessary for secant pile walls. However, penetrations will need to be opened in the secant pile walls after construction in order to maintain groundwater flow to the face of the bluff.

A third temporary retaining option which may be chosen by the contractor is a soil nail wall. Soil nails may be used to support the excavation along portions of the north side of the northbound tunnel. Soil nail walls are typically inexpensive; however, they cannot be used along the entire north side because the existing historic batteries are located very close to the alignment. Additionally, the transition from a soil nail wall to a different wall type will require special design considerations for the tunnel walls.

Construction of a slurry/diaphragm wall may be used as part of the permanent design. However, the connection between the slurry/diaphragm wall and the footing of the new structure is difficult to construct and may be prone to failure in a seismic event. All construction and shoring methods must remain outside the limits of the adjacent Presidio National Cemetery which is located along the south side of the southbound tunnel.

IX. ADDITIONAL EVALUATIONS

A. Fire Protection

Fire protection is required for tunnel design because of the risk of injury to motorists inside the tunnel. Recent fires in tunnels in California have lead to damage and fatalities.
Therefore, agencies have generated new considerations for tunnel safety that includes fire protection through facility design and providing multiple locations for people to escape.

There are a number of different requirements for providing escape possibilities from inside of a tunnel including smoke extraction, escape signing, fire and smoke resistant safe havens, construction integrity, communications, sprinkler systems and maintaining the integrity of technical installations such as lighting, communications and fire suppression systems. It is the objective of this design to adopt the following strategy for the Main Post and Battery Tunnels:

- Extraction of smoke from the tunnels by natural ventilation. While preliminary evaluations have indicated that forced air ventilation systems are not needed, their use cannot be precluded at this stage of design.
- Signs indicating points of safe haven and egress will be provided.

- Exits to the outside of the tunnel will be provided in the form of exit stairs and/or tunnel cross-passages from the center of the tunnels. Fire resistant sliding doors between the two tunnels (North Bound and South Bound) will be provided to ease access for First Responders.
- Construction integrity will be maintained through the use of either polypropylene fibers embedded in the concrete or through use of an insulating material to protect the concrete from spalling as well as protecting the reinforcing steel from excessive temperatures.
- Technical service systems will be protected by either deep embedment within the concrete or by placement within insulated ducts.
- Sprinkler systems may also be used to substantially reduce the heat, duration and ceiling temperature of fires. Sprinkler systems may also preclude the need for concrete protection from excessive temperatures as described above.

The most common insulating material used in tunnels worldwide is manufactured by PROMAT, a Belgian Company and a member of the ETEX Group. The board material can protect the tunnel concrete from 100 to 300 Megawatt fires while keeping the concrete temperature below 700 degrees Fahrenheit for the duration of the fire. This material is required for many tunnels in Europe, particularly when post fire structural integrity is a concern. However, a sprinkler system would almost certainly eliminate the need for the PROMAT type insulation. Caltrans will be the agency to approve the use sprinklers and other tunnel safety requirements.

B. Groundwater Controls

The inverts of Main Post Tunnels will be constructed from 5 to 13 feet below the existing grade. Groundwater above the invert of the southbound south wall of the Main Post Tunnel will be collected in the subdrain system that can be drained into the storm drain. Incidental water from rainfall and irrigation can be minimized by using a low-permeability soil in the upper two feet of the backfill zone.

The invert of the southbound Battery Tunnel will be constructed from 30 to 40 feet below the existing grade. High groundwater conditions will be encountered at the Battery Tunnels that will require installation of a drainage panel along the southbound south wall to collect water adjacent to the wall. The collected water will be conveyed under the tunnel slabs by a subdrain system and allowed to flow north along the top of the bedrock and into the rock fractures maintaining seepage at the face of the Battery bluff.

C. Waterproofing

Starting from the bottom of the excavation, a thin slab will be placed and finished smooth. A waterproofing membrane will then be applied to the thin slab and a thin protective concrete slab cast on the membrane. Invert reinforcing steel is then placed on the protective cover and the invert concrete can be poured to the grades shown. The membrane will be turned up at the outside edge around the invert slab. A waterstop is then cast into the invert concrete along the center of the outside walls and a hydrophilic waterstop may be used near the outside of the walls.

Tunnel roofing elements are sloped to provide a natural surface for runoff. A waterproofing membrane will be applied and protected with a thin concrete cover over the roof and from the top of roof and rolled down the walls to the top of invert concrete. The membrane will be protected down the walls with rigid wall panels such as board insulation during backfill.

D. Drainage And Sumps

The Doyle Drive drainage system is being designed to capture stormwater runoff before it enters the tunnels by locating drainage inlets outside the tunnel portals. The Battery Tunnels will have inlets intercepting stormwater at its west portal, while the Main Post Tunnels will have inlets at both the west and east portals. This is because of the sag curve/low point within the Main Post Tunnels near the Halleck Street Overcrossing.

Drainage sumps will be required at the low point in the Main Post Tunnels and at the lowest elevation in the Battery Tunnels in order to capture tunnel maintenance washdown water, fire suppression water, and any minor residual stormwater from vehicle spray. It is anticipated that fire protection demand volume flow rate will be in the magnitude of 500 gpm, while the volume flow rate of the washdown water will much smaller. As fire protection and washdown will never occur simultaneously, sumps need only be designed to accommodate fire suppression water. The captured water will be piped to a sump pit located so as to provide access to maintenance personnel and allow for the appropriate sewer connection for disposal. A drainpipe will be provided above the invert concrete along the south wall and will discharge into the stormwater collection system. Appropriate underdrains and/or weepholes will be provided along retaining walls to intercept groundwater seepage.

At the east portal of the Main Post Tunnels, groundwater monitoring indicates a perched groundwater elevation of approximately 8 feet. This water is perched on the marsh deposits and may be tidal influenced. It is anticipated that the perched water can be mitigated using a localized drainage system.

X. PROJECT MILESTONES (BASELINE)

Project EA: 04-163700	Structures P&Q Date	Structures PS&E Date
SAGGB: Doyle Drive	December 2009	April 2010

XI. MAIN POST TUNNEL SOUTHBOUND (BR. NO. 34-0163L)

Structure Type	Cast-in-place concrete, cut-and-cover tunnel. Tunnel supported on concrete invert slab cast on improved ground. Retaining walls at portals. Halleck Street profile accommodated at roof slab.
Length	1016’ along SB Line
Structure Depth	N/A
Abutments	N/A
Bents	N/A
Vertical Clearance	16’-6” minimum in tunnel. N/A at Halleck Street.
Temp Vertical Clearance	N/A
Barriers	Type 60 and Type 60D in tunnel. Type 26 (MOD) at Halleck Street.
Slope Paving	N/A
Approaches	Structure Approach will be Type N (30S)
Drains	Catch basin at low point of alignment. Other drains to be determined later.
Temp Range	43°F to 106° F
Joints	N/A
Utilities	Electrical, lighting, life\safety related utilities, storm drain
Safety Fence	Fence at top of portals.
Future Widening	None

XII. MAIN POST TUNNEL NORTHBOUND (BR. NO. 34-0163R)

Structure Type	Cast-in-place concrete, cut-and-cover tunnel. Tunnel supported on concrete invert slab cast on improved ground. Retaining walls at portals. Halleck Street profile accommodated at roof slab.
Length	909’ along NB Line.
Structure Depth	N/A
Abutments	N/A
Bents	N/A
Vertical Clearance	16’-6” minimum in tunnel. N/A at Halleck Street.
Temp Vertical Clearance	N/A
Barriers	Type 60 and Type 60D in tunnel. Type 26 (MOD) at Halleck Street.
Slope Paving	N/A
Approaches	Structure Approach will be Type N (30S)
Drains	Catch basin at low point of alignment. Other drains to be determined later.
Temp Range	43°F to 106° F
Joints	N/A
Utilities	Electrical, lighting, life\safety related utilities, storm drain
Safety Fence	Fence at top of portals.
Future Widening	None

XIII. RETAINING WALL NO. 8 (BR. NO. 34-0162)

Structure Type	Alternative 1: Tangent pile wall with tieback anchors. Alternative 2: Type 1 wall supported on CIDH piles. Cantilevered concrete slab supporting existing Lincoln Boulevard spanning over SB Doyle Drive for both alt’s.
Length	1219’ along wall layout line.
Structure Depth	2’-0” maximum at cantilever slab.
Abutments	N/A
Bents	N/A
Vertical Clearance	16’-6” minimum at cantilevered slab.
Temp Vertical Clearance	N/A
Barriers	Type 26 (MOD) at Lincoln Boulevard cantilevered slab. Type 60, Type 60D, and Type 60D (MOD) at face of wall.
Slope Paving	N/A
Approaches	N/A
Drains	Wall drainage to be determined later.
Temp Range	43°F to 106° F
Joints	Expansion joints and weakened plane joints as required.
Utilities	To be determined.
Safety Fence	Fence at top of wall. Fence on Type 26 barrier.
Future Widening	N/A

XIV. BATTERY TUNNEL SOUTHBOUND (BR. NO. 34-0161L)

Structure Type	Cast-in-place concrete, cut-and-cover tunnel. Tunnel supported on concrete invert slab cast on existing ground. Retaining walls at portals.
Length	860’ along SB Line.
Structure Depth	N/A
Abutments	N/A
Bents	N/A
Vertical Clearance	16’-6” minimum in tunnel.
Temp Vertical Clearance	N/A
Barriers	Type 60D in tunnel. Type 60 outside tunnel at retaining walls.
Slope Paving	N/A
Approaches	Structure Approach will be Type N (30D)
Drains	To be determined later.
Temp Range	43°F to 106° F
Joints	N/A
Utilities	Electrical, lighting, life\safety related utilities, storm drain
Safety Fence	Fence at top of portals.
Future Widening	None

XV. BATTERY TUNNEL NORTHBOUND (BR. NO. 34-0161R)

Structure Type	Cast-in-place concrete, cut-and-cover tunnel. Tunnel supported on concrete invert slab cast on existing ground.
Length	762’ along NB Line.
Structure Depth	N/A
Abutments	N/A
Bents	N/A
Vertical Clearance	16’-6” minimum in tunnel.
Temp Vertical Clearance	N/A
Barriers	Type 60D in tunnel. Type 60 outside tunnel at retaining walls.
Slope Paving	N/A
Approaches	Structure Approach will be Type N (30D)
Drains	To be determined later.
Temp Range	43°F to 106° F
Joints	N/A
Utilities	Electrical, lighting, life\safety related utilities, storm drain
Safety Fence	Fence at top of portals.
Future Widening	None

XVI. STRUCTURES COSTS

Structure Name	Structure Number	Cost	Area (SF)	Cost / SF
Main Post Tunnels - Alt. 1 Main Post Tunnels - Alt. 2	34-0163L/R	$97,274,000 $88,745,000	122,100 122,100	$797 $727
Retaining Wall No. 8 - Alt. 1 Retaining Wall No. 8 - Alt. 2	34-0162	$11,758,000 $14,807,000	32,000 31,200	$367 $475
Battery Tunnels - Alt. 1 Battery Tunnels - Alt. 2	34-0161L/R	$85,119,000 $93,531,000	100,700 100,700	$845 $929

XVII. RECOMMENDATIONS

Following the Type Selection meeting held at Caltrans headquarters on December 19, 2008, and further review, the following alternatives studied and presented are recommended for selection for final design:

- Main Post Tunnel: Alternative No. 2
- Retaining Wall No. 8: Alternative No. 1
- Battery Tunnel Alternative No. 1

These alternatives happen to be the least costly as well as more streamlined in terms of implementation.