Appendix A – Engineering Methodology, Environmental Engineering, and Permitting

A1 Introduction

A1.1 Methodology

This appendix presents the details of the engineering analyses completed to prepare the Technical Memorandum. Alignment engineering, environmental engineering, tunneling engineering, and geotechnical engineering disciplines provided input to the analysis of landings and corridors. The engineering analyses examined the locations of landings for the five categories of rail geometry, geotechnical conditions, environmental risks, constructability risks, and construction impacts. That table was presented in the main text. Then, the analyses focused on selected horizontal and vertical alignments within the corridors to examine potential fatal flaws with a San Francisco Bay (Bay) crossing.

This appendix presents the regional setting for the study, then our compilation and commentary on geotechnical data and the regulatory environment. It then presents details associated with the two considered tunnel technologies, immersed tube tunnel (ITT) and mined tunnel.

A1.2 Study Area

Since the scope of the initial engineering studies is only related to a new transbay tunnel, stakeholder agencies were limited to Bay Area Rapid Transit (BART) and regional and state rail providers.

The study area considered in this memo is limited to crossings of the Bay and approximately one block inland on each side of the Bay. The vicinity of the study area is shown on Figure A1. In San Francisco, landing sites from Fisherman's Wharf to Pier 70 were considered. In the East Bay, landing sites from Emeryville to Alameda Island were considered. The onshore alignment component of each landing was checked for its viability considering existing development and planned transit lines, but the development of onshore alignments is beyond the scope of this task.

As presented in the main text of this memorandum, landings SF-1 through SF-11 were defined for San Francisco. In the East Bay, landings EMY-1, OAK-1 through OAK-3, and ALA-A through ALA-C were defined. North, central, and south corridors were defined to group the potential landings. Alignments BART 1 through BART 4, Rail 1, and BART & Rail Combined were defined connecting the most promising landings. The engineering used to select the promising landings and examine the alignments is described in this Appendix.

Figure A1. Study area comprises the shorelines of San Francisco and Oakland/Alameda and points between.

A2 Environmental and Engineering Overview

A2.1 Rail Geometry Constraints on Landings

Rail and BART alignments have been considered. Horizontal and vertical alignment geometries are introduced in the main text of this memorandum. The cross sections showing the vertical alignments are included at the end of this appendix.

A2.1.1 Rail

It is assumed that any new rail connection across the Bay must tie into the Transbay Transit Center (TTC) and/or 4th and King Streets. A transbay connection that ties in south of the Downtown Extension (DTX) would have major limitations on service and operational scenarios. This assumption constrains a rail crossing landing to north of Mission Creek and south of the TTC.

A2.1.2 BART

BART is generally considered to land in San Francisco and run predominantly East-West along roadway corridors, although many landings could also accommodate North-South oriented alignments as noted.

BART running north-south through downtown San Francisco allows a possible connection on the waterfront near Pier 23; however, this location would only practically serve a connection on the East Bay in Emeryville or Berkeley. A north-south alternative can serve 3rd Street via Landing SF-6, but this corridor is heavily constrained by the Mission Rock development to the south, historic 3rd Street Bridge, and AT&T Park piles to the east.

A2.2 Environmental Setting

The following sections identify select agencies through which permits will likely be necessary. Engagement early on in the project planning can reduce the risk of permitting delays. This section introduces some of the requirements and risks associated with the major permitting process that would be required for a crossing. Details associated with permitting of the ITT option or the mined tunnel option are discussed in those respective sections. Our discussion of the permitting details assumes that a full environmental impact study and report will be procured for the potential alignments as design advances.

The Dredged Material Management Office (DMMO) would have the most involvement in an ITT option. The ITT would require permitting through the DMMO, which is a joint program of several stakeholder agencies. The DMMO requirements, concerns with large-scale dredging operations in the Bay, and sediment quality (hazardous materials) are discussed in the ITT section of this appendix. Onshore in San Francisco, the Maher Ordinance would likely be a consideration for any excavation for tunnel boring machine retrieval pit or transition structure. Maher zones are shown in Figure A2 below indicating the widespread coverage of fill in eastern San Francisco. While excavations in these areas is commonplace, they typically encounter materials that require disposal and handling as potentially hazardous material.

Although not a part of the DMMO, other stakeholders would likely include the Cities of San Francisco, Oakland, and Alameda. These stakeholders would likely have other permit requirements such as grading permits, building permits, etc., all of which would have associated fees.

A2.2.1 Maher Zone Requirements for San Francisco Landings

In 1986, the San Francisco Board of Supervisors adopted an ordinance to address concerns associated with the exposure of workers and the general public to hazardous materials after contaminated soil was discovered during several construction projects in San Francisco. These projects were mainly located in areas that were previously coves or shoreline that had been filled to create new land or used for disposal of earthquake debris after the 1906 Earthquake. Former Supervisor Bill Maher took the lead on preparing a bill to address the issue and thus, the Maher Ordinance (formally Article 20 of the San Francisco Public Works Code and now, Article 22A of the San Francisco Health Code) came to existence.

The ordinance was developed to assess the potential for the presence of hazardous levels of contaminants in the fill material beneath a proposed development and if concentrations of these contaminants presented a potential risk to workers or the general public. Additionally, testing required under the ordinance addresses the issue of material quality relative to California Code of Regulations, Title 22 waste disposal requirements, as elevated concentrations of metals and other organic compounds often require material for disposal be classified as hazardous waste under Title 22.

Properties with potential subsurface chemical contamination that require a grading or building permit are likely to be regulated under Article 22A of the San Francisco Health Code and Article 106A.3.4.2 of the San Francisco Building Code. The Maher Ordinance requires soil and groundwater analysis for a specified list of organic and inorganic chemical constituents and covers areas with: 1) Current or historical industrial use or zoning: 2) Areas within 100 feet of current or historical underground tanks: 3) Filled former Bay, marsh, or creek areas and: 4) Areas within 150 feet of a current or former elevated highway. Sites and areas covered per the Maher Ordinance are shown on Figure A2as shaded areas.

San Francisco Public Health (SFPH) implements the Maher Program jointly with San Francisco Planning (SFP) and the San Francisco Building Inspection (SFBI). Efforts are made to maintain communication among the San Francisco agencies. SFP and/or SFBI perform an initial environmental review or permit review of projects submitted to that department. If applicable, SFP or SFBI requires a project proponent to contact SFPH and enter in the Maher Ordinance Program. SFPH copies SFBI and the SFP on review letters. A project proponent may also apply to the Maher Program directly by submitting the Maher Program application and fee to the SFPH.

Properties with known or potential chemical contamination outside the current Maher area may be administratively added to Maher or SFPH may oversee the project per the San Francisco Voluntary Remedial Action Program.

The San Francisco Voluntary Remedial Action Program is authorized per State authority in the California Health and Safety Code Sections 101480-101490. Health and Safety Code Sections 101480 through 101483 establish a cleanup oversight program which allows a local health agency to supervise the remedial action taken at a site, set up cleanup goals at a site, and issue a letter or other document that certifies that the cleanup goals have been met.

All of the potential landings on the San Francisco side of the study will be subject to governance under Article 22A.

Implementing the Maher Ordinance can be expensive as the required analyses prescribed in the Article are numerous and expensive. Additionally, the results of the Article 22A study may reveal high material disposal costs based on the degree of material impact from contaminants and the potential for the classification of the material as hazardous waste under state or federal law for disposal purposes.

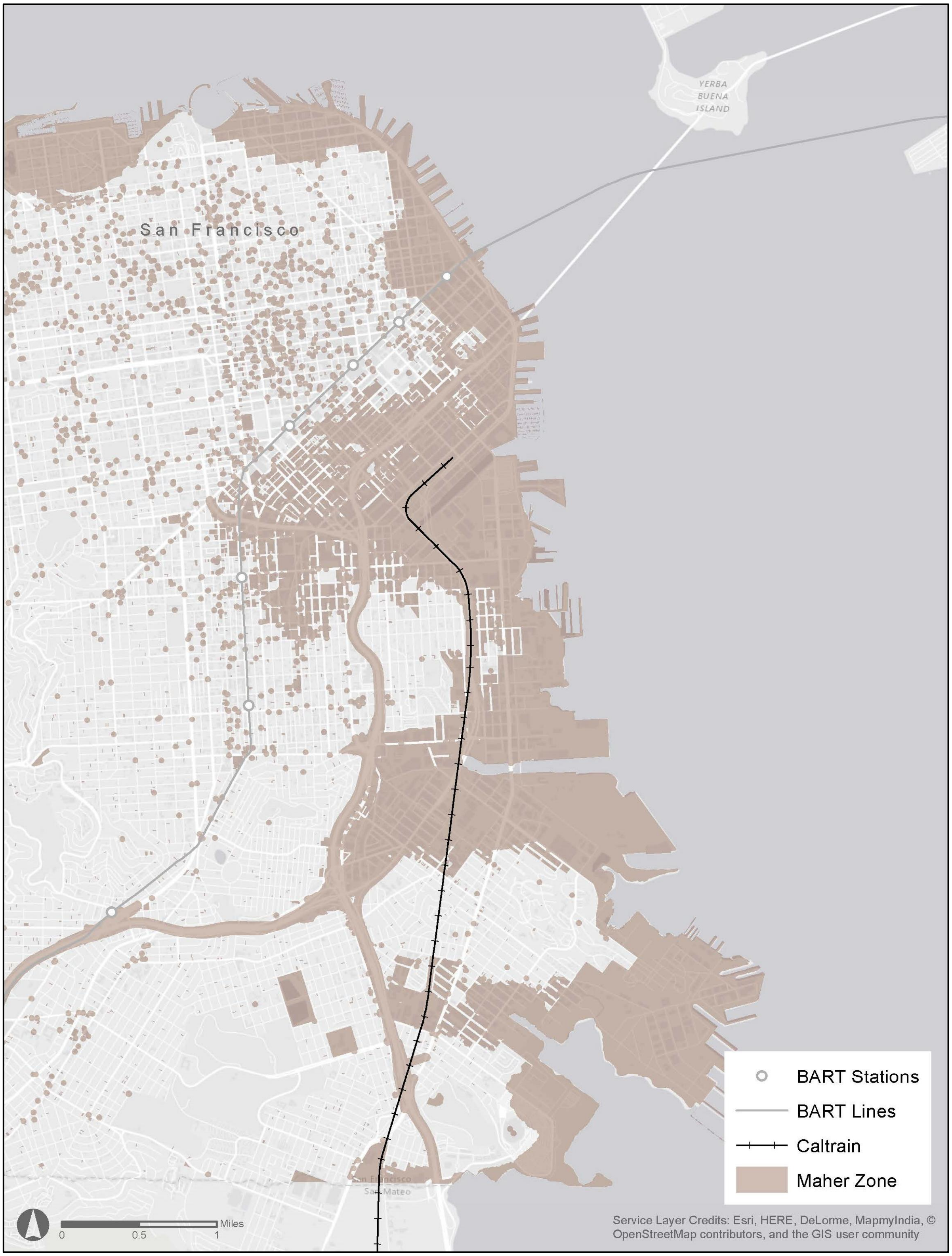

Figure A2. Maher zones in San Francisco – areas where fill soils contain potentially contaminated materials.

A2.3 Geotechnical and Geological Setting

The history of infrastructure in the Bay Area is closely tied to the challenging geotechnical conditions. Compressible clays, reclaimed land constructed without compaction, and regular seismic activity mean that a wealth of geotechnical studies are available for San Francisco and Alameda counties. For this study, we have avoided detailed evaluation of ground conditions and instead employed some key references that provide approximate conditions of the stratigraphy of the Bay and the near-shore margins. The information included in the following documents was used to develop the geotechnical and geological discussions in this memorandum:

- Harding Lawson Associates (HLA) and others' Liquefaction Study: North Beach, Embarcadero Waterfront, South Beach, and Upper Mission Creek Area, San Francisco, California (1992)
- Hitchcock and Helley's Characterization of Subsurface Sediments, Southern San Francisco Bay Area (2003)
- documents prepared for Caltrans by Earth Mechanics, Inc. and Fugro for the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project
- documents prepared for the original transbay tube by Parsons, Brinkerhoff, Quade, and Douglas (1965)
- Bruce E. Ross's *Pleistocene History of San Francisco Bay along the Southern Crossing* (1977)
- regional geology maps prepared for the USGS

Note that this list is not exhaustive. Many additional geotechnical documents were reviewed in the course of compiling this study and are included as references at the end of this memorandum.

The Bay Area is prone to earthquake shaking from several active tectonic faults (San Andreas, Hayward-Rodgers Creek, and others); however, as defined by the Alquist-Priolo maps, none of these directly cross the study area, defined as the area between the potential landing points of the corridors on each side of the Bay. The potential for severe ground shaking is of concern and contributes to the qualitative evaluation of potential corridors and landing areas. Seismic slope instability of dredged or natural slopes, lateral spreading of reclaimed land, and liquefaction have the largest potential to affect the study area. Site-specific studies of these phenomena are beyond the scope of this study, but the slopes and strata of concern are illustrated in Figure A3 below from the 1965 geotechnical study for the existing transbay tube.

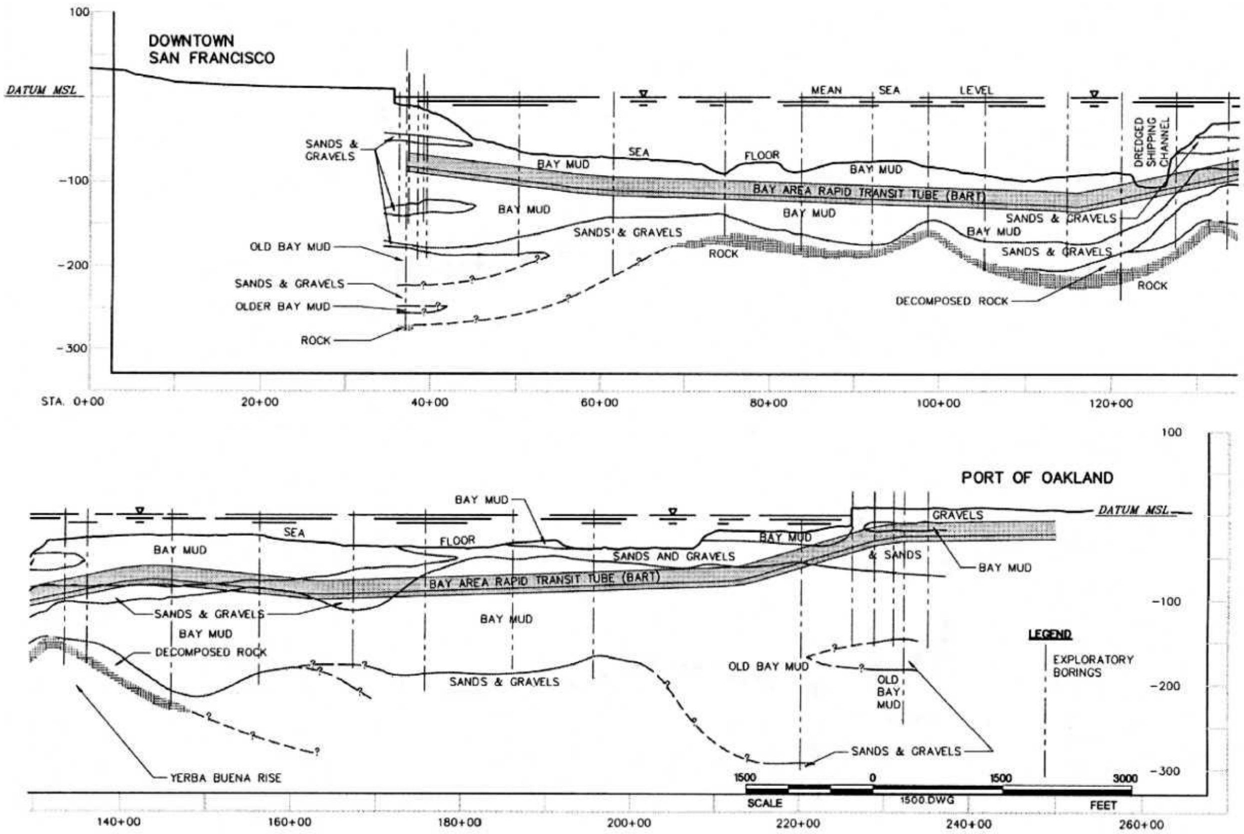

Figure A3. Interpreted Geotechnical Cross Sections of the Existing Transbay Tube Alignment across San Francisco Bay (from Parsons Brinkerhoff Quade and Douglas 1965).

Existing geotechnical infrastructure should also be noted for its information relevant to proposed corridors and landings. According to the report by HLA, the San Francisco Seawall (Seawall) was built between 1874 and 1924. It extends 2-1/3 miles from Fisherman's Wharf to Pier 50 and facilitated the infilling of eastern San Francisco. The Seawall generally comprises a rock-fill embankment constructed in a 45-foot-deep dredged channel, through which piles were driven to support a concrete quay wall. A sketch of Section 9a and 9b of the Seawall, constructed along the Embarcadero approximately between Howard Street and Main Street has been provided from HLA's report as Figure A4. It indicates the piles are tipped at 71 feet below mean sea level. These may be of concern to alignment options that will pass under or through the Seawall.

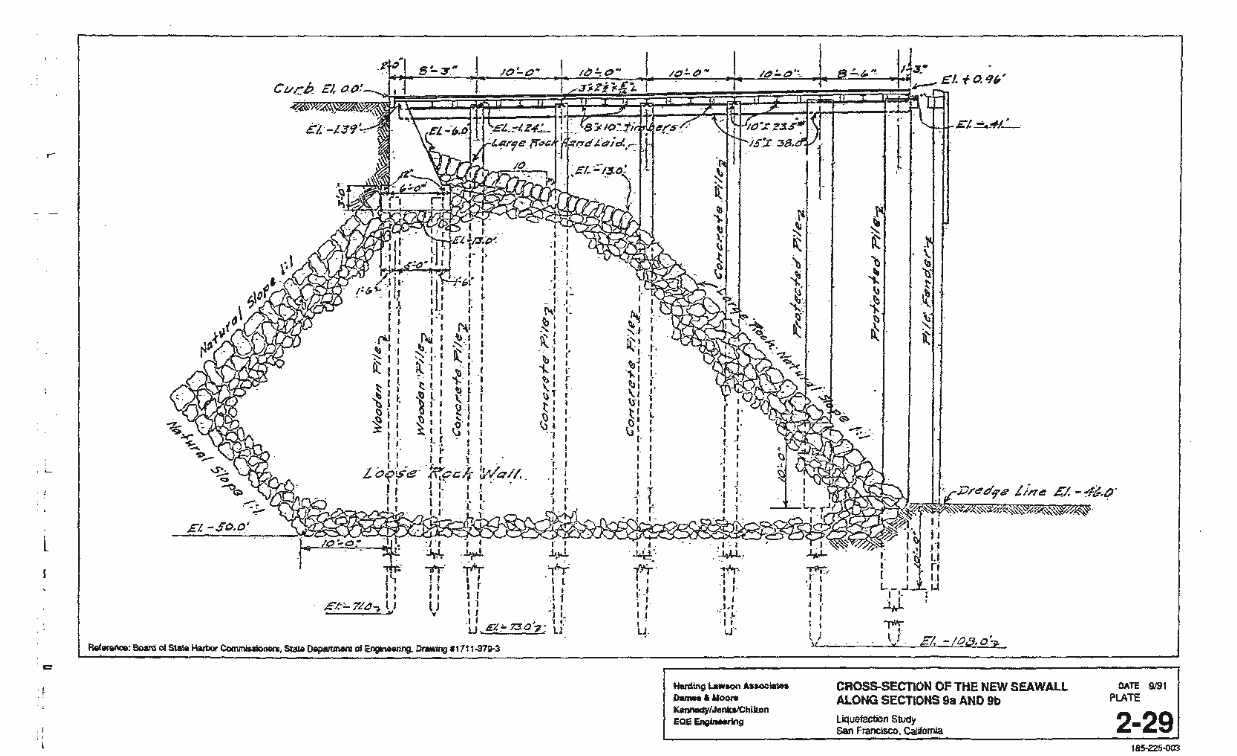

Figure A4. Cross Sections of the New Seawalls along Sections 9a and 9b showing Seawall piles extending to -71 feet (from HLA's 1992 Liquefaction Assessment Report).

A3 Mined Tunnel

A3.1 Characteristics of Design and Construction

Construction of a mined tunnel crossing the Bay will require a launch shaft into which the TBM will be lowered. In areas of high ground water and permeable soils, as are expected at the East Bay launch sites, shafts are typically constructed with an impermeable support system such as secant piles or slurry walls to create a structural shell. After the sub base of the structure is jet grouted to create structural support and an impermeable barrier, the interior of the structure is then excavated and a temporary slab placed. The TBM is launched at a depth that allows the cutter head chamber to be pressurized and creates a smooth transition for tunnel mining.

A similar receiving shaft will be built on the San Francisco side of the tunnel. These shafts are often retained to serve as ventilation housing or exiting facilities for the permanent operation of the system.

The preferred approach for mining long tunnels such as the Bay crossing is expected to comprise a single large bore tunnel containing two track ways separated by a partition wall. The single large bore has significant advantages over a twin bore system, including the use of two TBMs, the construction of cross passages between the bores, and other logistics such as manning the project with a higher amount of specialized labor.

Current fire codes require that no more than one train should be in a single ventilation zone. For a Bay crossing, with tight headways between trains, this will likely require ventilation plenums which can deliver ventilation at points along the tunnel length. The additional area above the train ways can be used as a plenum in a single large bore tunnel while the smaller dual tunnels would need to be enlarged to provide room for plenums. For BART, the expected outside diameter of a double track, single-bored tunnel is approximately 36 feet. For rail, the outside diameter is expected to be approximately 40 feet.

In contrast, the smaller, dual-bored tunnels are likely to be preferred through urban areas at each end of the crossing because they provide the correct track spread for center platform stations and smaller tunnels can be mined at shallower depths and in closer proximity to existing infrastructure.

The launch and receiving shafts have been extended for the purpose of creating the transition between the Bay crossing tunnel and the system extensions at each end. It is assumed that the tunneling configuration will transition from a large single-bored tunnel under the Bay to smaller dual-bored tunnels through urban areas at each end of the crossing although this work is not in the scope of the estimated costs.

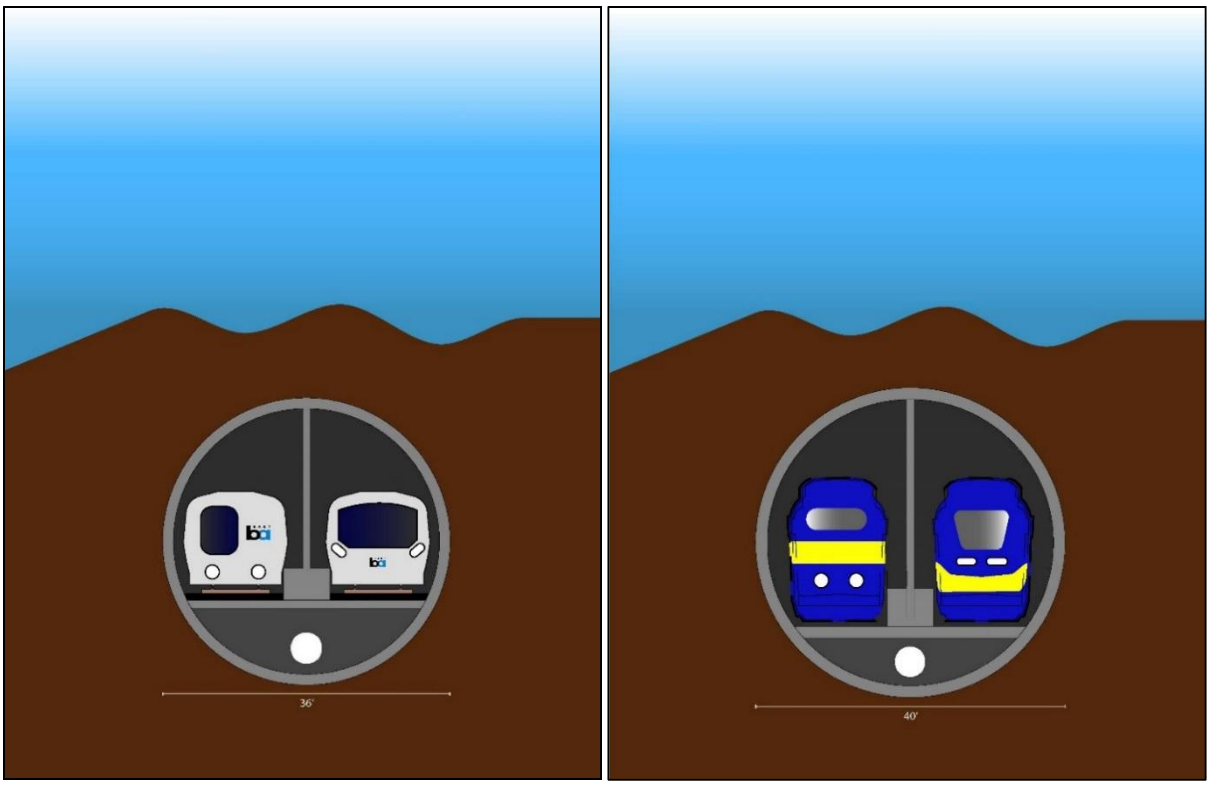

Figure A5. Schematic sections of BART and rail mined tunnel configurations.

A3.2 Geotechnical Considerations

For the alignments being considered, the uppermost soil layer is Young Bay Mud (YBM) ranging in depth from 20 to 120 feet. YBM is a normally consolidated, organic rich, marine clay. The YBM exhibits a high water content and very low strengths and is therefore prone to squeezing behavior around a tunnel excavation. This squeezing makes balancing the pressures at the cutter head more difficult and can also lead to reduced steering control of the TBM. The squeezing ground can also increase friction on the TBM shield making it more difficult to advance the machine. This effect can be mitigated by sizing the cutter head to increase the interstitial space around the shield and by injecting lubricants around the perimeter of the machine. This material is not ideal for tunneling because the pressures it exerts on the cutter head are highly variable. The vertical alignments have been set with a minimum cover of approximately two tunnel diameters to avoid it to the extent possible.

Very generally, underlying the YBM is Old Bay Clay (OBC), associated with older marine and alluvial deposition. This layer is over-consolidated with significantly higher undrained shear strengths than the YBM. The stratigraphy underlying the YBM toward the east side of the Bay transitions from marine deposited clays to alluvial sands and clays that are typically dense and stiff. In most near-shore areas, fill soils have been placed to reclaim areas or raise grades above the shoreline mud flats. Fill soils generally are considered potentially liquefiable, are potentially contaminated from previous site uses, and are of varying consistency. The YBM underlies the fill in many areas. The older alluvial deposits and OBC are conducive to tunnel mining because the material is relatively homogeneous, firm, and exhibits low to moderate abrasion which is important for long tunnels where maintenance of the wearing surface can be difficult. The schematic alignments shown in the attachments indicate tunnels constructed in the OBC layer or generally soil below the YBM.

A3.3 Environmental Risks and Permitting

The launch and retrieval pits would require construction permits on-land, but typical operations will not require engagement of permitting through the DMMO. The mining spoils would require offhaul and disposal, though the volume of excavated material is smaller for a mined tunnel than an immersed tube. A maintenance and emergency rescue plan would be required should a tunnel boring machine require extraordinary maintenance or repair while beneath the Bay. That plan would likely be coordinated with the DMMO and other stakeholders.

A3.4 Constructability

Site access and nearby laydown areas are important to an efficient mining effort. The East Bay launch locations appear to provide adequate area for construction operations. Alameda Island is not ideal for off haul and tunnel liner segment delivery by road since trucks would have to pass through residential areas and cross a bridge or tunnel for highway access. Barge access may be preferable for moving materials and nearby sites appear to have the potential to serve as loading docks for this project.

Risks for construction and likely mitigations include the following:

- high water inflow rates for the permeable sands at the East Bay launch sites
  - jet grouting of the granular material to reduce permeability
- cutter head wear during mining requiring maintenance access to the cutter head chamber
  - select pre-determined locations favorable to maintenance
- unanticipated ground conditions under the Bay
  - perform extensive geotechnical investigations for the alignment
- man-made obstacles such as piles and sunken ships near the San Francisco landing area
  - coffer dams near the San Francisco shoreline could be used to access and clear obstructions

A4 Immersed Tube Tunnel

A4.1 Characteristics of Design and Construction

This study considered ITTs carrying the following:

- two BART tracks
- two heavy rail tracks
- two BART plus two rail tracks for a total of four tracks

In each case, the same construction process would be followed.

A trench would be dredged in the Bay floor to receive the tunnel. This would be approximately 35 feet deep with side slopes of 1:1.5 – 1:3 (vertical:horizontal) depending on local conditions. The Bay floor is composed of soft mud, so the dredging process would not require excavation of rock. Dredged material would be loaded onto barges for disposal offsite. A bedding layer 3 to 5 feet deep would be applied to the bottom of the trench to support the tunnel segments.

Concurrently with the dredging operation, tunnel segments would be constructed in a casting/fabrication yard. For the purpose of this study, it has been assumed that concrete would be used for the tunnel segments, but steel would also be considered. Joints between segments would have to be designed to ensure any predicted movement could be accommodated. After casting watertight bulkheads are installed at both ends of each segment. Once the segments are ready for floating, the casting yard is flooded and the segments floated. The yard should be located close to the shore, preferably close to deep water.

The segments would then be floated into position assisted by barges. The buoyancy would be adjusted by ballast and the segments be lowered into position within the dredged trench and placed against the previous segment. The segments are pulled together with the aid of jacks and the water pressure acting on the free end helps to push the segment together resulting in a watertight seal. The water trapped between the bulkheads is then pumped out.

Engineering fill would be placed to the sides of the tunnel to provide lateral support and lock the tunnel in place. Finally backfill material would be placed over the tunnel to protect the tunnel and to prevent uplift.

A4.2 Tunnel Layout

Separate tubes would be provided for each track with dimensions to accommodate the operating requirements of each operator’s rolling stock. BART tubes would be sized in accordance with BART Facilities Standards and rail tubes in accordance with the DTX design criteria.

A longitudinal ventilation system would likely be most efficient in dealing with smoke from large fires; however, this would limit the number of trains within each ventilation zone, potentially impacting headways and operational efficiency. A point extract system with motorized dampers in the tunnels would allow the two dampers flanking the incident to be opened to contain smoke between the open dampers.

A utility corridor could be provided within the envelope of the tunnel allowing any ancillary equipment or utilities to be carried in addition to the running tubes.

A4.2.1 Two track

A two-track tunnel would have an external dimension of approximately 48 feet wide with separate tubes for each track. A utility and tunnel ventilation plenum would be provided between the running tubes. Doors would be provided at regular intervals to allow egress of passengers from one tunnel to the other in case of emergency evacuation.

For BART the height from top of rail to tunnel roof would be 13 feet. A width of 16.5 feet for each box would be provided which includes an allowance for a walkway on the inside of the tracks adjacent to the dividing wall. External dimensions of the tube would be approximately 40 feet wide by 23 feet tall.

For rail tracks the height from top of rail to tunnel roof would be 21 feet. A width of 17.5 feet for each box would be provided which includes an allowance for a walkway on the inside of the tracks adjacent to the dividing wall. External dimensions of the tube would be approximately 40 feet wide by 31 feet tall.

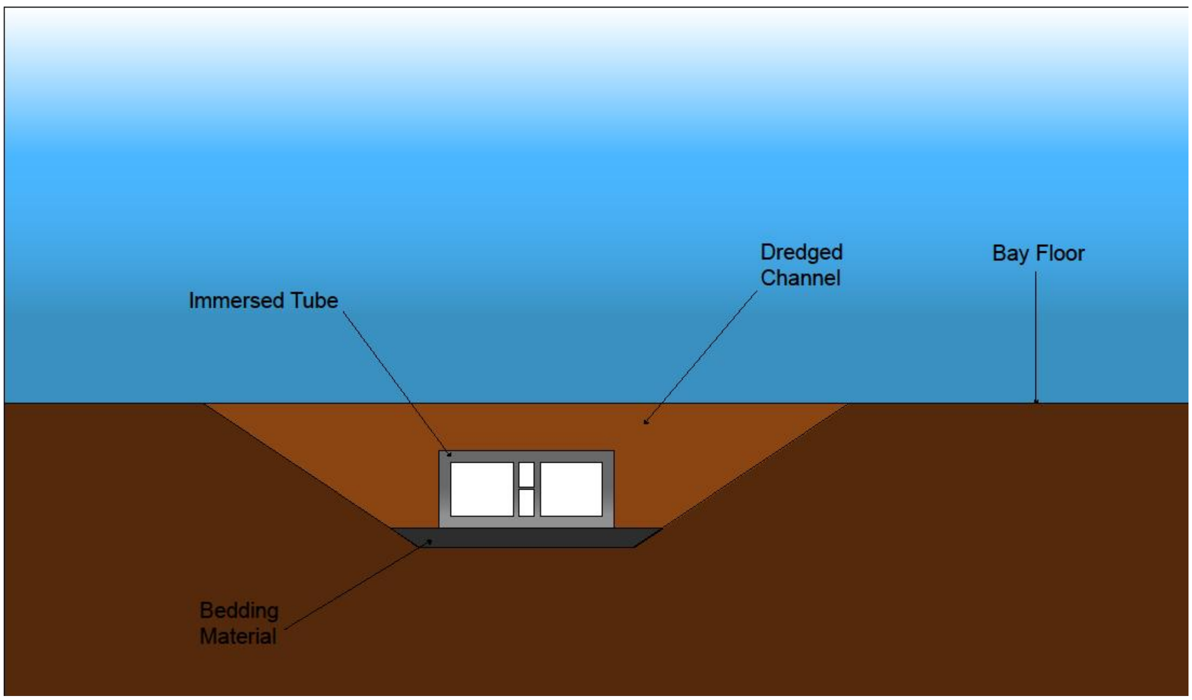

Figure A6. Two-track immersed tube construction schematic.

A4.2.2 Four track

A four-track tunnel would have an external dimension of approximately 57 feet wide with separate tubes for each track. A utility and tunnel ventilation plenum would be provided between the rail running tubes and above the BART running tubes. Doors would be provided at regular intervals to allow egress of passengers from one tunnel to the other in case of emergency evacuation.

For BART the height from top of rail to tunnel roof would be 13 feet and for rail the height would be 21.5 feet. Widths equivalent to the tunnels described above would be provided. External dimensions of the tube would be 80 feet wide by 31 feet tall.

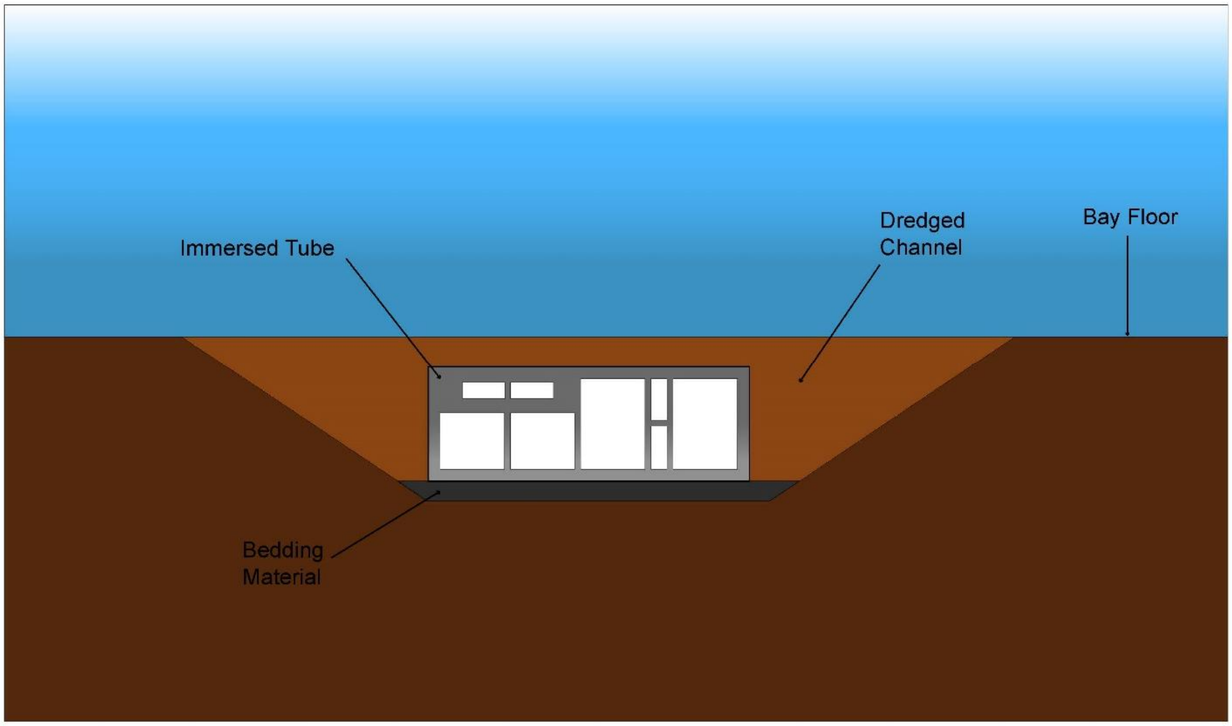

Figure A7. Four-track immersed tube construction schematic.

A4.3 Geotechnical Considerations

As discussed for the mined tunnel options, generally the Bay soil stratigraphy includes YBM overlying OBC or alluvial sands. The topography of the Bay floor generally slopes toward San Francisco to depths on the order of 75 feet below the water surface. The YBM thickness can vary from 0 to 20 feet thick near Alameda to over 120 feet thick near San Francisco. As a result, any immersed tube would be dredged in YBM and in some areas, into its underlying strata. As shown in Figure A8 below, the YBM near the Alameda Naval Air Station (NAS) is on the order of 20 feet thick, meaning the trench dredging for the immersed tube would extend into the underlying, relatively dense, Merritt Sands deposit.

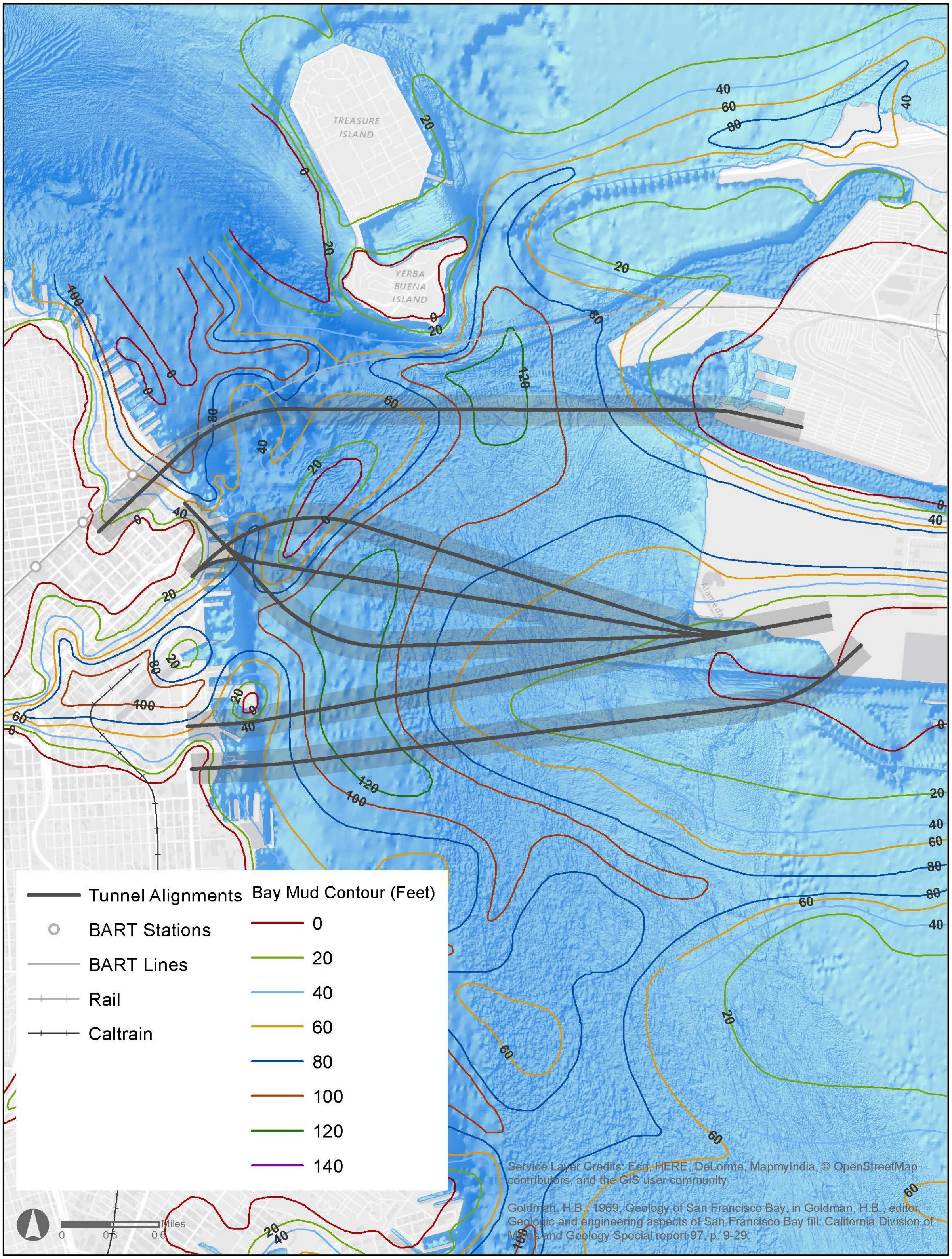

Figure A8. Potential tunnel or tube alignments in San Francisco Bay shown with bathymetry and approximate YBM thickness contours.

The natural grades of the near-shore Bay are sufficient to develop a seismically-induced lateral spreading condition where thicknesses of fill material have been placed to reclaim land. This includes areas of Alameda and Mission Bay in San Francisco. Much of this fill was placed hydraulically or otherwise with little compactive effort and could be graded zonally, resulting in pockets of liquefaction and differential strains. The resulting instability could affect transition structures and immersed tubes, and require ground improvement mitigation. Generally, the mined tunnel option would be less susceptible to damage associated with lateral spreading or shallow slope instability.

In some areas of the Bay, the YBM has been dredged to form steep slopes, such as for shipping channels or existing ports and wharf facilities. These facilities and the existing BART Transbay Tube have been evaluated by others for performance during seismic conditions, but a new cut or modification of the TBM topography should consider these existing facilities.

The YBM would also not provide stable bearing conditions for transition structures. Each landing area was examined for its nearby thickness of YBM for an evaluation of soil conditions for support of a transition structure. The presence of deep YBM does not preclude transition structure construction at a location, but ground improvement would likely be necessary for adequate bearing or uplift restraint. Figure A9 shows a schematic of a circular immersed tube section relative to the YBM stratigraphy.

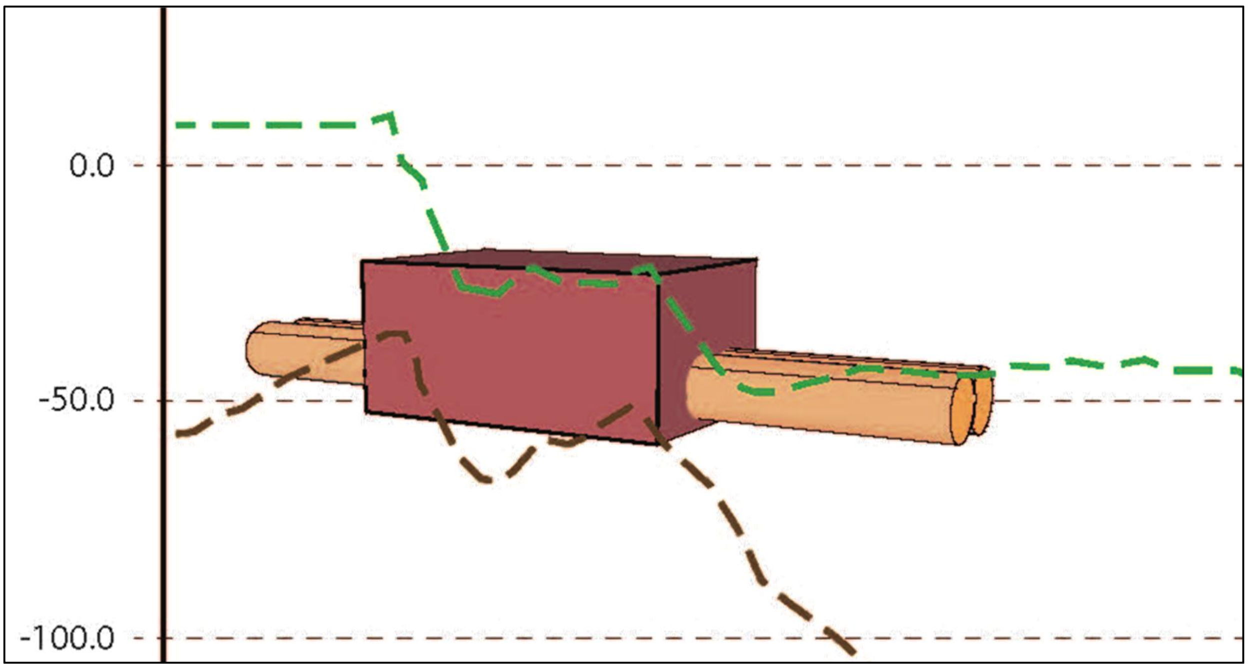

Figure A9. Surface stratigraphy (green), bottom of YBM (brown) shown with a schematic of an immersed tube (right) and transition structure. Where the structure is founded on YBM, ground improvement would likely be required. Cross section was cut approximately along the BART3 Alignment shown previous figures. Figure is not to scale.

Consideration of the potential for lateral spreading, thickness of YBM, and nearby steep subsea slopes was given to develop the ground conditions evaluation for each landing site. Those with significant thickness of YBM were indicated to be poorer ground conditions than those with shallower YBM. Nearly every potential landing site (except right at Mission Rock) has some risk of liquefaction or lateral spreading, so for preliminary evaluation that was not a large influence on ground conditions evaluation.

A4.4 Environmental Risks and Permitting

The environmental risks and permitting associated with large-scale dredging in the Bay would require significant investment of time procuring the permits (on the order of 2 years). Environmental risks include the potential for encountering contaminated soils, or unexpected stratigraphy. These risks would be managed by extensive subsurface investigation prior to completion of design, but are not well constrained at this early stage.

Disposal of the dredged material is a significant cost. The YBM cannot be easily reused as fill for other projects, and would require drying before offhaul to a landfill. Ongoing conventional dredging operations for Bay Area port facilities disposes of the dredged material in smaller, more manageable volumes. For a large-scale operation such as the immersed tube construction, dredged materials will likely require offhaul to a deep ocean disposal site approximately 55 miles offshore, which increases costs.

A4.4.1 DMMO Stakeholder Requirements

The Dredged Material Management Office (DMMO) was founded through the Long Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region program, the DMMO is a joint program comprising the following member agencies:

- U.S. Army Corps of Engineers, San Francisco District (USACE);
- The U.S. Environmental Protection Agency, Region IX (US EPA);
- The California Environmental Protection Agency (Cal EPA) San Francisco Bay Regional Water Quality Control Board (RWQCB);
- The San Francisco Bay Conservation and Development Commission (BCDC); and
- The California State Lands Commission (SLC).

Although not member agencies, the California Department of Fish and Wildlife (CDFW) (formerly California Department of Fish and Game, U.S. Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS) participate in the DMMO and the Project Coordination Meetings as commenting resources agencies.

The permitting process for a project of this magnitude to be constructed in the San Francisco Bay would likely take a minimum of two years to complete and possibly longer. The process would require the applicant to prepare a single permit application for submission through the DMMO. The DMMO would then schedule an inter-agency meeting that would likely include the following agencies:

- USACE
- BCDC
- RWQCB
- US EPA
- CDFW
- USFWS
- NMFS
- United States Coast Guard (USCG)
- San Francisco Bar Pilots

Individual agency permits would be issued by RWQCB (Water Quality Certification), BCDC (Major Permit), and CDFW (Streambed Alteration Permit). Given the magnitude of the project it is anticipated that a full Environmental Impact Statement document would be required to support project approval and the permitting process. This would include all of the special studies required to support permitting and consultation through the DMMO. This is anticipated to be a costly process and will likely require a minimum of two years to complete.

Construction Mitigation Monitoring

As a condition of permit there would likely be several construction mitigation measures that would have to be followed for both dredging and construction. These would likely include measures to mitigate the mobilization of suspended sediments away from the working areas (construction of silt fences) and water quality monitoring which may include total suspended solids, turbidity, etc. If mitigation monitoring indicates mitigation measures are ineffective at mitigating potential impacts, construction may have to cease and mitigation measures may have to be revised. This could have cost and schedule implications for the project.

Eel Grass

Eelgrass is an important part of the San Francisco Bay aquatic system as a habitat for commercially important and endangered fish as well as other aquatic fauna. Eelgrass provides water cleansing through filtration action and helps stabilize sediment in the San Francisco Bay through root action.

Dredging as well as other near-shore development activities have affected the eelgrass habitats and as such, these habitat areas have been identified as areas of concern for impact. In 2014, the National Oceanic and Atmospheric Administration and the National Marine Fisheries Service developed the California Eelgrass Mitigation Policy and Implementing Guidelines that provide guidance for impact minimization which may include mitigation measures such as limiting turbidity, light reduction, and sediment loading as well as seeding or transplanting in the case of unavoidable impacts or takes. As a condition of permit, regulatory agencies will typically require pre- and post-project surveys to identify the presence of eelgrass at or in the vicinity of a project area in order to mitigate potential impacts to the eelgrass ecosystem.

A4.4.2 Endangered Species Act - Section 7 Consultation

The Endangered Species Act (ESA) directs all federal agencies to work to conserve endangered and threatened species and to use their authorities to further the purposes of the Act. Section 7 of the Act, called "Interagency Cooperation," is the mechanism by which federal agencies ensure the actions they take, including those they fund or authorize, do not jeopardize the existence of any listed species.

Under Section 7, federal agencies must consult with the U.S. Fish and Wildlife Service (USFWS) when any action the agency carries out, funds, or authorizes (such as through a permit) may affect a listed endangered or threatened species. This process usually begins as an informal consultation. A federal agency, in the early stages of project planning, approaches the USFWS and requests informal consultation. Discussions between the two agencies may include what types of listed species may occur in the proposed action area and what effect the proposed action may have on those species.

If after discussions with the USFWS the agency determines that the proposed action is not likely to affect any listed species in the project area and if the USFWS concurs, the informal consultation is complete and the proposed project moves ahead. If it appears that the agency’s action may affect a listed species, that agency may then prepare a biological assessment to assist in its determination of the project’s effect on a species.

When a federal agency determines, through a biological assessment or other review, that its action is likely to adversely affect a listed species, the agency submits to the USFWS a request for formal consultation. During formal consultation, the USFWS and the agency share information about the proposed project and the species likely to be affected. Formal consultation may last up to 90 days, after which the USFWS will prepare a biological opinion on whether the proposed activity will jeopardize the continued existence of a listed species. The USFWS has 45 days after completion of formal consultation to write the opinion.

In making a determination on whether an action will result in jeopardy, the USFWS begins by looking at the current status of the species or "baseline." Added to the baseline are the various effects — direct, indirect, interrelated, and interdependent — of the proposed federal action. The USFWS also examines the cumulative effects of other non-federal actions that may occur in the action area, including state, tribal, local, or private activities that are reasonably certain to occur in the project area.

The USFWS's analysis is then measured against the definition of jeopardy. Under the ESA, jeopardy occurs when an action is reasonably expected, directly or indirectly, to diminish a species' numbers, reproduction, or distribution so that the likelihood of survival and recovery in the wild is appreciably reduced.

When the USFWS makes a jeopardy determination, it also provides the consulting federal agency with reasonable and prudent alternative actions. These alternatives are often developed with input and assistance from the federal agency. Alternatives must:

- be consistent with the purpose of the proposed project;
- be consistent with the federal agency's legal authority and jurisdiction;
- be economically and technically feasible; and
- in the Service's opinion, avoid jeopardy.

In some cases, the USFWS finds that an action may adversely affect a species, but not jeopardize its continued existence. When this happens, the USFWS prepares an incidental take statement for the proposed project. Under most circumstances, the ESA prohibits take, which is defined as harming (which includes killing) or harassing a listed species. Incidental take — take that results from an action but is not the purpose of the action — may be allowed when the USFWS approves it through an incidental take statement. The statement includes the amount or extent of anticipated take due to the action, reasonable and prudent measures to minimize the take, and terms and conditions that must be observed when implementing those measures.

After the USFWS issues its biological opinion, the federal agency then decides how to proceed. With an opinion that determines adverse effects, the agency can adopt the reasonable and prudent measures outlined in an incidental take statement and proceed with the project. If the USFWS makes a jeopardy determination the federal agency has several options:

- implement one of the reasonable and prudent alternatives
- modify the proposed project and consult again with the Service
- decide not to undertake (or fund, or authorize) the project
- disagree with the opinion and proceed
- apply for an exemption

A federal agency may apply for an exemption if it believes it cannot comply with the requirements of the biological opinion. The application is considered by the Endangered

Species Committee, comprised of Cabinet-level members from various federal agencies and administered by the Interior Department's Assistant Secretary for Policy, Management, and Budget. To be considered by the Committee for an exemption, a federal agency must have carried out the consultation in good faith and made a reasonable effort to develop and consider modifications or alternatives to the proposed action. It must also have conducted any required biological assessment and refrained from making any irreversible or irretrievable commitment of resources to the project during consultation.

The Section 7 Consultation could be a time-consuming process depending on the availability of required endangered species study information and whether that data exists at the time of the consultation or if it needs to be generated to support the consultation.

A4.5 Sediment Quality

A4.5.1 Available Data over Study Area

As part of the Core Capacity Study, The CCTS team identified the following potential sources of sediment data:

- Dredge Material Management Office (DMMO)
- San Francisco Bay Regional Monitoring Program
- Port of San Francisco Maintenance Dredging Sampling and Analysis Reports (SARs)
- Port of Oakland Maintenance Dredging SARs
- San Francisco District United States Army Corps of Engineers' Federal Channel Maintenance Dredging SARs

Based on a review of the information contained in the DMMO database and discussions with DMMO staff, there is limited sediment data available for areas of San Francisco Bay that are outside of active dredging projects (i.e., the data is specific and was generated to support specific dredging projects).

A4.5.2 Data Gaps

As part of the permit process the project will have to develop its own Dredging SAR for the selected alignment(s) of the immersed tube. This will require the collection and analysis of representative sediment samples over the width and length of the proposed submersed tube alignment to assess sediment quality so a determination of the proposed sediment management method can be developed.

A4.6 Dredge Material Disposal Options

A4.6.1 In-Bay Disposal

In-Bay disposal of sediments occurs at four designated aquatic disposal sites located throughout the San Francisco Bay. These include the Alcatraz Island Disposal Site, the San Pablo Bay Disposal Site, the Carquinez Strait Disposal Site, and the Suisun Bay Disposal Site. The LTMS Management Plan adopted in 2001 stipulated the reduction of in-Bay disposal using a series of reductions taking place over four, three year "step-down" periods ending in 2012. Beginning in 2013 the disposal of sediments at in-Bay locations is limited to 1.25 million cubic yards per year, a 48 percent decrease over the annual pre-2000 in-Bay disposal volume.

A4.6.2 Beneficial Reuse

Sediment dredged from San Francisco Bay may be beneficially reused for a variety of purposes such as wetland creation, levee maintenance, or construction fill. Substantial capacity for beneficial reuse still exists, but the distance of beneficial reuse sites from the majority of the dredging activity and the need for dredging projects to provide offloading equipment at certain sites remain challenges in providing economical reuse options. Existing beneficial reuse sites include the Montezuma Wetlands Restoration Project (regulated by Water Board Order No. R2-2012-0089), the Cullinan Ranch Restoration Project (regulated by Board Order No. R2-2010-0108), and Winter Island levee maintenance. At their own discretion, dredging contractors or the project sponsors may propose to use other permitted upland locations. All necessary environmental documentation must be completed for a site prior to it receiving any dredged material.

A4.6.3 Deep Ocean Disposal Site

Ocean disposal for Bay-dredged material occurs at the San Francisco Deep Ocean Disposal Site, approximately 55 miles (48 nautical miles) west of the Golden Gate and thus beyond the three nautical mile offshore limit of Water Board jurisdiction. Under the federal Marine Protection, Research, and Sanctuary Act, the EPA must concur with disposal at the San Francisco Deep Ocean Disposal Site.

A4.6.4 Landfill Disposal

In some extreme cases sediment sampling and analysis in near shore areas has indicated that dredged sediments are not suitable for in-Bay disposal, beneficial reuse, or deep ocean disposal due to high concentrations of chemical contaminants (e.g., coal tar waste [dense non-aqueous phase liquid] from former manufactured gas plants) present in the sediment. In these cases the sediments, if dredged, may have to be processed for disposal in a landfill. This typically requires a certain amount of dewatering and drying of the sediments in order to allow for landfilling. This can add significantly to the already expensive cost of landfill disposal.

A4.6.5 Landfill Use (Alternative Daily Cover)

Another potential beneficial use of dredged sediment is for use as alternative daily cover for active landfills that must cover the burial face of the landfill daily. However, as with the landfilling option, the material is required to be dried to a certain degree for use thus making this a more costly disposal option.

A4.7 Constructability and Cost Considerations

A4.7.1 Construction and Staging

The critical activities in the construction of an ITT would be dredging in the Bay and the casting/fabrication of the tunnel elements. A large yard would be required, likely in Alameda, with good access for material delivery. Road access through Alameda Island is limited and would require construction traffic to go through residential neighborhoods. Barge access could be utilized for some deliveries.

The yard would require a large, flat area that could be flooded to allow the floating of tunnel segment and gates to allow access to the Bay once floated. This would likely be constructed within the footprint of the existing island to avoid additional construction within the Bay.

Alternately, the fabrication yard could be in other areas of the West Coast or overseas depending on final construction cost considerations.

Approximately 3 to 4 m cubic yards of dredging would be required for the two-track BART option. This is approximately equivalent to the volume of material dredged within the Bay in a single year. The dredged material would be disposed of either on land in existing sites or dumped greater than 50 miles out to sea. In either case the dredged material would be removed by water rather than by road. A proportion of the dredged material would be classified as contaminated. This would require disposal in certified facilities and would attract a considerably higher disposal cost. For analysis purposes, it has been assumed that 15% of excavated material would be contaminated.

Each of the ITT alignments would require a crossing of the Trans Bay Cable, a high voltage DC submarine cable buried approximately 6 feet below the Bay floor. The cable, owned by SteelRiver Infrastructure Partners, was constructed in 2010. The cable could be spliced and potentially relocated to accommodate an ITT crossing. This would have to be carefully planned to minimize the impacts of down time and compensation would be payable to the owners and/or operators.

A4.7.2 Cost Variations

Based on the general assumptions stated in this section, a two-track immersed tube tunnel would cost approximately 40% more for BART and 60% more for conventional rail, than the equivalent 2-track mined tunnel. A 4-track ITT crossing containing 2- tracks of BART service and 2-tracks of rail service in the same structure would cost approximately 15% less than two separate ITT structures and 30% more than 2 separate, 2-track mined tunnels.

These cost differentials only consider the core bay crossing tunnels and landing/transition structures that would be associated with tunnel construction. On-shore tunnel extensions and new stations will have different relative cost profiles based on construction methodology.

A5 Limitations and References

A5.1 Limitations

This study did not examine some significant aspects of the future construction environment. These factors include:

- Climate change/sea level rise: Local predictions range, but regional agencies seem to be considering average estimates on the order of 11 inches by 2050 and nearly 3 feet by 2100. Station/guideway entrances, vent structures, and equipment would all need to be designed to accommodate these levels plus any additional factors due to increased storm activity. There are studies by SPUR and others in progress now looking at protection schemes for Mission Bay and Mission Creek specifically. The Central and Southern Embarcadero is also particularly vulnerable to sea level rise. Alameda Point has similar vulnerabilities, but these could be mitigated thought proper design.
- San Francisco Sewall: The condition of the seawall running from Pier 43 to Pier 50 is being assessed by the Port and targeted improvement measures are being proposed. Tunneling under this structure would need to be analyzed to ensure that activities would not undermine the rock dyke core or other components. It is assumed that these issues could be overcome with proper design.
- Mission Bay Development Coordination: Continues development in Mission Bay, including the proposed mixed use developments of Mission Rock, the Warrior Arena, and Pier 70,

which are all in various stages of approval and funding. The ability to plan some of the foundation, street, and coastal design elements in these major developments could vastly improve the future viability of rail transit service in the corridors.

- San Francisco Public Utilities Commission Central Bayside Tunnel: The possible planned new tunnel on Indiana Street or other corridors could impact the corridors and viability.
- DTX/Railyards Study: The ongoing DTX and Railyards Study by the CCSF will be completed in 2016 and may inform future project and corridor planning decisions, especially as related to DTX and rail service to 4^{th} and King/Townsend and TTC. New development opportunities associated with some of the options being studied could also change the value capture of certain BART alignments through Mission Bay or south SOMA.

A5.2 Reference Standards

The guiding standards used for BART and heavy rail geometric design are BART Facilities Standards (BFS) version 3.0 and the DTX Design Criteria produced for TTC version 1.0.

The DTX standard generally represents a combination of Caltrain and CHSR standards, with the most onerous condition being assumed in each case. For comparison, Caltrain and CHSR standards were also reviewed to ensure applicability.

A5.3 Critical Criteria

Key geometric criteria from the reference standards are listed in Table A1.

Criteria		BART	DTX
Horizontal Radius	Minimum	1,000 feet	1,070 feet
	Absolute Minimum	N/A	650 feet*
Gradient	Maximum	3.0%	1.0%
	Absolute Maximum	4.0%	2.0%
Superelevation	Maximum	6 inches	3 inches
	Absolute Maximum	8 ¼ inches	4 inches
Unbalance Superelevation	Maximum	2.75 inches	3 inches
	Absolute Maximum	4.5 inches	4 inches

Table A1: Key Geometric criteria

* An absolute minimum radius of 500 feet is stated in version 1.0 of the DTX Design Criteria, but in future work an absolute minimum radius of 650 feet was used. 650 feet was assumed for the current study.

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