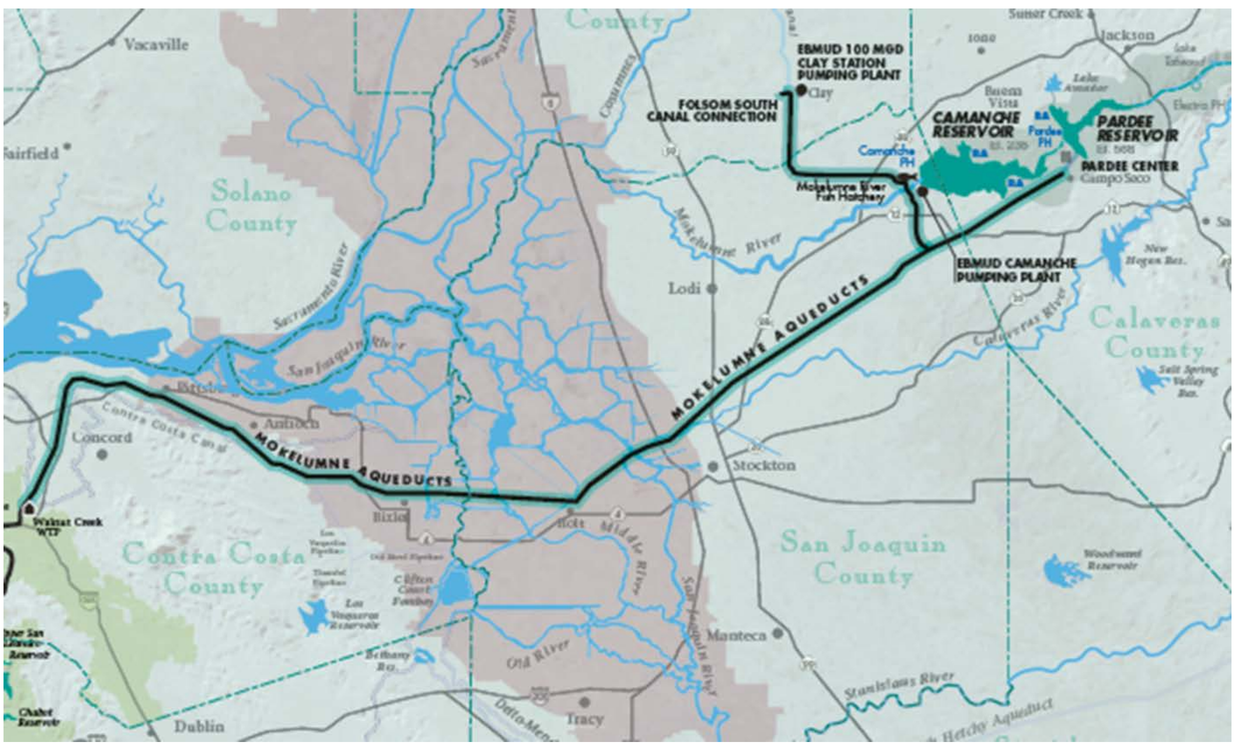
EAST BAY MUNICIPAL
UTILITY DISTRICT

Technical Memorandum No. 2

Delta Tunnel Study Conceptual Design



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Explanation of Abbreviations

AACE	Association for the Advancement of Cost Engineering
BDCP	Bay Delta Conservation Plan
bgs	below ground surface
cfs	cubic feet per second
EBMUD	East Bay Municipal Utility District
EPB	Earth Pressure Balance
EIR/EIS	Environmental Impact Report/Environmental Impact Study
ESA	Earth Science Associates, Inc.
g	gram
HDPE	high-density polyethylene
CD	consolidated-drained
CU	consolidated-undrained
I.D.	inside diameter
ksi	kilopound per square inch
kW	kilowatt
LiDAR	Light Detection and Ranging
MGD	million gallons per day
M	magnitude
msl	mean sea level
MWH	MWH Americas, Inc.
N/A	not available
n.d.	no date
O.D.	outside diameter
O&M	operation and maintenance
OPCC	Opinion of Probable Construction Cost
pcf	pound per cubic foot
PGA	peak ground acceleration

PSHA	Probabilistic Seismic Hazard Analysis
psi	pound per square inch
PVC	Polyvinyl chloride
ROW	Right-of-Way
SPAD	Strategy for Protecting the Aqueducts in the Delta
TM	Technical Memorandum
TBM	Tunnel Boring Machine
USBR	United States Bureau of Reclamation

EXECUTIVE SUMMARY

The existing EBMUD Mokelumne Aqueducts within the Sacramento-San Joaquin Delta (Delta) are known to be at risk of catastrophic failure due to flooding, seismic, and/or long term settlement hazards. EBMUD, in its 2007 report titled “Strategy for Protecting the Aqueducts in the Delta” (SPAD), recommended a tunnel across the Delta as the preferred long-term mitigation approach to these hazards. A conceptual design for replacing the existing aqueducts through the Delta area with a deep tunnel was developed for this study. Additionally, several pipeline alternatives were evaluated for a five mile reach of the tunnel.

The proposed Delta Tunnel is envisioned to be approximately 16.5 miles long, beginning west of Interstate 5 and ending at EBMUD’s Bixler Maintenance Yard. The tunnel depth and profile were developed to position the tunnel to avoid adverse impacts to piles supporting the existing aqueducts and at a depth where differential settlement from liquefaction can be accommodated by the carrier pipes. Based on these criteria, the target position of the tunnel invert was determined to be at elevation -125 ft. msl, but with variations to avoid flat segments and the western-most reach which rises to elevation -79 ft. msl. Due a range of factors and uncertainties inherent in this level of design development (conceptual phase), the actual tunnel vertical profile may vary either up or down by as much as 31 feet from this base position. As such a tunnel band is presented within which the tunnel is expected to be positioned in accordance with future geotechnical investigations and design development. The factors and uncertainties are geologic conditions, engineering properties of the soil materials, specifics of the liquefaction analyses, the need to slope each tunnel segment for construction to mine each heading uphill for drainage, and to slope each pipeline segment to facilitate dewatering during operation if necessary. Seven shafts are positioned along the Project to facilitate tunnel construction, contract packaging, and to provide future access for operations, maintenance, and repairs. Construction of the shafts is expected to be with structural slurry walls and reinforced concrete base slabs placed with tremie methods.

EBMUD’s existing aqueduct system uses three pipelines to convey water through the Delta. Two tunnel configurations were evaluated as part of this study: a single tunnel with two carrier pipes and a single tunnel with a single carrier pipe. To maintain separation of the source flows for water quality and treatment reasons, one alternative for the Delta Tunnel is designed to have two carrier pipes each 87 inches I.D.; one for the combined flows from Aqueducts 1 and 2, and one for the flow from Aqueduct 3. Preliminary calculations show that 0.625 inch thick steel carrier pipe is adequate to withstand internal and external loading. Based on this pipe in tunnel configuration and with allowances for pipe separation and tolerances, a segmental lined tunnel with an outside diameter of 21 feet was developed. The second configuration for the Delta

Tunnel, based on combined source flow arrangement, was also developed and consists of a 13.75 foot outside diameter segmental lined tunnel with a single 111 inch diameter carrier pipe.

1.0 INTRODUCTION

1.1 Purpose of Study

The East Bay Municipal Utility District (EBMUD) services the east side of the San Francisco Bay Area, providing water to over 1.3 million people. Water from the Mokelumne River is collected in the Pardee Reservoir on the western slope of the Sierra Nevada (**Figure 1-1**) and accounts for almost 90% of the raw water delivered to the East Bay Area (10% comes from the Sacramento River via the Freeport Diversion) through the 82-mile long Mokelumne Aqueduct System, which consists of three (3) large-diameter steel pipelines. The aqueducts are at risk of failure within the Sacramento-San Joaquin Delta (Delta) due to flooding, seismic hazards, and long term settlement. The purpose of the EBMUD Delta Tunnel Study is to develop a conceptual design and profile for the proposed tunnel to replace the existing aqueduct, and to evaluate potential impacts of the proposed Bay Delta Conservation Plan (BDCP) tunnels on the existing EBMUD aqueducts as well as the proposed Delta Tunnel.

The scope of the study is:

- Review existing geotechnical data (TM 1: Preliminary Geologic Characterization).
- Develop conceptual designs of a long tunnel, with either two or a single carrier pipe(s) to replace the Mokelumne Aqueduct System within the Delta between the San Joaquin Surge Control (Interstate 5) and the Bixler Maintenance Yard (TM 2: Delta Tunnel Study Conceptual Design)[1]
    - Develop a deep Delta Tunnel alternative for the full length with two carrier pipes.
    - Develop a deep Delta Tunnel alternative for the full length with a single carrier pipe.
- Prepare a responses and comments to the Bay Delta Conservation Plan (BDCP) EIR/EIS, for the proposed BDCP dual conveyance tunnels, relative to anticipated impacts to both the existing Mokelumne Aqueducts and the proposed Delta Tunnel (TM 3: Review of BDCP EIR/EIS)

[1] Originally this task also included a tunnel/pipeline alternative with a deep tunnel for the west segment of the alignment and a shallow pipeline from Stockton to Holt (eastern). This was alternative was later deleted.

- Develop a scope of work and budget estimates for preliminary and final design, including geotechnical investigations for the proposed Delta Tunnel (TM 4: Proposed Planning, Geotechnical Investigations and Design)
- Develop a shallow concept for the aqueducts as an alternative to the deep tunnel. This concept is for two shallow-buried piles supported on piles with twin microtunnels for each of the river crossings. (TM 5: Shallow Aqueduct Concept).

This study includes developing concepts for the following project components:

- Horizontal alignment for the all tunnel and tunnel/pipeline alternatives including the proposed location of the shafts.
- Vertical profile of the tunnel; positioning the tunnel in favorable ground based on geological and hydraulic conditions, construction considerations, and other factors e.g., O&M.
- Tunnel support and lining system designs.
- Shaft design.
- Pipeline design.
- Piping and valves for connections.

This technical memorandum also addresses construction related approaches and issues, and presents the opinion of probable construction costs for a base concept and one tunnel alternative as part of this study. The following sections present the basis for the study with design and construction assumptions, the conceptual design, and the opinion of probable construction cost.

1.2 Mokelumne Aqueducts Delta Tunnel

EBMUD's 2007 report, Strategy for Protecting the Aqueducts in the Delta (SPAD), recommended a tunnel across the Delta as the preferred long-term mitigation for earthquake and flood hazard risks to the existing aqueducts within the Delta. This report, along with several geotechnical reports and recent CPT investigations were used as the basis for geologic evaluations presented in TM-1: Preliminary Geologic Characterization. The tunnel designs presented herein are based on geologic conditions presented in TM-1, and engineering and construction considerations.

Conceptual design development focused on a base design case for a single Delta Tunnel with two carrier pipes over the full crossing of the Delta which is presented in this TM. As modifications to the base design, one alternative concept was advanced for comparison. This alternative was not developed to the same level as the base case, but was sufficiently advanced for comparison of design concepts and probable construction cost. This alternative is discussed in Sections 8 and 11 only.

The base design case for the proposed Delta Tunnel is an approximately 16.6 miles long (**Figure 1-2**) single 19 foot inside diameter (ID) tunnel excavated with a tunnel boring machine (TBM) and using precast concrete segments for initial support. Water is to be conveyed with two 87-inch ID steel carrier pipes constructed within the tunnel. The annular space between the carrier pipes and tunnel segmental concrete lining (initial tunnel support), will be filled with cellular concrete.

The preliminary criteria for locating and optimizing the Delta tunnel's vertical profile were to: 1) to avoid the existing aqueduct pile foundations and limit adverse impacts on those foundations, and 2) limit differential settlements from liquefaction such that the resulting strain in the pipelines is within accepted design criteria. The horizontal alignment for the proposed Delta Tunnel follows the existing Mokelumne Aqueduct ROW as much as practicable to control the cost of new property or easement acquisitions.

Shafts are to be located at both ends of the tunnel, with a shaft on the west side of the Delta at Bixler and on the east side of the Delta near I-5 on the edge of Stockton. Five other shafts are placed along the alignment at approximately three mile intervals to facilitate tunneling pipe placement, and to provide future access to the carrier pipelines.

MWH developed an understanding of the ground conditions along the proposed Delta Tunnel alignment by compiling the subsurface data, soil property data and stratigraphy information which led to the development of a geologic profile based on information contained in the SPAD report, as well as multiple other geotechnical reports based on investigations along the existing aqueduct. A summary of the geologic conditions anticipated are presented in the TM-1: Preliminary Geologic Characterization. Based on these geological conditions, the current tunnel study develops the tunnel design to a conceptual level. This study presents the proposed conceptual design with the proposed alignment and profile, tunnel cross section and piping, and provides an opinion of probable construction cost.

1.3 Limitations of Study

This report has been prepared by MWH Americas, Inc. The interpretations of data, findings, recommendations, or professional opinions presented are within the limits prescribed by available information at the time of conceptual design development when this report was prepared. In general, for this report, the geologic data are largely based on information obtained by others along the existing Mokelumne Aqueduct, which was made available for this study.

Limited new geotechnical data were obtained for this study and included twelve new CPT borings. In addition, the study excluded confirmation of the system hydraulics and the development of hydraulic criteria.

A listing of the data and reports utilized in the development of this study are included in Section 12.0, References. In the event that there are any changes in the nature, design or location of the project, or if additional subsurface data are obtained or any future additions are planned, the conclusions and recommendations contained in the report will need to be reviewed and updated.

2.0 PROJECT DATA

2.1 Existing Facilities

The existing Mokelumne Aqueduct System consists of three pipelines as follows:

- Aqueduct No. 1: 65-inch diameter built in 1929,
- Aqueduct No. 2: 67-inch diameter built in 1949 and
- Aqueduct No. 3: 87-inch diameter built in 1963.

The segment that is proposed to be replaced extends for approximately 16.6 miles across the Sacramento-San Joaquin Delta area. The delta reach presently consists of approximately 6 miles of buried pipeline, 10 miles of elevated pipelines, and three (3) major river crossings with about 0.5 miles of submerged pipeline. From east to west, the various reaches of the existing pipelines are described as follows:

From Stockton to the San Joaquin River, the buried pipes are in a greenway under a golf course and adjacent residential areas (**Figure 1-2**). At the east bank of the San Joaquin River, the San Joaquin waterway vault can be accessed via either a gate from a subdivision or from the top of a levee. The vault structure has an entry door, and houses all three (3) aqueducts within a common structure. The structure also contains flow meter panels and water sample sinks.

Upon crossing the west side of the San Joaquin River, the pipelines remain buried, continuing across Roberts Island through rural agricultural lands at an elevation of roughly 5 feet below sea level. West of the San Joaquin River, before Inland Drive, Aqueduct No. 3 has a vault structure that contains a manhole and a removable spool piece for entry and maintenance. This facility is one of three such structures (one for each pipeline) installed across Roberts Island as part of the Seismic Upgrades Project. The other two access structures are located off Jacobs Road and near the Holt Anchorage.

The pipes turn west at the Holt Anchorages at an overall angle of approximately 45 degrees, but incorporating an approximately 90 degree bend. In this area, Aqueduct No. 3 is encased in a large concrete anchor throughout the entire sweep angle. Smaller anchors support Aqueduct Nos. 1 and 2.

The pipelines are elevated across Trapper Slough, which is a short waterway. Aqueduct No. 1 is on concrete bents set upon timber piles. Aqueduct Nos. 2 and 3 are supported on steel bents bearing on concrete caps and piles. After Trapper Slough the pipes continue on elevated supports across Upper Jones Tract.

West of the City of Holt in the Upper Jones Tract, the ground level averages 10 feet below sea level. The existing pipelines are elevated along this portion of the alignment as follows:

- Aqueduct No. 1 is shown to be supported on concrete bents that replaced the original timber bents in the mid-1940s. The piles are timber. The concrete bents were embedded and fixed on concrete pile caps in 1990 following the Loma Prieta earthquake. The pipes rest on a saddle. Also, a few of the concrete bents were found to be cracked beyond repair and were reported to be replaced with steel bents.

- Aqueduct No. 2 is also supported on bents bolted to the pile caps.

- Aqueduct No. 3 is also shown to be on steel bents, with concrete caps and piles. The steel bents were seismically retrofitted in 2004 as part of the Seismic Upgrade – Elevated Project.

At the western edge of the Upper Jones Tract, all three of the aqueducts are buried as they cross beneath the Middle River. Aqueduct Nos. 1 and 2 are buried in a trench and supported on submerged timber piles installed in 1928. Aqueduct No. 3 is buried in a trench without piles under the Middle River.

The elevated system in place across the Upper Jones Tract for the aqueducts is also present across Woodward Island. At the western edge of Woodward Island, the system crosses the Old River in the same way it passes under the Middle River.

The system is elevated as it runs through the Orwood Tract, utilizing a system similar to that in the Upper Jones Tract. The final water crossing is over a short waterway named Indian Slough. Aqueduct No. 1 is on timber bents while Aqueduct Nos. 2 and 3 are on steel bents bearing on concrete caps and piles. Indian Slough Waterway Nos. 1 and 2 serve the Mokelumne Aqueduct Nos. 1 and 2. These facilities consist of concrete structures to housing isolation valves. The valves are activated by high flow/low pressure and drain the upstream reach of the pipeline to protect the downstream pipeline.

After the Indian Slough, the aqueducts transition from elevated supports to a buried system at the Bixler Maintenance Yard. The Bixler Low-Head Pumping Plant is located adjacent to Indian Slough. The purpose of the facility is to pump water from Indian Slough during a severe drought or following a complete outage of the pipelines crossing the Delta. MWH understands that this facility has been decommissioned.

2.2 Site Geology

The subsurface conditions at the site are divided into five different geologic strata. The overall description of each of the five strata identified is explained below, from youngest to oldest, and in more detail in TM 1: Preliminary Geologic Characterization. The subsurface conditions were a key consideration in identifying the vertical alignment for the proposed Delta Tunnel. The near surface geologic stratigraphy is comprised of the following**:**

- **Artificial fill** is found along much of the alignment, mainly along the roads and levees, and ranges from thin (less than a foot) to up to about 15-feet-thick. The fill mainly consists of mixed fine sands, silts and clays.

- **Marsh deposits** are derived primarily from the San Joaquin River as floodplain and flood basin deposits and minor natural levee deposits overlying the alluvial deposits. These deposits are interlayered with the organic peat deposits, and can be found above or below the organic layer. The marsh deposits are mainly comprised of silty clays, sandy silts, and clay silts.

- **Peat and Organic deposits** blanket much of the area, within the zone of tidal influence and alluvial deposits above tidal influences. In general, the organic deposits consist of compressible peat with varying amounts of silts and clays.

- **Holocene Alluvial deposits** are typically floodplain/basin and stream channel deposits that are loose to medium dense micaceous sand with low organic content; and soft to medium dense stiff micaceous silt, silty clay, clayey silt, and silt, commonly with carbonate, and locally with oxide nodules. Based on available field data reviewed during this study, these deposits are typically found between El. -20 to El. -70 ft msl and can be encountered to an elevation of -100 ft msl.

- **Pleistocene Alluvial deposits** are comprised of the Modesto and/or Riverbank Formations, which are generally characterized as dense to very dense silty sand, sand with gravel and very stiff to hard silty clay and clayey silt with gravel that can be slightly cemented and/or indurated.

For the purposes of tunnel evaluations, the upper three strata are combined into one unit. Although these three strata are geologically distinct and have different soil characteristics, they are all relatively soft or loose, unfavorable, and above the tunnel horizon, and do not directly affect the tunnel. The Holocene and Pleistocene Alluvial deposits are similar in composition, and vary primarily in geologic age, the density of the sands and consistency of the clays. Based on current data, a distinct interface between the two units was not identified. Therefore, these two strata are combined into one unit for the purpose of tunnel evaluations.

2.3 Aqueduct System Requirements

The aqueduct system criteria developed for this study are summarized below:

- Desired long-term raw water delivery capacity of 325 MGD.
- Desired interim raw water delivery, with Aqueduct No. 3 in service (pumped state) of 172 MGD.
- Aqueduct system capable of continuing operation during flood events.
- Aqueduct system capable of continuing service during and after a seismic event with only minor damage.

3.0 GEOTECHNICAL CONDITIONS

3.1 Soils and Soil Properties

The engineering properties of the soils were compiled from available data resulting from previous investigations in the project area (CWDD, 1981; ESA, 1992). This data was used to evaluate ground conditions, behavior, and loads, the stability of the soils in a seismic event, and to assist with setting the vertical alignment for the proposed Delta tunnel. The properties identified in TM-1: Preliminary Geologic Characterization are average values and do not incorporate the wide range of properties that are anticipated for the varied soil layers within each geologic unit. The soil properties listed are based primarily on correlations with general soil descriptions and blow counts obtained during previous field explorations as documented in various reports (ESA, 1992). Ranges of the engineering properties of the soils for the geologic strata encountered along the Stockton to Bixler aqueduct alignment are summarized in TM 1: Preliminary Geologic Characterization, Table 2.

The following ranges of soil properties summarized in **Table 3-1**, which were compiled from previous investigations at the project site (ESA, 1992), are:

Table 3-1: Approximate Ranges of Soil Properties

Stratum (1)	Natural Moisture Content (%)	Wet Unit Weight (pcf)	Undrained Shear Strength (2) (psf)	Shear Strength (3)		Compression Ratio (4) (%)
				Effective Cohesion (psf)	Effective Friction Angle (°)	
Fill	24±14 (36 tests)	100±14 (36 tests)	N/A (5)	N/A	N/A	N/A
Marsh	50±19 (69 tests)	102±16 (69 tests)	649±639 (14 tests)	310-680 (12 tests)	30-34 (12 tests)	20±14 (3 tests)
Peat & Organics	232±121 (145 tests)	73±18 (145 tests)	532±391 (16 tests)	240-660 (24 tests)	27-29 (34 tests)	53±9 (10 tests)
Holocene Alluvium	34±16 (672 tests)	118±15 (672 tests)	1,310±897 (54 tests)	0-200 (31 tests)	33-40 (31 tests)	20±7 (5 tests)
Pleistocene Alluvium	24±6 (89 tests)	126±8 (89 tests)	1,304±589 (17 tests)	N/A	N/A	N/A

Notes:
(1) See stratum description in the Site Geology section.
(2) Undrained shear strength equal to one-half of unconfined compressive strength.
(3) Shear strength from triaxial compression consolidated-undrained (CU) with pore water pressure measurement and consolidated-drained (CD) tests.
(4) Compression ratio from one-dimensional consolidation tests.
Source: ESA (1992).

3.2 Seismicity

The potential seismicity that could impact the site has been evaluated in several previous studies based on probabilistic methods using return periods. As part of the present work associated with the conceptual design for the proposed Delta Tunnel, MWH reviewed the previous probabilistic methods to determine the likely seismic hazard and peak ground acceleration associated with earthquakes, and the results are presented in TM 1: Preliminary Geologic Characterization.

A seismic study relevant to the project area (URS/JBA, 2007) identified four categories of active and potentially active seismic sources. The four seismic sources are the crustal faults underlying the Delta and San Francisco Bay area, thrust faults underlying the Delta, hypothetical seismic zones and the Cascadia subduction zone, as presented in TM-1: Preliminary Geologic Characterization.

The results of PSHA indicate that ground shaking hazards in the Delta area are not sensitive to the assumed recurrence model (whether a time-dependent or time-independent model is used), and have roughly similar results for both methods because the local hazards are dominated by the Delta seismic sources rather than other major faults in the region. Probabilistic analysis (EBMUD, 2007) undertaken indicate that most delta levees around the islands are expected to fail with a PGA of 0.1 g, which implies a catastrophic levee failure for a 100-year return period earthquake event. For the 500-year return period earthquake, levee failure is almost certain. The vulnerability of levees to fail under the 100-year and 500-year return period earthquakes was taken into account to assess the liquefaction hazards along the aqueducts alignments (EBMUD, 2007). In the vicinity of the aqueducts in the Delta, PGA values for the 100-year return period event range from 0.11 to 0.17 g and for the 500-year return period event, from 0.20 to 0.37 g. Due to the influence of Bay Area faults, the hazard decreases from west to east at these short return periods (McLeod, 2013).

3.3 Liquefaction

Liquefaction is a process in which strong ground shaking causes loose and saturated sediments to lose strength and to behave as a viscous fluid. This phenomenon can cause excessive ground deformations, failures, and temporary loss of soil bearing capacity, resulting in damage to structures. Ground failures can take the form of lateral spreading, excessive differential and/or total densification or settlement, and slope failure. Generally the liquefaction and associated ground deformation is a shallow soil profile phenomena that does not occur at depth due to higher stresses.

Liquefaction-induced ground deformation was reported during the 1906 San Francisco earthquake (M = 7.9) in three locations within and in the vicinity of the aqueducts in the Delta. Settlements of as much as 11 feet were reported south of Fairfield, along the Southern Pacific Railway through the Suisun Marsh; ground settlement of several inches was reported at the Southern Pacific Bridge Crossing over the San Joaquin River in Stockton approximately 4 miles from the east end of the proposed tunnel alignment; and settlement of 3 feet was reported at a bridge crossing over Middle River approximately 10 miles west of Stockton (Youd and Hoose, 1978). No liquefaction-induced ground deformations were reported in the Delta and Suisun Marsh during the 1989 Loma Prieta earthquake (M = 6.9) (California Department of Water Resources, 2013a).

Previous seismic studies indicate that vertical settlement is predicted due to dissipation of earthquake-induced pore-water pressures in zones where liquefaction occurs or excess pore pressures develop. Based on previous studies, the estimated seismic settlement is expected to range between 1 and 6 inches within the island tracts and between 2 and 12 inches in areas closer to (and within) the slough and river crossings (EBMUD, 2007). The seismic settlements between Holt and Stockton are estimated to be approximately 4 to 12 inches, and differential seismic settlements of 5 to 7 inches over short distances (120 feet) are possible.

The Delta and Suisun Marsh are underlain at shallow depths by various channel deposits and silty and sandy alluvium. Where saturated, these soils may locally be susceptible to liquefaction during earthquakes (California Department of Water Resources, 2013). In general, most soils within the upper two strata (artificial fill and marsh deposits) are liquefiable. The peat and organic soils (Stratum 3) are unlikely to be liquefiable, but could undergo significant strength loss and seismic deformation. The Holocene alluvial soils (Stratum 4) are variable, and include both liquefiable and non-liquefiable layers. Similarly, the Pleistocene alluvial soils (Stratum 5) are variable with a range of liquefaction susceptibilities, and although the sands are commonly more dense than in the Holocene they are still potentially liquefiable. For this study the Holocene and the Pleistocene were not differentiated, and liquefaction evaluations were based on soil characteristics without association to their geologic strata.

Liquefaction potential and settlement for this study were based on data obtained from twelve CPT probes conducted by Gregg Drilling in 2014 along the aqueduct alignment. The post-earthquake settlements were computed by Gregg Drilling and EBMUD using the geotechnical software CLiq (GeoLogismiki, 2014). MWH reviewed the calculations including: 1) an assessment of the applicability of the methods, 2) cross checks to the data provided by Gregg Drilling who performed the CPT probes, and 3) QC spot checks with manual calculations using equations presented in Youd et al. (2001), Zhang (2001), Zhang et al. (2002), Robertson (2009) and Robertson and Cabal (2012). The method is based on CPT data interpretation to compute the factor of safety against liquefaction triggering (FS), liquefaction potential index (LPI) and post-earthquake vertical settlements and lateral displacements. The CLiq calculations assumed an earthquake magnitude (Mw) of 7.0 and a peak horizontal acceleration at the ground surface (amax) of 0.2g and 0.4g. The results of these analyses were used to estimate ground differential movements, and associated strain in the tunnel and interior pipes as the primary factor in setting the tunnel depth profile as presented later in section 4.4 – Vertical Profile.

3.4 Subsidence

Subsidence was evaluated as part of the alternative study for shallow pipelines along the Holt to Stockton segment only. Subsidence for the remainder of the study area is not a factor for this study and was not evaluated because the depth of the proposed Delta Tunnel is below the susceptible soils. The magnitude of subsidence and differential subsidence are risk factors for the existing aqueducts and on several of the proposed shallow alternatives for new aqueducts through the eastern area of the Delta.

For more than 7,000 years, a balance existed between sediment influx to the Delta, production of organic sediment in the Delta, and export of sediment to San Francisco Bay. The equilibrium conditions promoted the development of peat to depths up to approximately 30 feet in some areas (California Department of Water Resources, 2013b). This equilibrium was first disrupted when large volumes of sediment influx occurred from hydraulic mining in the mid-1800s, then by subsequent reclamation of the Delta Tule marsh islands that took place from the late 1800s through about 1930. With passage of the Swamp and Overflow Act of 1850, the marshlands began to be drained for agricultural use. Levees were constructed around Delta islands to prevent floods and tidal overflow. Following levee construction, Tule marshes on island interiors began to die and were burned, drainage ditches were constructed at the perimeter of levees, and pumps were installed to transfer drainage water from the island interiors into the adjacent waterways. Most of the Delta cultivation was in 1922, and the Delta's present form dates from the 1930s.

The primary cause of land subsidence in the Delta is decomposition of organic carbon in the peat deposits. When the Delta islands were drained, the formerly saturated soils became oxygen rich and conditions favored microbial oxidation. When organic carbon is oxidized from peat soils, it is emitted as CO_2 gas to the atmosphere, thereby reducing the soil carbon pool and soil volume. Two other key processes that are contributing to subsidence in the Delta are: 1) soil densification caused by compaction from farm equipment, and 2) lowering of the water table which increases effective stresses. Additionally, wind erosion has been estimated to result in removal of 0.25 to 0.5 inch of topsoil per year (California Department of Water Resources, 2013b).

The rate of organic soil decomposition is related to temperature and moisture conditions. Historical subsidence rates in the Delta have been found to strongly correlate with the organic matter content of the soil and the age of the reclaimed island and have ranged from 1.8 to 4.6 inches per year, with higher rates in the central Delta. Areas that are at elevations lower than -5 feet can be assumed to have subsided. Long-term average rates of subsidence are 1 to 3 inches per year (California Department of Water Resources, 2013b). The subsidence rate between Holt and Stockton is estimated to be 1 to 3 inches/year and the differential subsidence over short distances (120 feet) could be approximately 1 to 2 inches/year.

4.0 ALIGNMENT AND PROFILE

4.1 Alignment and Shaft Siting Considerations

Selection of the proposed Delta Tunnel horizontal alignment and vertical profile is an exercise in addressing multiple factors. There is often a tradeoff and it is commonly not possible to fulfill all of the desirable factors. This subsection presents brief descriptions of the factors considered when setting the tunnel alignment and profile. Factors considered for the alignment include the existing ROW, the need for curves and/or angle points, and shaft locations with associated use and impacts at the ground surface. In determining both the alignment and the profile, construction and contracting were also major considerations.

4.1.1 Right of Way

EBMUD owns the Right of Way (ROW) within which the existing three aqueducts are situated. A primary consideration is to position the proposed Delta Tunnel within the existing ROW wherever this is practical. Use of the existing ROW reduces acquisition of land and easements, and associated complications with tunnel construction and aqueduct operation.

The existing ROW and alignment of the three aqueducts are shown on the tunnel plans (**Figure 4-1**). The ROW varies in width from 66 to 160 feet. The three aqueducts are in general centrally located within the ROW with Aqueduct 3 situated to the north, Aqueduct 2 to the south, and Aqueduct 1 in the center. The spacing between the aqueducts is typically between 15 and 25 feet, but is often greater especially at river crossings. The buffer between the aqueducts and the ROW limits varies from 15 to 50 feet based on aqueduct centerlines.

4.1.2 Operational Factors – Curves and Angle Points

The ROW and aqueducts are relatively straight in plan except for an angle of approximately 45 degrees at Holt. In addition to this directional change; there are also several shallow-angle bends in the ROW.

The two criteria related to the horizontal alignment are: 1) each angle point shall have a shaft for future access and to allow for tunneling; and 2) curves must have a radius of at least 1000 feet to facilitate tunneling. See the subsection to follow on horizontal alignment for discussions on the chosen alignment and each shaft locations.

4.1.3 Ground Surface Considerations at Shafts

Land use at the ground surface is a factor mainly for choosing shaft locations. In general, the proposed Delta Tunnel is expected to have little or no impact at the ground surface except at the proposed permanent shaft locations. A construction site larger than required for permanent access is needed at each shaft, both for the shaft and to stage tunnel construction. Each of the shafts has been located to be within or close to the existing ROW and the three existing aqueducts to minimize additional easement acquisition for the District. Additionally, a permanent tunnel access structure is required at each shaft location. Land use considerations at shaft locations included the following factors:

- **Development:** In choosing shaft locations, sites with substantial development such as residential houses, golf courses, and marinas were avoided to the degree practicable.

- **Existing Aqueducts:** Although a goal for setting the tunnel horizontal alignment is to stay within the existing ROW, the existing aqueducts are situated within this ROW and must remain operational throughout the construction period. Two approaches were used to work around the existing aqueducts at shaft locations consisting of: 1) setting the shaft between the aqueducts, and 2) offsetting the shaft from the existing aqueducts and acquiring new ROW. The temporary relocation of one or more of the aqueducts to accommodate a shaft was considered, but was not included as an option due to the complications with aqueduct relocation. Note that in some locations the aqueducts are supported on piles installed with a batter, and that the shafts need to avoid not only the aqueducts but also the pile foundations.

- **Access for Construction:** Each shaft location will be a major construction site needed to support shaft and tunnel construction, and it is desirable to be in close proximity to well established roads. Although this factor was considered in choosing shaft locations, in some situations shafts had to be sited in remote locations to avoid excessively long tunnel reaches.

- **Temporary Utilities:** Each shaft will need to be supported by electric power and water for construction including electricity, water, and communications. At many of the shaft sites, power lines would need to be extended and/or upgraded to support construction. See subsection 9.6 for estimated power requirements.

- **Social Impacts:** This item includes interference or disruptions to the normal social activities such as farming and ranching, use of roads and trails, and noise and other construction impacts at the shafts during construction. See subsection 4.1.4 to follow for details of these impacts.

- **Environmental Impacts:** Avoid placing shafts in wetlands or adjacent to waterways that may be affected by construction activities.

- **Manholes:** A permanent manhole is required for future pipeline access at each shaft. Therefore, the suitability of each site for a manhole was considered.

4.1.4 Construction Considerations

Several factors are considered in the identification of shaft locations and include its suitability as a construction staging area, with consideration of the availability of support facilities and potential impediments to construction, tunnel lengths between shafts, avoidance of the existing aqueducts pile supported foundations, and contracting strategies. Construction considerations for the shafts and overall project included the following factors:

- **Tunnel Reaches:** For long tunnel projects, there is a tradeoff of costs and schedule based on the tunnel length between shafts, short versus long tunnel drives. Although a sensitivity study of different tunnel drive lengths was not part of this study, review of other projects and common practice in the underground industry were used as a guideline. The efficiency and risks for tunnel construction typically increase with long tunnel drives. Long drives result in less efficient operations for muck hauling, water removal, transportation of personnel, segment delivery to the advancing face, and ventilation. Additionally, the TBM and supporting equipment need maintenance and repairs including cutter replacement, and these requirements and risks are magnified for long drives. To reduce these factors, it is desirable to limit each tunnel drive to about 15,000 feet (3 miles) or at a maximum 20,000 feet (3.75 miles) long. Future studies and design development should include a sensitivity study of the costs of shafts and optimum tunnel drive lengths to determine the most cost effective arrangement.

- **Existing Piles:** Sections of the aqueducts, both elevated and buried, are pile supported, and construction of shafts through the piles is impractical. Shaft construction using structural slurry wall methods is an option providing both structural support and a hydraulic cut-off. Slurry walls are constructed in panels with a clam shell or similar excavation equipment. Such equipment is not well suited to excavate through obstructions such as piles — including timber, concrete, and steel piles. The piles for the existing aqueducts are battered at between 1:12 and 1:3; therefore, the shafts need to avoid not only the footprint of the aqueducts, but also a buffer zone to the side to account for the pile batter. Depending on the aqueduct and associated pile batter, an offset of 25 or 30 feet was used, which includes a buffer of at least 10 feet to account for variations in pile length and batter.

- **Construction Access**: As a general rule well established roads are needed to access each shaft site during construction. One of the prime factors will be transportation of the TBMs, either to the shafts or from the shafts. Each shaft location will also have frequent equipment and material deliveries (e.g., precast segments), personnel, and muck haulage (at least for shaft construction). Additionally, entrance shafts will have muck haulage for the tunnel throughout tunnel construction. In some instances, the existing roads will need to be upgraded, or roads will need to be constructed to provide suitable access. Existing bridges will need to be checked for load capacities and if unsatisfactory will also need to be upgraded. See subsection 4.3 and Table 4-1 for detailed information and requirements for each shaft.

- **Tunnel Construction Considerations:** To allow for flexibility in tunnel staging and contracting as the project develops through design, all the shaft locations except at the west end at Shaft 7, are assumed to be useful as either an entrance or launch shaft with tunnel construction staging, or an exit only for TBM retrieval. Note that access at Shaft 4 is difficult, and it is preferable to use this as an exit shaft thereby minimizing the work at this location. Due to the higher tunnel invert elevation and desire to drive the tunnel uphill, Shaft 7 is expected to be an exit, not entrance, shaft.

- **Contracting:** Due to the overall length of the proposed Delta Tunnel project, anticipated construction schedule duration, and total construction cost using a single construction contract is not desirable. It is envisioned that multiple construction contracts which would allow more contractors to bid on the work for greater competition, potentially shorten the overall construction schedule and provide better flexibility in obtaining bonding. In selecting shaft locations and the tunnel vertical profile, consideration was given to the sequencing of construction for the tunnel reaches, and the likely need for some of the shafts to be in different tunnel construction contracts.

4.2 Horizontal Alignment

Many variations in the horizontal alignments are possible including a straight, linear tunnel, a tunnel that generally follows the EBMUD ROW, and an alignment that strictly follows the ROW with only minor deviations. Consistent with the direction provided by the District, the tunnel alignment and shaft locations presented in this study follows the existing EBMUD ROW and stays within the ROW with minor exceptions (e.g., Holt). The horizontal alignment is dictated primarily by the shaft locations, with each reach between shafts being straight or for some reaches, containing minor or gentle curves to follow the existing ROW to the extent practicable. The proposed tunnel alignment is presented in a series of 18 sheets.

At Holt, the existing aqueducts and the ROW have an angle point with an approximately 45 degree deflection. The horizontal alignment for the proposed tunnel at the change the ROW from a NE-SW to E-W trending can be accommodated with either an angle point at the shaft or with a large radius curve, and both alternatives are practical. The conceptual design uses a curve with a 1,300-foot radius. A curve layout was used at this location primarily to avoid a large and complex shaft that would have been necessary to accommodate tunneling from the shaft in obtuse directions (not in-line with each other). A 1,300-foot radius curve can be easily accommodated and is suitable for construction with a tunnel boring machine (TBM). The main detriment to using a curve is that the tunnel alignment deviates from the existing ROW requiring the acquisition of additional surface and subsurface ROW. See the following sections on shaft locations and proposed ROW acquisition requirements for details.

4.3 Shaft Locations and Tunnel Reaches

The two end shafts and the Holt shaft are based on the aqueduct and ROW geometry. A shaft is located at the directional change in the alignment at Holt — although the tunnel is presently configured as a curve rather than an angle point to accommodate the change in direction, siting a shaft at this location allows for flexibility as the design develops. The spacing of the shafts is dictated by tunnel construction practicalities such as for muck haulage, ventilation, power, and access of personnel to the TBM; essentially optimizing construction efficiencies and schedule. These factors limit the practical distance for tunnel drives to approximately three miles. Using this as a guideline, approximately seven shafts are needed, and the spacing works well with one shaft between the east end of the proposed tunnel alignment and Holt, and three shafts between Holt and the west end of the proposed tunnel alignment.

Individual shafts are positioned to stay within the ROW where practical, avoid piles supporting the existing aqueducts, reduce impacts, and provide for construction support as presented previously.

The two end shafts are assumed to be exit shafts since the tunnel profile rises and is shallowest at the end points, and there is a preference for tunnels to be excavated up gradient. For the purposes of this conceptual design study, the five other shafts were assumed to be useful for either *entrance* or *exit* points for tunneling to allow for staging and contracting flexibility. Shaft locations are shown in detail in a **Figure 4-2** (7 sheets) and are summarized with pertinent information in **Table 4-1**.

Table 4-1 Proposed Construction Shaft Summary

Shaft	Location	Station(1)	ROW (ft.)	Aqueduct Position and Support	Function and Comments
1	East end near I-5	1840+75	160	• All three aqueducts buried • Aqueduct No. 1 on piles (1:12 batter)	• Exit shaft • Located west (downstream) of interconnect facility • Located between the aqueducts
2	Roberts Island – West of San Joaquin River by 1 mile	1990+00	160	• All three aqueducts buried • Aqueduct No. 1 on piles (1:12 batter)	• Entrance or Exit • Offset to south to avoid aqueduct relocations
3	Holt	2126+00	100	• All three aqueducts buried • Aqueduct No. 1 on piles (1:12 batter) • Transition to all three elevated and on piles at 2130+00	• Entrance or Exit • Realignment with curve to replace angle points
4	Middle of Jones Tract	2292+00	100	• All three aqueducts elevated and on piles	• Exit (difficult access for Entrance) • Offset south of aqueducts to avoid aqueduct relocations
5	West end of Jones Track at Middle River	2443+75	Uncertain – likely 66 with >100 at river crossing	• Aqueduct Nos. 1 and 2 elevated and on piles • Aqueduct 3 buried and not on piles	• Entrance or Exit • Offset north of aqueducts at ROW width transition
6	Orwood East	2578+50	Varies – 100 to 125	• All three aqueducts elevated and on piles	• Entrance or Exit • Offset south of aqueducts near angle point
7	West end at the Bixler Maintenance Yard	2715+70	N/A – shaft in EBMUD Bixler Maint. Yard	• All three aqueducts buried and not on piles	• Exit shaft • Located east (upstream) of interconnect facilities • Offset from aqueducts

Note:
(1) Stationing is the existing aqueduct stationing and is not adjusted for the revised tunnel alignment.

- **Shaft 1:** This shaft is situated immediately to the west/downstream of the interconnect facility. Because it is an exit shaft and there is a wide spacing between the aqueducts, it fits between the aqueducts and the Kinder Morgan pipeline without relocations. Space is provided to allow for the piping to connect to the existing aqueducts at 45 degree angles and for combining Aqueduct Nos. 1 and 2 before entering the shaft. No permanent land acquisition is needed.

  Access is relatively easy with the proximity to Interstate 5, and from Brookside Road and W March Lane. However, there may be sensitivities to construction and construction traffic in the residential neighborhood and near the school.

- **Shaft 2:** This shaft is situated on Roberts Island approximately equal distances from the entrance and the directional change at Holt. Because the ROW at this location is 160 feet wide, there is room to locate the shaft within the ROW. However this would require relocation of one or more of the aqueducts during construction which is not practical. All three (3) aqueducts are buried with Aqueduct Nos. 1 and 2 pile supported. Relocating Aqueduct 3 would not be beneficial since the remaining piles would still interfere with the shaft. Therefore, the shaft is located south of the aqueducts and will require permanent acquisition of land for the shaft and manhole, and the tunnel. Land in this area is agricultural.

  Access is moderately easy using rural roads from Highway 4 to the south and potentially the San Joaquin River and Burns Cutoff (slough connected to the river), along with rural roads. The existing rural roads will likely need to be upgraded for construction traffic. The site is also two miles from a railroad and less than a mile from port facilities on Rough and Ready Island to the southeast.

- **Shaft 3:** This is the site of the directional change in the existing aqueducts near Holt, and a horizontal curve (rather than an angle point) is assumed as discussed above. The shaft is situated at the east end of the curve so that tunneling out of the shaft can be straight in one direction which is to the east. At this location, the roads would not need relocation, and there would be no interference with the existing aqueducts. Although the choice of a curve and a shaft at this location is relatively free from construction complications, it will require the acquisition of several acres of land since the new alignment deviates from the existing ROW. This shaft as configured would be available for use as an entrance shaft for tunneling in both directions. This configuration allows the greatest flexibility for tunnel staging and contracting.

Access is moderately easy using rural roads from Highway 4 one half mile to the south and rural roads. The existing rural roads will likely need to be upgraded for construction traffic. Since the existing aqueducts are elevated to the west, access from that direction is complicated by the need to pass over or under the pipelines. The shaft is also 200 yards from a railroad to the south.

- **Shaft 4:** This shaft is situated on Jones Tract approximately three miles from the Holt shaft. Because the ROW at this location is only 66 feet wide and all three aqueducts are pile supported, it is impractical to locate the shaft within the existing ROW. Therefore, the shaft is situated outside the exiting ROW to the south and as close as possible to Aqueduct 2. An offset to the north would have complications with a ditch and the railroad tracks, and was therefore not used. Using an offset from the aqueducts avoids the need to relocate aqueducts, but requires the permanent acquisition of land for the shaft and manhole, and the tunnel.

  Jones Tract is a relatively isolated region of agricultural land, and the shaft is located in the middle of that area. Therefore, access is difficult since it is approximately three miles from Highway 4 without direct connection with paved roads although there are farm roads nearby. It is expected that the roads would need substantial upgrades to sustain construction traffic. Although the railroad is within 100 yards, it is on the other side of the elevated aqueducts making access difficult. Due to difficult access, it is assumed that this would be an exit shaft rather than an entrance shaft for tunneling.

- **Shaft 5:** This shaft is situated at the west side of Jones Tract adjacent to the Middle River. The ROW at this location increases to over 100 feet wide as the aqueducts change from elevated to trenched for the river crossing. A crucial factor is that Aqueduct Nos. 1 and 2 are elevated and on piles up to the river crossing, and that Aqueduct 3 is buried and not on piles within 1,000 feet of the river crossing. Shaft 5 is strategically located to the north of the existing aqueducts to take advantage of the angle and offset in the Aqueduct 3 alignment. No aqueduct relocations are needed. Note that West Bacon Island Road provides access to the construction site and it goes over the aqueducts at this location. A small permanent land acquisition will be necessary; however it appears from satellite images that this land is not developed.

  Jones Tract is a relatively isolated region of agricultural land, and the shaft is located on the western edge approximately three miles from Highway 4. Access is moderately difficult since it is without direct access from major roads. West

Bacon Island Road provides access, but would likely need to be upgraded for construction traffic. It may be possible to utilize the railroad or the Old River which are both within a few hundred yards.

- **Shaft 6:** This shaft is situated at Orwood East approximately 2.6 miles east of Bixler. This location is preferred over a site farther east because of a marina at the Old River. Additionally, the site chosen avoids interference with the road crossing over the existing aqueducts immediately to the west. In this area all three aqueducts are elevated and supported on piles, and the aqueducts and ROW go through a minor angle point. The piles do not allow siting the shaft at or near the aqueducts. Because of the angle point, the construction shaft can be located on the inside of the bend without requiring aqueduct relocations, and with only a small permanent land acquisition.

  Access is moderately easy using Orwood Road, and other rural roads from Highway 4 and Byron Highway to the south and west. Orwood Road is paved but may still require upgrade for construction traffic. It may also be possible to utilize the railroad which is within a couple hundred yards.

- **Shaft 7:** This shaft is situated in EBMUD's Bixler maintenance yard and immediately to the east/upstream of the interconnect facility. The shaft is offset from all three aqueducts. Space is provided to allow for the piping to connect to the existing aqueducts at a 45 degree angle and for combining Aqueduct Nos. 1 and 2 after exiting the shaft. The shaft is located east of the existing (and abandoned) pump building. No permanent land acquisition is needed.

  Access is relatively easy using Bixler and Orwood Roads to Highway 4 and Byron Highway to the south and west. Orwood Road and Bixler Roads are paved but may still require upgrade for construction traffic. It may also be possible to utilize the railroad which is within a couple hundred yards.

Based on these shaft locations, the tunnel is divided into six reaches as summarized in **Table 4-2**.

Table 4-2: Tunnel Reach Summary

Reach	Shafts	Length (feet)	Length (miles)	Comments
I	1-2	14,925	2.8	Goes beneath San Joaquin River
II	2-3	13,600	2.6	
III	3-4	16,250 (1)	3.1 (1)	Curve at east end (1,300 feet radius and 53 degrees) (1)
IV	4-5	15,175	2.9	
V	5-6	13,475	2.6	Woodward Island below Middle and Old Rivers Crosses path of proposed BDCP Tunnels
VI	6-7	13,720	2.6	
	Totals	**87,145 (1)**	**16.5 (1)**	

Note:
(1) The curve decreases the reach length by 350 feet relative to the existing aqueduct alignment and stationing.

4.4 Vertical Profile

The vertical profile for the proposed Delta Tunnel was determined considering the minimum depth along the alignment needed to provide for suitable long term stability of the tunnel and to avoid impacts to the existing aqueducts during tunnel construction. With this minimum as a base, the two additional factors of 1) tunnel operation and maintenance, and 2) tunnel construction, staging and contracting were evaluated to determine the tunnel profile. The following subsections describe the various factors used to determine the tunnel depth and profile.

4.4.1 Minimum Depth Criteria

The minimum depth of the proposed Delta Tunnel is based on situating the tunnel in stable ground for long term performance and avoiding settlement induced impacts to the existing pipelines during tunnel construction, with consideration of construction factors such as settlement and construction staging. The minimum depth uses the tunnel crown as a baseline with consideration of the following factors:

- **Liquefaction:** To reduce the potential for damage to occur during a seismic event, the tunnel needs to be positioned such that liquefaction and associated settlements do not impact the integrity of the tunnel and the fully encapsulated pipelines. Liquefaction potential and settlements were evaluated using the recent CPT data and soil liquefaction assessment software (CLiq) by EBMUD and

Gregg Drilling, which was reviewed and back checked by MWH using hand calculations as described above in Section 3.

Evaluations were based on PGA's of 0.2 g and 0.4 g, approximately corresponding to recurrence interval events of 100 and 500 years, respectively. For the 0.4 g evaluations, calculated ground surface settlements range from 3.0 to 13.25 inches. Settlements decrease with depth in an irregular random fashion corresponding to the different soil types present. In accordance with allowable strain calculations (see section 7.4 – Pipe Settlement and Distortions) a guideline of two to three inches of settlement was used to set the vertical position of the pipe. Due to the variability of the geology and potential discontinuous nature of liquefaction, it was assumed that the differential settlement was equal to the total settlement. For a settlement of 2 to 3 inches, the calculated depths typically range from 65 to 115 feet (20 to 35 m) below the ground surface (typically at -10 ft ms.). There is one exception at CPT-12 (east end of the proposed tunnel) in which the calculated settlement occurs at a depth of 130 feet (40 m), but the ground surface is higher resulting in approximately the same elevation. Based on these evaluations the tunnel invert was set at an elevation of -125 feet, placing the springline approximately at the 2- to 3-inch settlement position.

- **Tunnel Excavation in Stable Ground:** To facilitate tunnel excavation and reduce complications during tunneling, it is beneficial to locate the tunnel in dense stable ground, while avoiding loose and/or soft soils such as peat. Although it would be possible to excavate the tunnel through soft soils, tunnel excavation would require that ground improvement techniques be employed to stabilize the ground which would be costly. The tunnel vertical alignment is situated in the Holocene or Pleistocene deposits, in somewhat denser materials, avoiding the recent organic and unconsolidated soils.

- **Settlement of Piles and Aqueducts:** Tunnel construction is expected to result in some lost ground and there is an expected zone of settlement extending above the tunnel. Settlement estimates within this zone attenuate and are distributed over a wider zone of influence for higher elevations above the tunnel. For an evaluation of the lost ground and settlement see the Construction Considerations section of this TM.

  Piles support one or more of the aqueducts for the majority of the approximately 17 mile segment of the existing aqueducts to be replaced by the proposed Delta Tunnel. Although some reaches of the aqueducts are not pile supported, these are intermittent and relatively short. In general, depths of the pile tips reportedly range from 20 to 60 feet below the ground surface. The maximum reported pile tip depths were identified and presented previously and are depicted as the thick orange line on the Geologic Profile (TM-1: Preliminary Geological Characterization and **Figure 4-3** herein).

Settlement of the piles and resulting damage to the aqueducts is based on: 1) the distribution and attenuation of settlement resulting from ground loss, 2) the behavior of existing piles and aqueducts, and 3) the structural tenacity of the pipelines. There are many variables and unknowns associated with these factors. See the subsection titled Ground Loss and Settlement for additional information. Based on existing information and at this stage of design development it would be impractical to develop a definitive assessment of settlement effects. Regardless, using our understanding of ground behavior, a buffer of one to two tunnel diameters between the piles and the tunnel was determined to be a reasonable estimate for planning purposes and this study. The proposed Delta Tunnel shown is designed to be at least two diameters (42 feet) below the reported pile tips, and the top of the tunnel band is at least one diameter (21 feet) below that.

In summary**,** the tunnel profile indicated herein is approximate and to account for uncertainties and future design development, a tunnel band is shown within which the final vertical alignment of the proposed Delta Tunnel is expected to be situated. This band accounts for several factors including: 1) system hydraulics (not included with this study), 2) sloping of each tunnel reach for construction and pipe drainage, and 3) optimization of the vertical alignment or profile of the project based on the results of future geotechnical investigations and analysis.

4.4.2 Pipeline Operational Considerations

For operation, inspection, maintenance and repair (O&M) of the pipeline, high points and low points in the profile must be accessible and occur only at manholes. Placing a manhole at the high points allows for blow-off assemblies to be located at the high points. With low points at manholes, sediment trapped at low points can be relatively easily accessed for removal, and the pipelines can be completely drained for inspection, maintenance, and repair. Although the pipeline shown is flat, each reach will actually be sloped — and the tunnel band shown is included, in part, to allow for this requirement. For a 20 foot elevation difference in a 3-mile long reach between shafts, the slope would be approximately 0.125 percent.

4.4.3 Tunnel Construction and Staging

Tunnel excavation is facilitated by tunneling in the uphill direction where possible, and limiting the depth to within the technology limits for TBMs. These factors affect the depth and profile of the tunnel, and are discussed in detail in Section 5 – Tunnel Conceptual Design and Construction.

4.4.4 Costs

In general, the cost of tunnels increases with depth due to higher costs for the deeper shaft construction, difficulty with pressures and ground control, and lower efficiencies such as for muck removal and materials delivery. To reduce costs, shallower shafts and tunnels are beneficial.

4.4.5 Depth and Profile Summary

The deepest of the depth criteria factors presented above, ground and tunnel differential movement, within stable ground, and avoidance of existing piles, was used to set the minimum tunnel depth (maximum tunnel elevation). The controlling criterion is generally placement of the tunnel such that differential movements are within acceptable limits. In a few locations, one or both of the other two criteria result in a similar minimum tunnel depth.

Several different scenarios can be used to stage tunnel construction, with variations in the number of construction contracts, which shafts are entrance or exit points, and the direction of tunneling. Similarly, incorporation of O&M requirements (high points, low points, and slopes) can be accomplished in several different profile configurations. Note that the construction and O&M requirements are complimentary, and both can be accommodated with the same tunnel profile. However, there are multiple tunnel vertical profiles that could be used to fulfill these requirements. Because of the limited geotechnical investigations conducted to date, the level of design development (conceptual), and likely variations in the approach to tunnel contracting and staging, it would be premature to develop a single tunnel profile. Therefore, to cover the range of potential profiles, the vertical alignment is represented by an envelope or band is presented as the tunnel profile. The profile will likely be optimized in future studies based on additional geotechnical investigations while allowing for a range of staging options. The tunnel can be positioned anywhere within this band allowing for flexibility in construction, staging, and contracting of the tunnel construction. The profile band is presented in **Table 4-3** and on **Figure 4-3** (2 sheets). Within this band, a single tunnel profile is shown representing an average position for the tunnel with an invert elevation of -125 feet for reaches I through V, and rising to elevation –80 feet at the west end of reach VI. This tunnel profile is used in this study as the basis of the OPCC. Note that the shafts will need to be deeper than the tunnel invert, as discussed in Section 6 herein.

Table 4-3: Tunnel Band / Profile Summary (1)

Shaft	Location	Station	Tunnel Elevation (feet)		Ground Surface Elevation (feet)(3)	Approximate Depth to Tunnel Invert (feet) (4)	
			Maximum Crown	Minimum Invert (2)		Minimum	Maximum
1	East end near I-5	1840+75	-65	-136	4	90	140
2	Roberts Island	1990+00	-84	-136	-3	102	133
3	Holt	2126+00	-84	-136	2	107	138
4	Middle of Jones Tract	2292+00	-84	-136	-8	97	128
5	West end of Jones Tract at Middle River	2443+75	-89	-141	-8	102	133
6	Orwood East	2578+50	-89	-141	-10	100	131
7	West end at Bixler Maintenance Yard	2715+70	-48	-89	15	84	104

Notes:
(1) See **Table 6-1** for shaft depths.
(2) Tunnel band is greater than tunnel diameter (21') to accommodate for geologic uncertainties and constructability considerations, e.g., slopes between shafts for construction and O&M factors.
(3) This is the existing ground surface elevation. The ground surface will be raised during construction.
(4) Does not include allowance for buildup of ground surface for flood protection.

4.5 Right of Way, Easements and Property Acquisitions

A key consideration in setting the tunnel horizontal alignment was to utilize the existing aqueduct ROW and existing EBMUD land to the extent practicable. Permanent land acquisition will be necessary at several locations since the shafts and manholes installed in the shafts are outside existing EBMUD ROW. Land acquisition will be necessary not only for the shafts and manholes, but also to transition the tunnel from these shafts to the existing ROW.

Shaft and tunnel construction will require staging areas at each shaft location. The staging area includes the shaft with additional space for construction support and laydown area. The additional room is needed for one or two cranes, and site access roads, and room for office trailers, worker facilities, materials laydown, temporary muck storage, and miscellaneous work areas. As a guideline, EBMUD should plan on acquiring temporary construction easements of approximately three to five acres at each shaft location. If this is not practical a construction site as small as one acre can be used, but with a reduction in construction efficiency. The minimum work areas at each shaft are shown in **Figure 4-2 (a - g)** and the pertinent data for each is summarized in **Table 4-4**. For planning and budgeting purposes MWH recommends that five areas be assumed for each work site.

Additionally for each contract, a construction site area for offices, laydown of materials, equipment, parking, and maintenance is needed. Ideally these areas would be adjacent to the main shaft construction site, but remote areas nearby can be used. For land area estimates, it is assumed that three contracts would be running simultaneously with five acres needed for each construction site area for each contract. In addition, each construction contract would need to arrange for manufacture and storage of precast concrete segments. The precast segment plants would likely be located offsite and this operation may be established at an existing precast concrete plant or be set-up as a standalone temporary plant. Due to the size of the project, it is anticipated that the precast plant will be established in the region rather than using an existing plant at a more distant location in California and transporting the segments over great distances.

Table 4-4 summarizes approximate land needs, property acquisition requirements, as currently envisioned for the project. See section 11 for the costs of land acquisition.

Table 4-4: Land Requirements at Shafts

Location	Description	Permanent Land Acquisition (acres)	Construction Easement (acres)	Comments
Base Areas	Main area for Contractor	None	3 contracts at 5 acres each	Assumed to be in vicinity of project, but not necessarily at any one shaft.
Segment Plants	Concrete Segment Manufacturing	None	5 to 10 (1) (offsite)	Several likely needed (2). Could be any industrial area in the northern California.
Shaft 1	East end near I-5	None	None	Tight construction site with nearby school and residences, and potentially difficult road access.
Shaft 2	Roberts Island	1	3.5 to 5.0	Shaft in-line with aqueducts. Requires temporary relocation of Aqueduct Nos. 2 and 3.
Shaft 3	Holt	4.5	3.5 to 5.0	Some overlap of permanent and construction areas. Lower Jones Road crosses alignment.
Shaft 4	Middle of Jones Tract	1	3.5 to 5.0	Shaft slightly offset from existing aqueducts.
Shaft 5	West end of Jones Tract at Middle River	1.5	3.5 to 5.0	Shaft offset from aqueducts but uses geometry to maintain tunnel mostly in existing RoW.
Shaft 6	Orwood East	1	3.5 to 5.0	Shaft offset from aqueducts but uses geometry to maintain tunnel mostly in existing RoW.
Shaft 7	West end at Bixler Maintenance Yard	None	None	Located in EBMUD's Bixler Maintenance Yard with a large tract to the south for staging.
Totals		**9**	**32.5 to 40**	**There is substantial overlap of the areas.**

Notes: (1) Not included in area total.
(2) Multiple plants may be needed depending on whether contractors all procure the precast segments from the same supplier.

5.0 TUNNEL CONCEPTUAL DESIGN AND CONSTRUCTION

Tunnel construction considerations focus on several factors: 1) depth and profile to facilitate tunnel excavation, and 2) tunnel cross section to accommodate excavation and support methods, and final piping configuration.

5.1 Tunnel Staging, Depth and Profile Considerations

Practical tunnel construction involves tunneling in the uphill direction where possible, and limiting the depth to within the technology limits for TBMs as discussed below:

- **Tunnel Uphill**: Tunnel excavation for each tunnel reach is preferable in the uphill direction for water control, muck removal, and safety of the workers in the event of large water inflow. With consideration of the very long and relatively low gradient of the tunnel, a slope of 0.125 percent is used as the minimum desirable grade. The direction of tunneling, and therefore the vertical profile of each reach, is dependent on which shafts are used for launching the TBMs (entrances) and which are used for reception or exits. In some instances, the shaft and tunnel depths may be deeper than the minimum to achieve the required minimum slope for the tunnel and to tunnel in an uphill direction.

- **Depth for TBM Operation**: The proposed Delta Tunnel is expected to be excavated with a pressurized face or closed face TBM, which may be either slurry (STBM) or an earth pressure balance (EPB) machine (Appendix A). With the anticipated maximum tunnel depth of approximately 125 to 150 feet to the tunnel invert the tunnel depth is within the practical range of both pressurized face TBMs, slurry and EPB machines.

Also see Tunnel Excavation Methods in Section 9 – Construction Considerations.

5.2 Tunnel Cross Section

In the development of a conceptual design for the proposed Delta Tunnel, a two-pass tunnel excavation method is considered to be the favored approach in order to maintain the underground opening and install the pipelines. In a two-pass approach, the tunnel is excavated with installation of initial support, the precast segmental lining system. After completion of the excavation and initial lining system, the carrier pipes and backfilling of the annulus between the carrier pipes and segmental lining would be performed. A two-pass system is necessary to accommodate two pipes in a single tunnel and because of the high pressures in the pipelines.

The precast concrete segmental lining would be bolted or doweled together into a ring with gasketed joints. Design is based on a compression ring, which must be retained during tunnel operation. As an alternative to a two-pass system, a one-pass system was considered. However, the internal design pressure is up to 300 psi (692 feet of water head), which would exceed the external pressure from ground and water loads, thereby placing the lining in tension. Tension in the lining would result in structural problems and would not be watertight. Therefore, a secondary or final lining, utilizing carrier pipes inside the tunnel, are designed to transmit the water and withstand the high internal water pressure.

The use of two carrier pipes in the tunnel is a practical and common approach to conveyance systems, and in this instance, required to maintain separation of the water sources. The tunnel cross section consists of two 87-inch I.D. permanent carrier pipes installed within the segmentally lined tunnel. A clearance of 18 inches is provided for separation of the pipes. Additionally, 18 inches is provided between the pipes and the initial support/lining system on each side which allows for a minimum clearance of 12 inches and a pipe tolerance of 6 inches to correct for alignment and grade variations. The initial tunnel support system, the precast segmental liner, is expected to be approximately 10 to 12 inches thick which results in a tunnel outside diameter (O.D.) of approximately 21 feet as shown in **Figure 5-1**.

5.3 Tunnel Initial Support

A segmental concrete lining installed behind a TBM is envisioned to be the initial support system for the tunnel. Design of the segmental liner incorporates evaluation of ground and water loads on the completed ring, thrust from the TBM, and handling loads. TBM segments typically vary from 10 to 12 inches thick for this tunnel diameter. Theoretical calculations based on 100-feet of overburden and 90 feet hydrostatic pressure were performed to assess the required segment size. They indicate that segments in this range could generate the required structural strength. Reinforcing is included in the segments for structural capacity, to handling stresses, and to control cracking. Both fiber-reinforced and steel rebar cage designs are used in practice. For many segment designs for tunnels of a similar diameter, current practice in the industry has been to use fiber reinforcing.

Several different segment geometries and configurations are possible and have previously been used on similar sized projects: Variations include, trapezoidal, rhomboidal, and tapered, segments; with some using universal segments. A likely configuration for the proposed Delta Tunnel is five main segments plus a key near the crown. Each ring of segments is rotated left or right from the previous ring to offset the joints. Bolts and/or dowels would connect segments across the joints.

Design of the segments, the initial support system, is the responsibility of the contractor(s) as the design can vary based on its means and methods to be employed on a particular project. The design engineer prepares the design of the initial support system for determining project cost and to establish the minimum requirements to be specified. Design factors include: 1) ground, water, and handling loads, 2) the TBM type, thrust loads, and jack positions, 3) joint design including gaskets and bolts, and 4) geometry/configuration of the segments in each ring for both straight tunnel reaches and curves.

The concrete segments are commonly manufactured at precast plant in the vicinity of the project, but not necessarily onsite, such as within the Stockton and Sacramento area. These precast plants could even be located anywhere in the northern California area, but with an increase in transportation costs. Existing concrete precast plants could be used, or project-specific plants and yards could be developed. Each contractor is responsible for design and fabrication of their own segments. However, with several tunnel contracts for the Delta Tunnel Project, one supplier may ultimately supply segments for all contracts, thus providing schedule and cost benefits to the overall program.

5.4 Ground Loss and Settlement

Ground loss and ground settlement commonly occurs as a result of tunnel excavation. A preliminary evaluation of ground loss at the tunnel crown was estimated for this study based on 1 percent face loss, 1 inch overcut of the cutter beyond the shield, and 1 inch ground loss at the end of the shield as the ground moves onto the segments. Annulus grouting is performed at the tail shield between the ground and the liner to replace some ground and reduce settlements, however grouting is not completely effective in preventing ground loss. Based on these assumptions and preliminary calculations, the total ground loss is estimated to be 4 percent of the face which equates to 8 inches across the tunnel at the crown. With careful tunnel excavation, primarily the diligent use of pressurized slurry outside the TBM and immediate complete annulus grouting outside of the concrete segments, these ground losses can be substantially reduced or eliminated, resulting in a combined ground loss of approximately 1 percent. However, these practices are dependent on the contractor’s means and methods, and cannot be relied upon for each contract and at every location along all tunnel reaches. Therefore a conservative estimate of 4 percent is used as the basis for comparison in this study.

Note that this lost ground is for routine tunneling and does not include complicating factors such as tunnel curves and work stoppages, nor does it include excessive ground loss such as from over excavation or loss of face pressure. These additional factors can result in substantial ground loss several times the magnitude of ground loss in controlled conditions. Ground settlement will need to be evaluated in detail in future design phases based on actual TBM type, tunneling methods, and details of TBM operation (face pressure), which affect the actual settlement experienced.

Some of these factors can be controlled with a tight design and careful construction, but other factors are unavoidable. Therefore, actual ground loss and settlement could be substantially different from these preliminary estimates.

Several factors are in play to reduce the magnitude of settlement and effects of the settlement experienced at the ground surface and at the pile tips. These include: 1) a settlement trough that becomes wider above the tunnel, thereby distributing lost ground over a wider area and reducing settlement at each location, 2) bulking of soil material to a less-dense state which attenuates ground loss, and 3) a lag factor in which the settlement occurs gradually behind the TBM as the tunnel advances, similar to a wave traveling behind the tunnel face, and eliminates abrupt ground movements. Finally, the effects of settlement vary with the structures being impacted and the depths of the foundations for those structures. Therefore, MWH recommends that ground movements, and the effects of those movements on structures be evaluated in future design development. These evaluations should include not only settlement in normal operating conditions, but also unexpected conditions, which may result in localized large settlements and even sinkholes.

5.5 Tunnel Backfill

After installation of the carrier pipes, the tunnel (space outside the pipes and inside the segmental concrete lining) is designed to be backfilled to fill the void and provide uniform support for the pipes. Cellular concrete is almost universally the material of choice due to its flowability, durability, and low cost. The unconfined strength is commonly between 150 and 500 psi, although the properties can vary outside this range as needed to meet project requirements.

The carrier pipes will need to be securely supported and anchored in the tunnel during backfilling to avoid movement and floatation during the backfilling operation. Multiple lifts of backfill are often used to reduce floatation problems and to control the temperature rise from the heat of hydration of the cement. The backfill is commonly introduced through ports in the carrier pipe. Backfill placement is tracked and verified with several systems including return flows, truthing pipes (free air flow is blocked by the backfill), inferred sensing, and verification of the volume placed. MWH recommends that the cellular concrete backfill properties and installation procedures be determined and specified during detailed design.

After backfilling, voids can be present at the crown due to backfill placement methods, settlement and shrinkage, and immediately outside the carrier pipe due temperature changes and backfill shrinkage. Contact grouting is used to fill the crown void which often remains due to settlement and shrinkage of the backfill. Similarly, skin grouting is used to provide intimate contact around the perimeter of the pipe and fill the small gap remaining after backfilling and curing. Both of these grouting programs are conducted from ports in the carrier pipes. Grouting after backfilling is not always necessary, and the need and specifics of these programs should be determined in subsequent design phases.

6.0 SHAFT DESIGN AND CONSTRUCTION

Shafts are necessary for tunnel construction and to install permanent manholes for pipeline O&M. The size of the shafts are dictated by construction requirements, primarily tunnel and TBM diameter and the need to move trains through the shafts and efficiently access them for muck removal. Shaft sizing and design is commonly the responsibility of the contractor. The following information is provided to support conceptual design. Some shafts will be launch or entrance shafts used to insert the TBM and to support tunneling such as muck removal, personnel and materials access, utilities and future staging for carrier pipe installation. Exit or reception shafts are used to remove the TBM and can also be used to stage pipe installation and backfilling the tunnel outside the pipes. Based on requirements for similar projects, shafts can be circular or rectangular in plan. For the entrance shafts, rectangular shafts are assume and they are expected to have internal clear dimensions of 80 feet by 32 feet, while exit shafts are expected to be circular and at least 32 feet in diameter.

6.1 Support and Lining

Shaft construction presents a challenge due to the depths required and the presence of granular saturated alluvium. Several methods were considered in evaluating shaft design and construction including conventional structural slurry walls, arched/cellular structural slurry walls, tangent pile walls, ground freezing, and jet grouting. Other methods that could be considered but are not applicable include sunken caissons, conventional ring beams and lagging, and sheet piles. MWH recommends that arched/cellular slurry walls be used as the basis for this conceptual design due to the system's applicability to the difficult ground conditions for these shafts and its successful use on other recent projects. The system of arched/cellular structural slurry walls is a relatively new concept that has been used successfully on several projects. The concept is to construct the slurry walls as a series of arches or intersecting circular cells with internal slurry walls as internal bracing as shown in **Figures 6-1 and 6-2.** Cutouts at the bottom of the internal slurry walls are used to allow for insertion of the TBM and passage of tunnel support trains.

The base for the shaft is a reinforced concrete slab pinned to the slurry walls and poured with tremie methods. The slab is structural and needs to be several feet thick to provide the necessary restraint to uplift. The base slab is commonly set below tunnel elevation by several feet to facilitate tunneling activities. The slurry walls extend some distance below the bottom of the base slab to reduce uplift and provide passive resistance from lateral ground loads during construction when the interior is excavated but before the base slab is in place. Extension of the slurry walls also improves ground stability and increases the seepage path for groundwater moving up into the bottom of the shaft. Actual shaft design details are commonly the responsibility of the contractor. For planning purposes it is assumed that the base slab is two feet below the tunnel invert, the slab is eight feet thick, and the slurry walls extend 30 feet below the bottom of the slab which is 40 feet below tunnel invert.

6.2 Earthwork

The ground surface at five of the seven shafts is below the assumed flood elevation, and earthwork will be required to construct an elevated platform for flood protection, both for safety during construction and to provide for future access at each permanent manhole. The permanent pad elevation should be determined during subsequent design phases. For the purposes of shaft construction, the Contractor will need to determine the design flood level which may be either higher or lower than the permanent pad. The pad elevation will likely be based on the 100 or 200 year event plus an appropriate freeboard. Additionally, each shaft will require a waterproof extension several feet above the pad for additional freeboard. For a dry staging area during a flood, a preliminary minimum area of 25,000 square feet estimated, although the Contractor may choose to construct a larger area to facilitate construction, especially at entrance shafts.

6.3 Shaft Depths

Shaft invert depths are dictated by the tunnel profile and the top of the working pads which are necessary for flood protection. **Table 6-1** presents the range of shaft depths based on the tunnel profile band, and approximate ground surface elevations to mitigate against flooding. The table also presents the required depths of excavation inside the shafts which are estimated to be 10 feet below tunnel invert, and the total depths of the slurry walls which are estimated to be 18 feet below tunnel invert.

Table 6-1: Shaft Depth Summary

Shaft	Location	Range of Tunnel Invert Elevations[1] (feet)		Current Ground Surface Elevation (feet)	Raised Ground Surface [2] (feet)	Approximate Depth to Tunnel Invert [2] (feet)		Maximum [3] Excavation Depth (feet)	Maximum [3, 4] Slurry Wall Depth (feet)
		Highest	Lowest			Minimum	Maximum		
1	East end near I-5	-86	-136	4	+3	93	143	153	183
2	Roberts Island	-105	-136	-3	+10	112	143	153	183
3	Holt	-105	-136	2	+5	112	143	153	183
4	Middle of Jones Tract	-105	-136	-8	+15	112	143	153	183
5	West end of Jones Tract at Middle River	-110	-141	-8	+15	117	148	158	188
6	Orwood East	-110	-141	-10	+17	117	148	158	188
7	West end at the Bixler Maintenance Yard	-69	-89	15	-	84	104	114	144

Notes:

(1) Based on tunnel band.

(2) Based on elevated platform elevation of +7' msl to account for a design flood water level at elevation of +4 msl and 3 feet of freeboard (except for shaft 7 which is at elev. + 15' msl).

(3) Based on lowest tunnel invert within tunnel band.

(4) Assumes slurry walls are 30 feet below bottom of excavation which is 40 feet below tunnel invert.

6.4 Permanent Access and Manholes

To provide access for inspection, maintenance and repairs, a manhole is required at each shaft location. The manholes are required to be suitable for access by personnel and small equipment up to approximately four feet across. It is expected that the access manholes would be used infrequently for inspections during operation. As such it is assumed that it is more cost effective to use temporary equipment brought in for each entry use, rather than have dedicated equipment such as hoists, pumps, lighting, and ventilation installed permanently.

The dual carrier pipe configuration within the proposed Delta tunnel results in an unusual and moderately complex situation for access. The concept for access consists of a five foot I.D. vertical manhole with a 16 foot square chamber at the bottom encompassing both pipes as shown in **Figure 6-3**. Each pipe has a 36 inch access manway with a blind flange. Personnel and equipment can be lowered down the shaft and stage work on the platform at the top of the pipes. It is expected that groundwater will slowly seep into the accesses and the chamber thereby filling the manholes with water over time, and requiring the accesses to be dewatered for each use. Although it would be possible to design the accesses with tight water controls, there would still be some seepage and maintaining an open access would require dedicated pumping systems.

Most of the accesses are in semi-remote locations that are accessible to the public and without security. As a hindrance to unauthorized access and to deter vandalism a two stage system designed to gain access to the manholes. The manhole has a locking cover and is housed inside a vault with a removable concrete panel. This system also provides a measure of safety to prevent falls down the manhole in the event that the lid at the ground surface is removed.

7.0 PIPE, PIPING AND VALVES

7.1 Existing Aqueduct System

This section is based on information presented in documents provide by the District, including the Alternative Study (EBMUD, 2007), contract and construction drawings, and technical papers for the interconnect facilities (Cain, Tong, and Terentieff, 2009) and (McLeod, 2009), and personnel communications. The three existing aqueducts have a combined maximum gravity fed capacity of 199 MGD and maximum pumped capacity of 326 MGD. The gravity flow is distributed between the three aqueducts as follows:

- Aqueduct No. 1: 65-inch diameter 41 MGD
- Aqueduct No. 2: 67-inch diameter 53 MGD
- Aqueduct No. 3: 87-inch diameter 105 MGD

The three aqueduct system is normally operated to separate the flows from the District's two primary water sources, the Mokelumne River through Pardee Reservoir and the Sacramento River through the Folsom South Canal (Comanche Pumping Plant). Water from these two sources requires two different water treatment systems. Therefore, the District maintains two essentially independent systems, with Aqueduct Nos. 1 and 2 handling flows from the Folsom South Canal (Comanche Pumping Plant), and Aqueduct 3 from Pardee Reservoir.

Due to their design and age, Aqueduct Nos. 1 and 2 are more vulnerable to damage than Aqueduct 3, especially through the Delta region. In the event that Aqueduct Nos. 1 and/or 2 are damaged, two interconnection facilities allow for an increase in system capacity by transferring flows to Aqueduct 3. The interconnection facilities are located at either end of the Delta region at Stockton and Holt, and are shown on **Figure 4-1** (Plan Set) and **Figure 4-2** (Close views of shafts 1 and 7). With the Aqueduct Nos. 1 and 2 out of service through the Delta region, the interconnection facilities allow for a system capacity of 162 MGD (250 MGD when pumped) in comparison to Aqueduct 3 by itself of only 105 MGD. The interconnections can also be used for O&M, upgrades and repairs to Aqueduct Nos. 1 and 2.

7.1.1 Operational

Based on information provided by the District, design of the piping for the tunnels needs to maintain or improve upon the existing system operational parameters consisting of the following:

1. **Design Pressure:** 300 psi
2. **Total Combined Flow:**
   - Gravity: 199 MGD
   - Pumped: 326 MGD
3. **Flow Separation:** Flows from Aqueduct Nos. 1 and 2 combined are required to be separate from Aqueduct 3 flows.
4. **Flows:**
   - Aqueduct 1 and 2 combined flow: 94 MGD with gravity flow
   - Aqueduct 3 flow: 105 MGD with gravity flow
5. **Interconnections:** The existing interconnection facilities need to remain operational with the new tunnel to provide for operational flexibility.

7.2 Alternatives Pipe Configurations in Tunnel

Several alternative pipe configurations are possible for the tunnel ranging from a single large carrier pipe to two or three carrier pipes within the tunnel excavation. Due to the requirement to maintain separation of flows from Aqueducts 1 and 2 combined, and Aqueduct 3, a two pipe arrangement is the most likely configuration. For comparison, the following alternative configurations could be considered in future design evaluations:

- **Three Pipes:** Continuation of the existing Aqueduct sizes. The excavated tunnel would be approximately 18 feet in diameter (OD).
- **Two Pipes:** Each pipe 87 inches I.D. The excavated tunnel would be approximately 21 feet in diameter.
- **One Pipe:** Combining all flows into a single pipe approximately 111 inch I.D. The excavated tunnel would be approximately 14 feet in diameter.

The above tunnel excavated diameters are based on separations of 12 to 18 inches between individual pipes and the pipes from the tunnel initial support system. The use of three pipes is a possible alternative to more efficiently use the cross sectional area within the tunnel, and with a tunnel diameter of 18 feet rather than 21 feet. However, installation of three pipes within the tunnel results in higher hydraulic friction losses, additional costs for the pipe material, more welding of joints, and a more complex support system for the pipe during placement of the backfill to encase the pipes. Therefore, there does not appear to be a substantial benefit to using three pipes in the tunnel rather than two pipes. However, operational considerations, flexibility, and redundancy for the water system may have benefits to the District. For the proposed base case configuration, two 87 inch I.D. pipes, this configuration provides adequate capacity for the existing Aqueducts with one pipe dedicated to Aqueduct 3 flow, and one pipe dedicated to the combined flow of Aqueduct Nos. 1 and 2. See previously presented **Figure 5-1**.

7.3 Steel Pipe Design

A preliminary evaluation of the steel pipe was conducted to determine approximate pipe thickness. These evaluations are based on the pipes being installed in the tunnel after excavation and support and with the tunnel backfilled with cellular concrete. Calculations were performed for internal loading, external loading (buckling) and handling. Results show that a pipe wall thickness of approximately 0.625 inches is needed for 42 ksi steel. For the conditions evaluated, internal pressure was the governing condition for pipe wall thickness. The required thickness may range from 0.5- to 0.75-inch with different steel strengths, design criteria and loading conditions. The following summarizes these evaluations.

7.3.1 Basis of Design

Steel pipe design for proposed Delta Tunnel was preliminarily designed with consideration of the following conditions:

- Twin Pipes: 87 inch I.D including ¾ inch CLM resulting in a steel I.D of 88.5 inches.
- Single Pipe: 111 inch I.D including ¾ inch DLM resulting in a steel I.D. of 112.5 inches.
- Internal water pressure: 300 psi.
- Groundwater (external) pressure at the invert: 120 feet corresponding to 52 psi
- Vacuum pressure: 14.7 psi.
- Steel type: 60 ksi ultimate/42 ksi yield.
- Allowable stress of 1/2 to 2/3 of yield strength.
- No load sharing between the steel pipe and the surrounding backfill.

7.3.2 Internal Loading

The required thickness of the steel plate was determined based on the lower end of the allowable range. Based on this calculation and the above bases, the required thickness was determined to be 0.625 inch for the 87 inch pipes and .875 inch for the 111 inch pipe. The steel thickness may be reduced with the use of higher strength steel and/or calculations incorporating load sharing with the backfill.

7.3.3 External Buckling

Critical buckling pressure was estimated using published graphs based on Amsultz and Jacobsen approaches. Critical buckling pressure is a function of steel thickness, pipe radius, gap size, and steel type. Critical buckling pressure was estimated based on the available graphs for 38 ksi steel (no graphs were available for 42 ksi steel) and the following assumptions:

- Steel thickness equal to 0.625-inch as determined for internal pressure
- D/t =140
- Gap between steel and surrounding backfill concrete due to shrinkage and temperature differential

The critical buckling pressure was estimated as 200 psi which results in a factor of safety of approximately 3 (using 38 ksi steel). The factor of safety would be greater using steel with 42 ksi strength. Note however that there could be situations during construction which present a buckling risk on the pipe including backfilling and grouting, and external flooding. These conditions will need to be evaluated by the contractor as part of his means and methods.

7.3.4 Handling

Pipe thickness for handling and construction requirements was evaluated using the following AWWA criteria for loading and unloading, transportation, and lifting:

- t = (D+20)/400
- t = D/240 (mortar lined)

Based on these criteria the required pipe wall thickness was determined to be 0.29 inch. Therefore handling is not the governing criterion.

7.3.5 Summary

On the basis of the results of analyses for different load cases, corresponding required thicknesses have been calculated. In accordance with the results the required thickness for internal loading, external loading, and handling requirements indicate that internal water pressure is the governing factor for the pipe wall thickness design. Based on the results for 42 ksi steel, a carrier pipe with a 0.625-inch thickness meets the design and construction requirements. The required pipe thickness varies in accordance with the steel strength used for design.

7.4 Pipe Settlement and Distortions

Ground movements, primarily from liquefaction, are expected to impart deformations onto the pipelines in the tunnel. Evaluation of the interaction of the tunnel and interior pipelines with the ground is complex. A prime consideration is the variation of the ground conditions which result in differential movements as the tunnel and pipelines traverses different geologic strata. Evaluation of the conditions ad effects commonly utilizes complex three-dimensional finite element (or finite difference) computer programs. Such a complex model is beyond the scope for this conceptual evaluation, and therefore, a simplified method was used. To evaluate the ability of the pipelines to accommodate settlement and differential settlement the following document the ASCE Guidelines for the Design of Buried Steel Pipe (2001) was used. Appendix A of the referenced document presents longitudinal strain limits due to ground movements from several sources including earthquakes and landslides. Results are as follows:

- **Operable Limits** (Based on gross section yielding of the pipe cross section):
  - Tension strain: 2%
  - Compression strain: 0.33%
- **Pressure Integrity Limits** (Based on significant pipeline distortion in which repair or replacement is necessary)**:**
  - Tension strain: 4%
  - Compression: 1.25%

Due to the critical nature of the pipelines and the inaccessibility for repairs/replacement, the Operable Limits were used as the basis for design, with 0.33 percent as the allowable strain.

The strain experienced by the pipelines is a function of the actual distortion (differential settlement), pipe diameter, and length over which the distortion occurs. A calculation was made based on an offset in the pipeline over a given length assuming a double (reverse) curve configuration such that the ends remained parallel but not in line. Using an allowable strain of 0.33%, the allowable distortions were calculated to be:

- Length of 31 ft (4 pipe diameters and 1.5 tunnel diameters): 2.6 inches.
- Length of 42 ft (6.5 pipe diameters and 2 tunnel diameters): 4.8 inches.
- Length of 100 feet: (5 tunnel diameters): 27 inches.

These allowable distortions were matched with the expected liquefaction settlements to determine the tunnel depth as presented above in Section 4.4 – Vertical Profile.

7.5 Piping Configuration

7.5.1 End Shaft Piping and Access

The piping configuration at shafts at either end of the tunnel need to fulfill the following criteria:

1. Combine Aqueduct flows,
2. Provide for continued operation of the interconnect facilities,
3. Transmit the flows from near the ground surface down the shaft to the tunnel, and
4. Provide for access of personnel and equipment to the shafts and tunnel.

To fulfill the above operational criteria, tunnel shafts 1 and 7 are located between the interconnect facilities. To avoid disruption of service or relocating the aqueducts, the construction shafts are offset from the pipelines as described below. Due to this offset, laterals are needed to join the Aqueducts with the shaft piping; and for hydraulic efficiency, the laterals are designed to be at 45 degrees with curved radius bends.

The tunnel piping is designed to work independently of the interconnection piping and to allow full operation of the interconnection facilities. The primary purpose of the interconnect facilities is to improve system capacity in the event of damage or failure to Aqueduct Nos. 1 or 2 through the Delta. The interconnection valves and piping can also be used to help divert flows to the carrier pipes in the proposed Delta Tunnel at the end of construction.

With construction of the proposed Delta Tunnel, the risk to the existing aqueducts through the Delta would essentially be mitigated, and the primary function of the interconnection facilities is negated. Therefore, the District may consider decommissioning the interconnection facilities after tunnel construction. However, the interconnection facilities may still serve beneficial purposes such as allowing for operational flexibility especially for inspection, maintenance and repairs. Depending on design and operational factors, it may be beneficial to incorporate the tunnel piping and the interconnection facilities into a common piping and valve structure. MWH recommends that future design development address the tunnel piping and interconnection facilities in light of the overall Aqueduct system requirements.

Access of personnel and equipment is provided at shafts 1 and 7 with a 5-foot diameter steel riser extending above the twin 87 inch steel pipes a shown in **Figure 7-1**. The top of the vertical pipe sections transitions to horizontal in a large radius curve for hydraulic efficiency, with the riser extending vertically from the bend. The bottom of the vertical pipe sections transitions to horizontal with an abrupt 90 degree angle point. Although the angle point is not as hydraulically efficient as a large radius bend, it is used to provide a horizontal surface as a landing for personnel and equipment lowered down the vertical pipe. The two 87 inch pipes are anchored to the shaft wall and encased in concrete to provide confinement and protection from damage.

The flows from Aqueduct Nos. 1 and 2 are combined or split with a simple wye connection with reducer transitions from the existing 65 and 67 inch diameter aqueducts to the new 87 inch pipes. No additional valves are included in the design since the existing interconnection facilities have the ability to shut off and reroute flows in each of the three Aqueducts. The piping configurations at shafts 1 and 7 are different from each other and are illustrated in **Figures 7-2 and 7-3**, respectively.

7.6 Corrosion Protection

Corrosion protection for steel water pipes in tunnels is commonly provided by passive systems with monitoring and possible use of cathodic systems. A common design is to use interior cement mortar lining and exterior polyurethane and/or cement mortar coating. The joints must be welded completely from the inside, which is commonly a full penetration butt weld with a backing plate. Experience has shown that it is impractical to apply a synthetic coating to the exterior of the pipe at joints due to the heat from welding. The cellular concrete backfill provides a high pH and low oxygen environment, which reduces the rate of corrosion and oxidization on the pipe. Finally, the pipes should be electrically isolated at both ends of the tunnel. Detailed studies are recommended for the design phase to evaluate the corrosive potential of the groundwater, passive measures, in-situ corrosion evaluation systems, and the need for active cathodic protection.

8.0 TUNNEL ALTERNATIVE ANALYSIS

Based on water quality and O&M considerations, it would be prudent to have two independent carrier pipes in the tunnel to maintain separation of flows from the different water sources (i.e., Pardee Reservoir and the Sacramento River). In this arrangement, two 87-inch diameter pipes are needed to meet the flow requirements and therefore the tunnel would need to be approximately 21 feet in diameter (OD) as shown in **Figure 5-1**. However, the two-carrier pipe configuration is not the optimum and most cost effective arrangement due to the large tunnel diameter, requiring a high volume of excavation, to accommodate the piping and the significant void space to be backfilled to encase the pipes.

As an alternative, and to reduce project costs, MWH developed a tunnel concept with a single larger diameter carrier pipe. The single carrier pipe design consists of a 111 inch diameter steel pipe installed within a 13.75 foot diameter (OD) tunnel as shown in **Figure 8-1**. The single carrier pipe is expected to have comparable flow capacity to the smaller twin carrier pipe arrangement. Thus the tunnel diameter could be reduced significantly (7-ft.) and the cross-sectional area reduced by over half. However, the single carrier pipe arrangement would result in system-wide operational implications and inefficiencies relating to the combining the water sources with differing water qualities at Stockton, and likely increase treatment costs. Additionally, the use of a single carrier pipe in the tunnel reduces operational flexibility for inspection, maintenance, and repairs.

A cost comparison of the two tunnel alternatives based on two or one carrier pipes was developed and is presented in Section 11. For the comparison, all factors of the tunnel and system design were assumed to be the same except for the tunnel size and cross section.

9.0 CONSTRUCTION CONSIDERATIONS

9.1 Contracting Approach

Due to the size of the project as well as cost and schedule considerations, the use of multiple contract packages with staggered start dates is recommended for efficiency and to best utilize the resources of contractors. The project entails seven shafts and six tunnel reaches. Each contract would include one or two shafts and one or two tunnel reaches. A major challenge will be to stage the construction to avoid construction interferences such that two different contractors will not need to use a given shaft at the same time. For this conceptual design, it is assumed that the District's project delivery method is conventional design-bid-build.

There are a wide range of packaging options that could be used. The following presents one logical contract packaging outline to construct the project with four separate construction contracts. This contract packaging approach is based on a relatively compact schedule.

Table 9-1: Tunnel Construction Packaging - Typical

Contract Package	Reaches	Shafts	Phase [1]			Key Shaft Needed	Comments
			1	2	3		
A	I	1 and 2	I (2 to 1)				Contractor vacating Shaft 2 is on the critical path.
B	II and III	3 and 4	III (3 to 4)	II (3 to 2)		2	Contractor vacating Shaft 4 is on the critical path.
C	IV and V	5		IV (5 to 4)	V (5 to 6)	4 & 6	
D	VI	6 and 7	VI (6 to 7)				This contract is not on the critical path and could be delayed.

Notes:
[1] Within each phase, the contracts would be staggered to avoid simultaneous bidding (see text).

Using this contract packaging approach, three of the four contractors would be working simultaneously. Note that Contractor D could be either in Phase 1 or phase 2, or could start at an intermediate time, but in either case there would be three contractors working simultaneously in either Phase 1 or 2. A crucial feature of this approach is that three of the shafts will be used by different contractors at different times, and that the handover is a potentially large liability if it is delayed. This approach presents a contracting strategy to construct the project relatively quickly. Depending on funding and project requirements, a more relaxed approach could be used with buffer times between shaft handovers, contracts starting later in each phase, and additional phases.

Although there are several contracts in each phase, the bidding and construction would be staggered such that the bid period for each would be independent. This staggering is necessary to avoid overwhelming the industry with multiple bids at the same time and to obtain competitive pricing. Additionally, there is a limited number of tunneling contractors and their availability to bid changes over time based on their current project load. An example staggering is indicated by the left-to-right position of the work items within each phase.

9.2 Shaft Construction

The chosen method of shaft support is structural arched/cellular slurry walls. The arched shape of the walls is used to carry ground loads with no additional support or with minimal support. Slurry walls are also used for bracing across the excavation.

These slurry walls are constructed in vertical panels using a special clam bucket for excavation. Slurry is used to stabilize the trench walls with fluid pressure. The slurry pressure results from: 1) the slurry level inside the trench exceeding the groundwater level by several feet, and 2) slurry is denser than water. Following excavation of each panel, a reinforcing cage is inserted, and the panel is backfilled with concrete using tremie methods.

The following presents the construction sequence at each shaft:

1. Slurry walls are constructed with excavation and backfilled with concrete.
2. Soil within the shaft is excavated in the wet. (Note that the excavation extends below the tunnel invert to allow for construction of the base slab.)
3. Reinforcing for base slab is lowered to the bottom and shear pins are installed by divers.
4. Concrete is placed with tremie methods.
5. Water is pumped out of the shaft preparing it for tunnel construction.

To control the ground and groundwater outside the shaft at the tunnel breakout, special provisions are needed. A grout bulb is often used to stabilize the ground. Additionally a ring seal using a rubber gasket type of arrangement is often placed at the breakout to prevent groundwater from flowing into the shaft at the tunnel breakout.

9.3 Tunnel Construction

9.3.1 Approach to Tunneling

Tunneling is designed to utilize a two-pass construction method in which the tunnel is excavated with installation of initial support followed by installation of the final linings, e.g., carrier pipes. The tunnel space between the carrier pipes and the initial support is then backfilled with cellular concrete. Following backfilling, remaining voids may be filled with a combination of contact grouting and skin grouting. The need for grouting after backfilling should be determined as part of the design process and quality control measures.

9.3.2 Tunneling Machines and Methods

Ground conditions consist primarily of fine and coarse grained alluvial material. The water table is at the ground surface (below sea level) and could be higher in flood events. In these conditions the only practical tunneling method is with a closed face pressurized TBM (Appendix A). Based on existing information and the state of practice for the tunneling industry, either a slurry machine or earth pressure balance (EPB) machine could be used. Both tunneling machines use a pressurized mixture of soil and conditioners to control the ground at the tunnel face. Conditioning agents commonly consist of bentonite and/or foam to create slurry or a paste. For slurry machines, muck is removed with pressure controlled pipelines then transported out of the tunnel in slurry lines to a separation plant. For EPB machines, muck is removed with a screw auger then transported out of the tunnel in muck cars. The Contractor is responsible for choosing and designing the TBM, although the designer may place certain requirements or limitations on the TBM. More recent state-of-the-art developments allow for a combination of both methods in which the TBM is preferentially in EPB mode, then switches to slurry mode when needed.

The segmental concrete initial support system is erected within the tail shield of the TBM and remains behind as the TBM advances. Brushes with grease form a seal to control groundwater from entering through the shield-to-support interface. The segments are also used for thrust restraint to advance the TBM. After the segmental lining is in place, contact grouting is used to fill the annulus or void between the ground and the lining and to provide firm uniform ground contact with the segments.

9.3.3 Tunnel Drives

It is desirable and more efficient to excavate the tunnel in an uphill direction. The conceptual profile presents the tunnel as flat, but with a vertical band to allow for a slope to be incorporated into each tunnel reach. It is expected that future design phases will identify and optimize the tunnel profile and gradient for each tunnel reach. There are several considerations and restrictions for developing the appropriate tunnel slope and construction of each tunnel reach:

Table 9-2: Tunnel Reach Construction Directions

Reach	Preferred Tunneling Direction	Comments
I	West to East	Desirable to slope up to the east, but there are potentially liquefiable soils at depth at shaft 1, thus requiring a deeper shaft that may require a slope up to the west.
II	Either	Tunnel band is flat and tunnel can be set to slope in either direction.
III	East to West	Shaft 4 has difficult access and it is desirable to utilize it as an exit, not an entrance, shaft. Therefore it is preferred to have a high point at shaft 4 and tunnel from the east to the west.
IV	West to East	With shaft 4 preferred as an exit and a high point, tunneling would naturally be from the west to the east.
V	Either	Tunnel band is flat and the tunnel can be set to slope in either direction. Note that the tunnel band is slightly deeper for this reach to account for clearance below deep piles, and potentially deeper liquefiable soils associated with the Old River and the Middle River.
VI	East to West	Tunnel rises to the west at the end of the Delta.

Tunneling for long drives has some inherent risks resulting from wear on the equipment, especially the cutter head, and the probability of mechanical malfunctions. To address these issues, long tunnel drives commonly incorporate safe havens approximately every mile along the tunnel, depending on the ground conditions, including abrasiveness of the soils, external hydrostatic pressures, and geology. These safe havens consist of a large bulb of grout stabilized ground around the tunnel. Jet grouting is commonly used due to its thorough coverage and effectiveness in most soil types. Design details, especially the effective diameter of each column and corresponding column spacing are highly dependent on the soil type and density. Grouting is staged from the ground surface and is completed prior to the TBM reaching the safe haven. When the TBM reaches a safe haven it excavates partly through the stabilized ground, then the cutter head is retracted allowing access to the face. Workers can then replace and/or repair cutters on the face under near atmospheric conditions. This is also an opportunity to conduct maintenance and repairs of mechanical and electrical system components.

9.4 Carrier Pipe Installation and Tunnel Backfill

9.4.1 Pipe Installation and Welding

Two steel pipes (or 111-inch riser pipe for the 13.75-ft diameter tunnel alternative) are designed for water transmission inside the tunnel. For long tunnels, the pipe segments are individually transported into the tunnel and the pipeline is assembled in the tunnel. The alternative method of pushing in a completed pipe string is not practical for long tunnels. A pipe carrier is a specially designed trolley that is used to move the pipe and to position it for proper mating with previously placed pipe segments. Because two pipes are being installed, the contractor will need to fabricate a special cradle system to hold and secure the pipe inside the tunnel. This cradle system will need to have adjustments to position the pipelines at the proper line and grade.

After the pipes are installed, the joints are welded from inside of the pipes. A full-penetration butt weld with a backing plate is commonly used, although a lap joint with fillet weld(s) can be considered.

9.4.2 Tunnel Backfilling and Grouting

Following installation and welding of the pipes, the space outside the pipes is backfilled with cellular concrete, and remaining voids can be grouted if necessary. Descriptions and details are presented above in subsection 5.5 – Tunnel Backfill.

9.5 Muck Removal and Disposal

Removal of the excavated muck material or spoils varies depending on the TBM used and the Contractor’s preference. If an EPBM is used the muck is transported from the face through the tunnel on muck cars or conveyor belts. A crane hoists the muck out of the shaft and either directly loads it into trucks or dumps it on a pile for future removal. A vertical conveyor can also be used to lift the muck from the shaft. If the slurry TBM is used, a slurry pipeline transmits the muck from the face through the tunnel and out of the shaft. Booster pumps are often necessary. At the ground surface a separation plant is used to separate the soil particles from the slurry, and the slurry is then reconditioned and reused.

The tunnel muck is expected to consist of sand and gravel with a high clay content, and a high moisture content. Tunnel muck is generally not useful as structural fill, but it can be used for general fill where settlement is not a concern.

Disposal of the muck for this project could be costly if the District needs to pay for transportation and disposal offsite. Furthermore, if the Contractor uses foam with the TBM, the muck will likely be subject to special environmental disposal requirements. The in-place volume of excavation is approximately 1.12 million cubic yards. With a bulking factor of 25 to 40 percent, the muck volume to dispose of is approximately 1.4 to 1.6 million cubic yards. If this muck volume is placed uniformly over an area of 50 acres the fill would be approximately 17 to 20 feet high. If a beneficial use of the muck is not available, then the District may consider placing the fill on an existing plot of land that they currently own, such as near Bixler. The ground load from the fill would result in substantial consolidation of the clays and the peat, and the area of settlement would extend away from the actual fill area. The consolidation could be accelerated with the use of wick drains installed before fill placement. Potential bearing capacity failure near the edges of the fill also needs to be evaluated during design.

9.6 Additional Considerations

Construction for each contract will require a main staging area and a work site at each shaft. The main staging area is for project administrative office, equipment storage, and materials storage. This site should be three to five acres although smaller areas can be used if necessary. A staging area is needed at each shaft site for the shaft itself, crane(s), access roadways, site trailers, temporary material laydown, worker hangout and showers, and tunnel support facilities. These sites should be at least three to four acres although smaller areas can be used if there is land access or ROW constraints.

Each construction shaft site requires substantial infrastructure to support construction including haul roads, power, and water. Haul roads need to be sufficient to handle not only frequent muck haulage and pipe delivery, but also delivery of the TBM, crane, and potentially other heavy construction equipment. It is expected that all local roads below the level of highways will require upgrading for construction. Power requirements at each construction site with a single TBM are expected to range from 5 to 10 MW, although up to 15 MW may be beneficial for some contractors and tunneling methods. These power requirements include at least 2.5 MW for the TBM, plus loads for a conveyor system, slurry separation plant, trains (loci), ventilation, lighting and other miscellaneous electrical.

10.0 OPERATIONAL CONSIDERATIONS

10.1 Aqueduct Operations

Under normal conditions the three aqueducts operate with gravity flow at a combined capacity of 199 MGD. This capacity can be increased up to 326 MGD with pumping; however, pumping is avoided when possible due to the high cost of power. The two-pipe configuration of the tunnel is expected to have the same flow capacity during both gravity and pumped conditions.

Due to the two water sources and their associated different water qualities, a primary requirement of the District is that the flows are separate, and this is achieved with the two-pipe configuration. Aqueduct Nos. 1 and 2 are combined into at common 87-inch pipe outside of the shafts which, and Aqueduct 3 is an uninterrupted continuous 87-inch pipe through the shafts and tunnel. The tunnel entrance and exit shafts are located inside of the two interconnection facilities, which allow those facilities to divert flows from Aqueduct Nos. 1 and 2 to Aqueduct 3 and are allowed to function the same as before tunnel construction. However, as stated above in Section 7, the primary need for the interconnection facilities, which is to transfer flows if an aqueduct is damaged, is negated by the tunnel — although they would still be useful to manage flows between the aqueducts for inspection, maintenance and repairs.

As an alternative to the base design case of twin carrier pipes in the tunnel, an concept was developed for a single 111 inch carrier pipe in a smaller diameter tunnel for comparison purposes (see Section 8.0). A single carrier pipe would require combining the flows from all three existing aqueducts, and result in a substantial loss in operational flexibility for the water system. If this alternative is to be implemented, the District would need to evaluate system-wide impacts, and implement alternative measures to achieve water quality and treatment goals for water from the different water sources.

10.2 Inspection, Maintenance and Repairs

Inspection of the carrier pipes in the Delta Tunnel is not expected to be a common activity; however, manholes in the construction shafts at approximate 3-mile intervals provide access for dewatering when needed. Seven accesses are provided, one at each end of the tunnel and five intermediate locations in the central portion.

> **End Accesses**: The vertical shafts at the end of the tunnel would be the location of vertical 87-inch aqueduct riser pipes (or 111-inch riser pipe for the 13.75-ft diameter tunnel alternative) for water transmission, with five foot diameter extensions to the ground surface for access. Thus, workers and equipment would be lowered through the aqueduct pipes once the tunnel system has been dewatered.

Central Accesses: Each of the central manholes is 5 feet in diameter to accommodate personnel and supporting safety systems. A wide chamber with flat landing at the bottom of each manhole facilitates work at the tunnel level and allows access to both pipelines. The pipelines are accessed with 36 inch diameter bolted blind flanges.

Inspection of the carrier pipes would be performed based on visual inspections and non-destructive testing (e.g., radiographic inspection of welds). The accesses could also be used for relining of the pipes if needed.

The accesses are designed for infrequent use, and complete access and safety systems will be required for personnel entry. The manholes and chambers are not expected to be watertight, and are expected to fill with water over time thereby requiring dewatering with a portable pump before use. Other systems needed for access include a means of egress and exit along with a backup system, ventilation, lighting, communications, and a system for the delivery and retrieval of equipment and materials.

11.0 OPINION OF PROBABLE CONSTRUCTION COST

This section describes the construction approach, assumptions, and anticipated ground conditions used as a basis to provide an Opinion of Probable Construction Cost and preliminary construction schedule) for the proposed Delta Tunnel, for the three alternatives . As with all Opinions of Probable Construction Cost prepared by MWH and others, the results are classified according to AACE International – formerly the Association for the Advancement of Cost Engineering (AACE).

11.1 Estimating Methodology

11.1.1 Pricing Basis of Construction Cost Estimate

The Opinion of Probable Construction Cost (OPCC) reflects the estimator's opinion as to the probable costs that a "prudent" contractor would include in his tender to construct the defined facilities. The OPCC does not capture framework costs borne by the owner for pre-construction activities or for expenses related to the management and support of field construction activities. The OPCC is intended to be an indication of fair market value and is not necessarily a predictor of lowest bid. Fair market value is assumed to be a mid-range tender considering four or more competitive bids. Finally, OPCC pricing is predicated on the contractor's compliance with all contract specifications and design parameters during field execution activities.

11.1.2 Estimate Classification

As noted above, estimates are usually classified in accordance with the criteria established by the Association for the AACE's Cost Estimate Classification System referred to as Standard Practice 18R-97. The AACE Cost Estimate Classification System maps the various stages of project cost estimating together with a generic maturity and quality matrix, which can be applied across a wide variety of industries and capital infrastructures.

This estimate is considered consistent with Class 5 classification criteria described by AACE as:

> ***Class 5 Estimate*** *is prepared based on limited information, where the preliminary engineering is from 1 to 5 percent complete. Detailed strategic planning, business development, project screening, alternative scheme analysis, confirmation of economic and or technical feasibility, and preliminary budget approval are needed to proceed. Examples of estimating methods used would be equipment and or system process factors, scale-up factors, and parametric and modeling techniques. The expected accuracy ranges for this class estimate are –15 to –30 percent on the low side and +20 to +50 percent on the high side.*

Although there are many factors depending on the type and complexity of the project, generally MWH interprets the classes defined by AACE as the following scopes/work efforts:

- Class 5: Conceptual Design - between 0 and 2 % design;
- Class 4: Preliminary Design Phase - between 1 and 15% design complete;
- Class 3: Design Development Phase – between 10% and 40% design complete;
- Class 2: Construction Document Phase – between 30 to 75% design complete.
- Class 1: Check Estimate – between 65 to 100% design complete

11.1.3 Estimating/Scheduling Methodology or System

To support productivity and pricing assumptions, multiple software tools are available. For estimating process for water conveyance facilities, the Timberline (TL) cost estimating software coupled with the Richardson Cost Database were used. Estimates of heavy-civil infrastructure are completed in International Project Estimator (IPE) software coupled with a proprietary in-house crew database. Both estimating systems are well known industry tools and are updated yearly. Other commercial pricing databases including RS Means, Mechanical Contractors Association (MCA) and National Electrical Contractors Association (NECA) are also available.

Detailed construction schedules are completed in Primavera P6 project management software.

The following table summarizes the typical estimating methodology employed relative to AACE cost estimate classification:

AACE	System	Methodology
5	Excel	Parametric/Stochastic
4	Excel	Semi-detailed Unit Price
3	IPE/TL	Detailed Crew Analysis
2	IPE/TL	Detailed Crew Analysis w/ Budget Quotes
1*	IPE/TL	Detailed Crew Analysis w/ Firm Quotes

* Class 1 cost estimates are reserved for actual contractor proposals that factor in final subcontractor quotes and firm vendor materials pricing.

11.1.4 Estimating Accuracy and Contingency

AACE provides guidance with respect to estimating accuracy and typical contingencies. Estimating accuracy has been addressed by the probabilistic analysis of the price variability as described in the table below. This table provides some basic guidance from AACE regarding contingency level recommendation relative to estimate class and input design.

AACE	Design	Accuracy Range	Typical Contingency
5	<5%	-35% to +50%	20% to 40%
4	<15%	-25% to +35%	10% to 30%
3	10%-40%	-15% to +20%	5% to 20%
2	50%-99%	-10% to +20%	0% to 10%
1*	100%	+/-5%	0% to 5%

*Class 1 estimates are reserved for actual contractor proposals that rely on finalized bidding documents and access to all pre-tender addendums.

Based on the level of detail of the design presented in this memorandum, and based on the limited geotechnical investigations, etc. contingency allowances were applied to minimize the risk of cost deviation in relation to future quantity refinement. It would be appropriate to allow a contingency in excess of 20%.

11.1.5 Quantities

Preliminary conceptual design sketches and/or other available project engineering conceptual design criteria and information were used to determine the OPCC quantity basis. The furnished quantity inputs were not validated by the estimating team and remain a source estimate deviation until future design refinement allows for rigorous verification of the quantity basis.

11.1.6 Direct Cost Development

Directs costs representing the Project's fixed physical scope have been estimated against a work breakdown structure (WBS) to organize the estimate details. Direct cost detail is decomposed to multiple sub-levels, which are referred to as item activities. Class 5 and 4 estimates typically apply all-in unit prices against the line item quantities whereas Class 3 and 2 estimates derive pricing under a crew based productivity analysis per line item.

11.1.7 Indirect Cost Development

Indirect costs representing the contractor's time related variable field management expenses or general conditions (GCs) costs are factored to Class 5 and 4 OPCCs in a top-down approach as a function of running direct costs. For Class 3 and 2 OPCCs, indirect costs are estimated in a bottoms-up fashion to determine actual resource needs in relation to the proposed construction duration schedule.

11.1.8 Estimate Adders

Similarly, in accordance with normal practice for Class 5 estimates, add-ons representing the contractor's allowances for home office overhead expenses, sales taxes, insurance costs, risk provision and fee are added to the cost estimate as a function of running direct costs.

11.1.9 Labor Rate Development

As a Class 5 cost estimate, this estimate relies on all-in historical database prices and does not involve development of hourly rates for labor and equipment resources. A more detailed approach using all-inclusive labor rates built-up from local wage determinations would be used for future preliminary design and final design phases (i.e. Class 3 and 2) estimate updates.

11.1.10 Equipment Rate Development

In a similar manner to the labor rate development, this Class 5 cost estimate has generally relied on all-in historical database prices and has not typically required development of hourly rates for equipment resources,

11.1.11 Escalation

Estimated capital costs reflect current (Q4-2014) price levels, consistent with the OPCC published date, and does not include adjustments for forward cost escalation.

11.1.12 Allowances and Contingency

Allowances have been made in the estimate where there is not a developed conceptual design for a specific feature, but it is required for construction. These items have been identified as allowances in the estimate. The only specific allowance included in the estimate is an allowance for unlisted items which has been included to cover items that are known to be included in the works but have not been detailed or measured at this early stage of design .

The OPCC excludes an allowance for the owner's management reserve, which represents the owner's contingency for changed field conditions.

11.1.13 Market Conditions

Unprecedented market volatility has been a significant factor in contractor pricing over the last several years. Current market conditions have shown an aggressive approach to pricing with contractors assuming more risk to win project work. Consequently, while the market price may be significantly under the reported "fair valuation" of the OPCC, owners need to be aware of the increased potential for claims and other compensation demands that contractors may employ to offset aggressive bidding strategies. This could affect the final price of the work being performed.

11.2 Delta Tunnel Alternatives

11.2.1 General

OPCCs were prepared for the two tunnel alternatives, a single large diameter tunnel with two carrier pipes, and a single smaller diameter tunnel with one carrier pipe:

1. **Base Tunnel Case, Two Carrier Pipes:** A 16.5 mile long tunnel from Stockton (I-5) to Bixler, across the Sacramento San Joaquin River Delta, with seven shafts and constructed in six tunnel segments. The tunnel is designed to be excavated to 21 ft diameter using a pressurized face TBM and lined with precast concrete segments (19 ft ID). The final lining will consist of two 87 inch diameter steel carrier pipes. The steel pipes will be secured in the tunnel and the annulus between the segmental lining and the pipes will be backfilled with a cellular concrete. For procurement of the construction contracts, assume four contracts are needed.

2. **Alternate Tunnel Case, Single Carrier Pipe**: A 16.5 mile tunnel from Stockton (I-5) to Bixler, across the Sacramento-San Joaquin River Delta, with seven shafts and constructed in six tunnel segments. This tunnel alternative is designed to be excavated to 13.75 ft diameter using a pressurized face TBM and lined with precast concrete segments. The final lining consists of a steel carrier pipe 111 inches in diameter, and the annulus between the segmental lining and the steel pipe will be backfilled with cellular concrete. All other factors for this alternative are the same as for the base concept.

A comparison of the costs for these two cases is included in the appendix of this report.

11.2.2 Base Concept

The OPCC for the base concept was prepared using the conceptual design presented herein with the following components:

- **Tunnel:** 16.5 miles long and excavated to 21 ft diameter using a pressurized face TBM (slurry or EPB machine) and precast concrete segments for initial support.

- **Twin Steel Pipes:** Each 87-inch diameter with cellular concrete backfilling the tunnel outside the pipes.

- **End Shafts:** Two shafts, one at each end of the project, with vertical riser pipes and permanent access for personnel in the future. The shafts are also assumed to be used for tunnel construction including TBM retrieval.

- **Intermediate Shafts:** Five shafts with vertical manholes for permanent personnel access in the future. The shafts are also assumed to be used for tunnel construction including TBM launching and retrieval.

- **Piping:** Two sets of piping, one at each end of the project, to connect the existing aqueducts to the tunnel and to combine/split flows.

Construction was assumed to be in four separate contracts in accordance with the following:

- **Contract A**: Construction of shafts 1 and 2, and tunnel reach I with a length of 14,925 feet.

- **Contract B**: Construction of shaft 3 and 4, and tunnel reaches II and III with a combined length of 29,850 feet.

- **Contract C**: Construction of shaft 5, and tunnel reaches IV and V with a combined length of 28,650 feet.

- **Contract D**: Construction of shafts 6 and 7, and tunnel reach VI with a length of 13,420 feet.

The OPCC assumes a rational and phased construction schedule which contracts are sequenced over a ten year period.

11.2.3 Single Pipe in Tunnel Alternative

The OPCC for this alternative concept was prepared using the same assumptions as for the base concept, except with is a single 111 inch diameter pipe in a 13.75 foot diameter tunnel.

11.3 Assumptions and Limitations

Conceptual design of each tunnel alternative was developed to the extent necessary to provide an initial comparison of potential costs. Conceptual level details were prepared for each of the alternatives to the extent necessary to size major project features and to identify construction considerations. Construction of a new water conveyance tunnel is anticipated to begin until 2020 or later. The OPCC estimate was prepared in 2014 dollars. No cost escalation was included.

The tunnel conceptual designs are based on the following:

- Existing geologic information was used to develop the preliminary geologic profile.
- Tunnel and shaft design development was to the conceptual level.
- Contracting strategy assumes design-bid-build project delivery method and includes multiple contract packages.
- Contracts will be staggered and let every six months in order to maximize competition.
- Construction schedules are only conceptual and may not include all schedule factors. Estimates of construction duration are presented in the tunnel and alternative discussions as appropriate.
- Comparative environmental impacts for each alternative were not considered.

11.3.1 Construction Methodologies

- **Methods of Tunnel Excavation:** Slurry or EPB TBM.
- **Initial Ground Support:** Precast concrete segments.
- **Excavation Progress Rate of TBM:** Average 50 feet/day.
- **Anticipated Construction Method of Shafts:**
  - Slurry walls for support (other methods are available).
  - Internal excavation with clam bucket in the wet.
  - Base slab placed with tremie methods.
  - Permanent manhole and chamber.
  - Mortar lining in carrier pipes within the shafts to be field installed.

- **Normal Working Hours:** Five (5) days/week with two 10-hour shifts/day for tunnel and underground production work, one (1) 10-hour shift per day for surface work and shafts/portals excavation.

- **Competitive Bidding Process:** A bid for all work completed under the four (4) construction packages and accepted bid prices not to include unplanned allowances.

- **Construction Support Facilities:** All construction support facilities and utilities provided by and/or upgraded by Contractor.

- **Costs for Risk:** The costs for risk have been assumed to be carried in the Contractors Home Office Overhead and Fee/Profit percentages.

11.3.2 Assumptions / Exclusions

The OPCC estimate incorporates the following assumptions or qualifications:

- Pricing basis is on the 3rd quarter of 2014.
- Suitable waste area for excavated material disposal is located within 20 miles of the project site.
- Sufficient and qualified craft labor resources are available without significant wage premiums.
- Sufficient and viable construction equipment resources are available without major premium.
- Industry standard commercial terms will be applied to all procurements.
- Owner has sufficient and qualified personnel to manage the project to stated cost and time objectives.
- Sufficient supply of qualified contractors will tender competitive bid proposals.
- The contracting strategy maximizes competition and promotes project objectives.
- Competitive bid conditions will prevail at tender time.
- No external or internal delays to achieving the project approval.
- Stable resource market conditions and minimal geo-political disruptions.
- No vendor quotes were obtained.

As developed, the OPCC excludes the following program costs:

- Property purchase or land rights expenses.
- Owner's project management and administrative costs; construction management costs; and design and engineering support during construction expenses.
- Owner's management reserve for changed field conditions
- Property or consumption taxes
- Water rights and use fees
- Facility capital costs.
- Interest during Construction (IDC).
- Unconventional environmental mitigation measures.
- Exposure to hyper-inflationary or hyper-deflationary market conditions.
- Levee improvement and river bank erosion mitigation costs.
- Costs associated with improvements to local infrastructure.
- Mitigation of flooding impacts.
- Mitigation of wildlife habitat loss.
- Excessive stream flow releases.
- Owner insurance coverage policies.
- Overly prescriptive permit conditions or specifications.
- Uncommon natural events such as earthquakes and severe weather impacts.
- Demolition and removal of the existing aqueducts.

11.3.3 Contingency

Contingency is added to the OPCC estimate to account for unknown risks or unforeseen market conditions. Given the level of accuracy for this estimate (Class 5), a contingency of 20% on all project components and costs including overhead, bonding, and insurance was added into the estimate. The OPCC excludes an allowance for the owner's management reserve, which represents the owner's contingency for changed field conditions or other unknown situations or issues.

11.4 Cost Comparisons

Construction cost opinions for the two tunnel alternatives: a larger diameter tunnel with two carrier pipes (base case) and a smaller diameter tunnel with single pipe are presented in the following table.

Table 11-1: OPCC Summaries – Tunnel and Tunnel / Pipeline Alternatives

Alternatives	Estimate ($ Million)
Base: 21-ft diameter tunnel Stockton to Bixler, two 87” carrier pipes	1,652
Alternative: 13.75 ft diameter tunnel with a single 111” pipe	1,234

Construction cost opinions for the base concept with twin carrier pipes in the tunnel and the alternative for a single carrier pipe in a smaller diameter tunnel show that there could be a reduction of approximately $418 million which is a savings of approximately 25 percent for the project. However, the single carrier pipe approach would result in system-wide operational implications and inefficiencies relating to different water sources and water qualities, and associated treatment methods. Additionally, the use of a single carrier pipe in the tunnel reduces operational flexibility for inspection, maintenance, and repairs.

11.5 Land Acquisition

The construction shafts and associated permanent manholes for future access are offset from the existing aqueducts to allow for construction while maintaining operation of the current water delivery system. An effort was made in design to minimize the land acquisition by using the existing ROW to the degree practicable. However, at shafts 2 through 6 EBMUD will need to purchase land for a permanent ROW and obtain temporary construction easements. Land and easement requirements are presented previously in Table 4-4. Based on an estimated acquisition cost of $10,000 per acre (ref. EBMUD) the estimated project costs for the project are:

Permanent Acquisition: 9 Acres at $10,000/acre = $90,000

Construction Easement: 40 Acres at $10,000/acre = $400,000

Total = $490,000

11.6 Construction Schedule

The Class 5 CPM schedule for the proposed Delta Tunnel is presented in Appendix B of this TM.

11.6.1 Basis of Schedule

A Construction Schedule was developed for the proposed Delta Tunnel to support preliminary planning efforts. The presented construction schedule, which includes any resulting conclusions on project financial or economic feasibility or funding requirements, has been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final duration of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions, inflation pressure, actual site conditions, final project scope, implementation schedule, continuity of personnel and engineering, and other variable factors. Additionally the overall project construction duration is highly dependent the staging and overlap of the different construction contracts which is determined by the owner based on the completion deadline, cost considerations, and risks. Therefore, final project duration will vary from the estimates presented here. Because of these factors, project feasibility, benefit/cost ratios, risks, and funding needs must be carefully reviewed prior to making specific financial decisions or establishing project budgets to ensure proper project evaluation and adequate funding.

11.6.2 Scheduling Methodology

The construction schedule developed under this study was prepared using a parametric scheduling methodology. Using a simplified high level work breakdown structure (WBS), major project scope elements were organized into a multi-tiered template to focus the scheduling effort to items of significance defined as schedule drivers. Parametric or top-down schedules use rules of thumb, parametric models, analogies, or scheduling estimating relationships (SERs) to estimate activity durations.

The schedule presented is for the base case, the 21-ft diameter tunnel with two steel pipes encased within the tunnel. The schedule is based on an average TBM excavation rate of 50 feet per day.

11.6.3 Exclusions

The construction schedule excludes the following program tasks or time constraints:

- Owner internal approval duration
- Regulatory approval duration
- Procurement/financing delays
- Excessive weather conditions

11.6.4 Assumptions

The construction schedule incorporates the same assumptions, as appropriate, as for the OPCC. Additionally, it is assumed that work will be executed throughout the year without scheduled winter breaks.

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FIGURES

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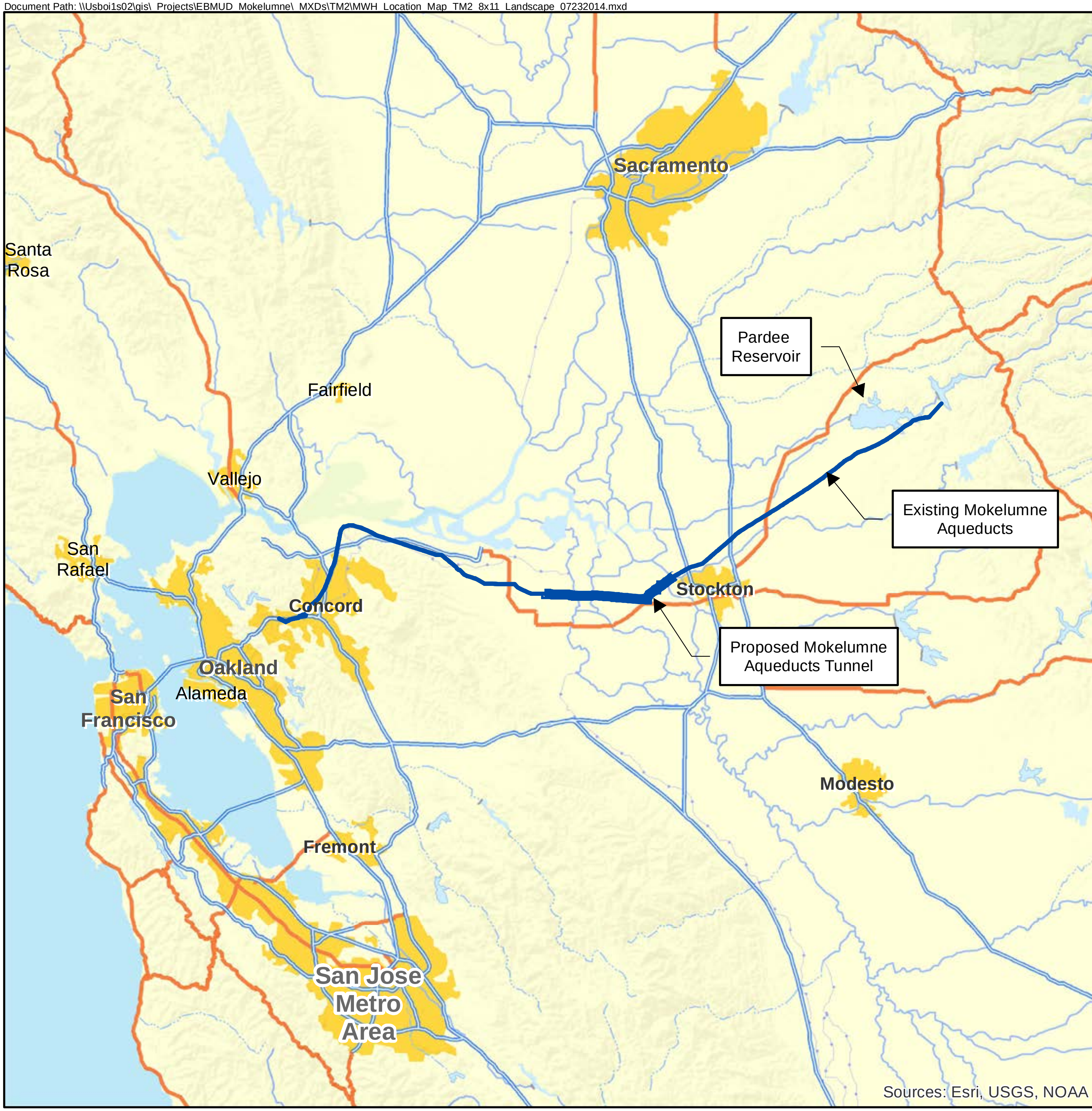

LEGEND

Mokelumne Aqueducts Tunnel

Mokelumne Aqueducts Alignment

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TITLE:

Location Map

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

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LEGEND

- Boring (Multiple Consultants)
- BDCP Boring
- CPT
- Shaft
- Proposed Mokelumne Aqueduct Tunnel
- Existing Mokelumne Aqueduct Alignment
- BDCP Approximate Proposed Alignment
- Interstate
- Highway
- Major Road
- Local Road
- County

Date Saved: 7/23/2014

N W E S

0 1 2
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TITLE:
Site Plan

PROJECT:
Mokelumne Aqueducts Delta Tunnel Study

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

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FIGURE
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LEGEND

- Construction Shaft
- Boring (Multiple Consultants)
- BDCP Boring
- CPT
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- County
- Map Index

Date Saved: 11/24/2014

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0 1 2
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TITLE:
Delta Tunnel Plan Set

PROJECT:
Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
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Datum: North American 1983
Units: Foot US

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FIGURE
4-1a

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LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary

18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

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TITLE:

Delta Tunnel Plan Set - Sheet 1 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

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FIGURE 4-1b

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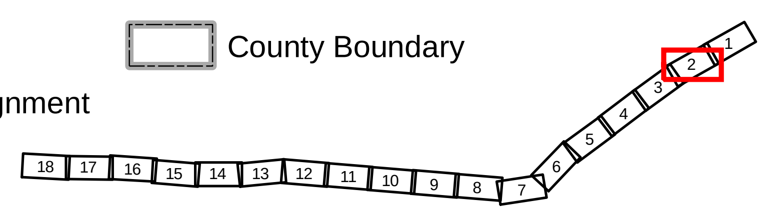
LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



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TITLE:

Delta Tunnel Plan Set - Sheet 2 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

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FIGURE 4-1c

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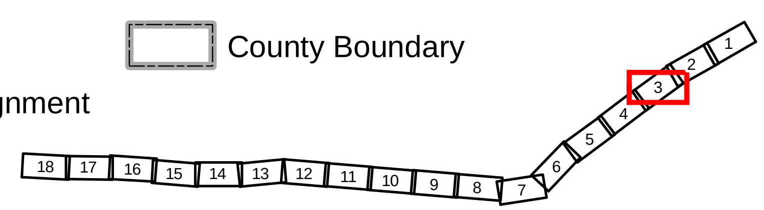
LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



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1 inch = 400 feet

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TITLE:

Delta Tunnel Plan Set - Sheet 3 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

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FIGURE

4-1d

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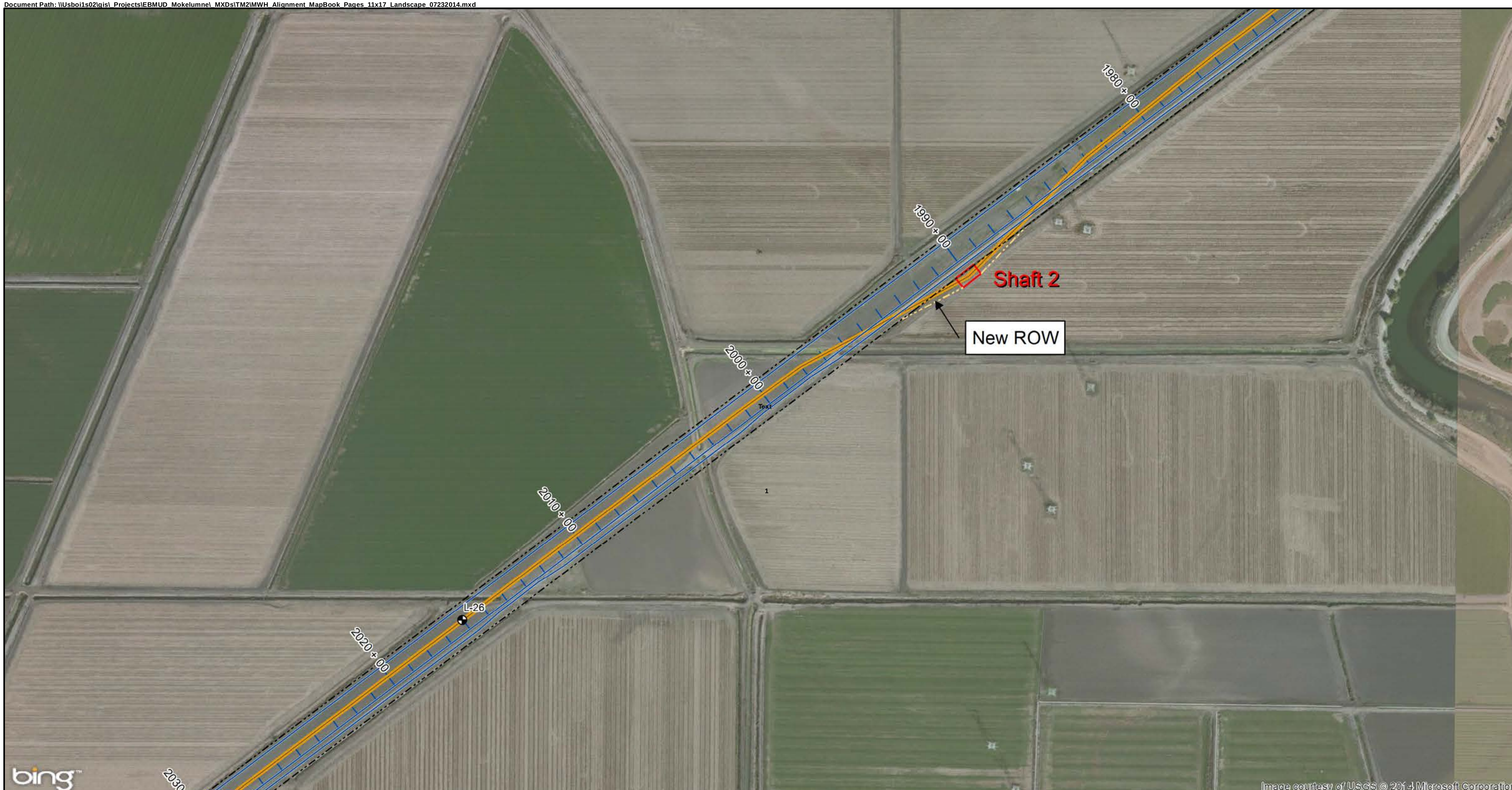

LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary

18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

N W E S

0 400 800

Feet

TITLE:

Delta Tunnel Plan Set - Sheet 4 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

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FIGURE 4-1e

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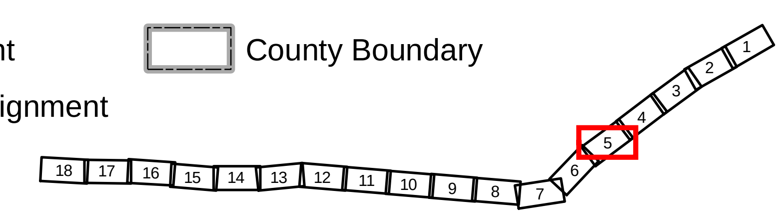
LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



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1 inch = 400 feet

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Feet

TITLE:

Delta Tunnel Plan Set - Sheet 5 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

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FIGURE

4-1f

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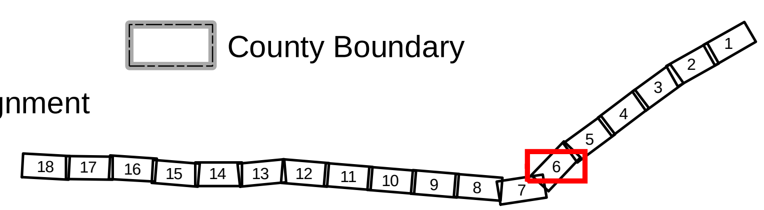
LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



Note: Stationing is approximate.

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1 inch = 400 feet

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0 400 800

Feet

TITLE:

Delta Tunnel Plan Set - Sheet 6 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

EBMUD

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FIGURE

4-1g

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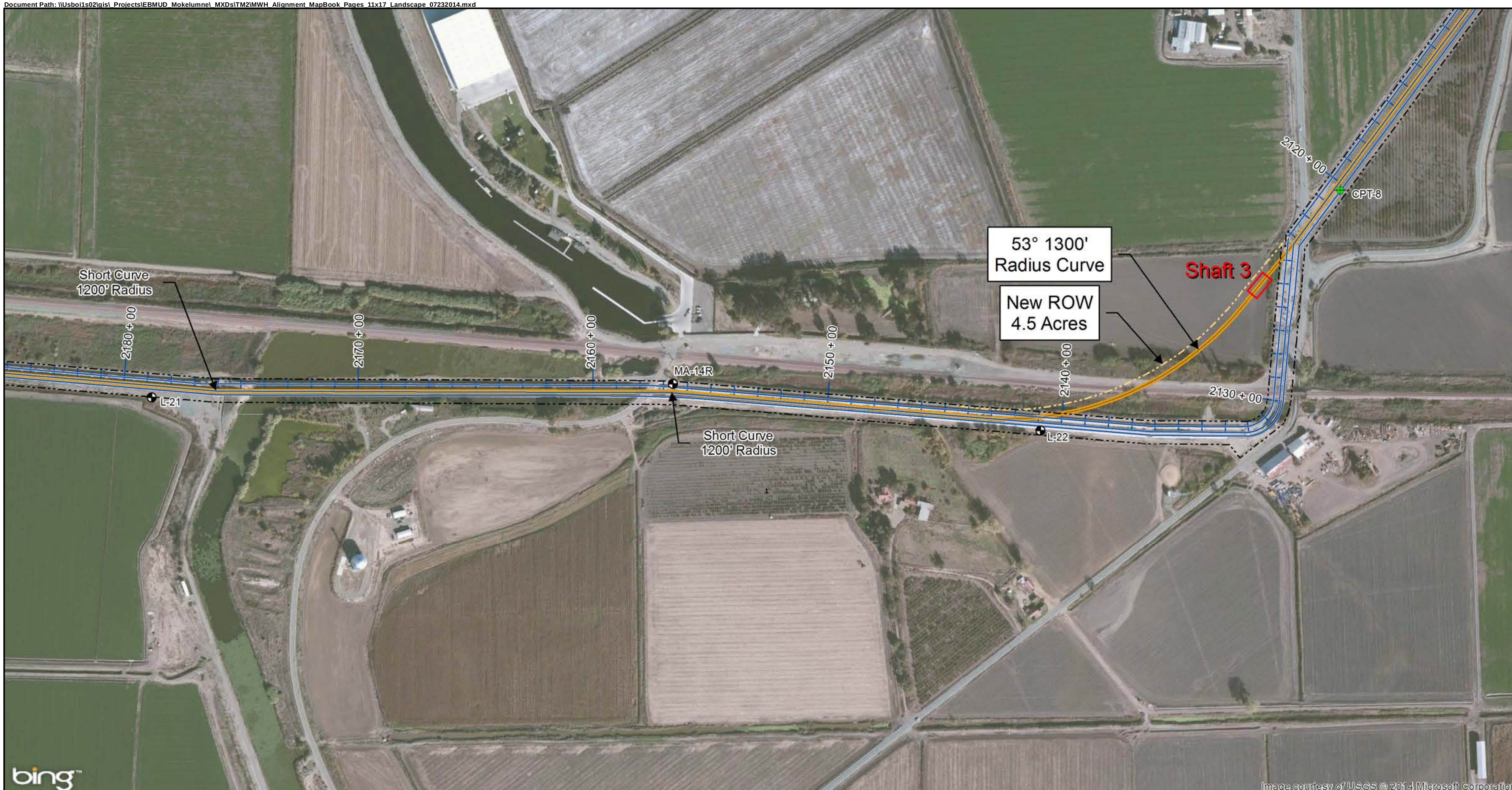


LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary

18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

N W E S

0 400 800

Feet

TITLE:

Delta Tunnel Plan Set - Sheet 7 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

EBMUD

MWH

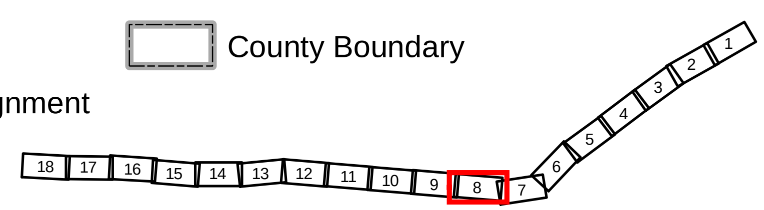
FIGURE

4-1h

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Alignment_MapBook_Pages_11x17_Landscape_07232014.mxd

LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

N W E S

0 400 800

Feet

TITLE:

Delta Tunnel Plan Set - Sheet 8 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

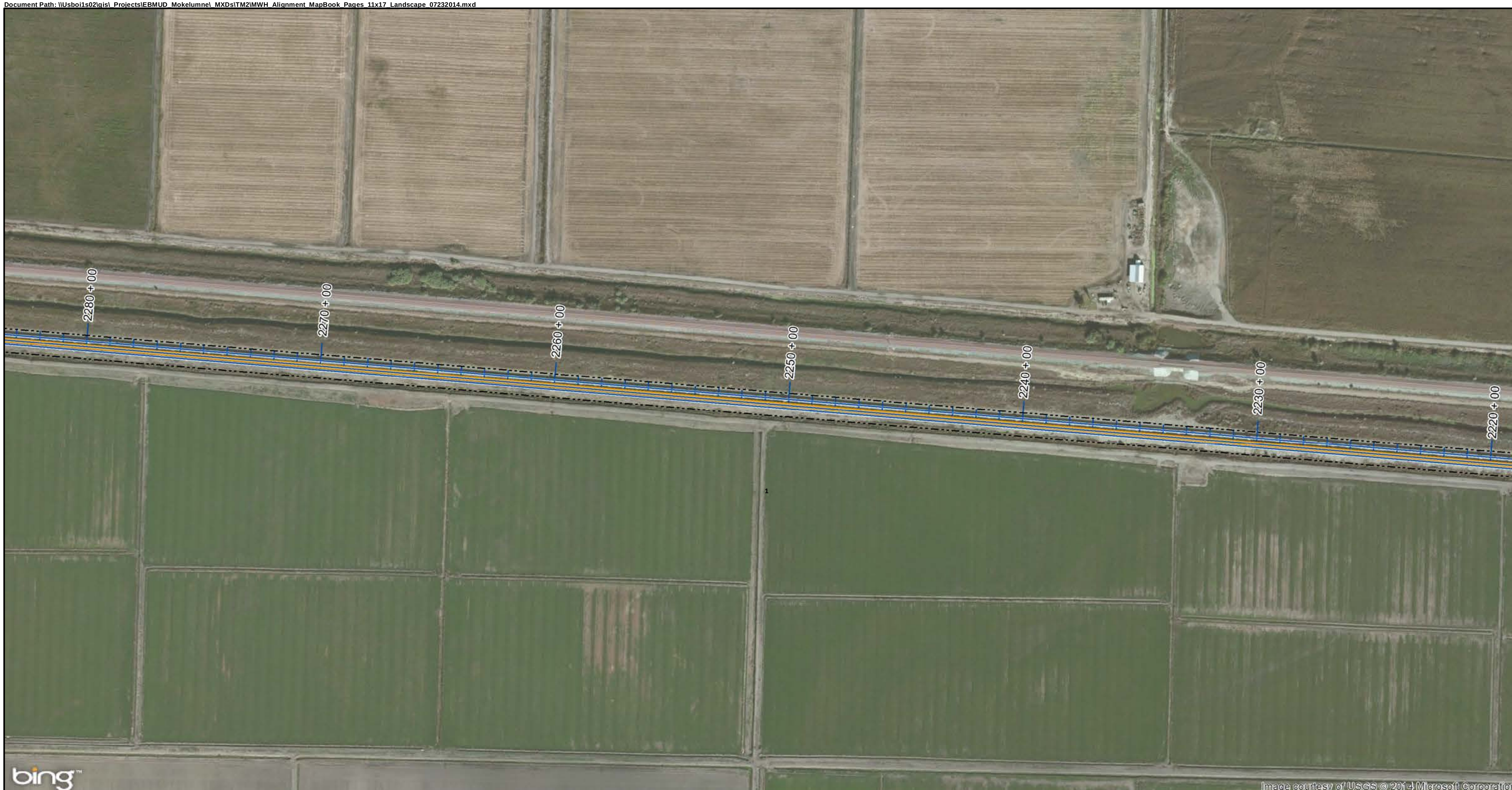
DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

EBMUD

MWH

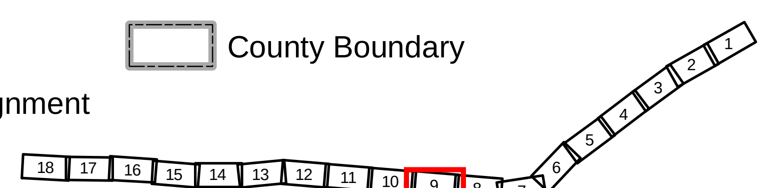
FIGURE

4-1i



LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

N W E S

0 400 800
Feet

TITLE: Delta Tunnel Plan Set - Sheet 9 of 18

PROJECT: Mokelumne Aqueducts Delta Tunnel Study - TM2

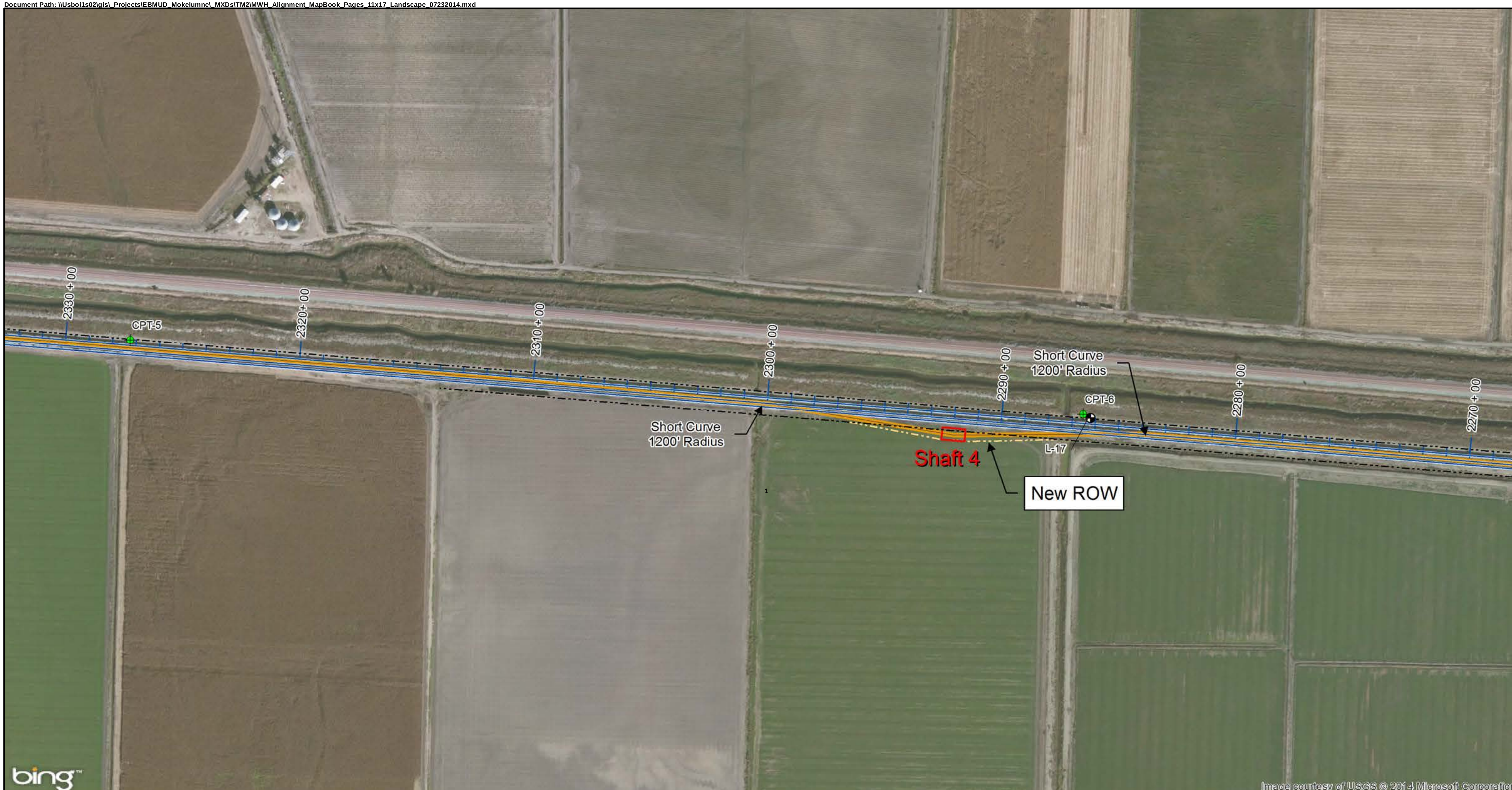
DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

EBMUD

MWH

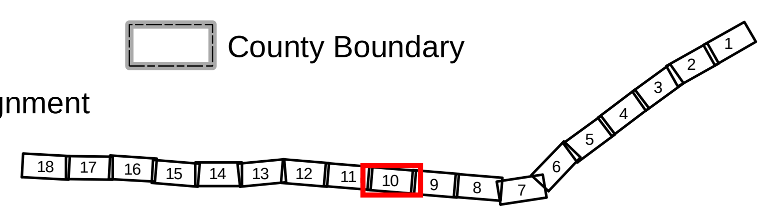
FIGURE 4-1j

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Alignment_MapBook_Pages_11x17_Landscape_07232014.mxd



LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

N W E S

0 400 800
Feet

TITLE:
Delta Tunnel Plan Set - Sheet 10 of 18

PROJECT:
Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

EBMUD

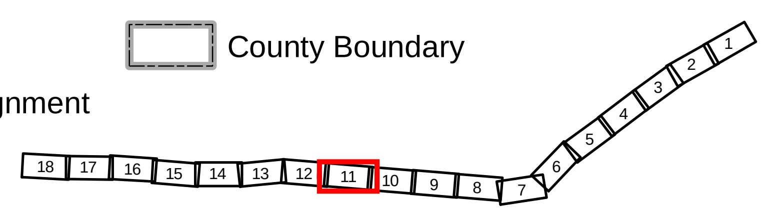
MWH

FIGURE
4-1k

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Alignment_MapBook_Pages_11x17_Landscape_07232014.mxd

LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

N W E S

0 400 800

Feet

TITLE: Delta Tunnel Plan Set - Sheet 11 of 18

PROJECT: Mokelumne Aqueducts Delta Tunnel Study - TM2

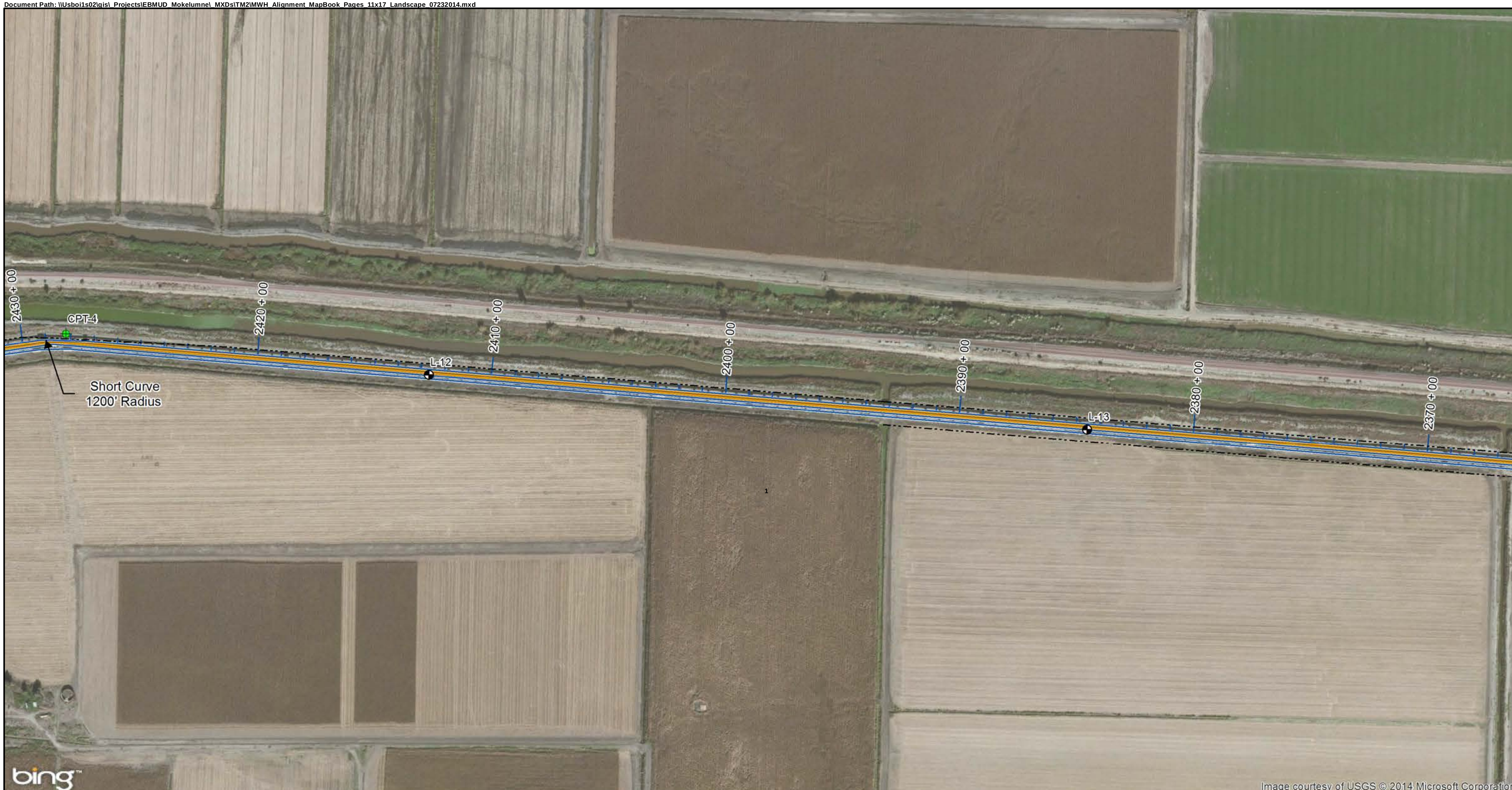
DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

EBMUD

MWH

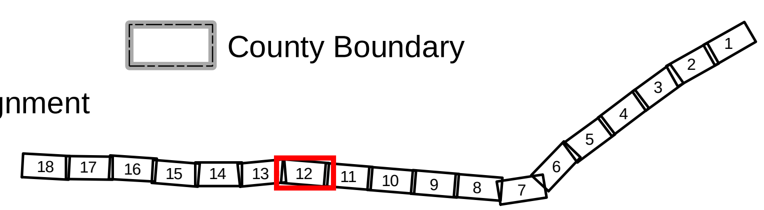
FIGURE 4-1l

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Alignment_MapBook_Pages_11x17_Landscape_07232014.mxd



LEGEND

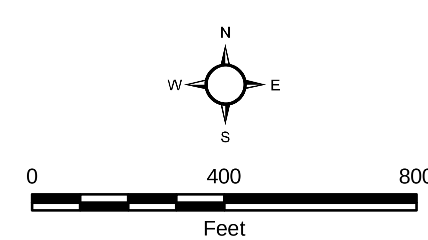
- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet



TITLE:

Delta Tunnel Plan Set - Sheet 12 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

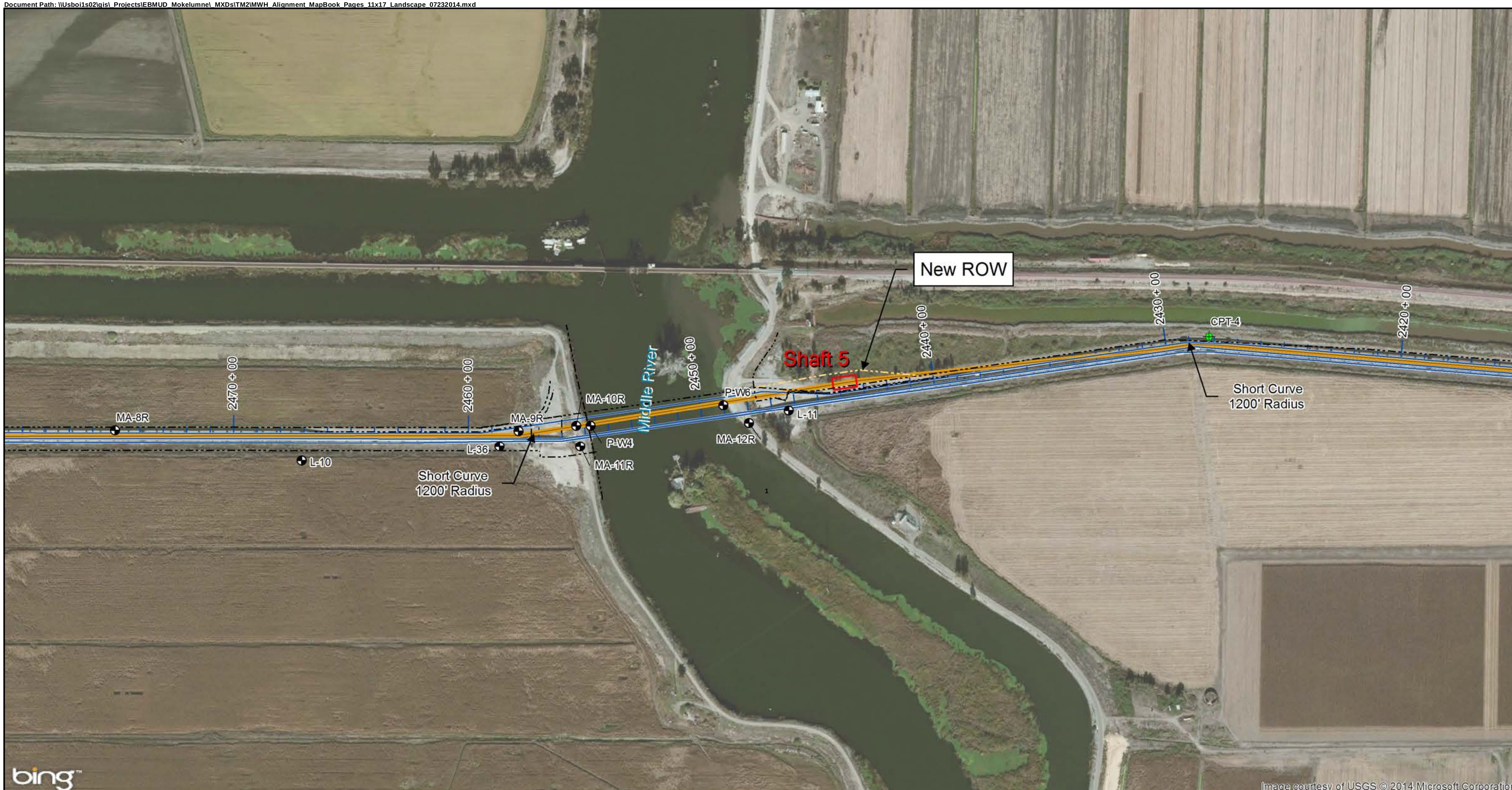
EBMUD

MWH

FIGURE

4-1m

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Alignment_MapBook_Pages_11x17_Landscape_07232014.mxd



LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary

18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

N W E S

0 400 800

Feet

TITLE: Delta Tunnel Plan Set - Sheet 13 of 18

PROJECT: Mokelumne Aqueducts Delta Tunnel Study - TM2

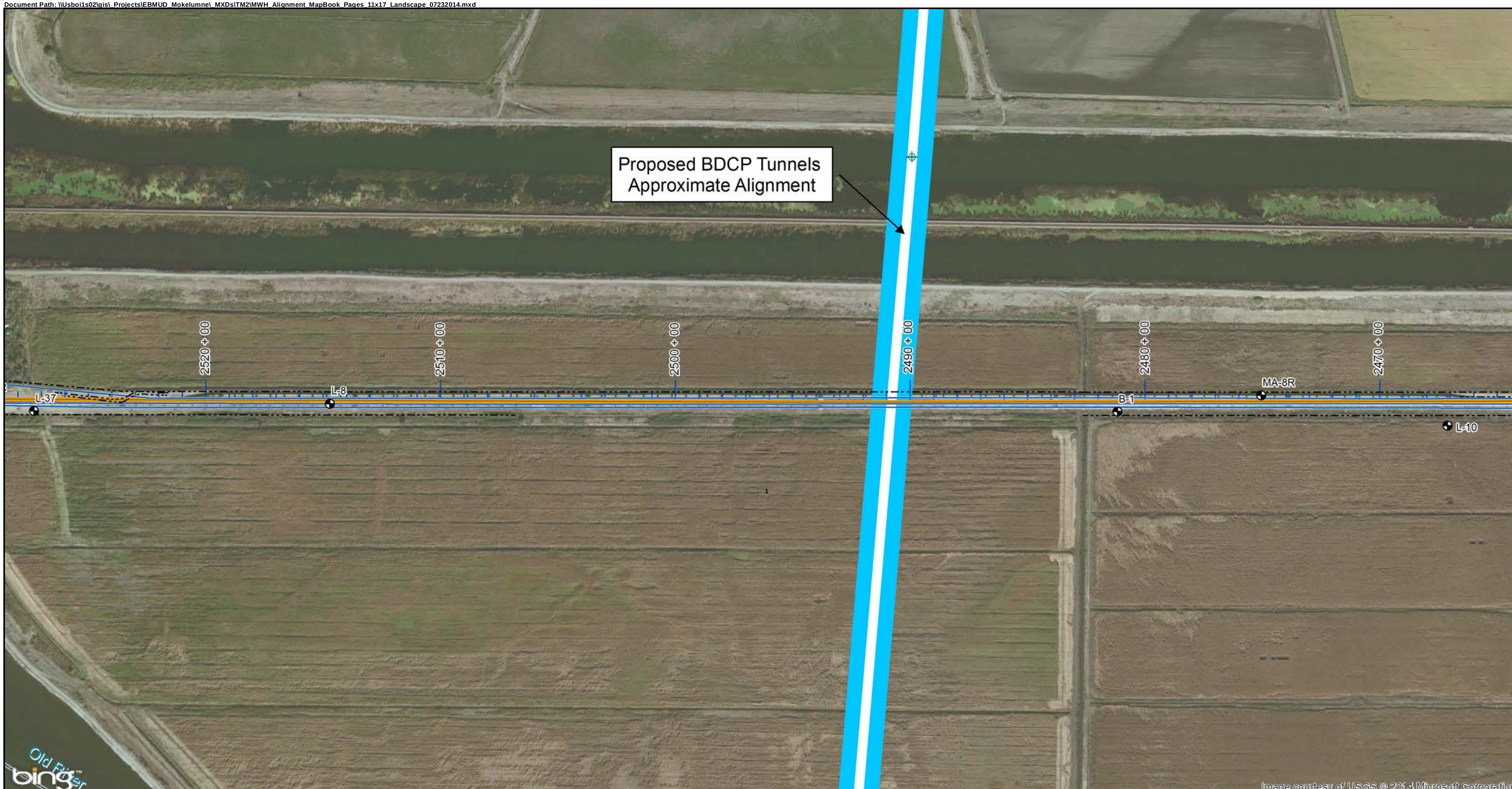
DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

EBMUD

MWH

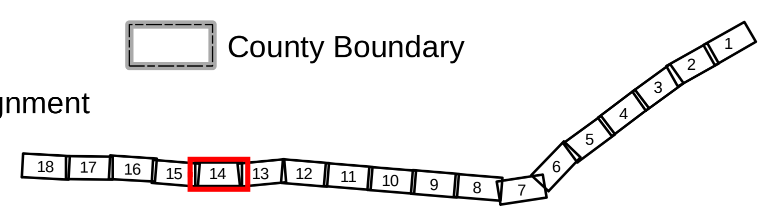
FIGURE 4-1n

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Alignment_MapBook_Pages_11x17_Landscape_07232014.mxd



LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

N W E S

0 400 800

Feet

TITLE:

Delta Tunnel Plan Set - Sheet 14 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

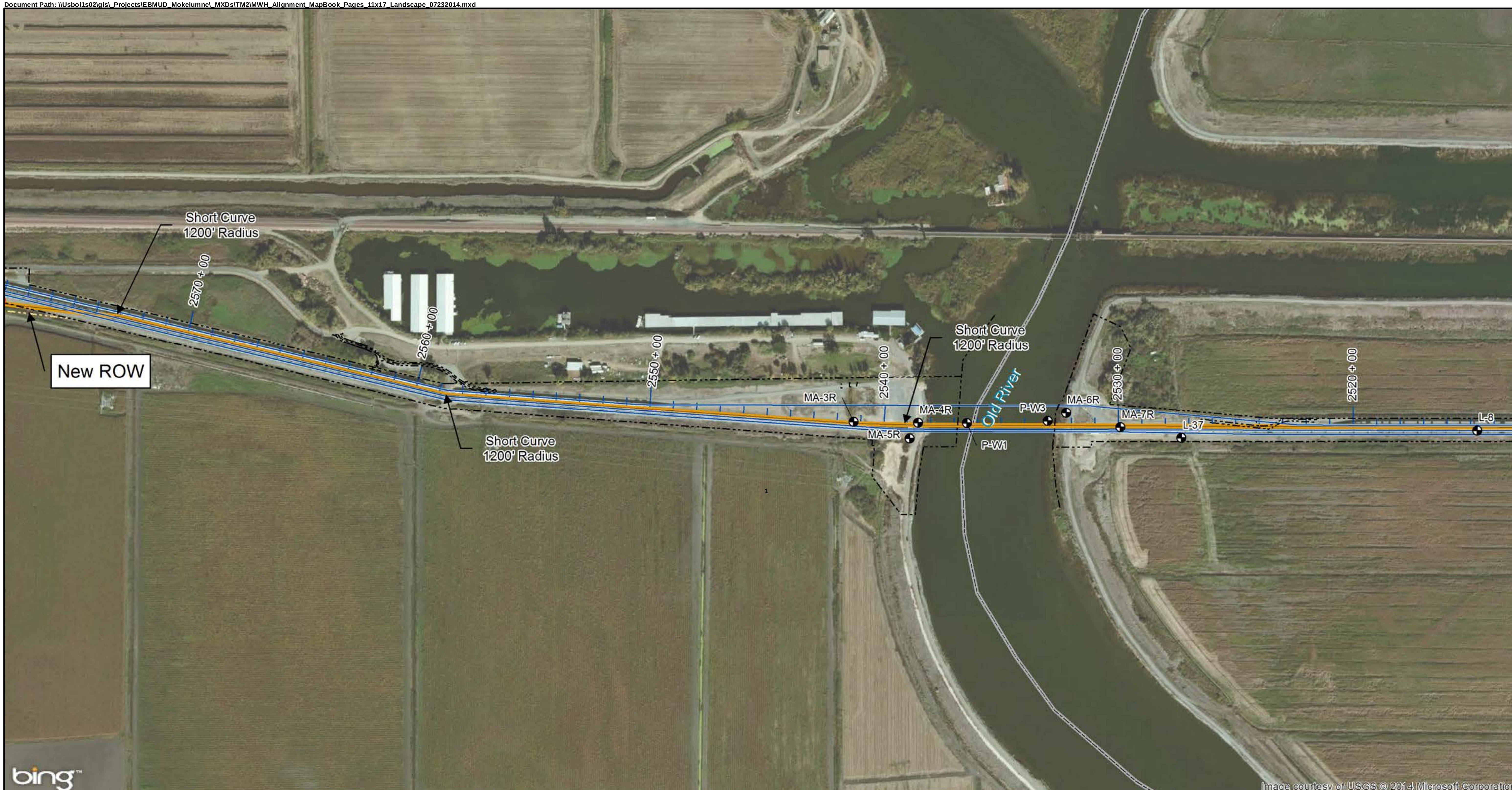
EBMUD

MWH

FIGURE

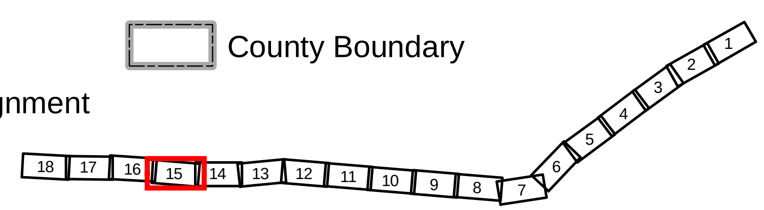
4-1o

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Alignment_MapBook_Pages_11x17_Landscape_07232014.mxd



LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

N W E S

0 400 800

Feet

TITLE: Delta Tunnel Plan Set - Sheet 15 of 18

PROJECT: Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

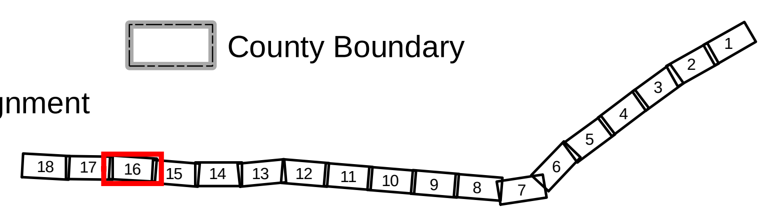
EBMUD

MWH

FIGURE 4-1p

LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

N W E S

0 400 800

Feet

TITLE:

Delta Tunnel Plan Set - Sheet 16 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

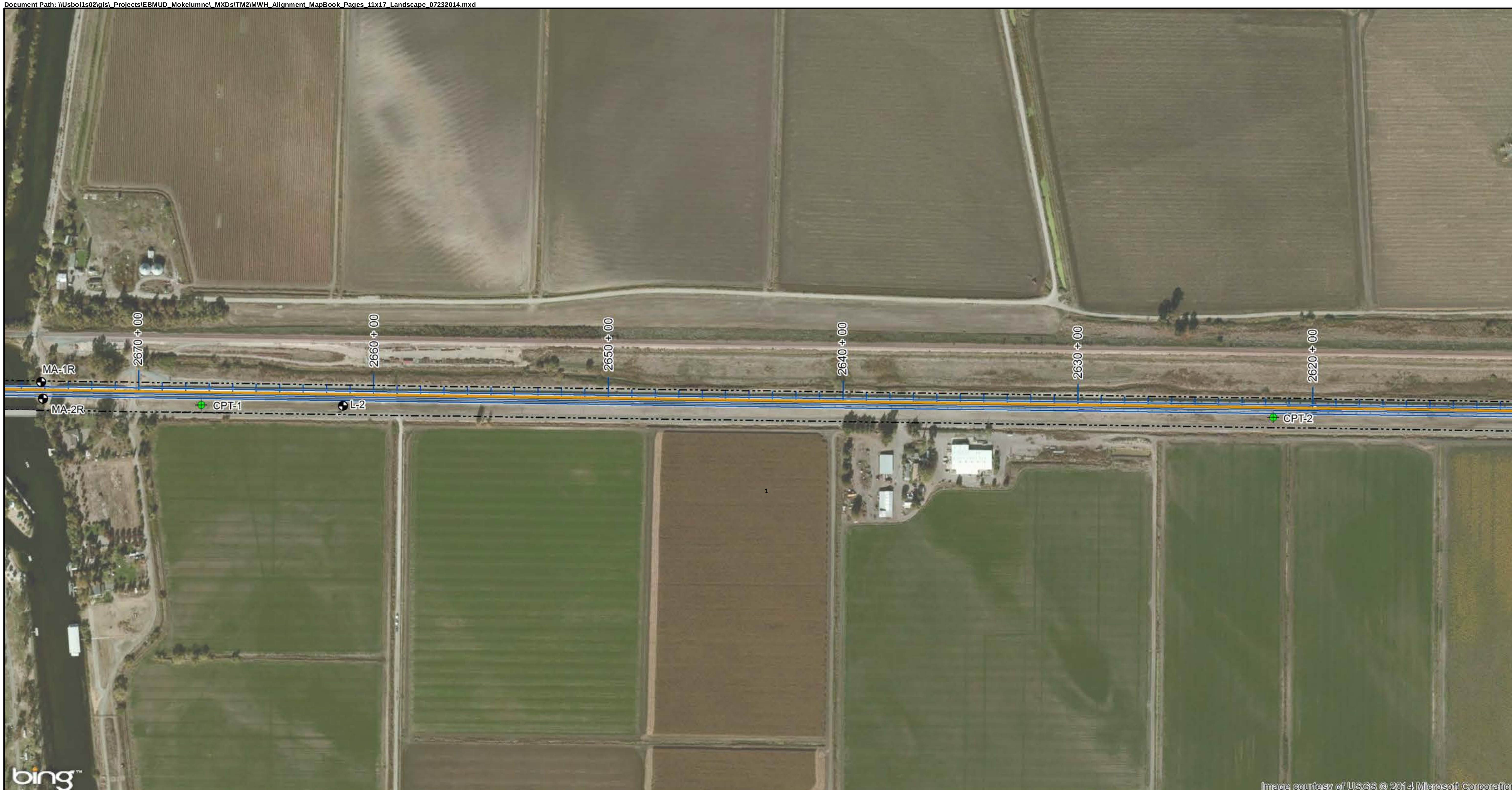
EBMUD

MWH

FIGURE

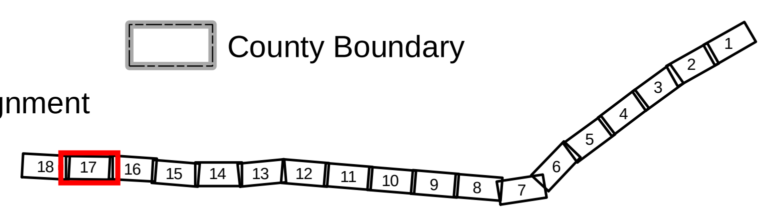
4-1q

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Alignment_MapBook_Pages_11x17_Landscape_07232014.mxd



LEGEND

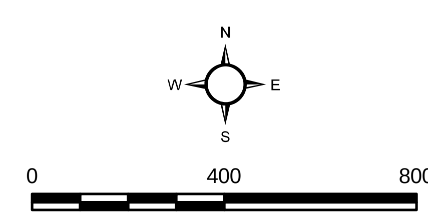
- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet



TITLE:

Delta Tunnel Plan Set - Sheet 17 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

EBMUD

MWH

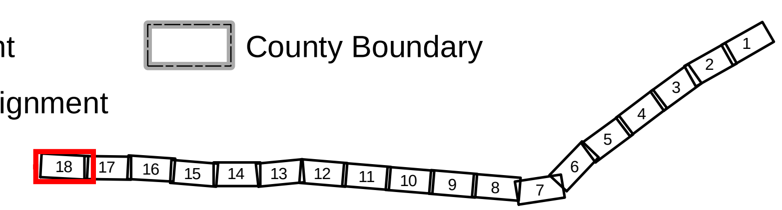
FIGURE

4-1r

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Alignment_MapBook_Pages_11x17_Landscape_07232014.mxd

LEGEND

- Mokelumne Aqueduct Boring
- BDCP Boring
- CPT
- ROW
- Existing Mokelumne Aqueduct Alignment
- Proposed Delta Tunnel Alignment
- Approximate Proposed BDCP Alignment
- Interstate
- Highway
- Major Road
- County Boundary



Note: Stationing is approximate.

Date Saved: 7/24/2014

1 inch = 400 feet

N W E S

0 400 800

Feet

TITLE:

Delta Tunnel Plan Set - Sheet 18 of 18

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM2

DATA REFERENCE(S): Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot US

EBMUD

MWH

FIGURE 4-1s

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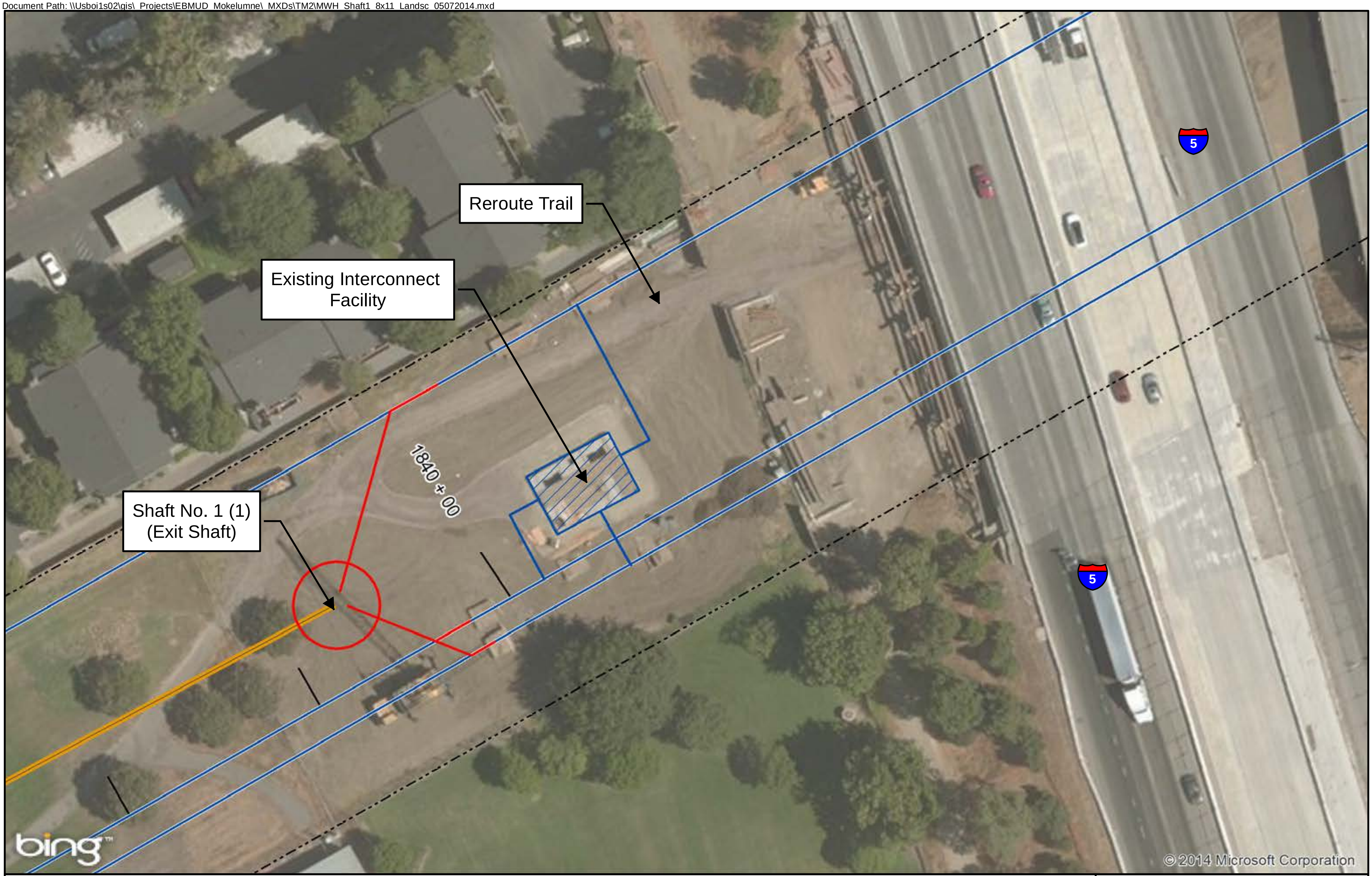


LEGEND:

- Mokelumne Aqueduct Alignment
- Proposed Tunnel Alignment
- ROW

Note:
1. Design and sizing of shaft by contractor.

N W E S

Updated: 7/23/2014

1 inch = 60 feet

0 30 60 120 Feet

TITLE:
Proposed Shaft 1

PROJECT:
Mokelumne Aqueducts Delta Tunnel Study

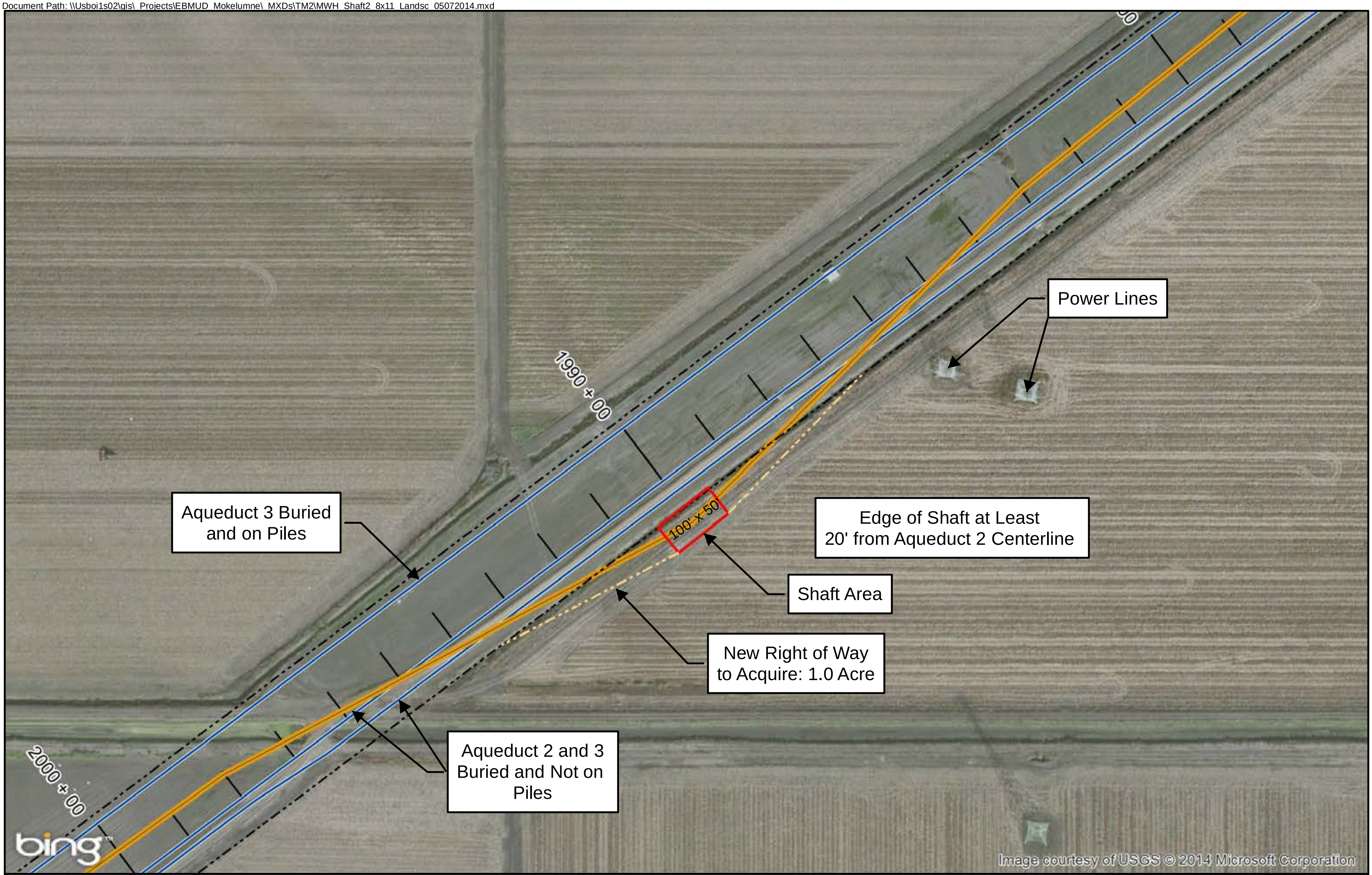
REFERENCE(S):
NAD 1983 StatePlane California III FIPS 0403 Feet

EBMUD

MWH

FIGURE:
4-2a

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Shaft2_8x11_Landsc_05072014.mxd



LEGEND:

- Mokelumne Aqueduct Alignment
- Proposed Tunnel Alignment
- ROW

Note:
1. Design and sizing of shaft by contractor.

N W E S

Updated: 7/23/2014

1 inch = 200 feet

0 100 200 400 Feet

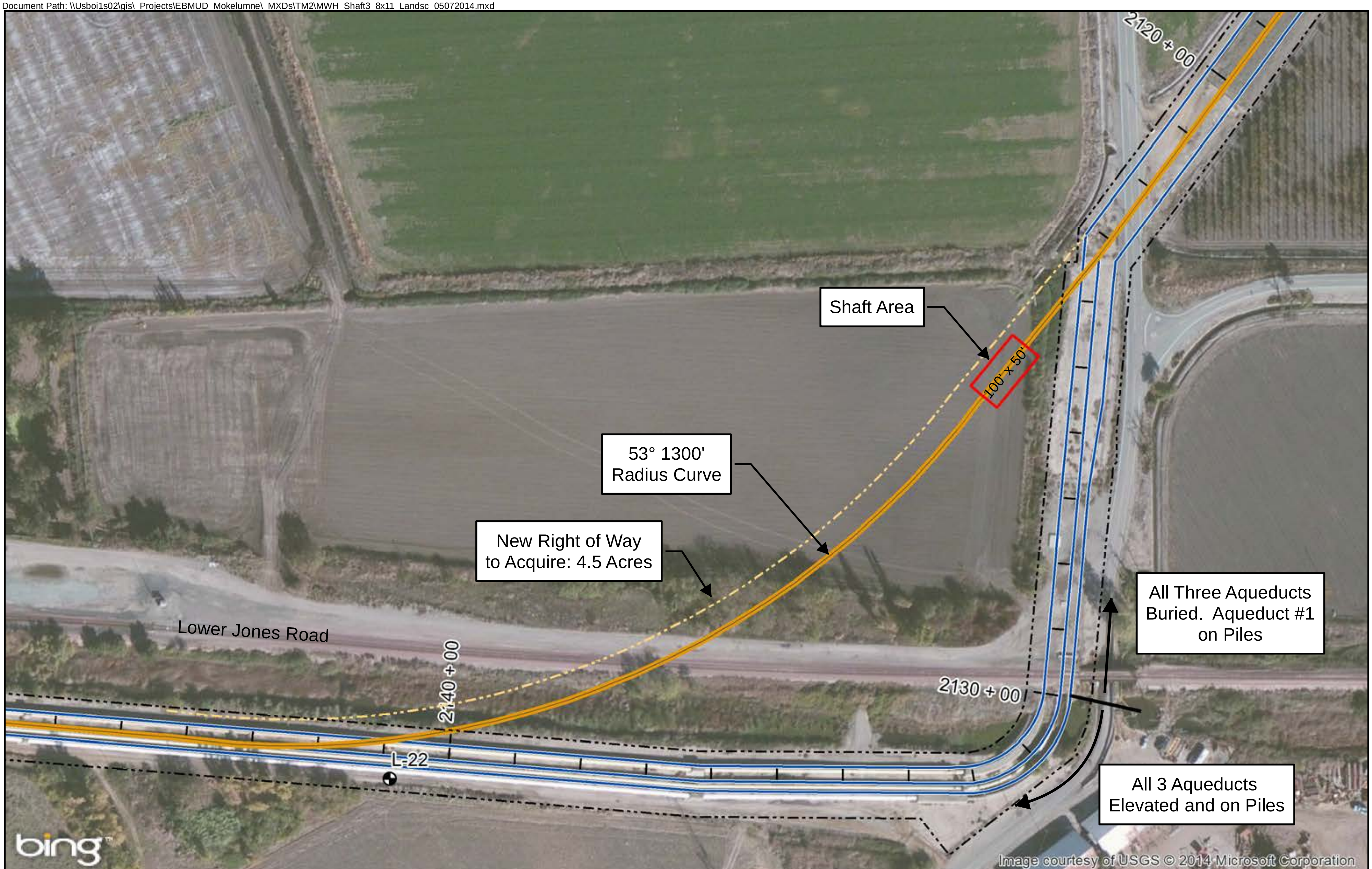
TITLE:
Proposed Shaft 2

PROJECT:
Mokelumne Aqueducts Delta Tunnel Study

REFERENCE(S):
NAD 1983 StatePlane California III FIPS 0403 Feet

EBMUD MWH

FIGURE: 4-2b



LEGEND:

- Mokelumne Aqueduct Boring (Multiple Consultants)
- Mokelumne Aqueduct Alignment
- Proposed Tunnel Alignment
- ROW

Note:
1. Design and sizing of shaft by contractor.

N W E S

Updated: 7/23/2014

1 inch = 200 feet

0 100 200 400 Feet

TITLE:
Proposed Shaft 3

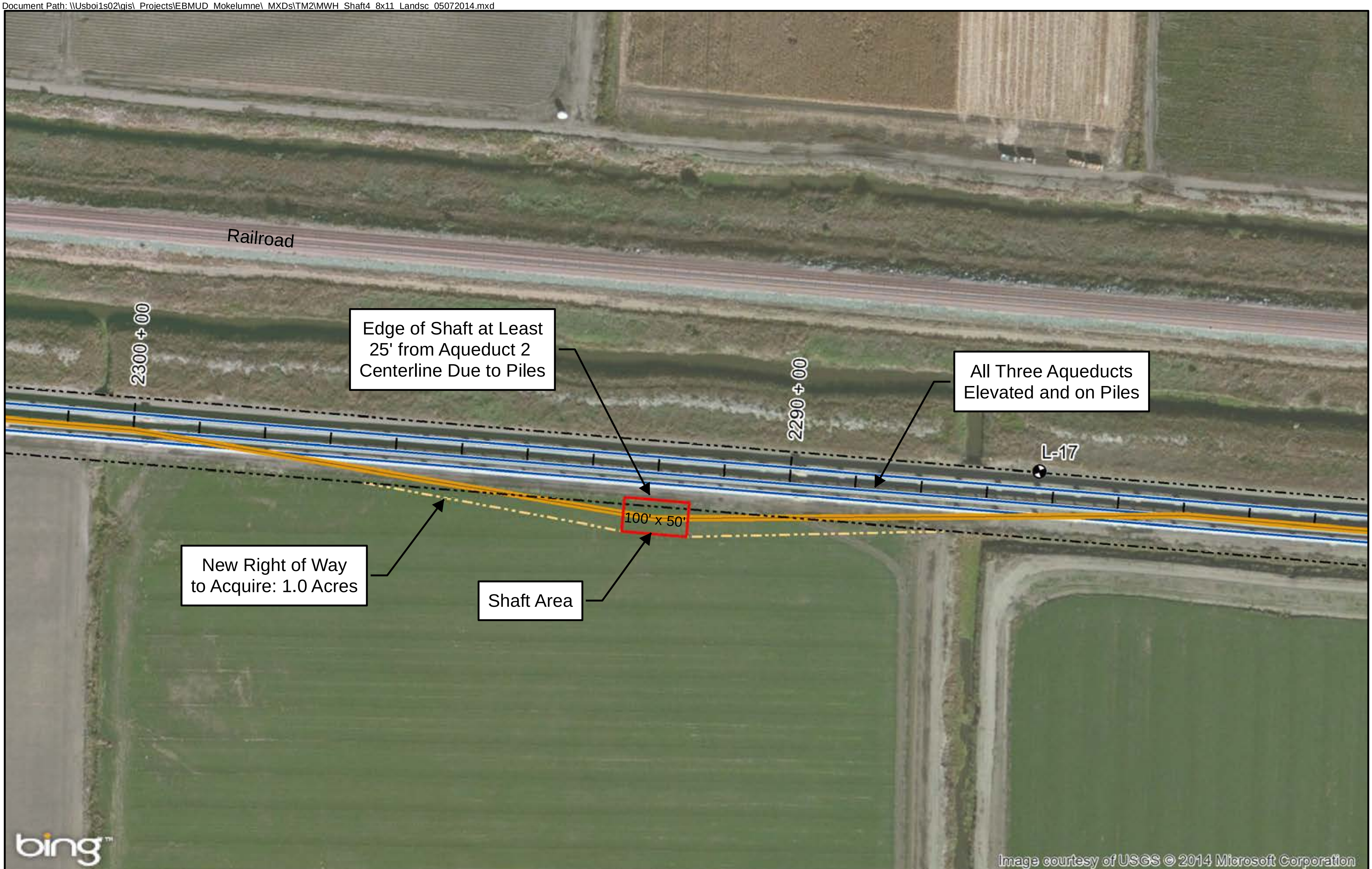
PROJECT:
Mokelumne Aqueducts Delta Tunnel Study

REFERENCE(S):
NAD 1983 StatePlane California III FIPS 0403 Feet

EBMUD MWH

FIGURE: **4-2c**

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Shaft4_8x11_Landsc_05072014.mxd



LEGEND:

- Mokelumne Aqueduct Boring (Multiple Consultants)
- Mokelumne Aqueduct Alignment
- Proposed Tunnel Alignment
- ROW

Note:
1. Design and sizing of shaft by contractor.

N W E S

Updated: 7/23/2014

1 inch = 200 feet

0 100 200 400 Feet

TITLE:
Proposed Shaft 4

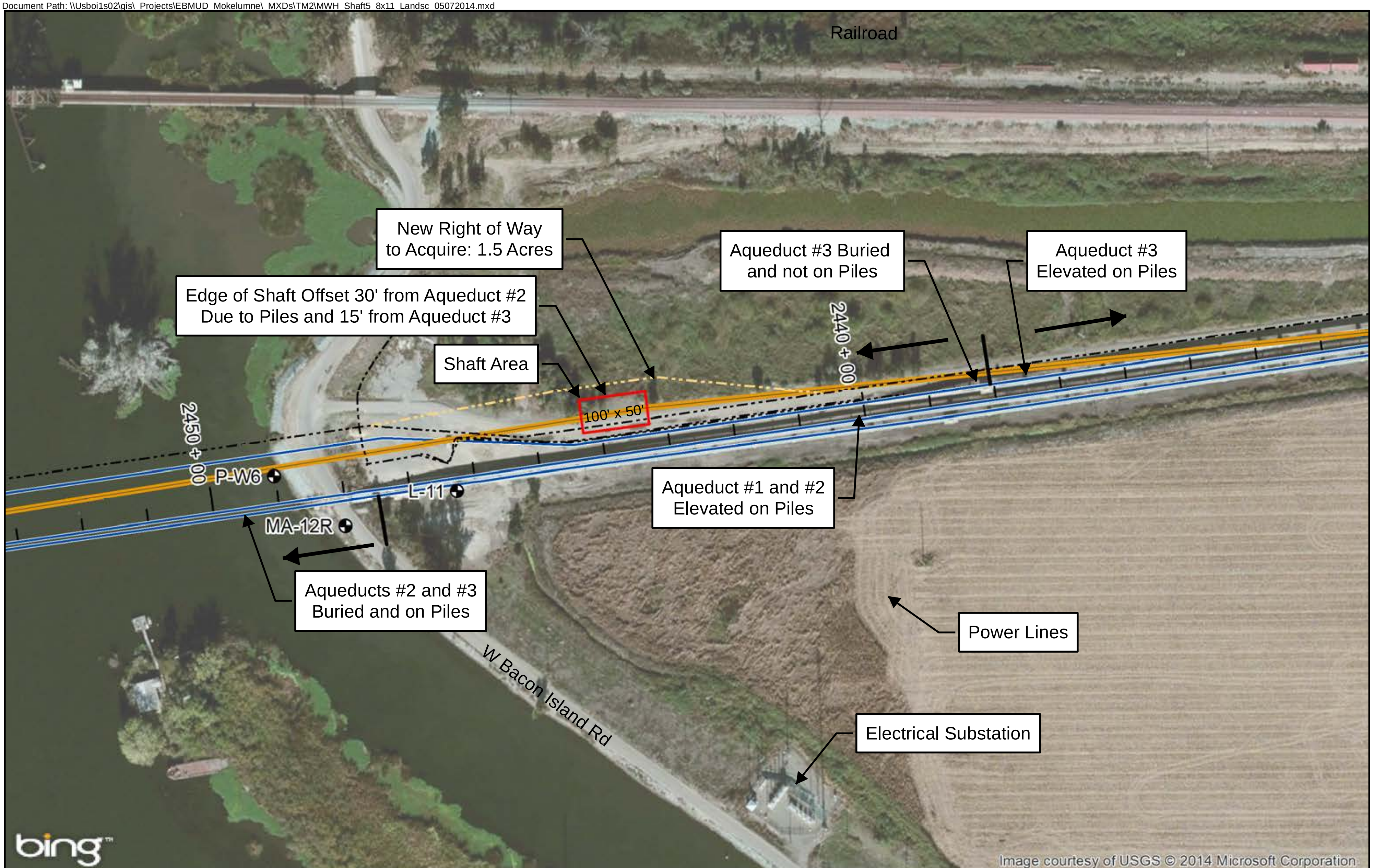
PROJECT:
Mokelumne Aqueducts Delta Tunnel Study

REFERENCE(S):
NAD 1983 StatePlane California III FIPS 0403 Feet

EBMUD MWH

FIGURE: 4-2d

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Shaft5_8x11_Landsc_05072014.mxd



LEGEND:

- Mokelumne Aqueduct Boring (Multiple Consultants)
- Mokelumne Aqueduct Alignment
- Proposed Tunnel Alignment
- ROW

Note:
1. Design and sizing of shaft by contractor.

N W E S

Updated: 7/23/2014

1 inch = 200 feet

0 100 200 400 Feet

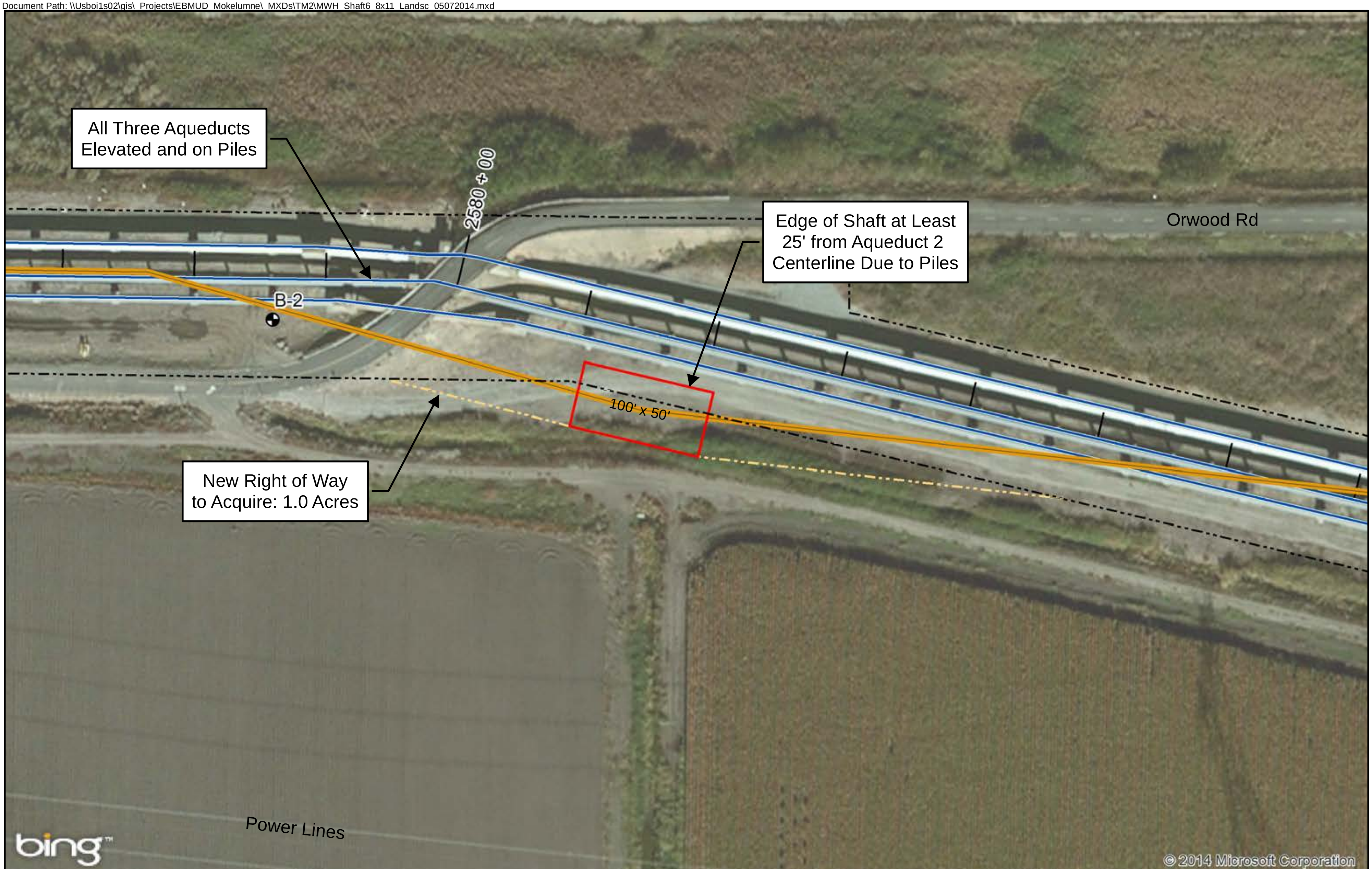
TITLE:
Proposed Shaft 5

PROJECT:
Mokelumne Aqueducts Delta Tunnel Study

REFERENCE(S):
NAD 1983 StatePlane California III FIPS 0403 Feet

EBMUD MWH

FIGURE:
4-2e



LEGEND:
- Mokelumne Aqueduct Boring (Multiple Consultants)
- Mokelumne Aqueduct Alignment
- Proposed Tunnel Alignment
- ROW

Note:
1. Design and sizing of shaft by contractor.

N W E S

Updated: 7/23/2014

1 inch = 100 feet

0 50 100 200 Feet

TITLE:
Proposed Shaft 6

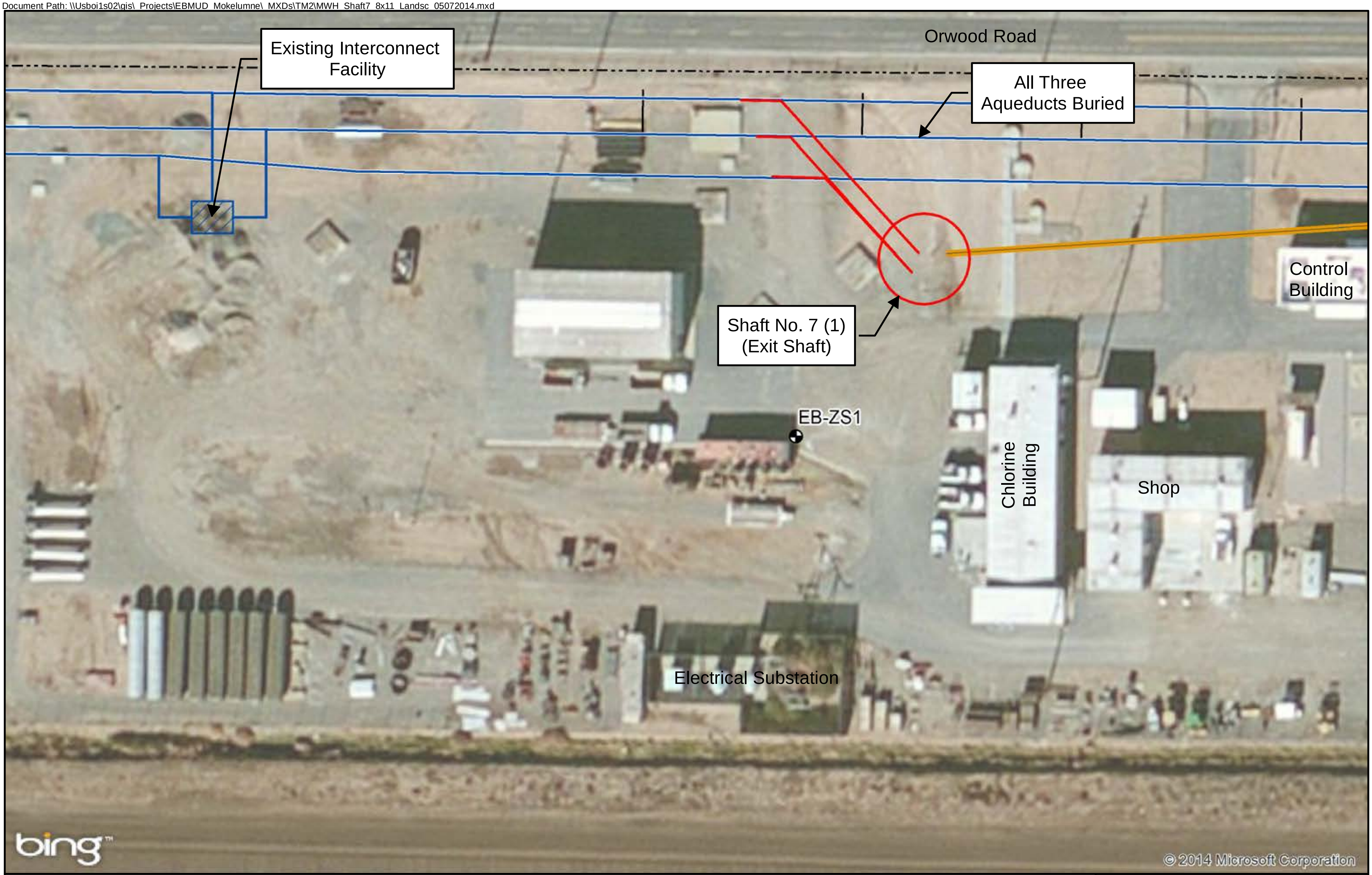
PROJECT:
Mokelumne Aqueducts Delta Tunnel Study

REFERENCE(S):
NAD 1983 StatePlane California III FIPS 0403 Feet

EBMUD MWH

FIGURE: 4-2f

Document Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_Shaft7_8x11_Landsc_05072014.mxd



LEGEND:
- Mokelumne Aqueduct Boring (Multiple Consultants)
- Mokelumne Aqueduct Alignment
- Proposed Tunnel Alignment
- ROW

Note:
1. Design and sizing of shaft by contractor.

N / W / E / S

Updated: 7/23/2014

1 inch = 60 feet

0 30 60 120 Feet

TITLE:
Proposed Shaft 7

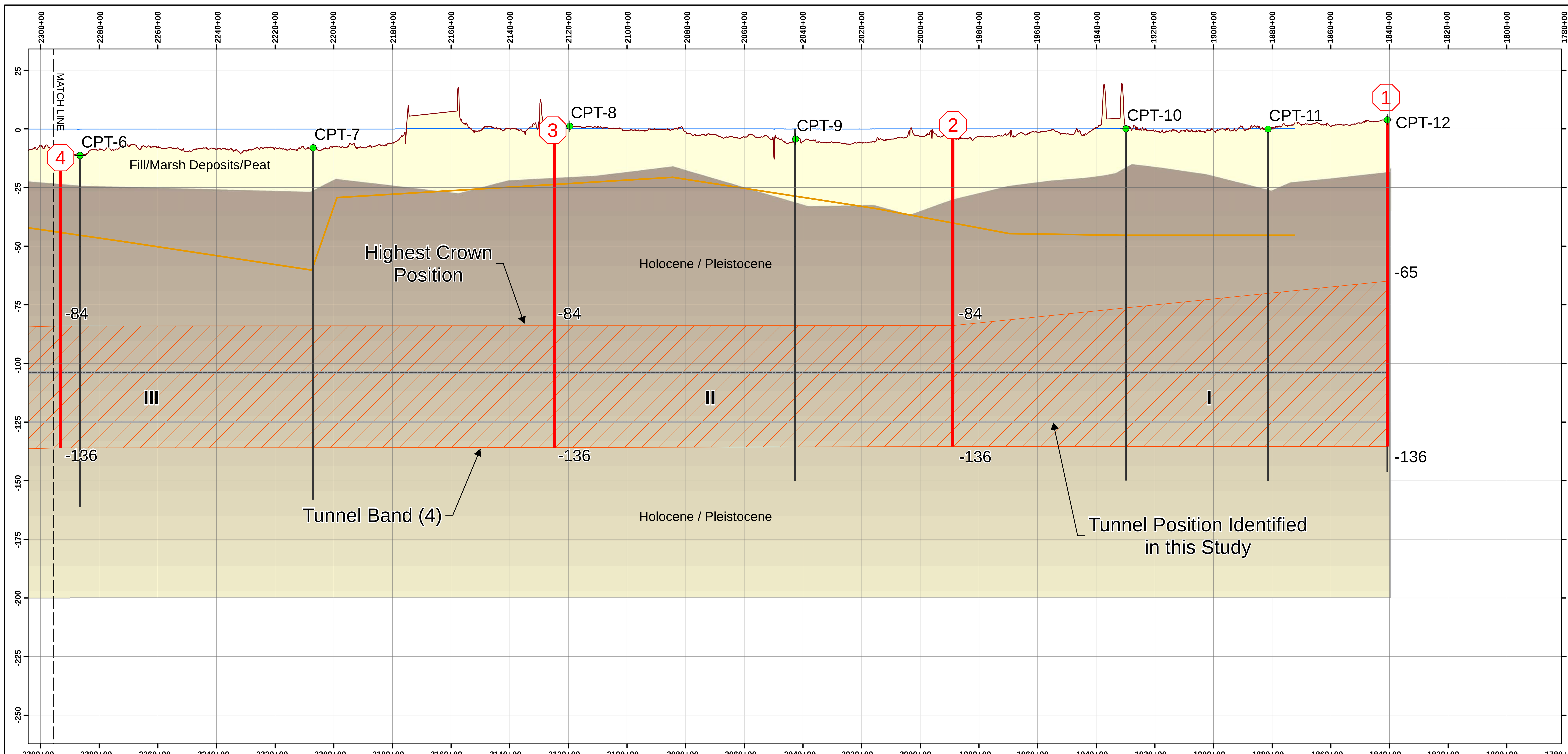
PROJECT:
Mokelumne Aqueducts Delta Tunnel Study

REFERENCE(S):
NAD 1983 StatePlane California III FIPS 0403 Feet

MWH

FIGURE: 4-2g

Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_XSec_Page2_Pile_Liquid_22x34_Landscape_7_23_14.mxd



LEGEND

- CPT
- Shaft
- Mokelumne Delta Tunnel
- Proposed BDCP Tunnel Alignment
- Ground Surface
- Mean Sea Level
- Pile Tips
- Tunnel
- Tunnel Band

Geologic Unit

- 1 - 3 Fill/Marsh Deposits/Peat
- 4 - 5 Holocene / Pleistocene

Notes:

1. Stationing is approximate.
2. Horizontal: 1 inch = 2,000 ft
3. Vertical: 1 inch = 25 ft. (80 to1 Vertical Exaggeration)
4. Upper line is highest possible tunnel crown. Lower line is likely lowest tunnel invert.
5. Position based on figure 3-21 in the draft EIR/EIS (2013).
6. Maximum depth based on text and figure 11-6 in the Conceptual Engineering Report (2010, CDWS).

Source:
CWDD, 1981
ESA, 1992
Treadwell & Rollo, 2010
URS, 2007
LiDAR Data from DWR, 2007

0 4,000 8,000
Feet

TITLE:

Proposed Delta Tunnel Profile

PROJECT:
Mokelumne Aqueducts Delta Tunnel Study

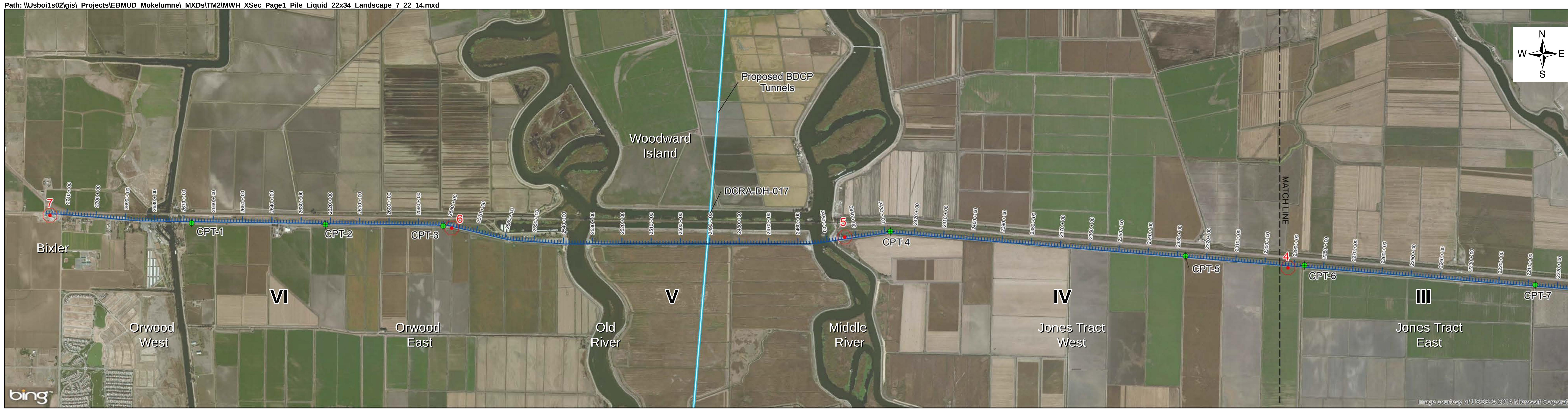
DRAWING REFERENCE(S):
Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Horizontal and Vertical Units: Foot US

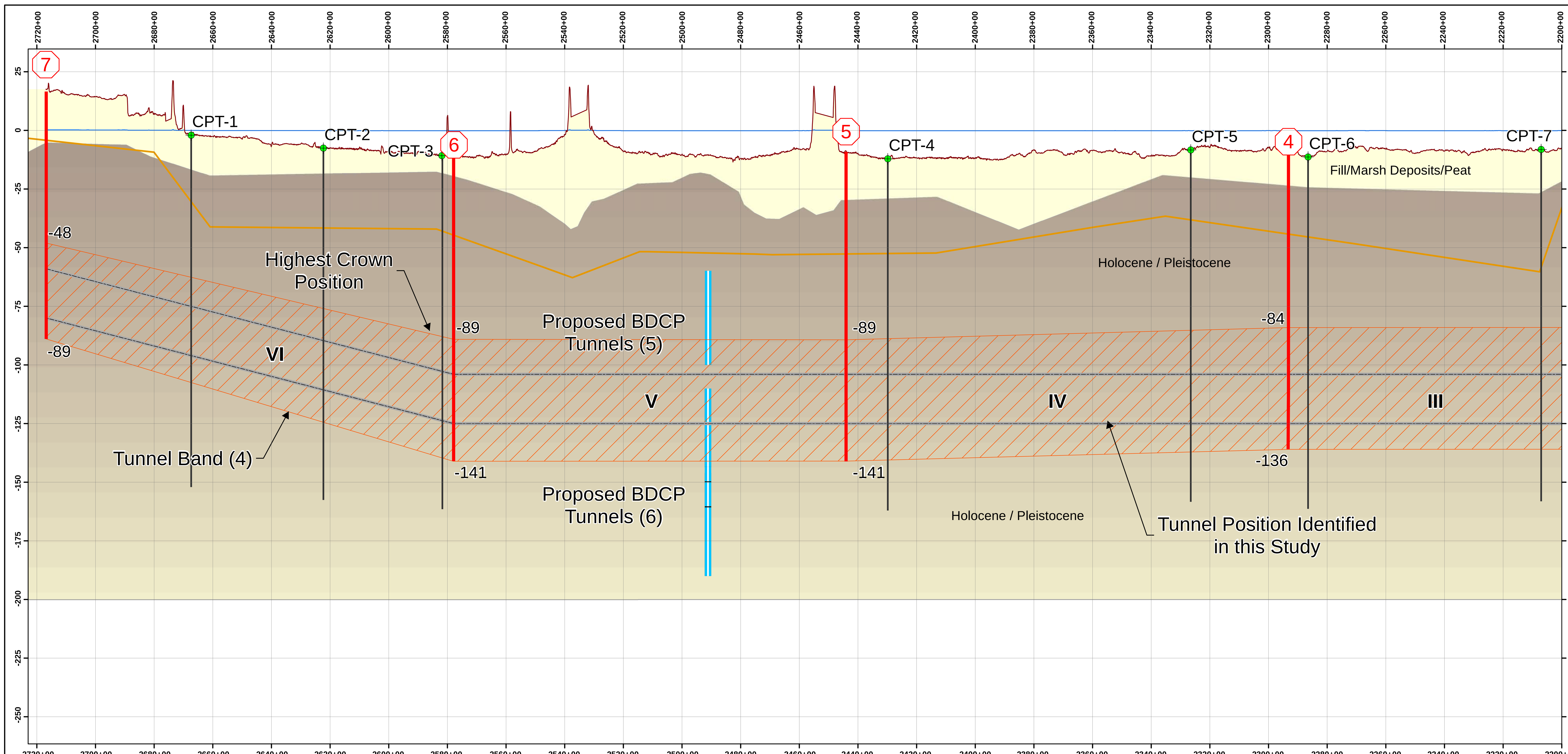
MWH

Updated: 7/24/2014

FIGURE
4-3a

Path: \\Usboi1s02\gis_Projects\EBMUD_Mokelumne_MXDs\TM2\MWH_XSec_Page1_Pile_Liquid_22x34_Landscape_7_22_14.mxd





LEGEND

- CPT
- Shaft
- Mokelumne Delta Tunnel
- Proposed BDCP Tunnel Alignment
- Ground Surface
- Mean Sea Level
- Pile Tips
- Proposed BDCP Tunnels
- Tunnel
- Tunnel Band

Geologic Unit

- 1 - 3 Fill/Marsh Deposits/Peat
- 4 - 5 Holocene / Pleistocene

Notes:

1. Stationing is approximate.
2. Horizontal: 1 inch = 2,000 ft
3. Vertical: 1 inch = 25 ft. (80 to1 Vertical Exaggeration)
4. Upper line is highest possible tunnel crown. Lower line is likely lowest tunnel invert.
5. Position based on figure 3-21 in the draft EIR/EIS (2013).
6. Maximum depth based on text and figure 11-6 in the Conceptual Engineering Report (2010, CDWS).

Source:
CWDD, 1981
ESA, 1992
Treadwell & Rollo, 2010
URS, 2007
LiDAR Data from DWR, 2007

0 4,000 8,000
Feet

TITLE:

Proposed Delta Tunnel Profile

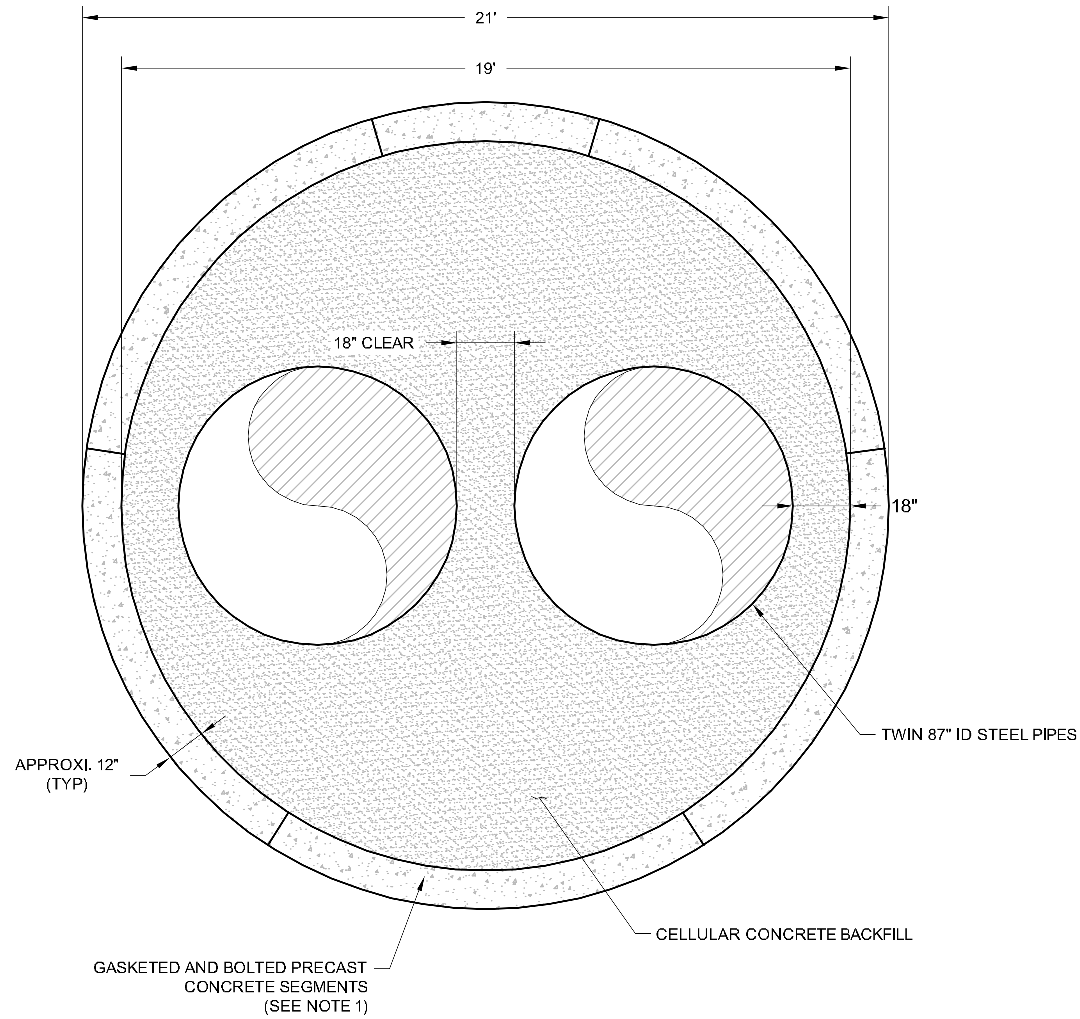
PROJECT:
Mokelumne Aqueducts Delta Tunnel Study - TM2

DRAWING REFERENCE(S):
Coordinate System: NAD 1983 StatePlane California III FIPS 0403 Feet
Horizontal and Vertical Units: Foot US

MWH

Updated: 7/24/2014

FIGURE
4-3b



NOTE:

1. FINAL DESIGN BY CONTRACTOR.

TITLE: TYPICAL TUNNEL CROSS SECTION
TWIN PIPES

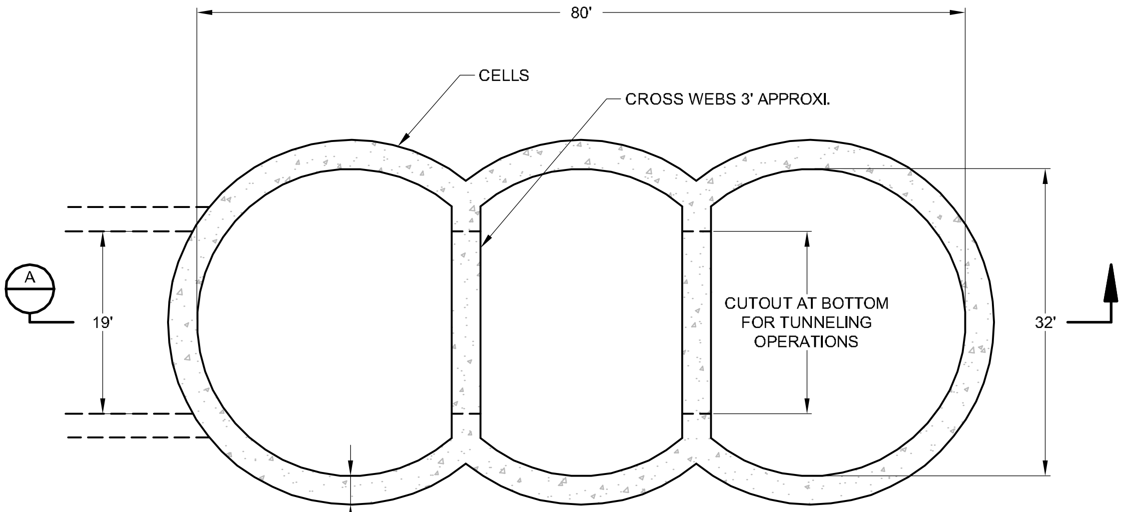
PROJECT: Mokelumne Aqueducts Delta Tunnel Study - TM3

DATA REFERENCES:

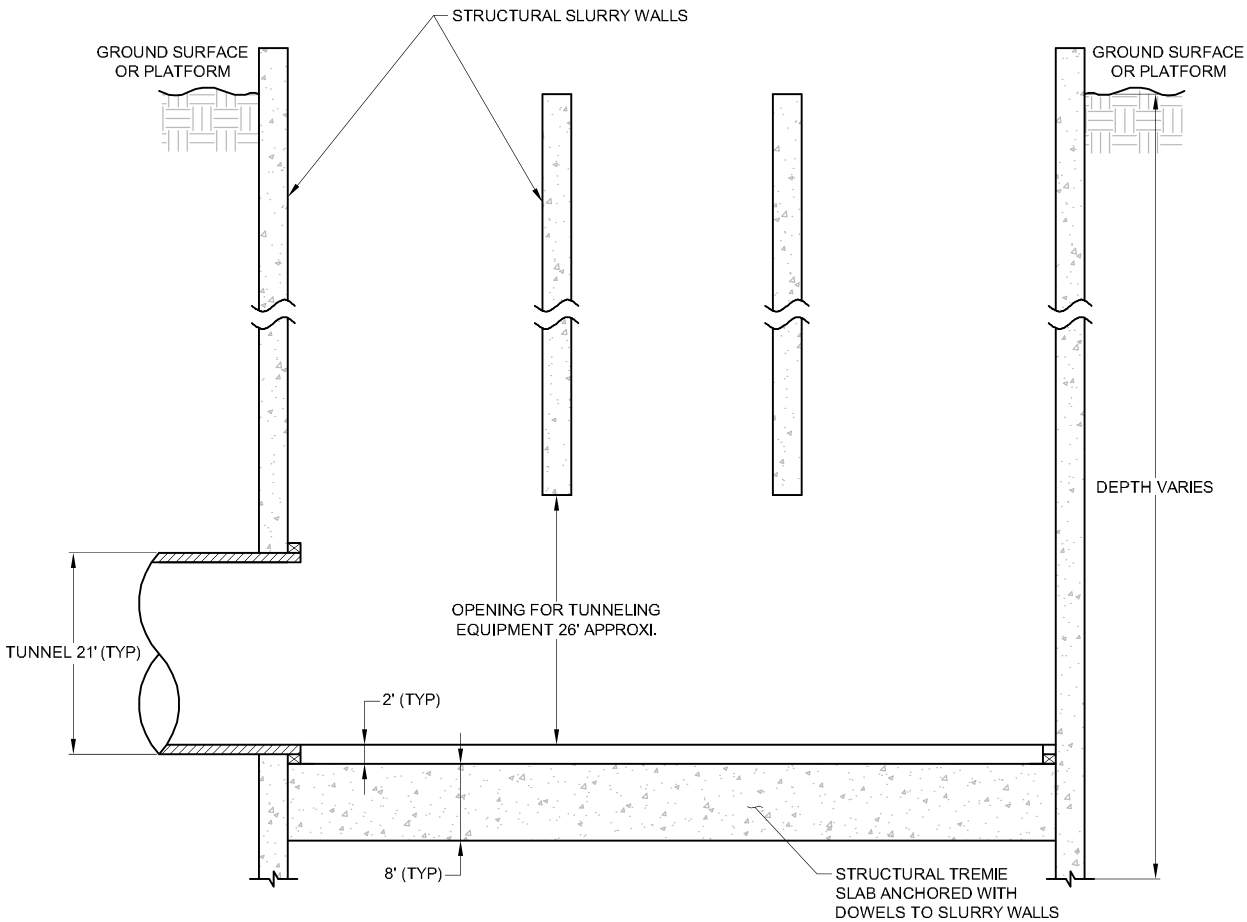
EBMUD

MWH

FIGURE: 5-1



PLAN
NOT TO SCALE



SECTION
NOT TO SCALE

NOTE:

1. SHAFT DESIGN AND SIZE DETERMINED BY CONTRACTOR.

TITLE:
CONSTRUCTION LAUNCH SHAFT- TYPICAL

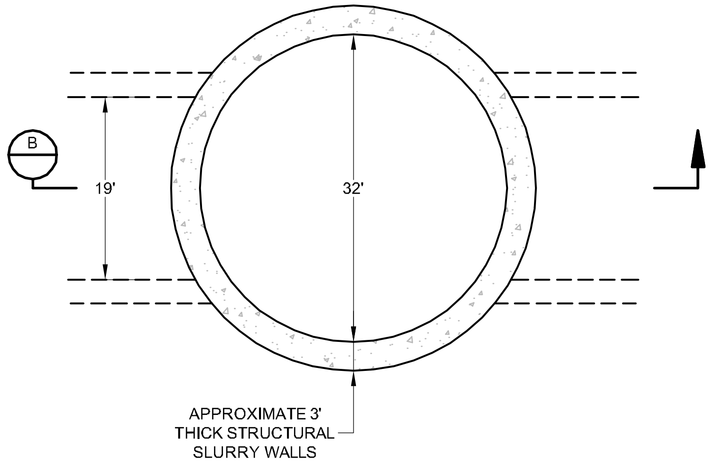
PROJECT:
Mokelumne Aqueducts Delta Tunnel Study - TM3

DATA REFERENCES:

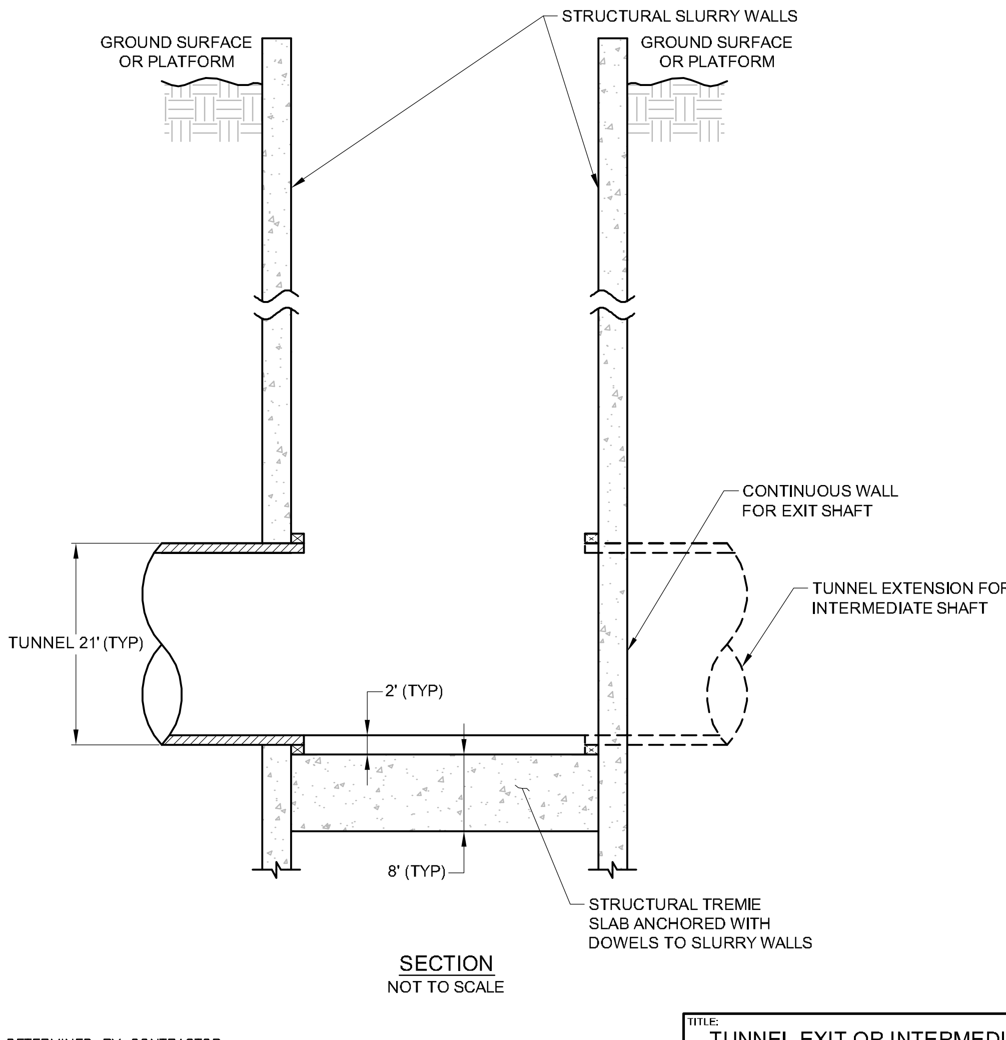
EBMUD

MWH

FIGURE:
6-1



PLAN
NOT TO SCALE



SECTION
NOT TO SCALE

NOTE:

1. SHAFT DESIGN AND SIZE DETERMINED BY CONTRACTOR.

TITLE:
TUNNEL EXIT OR INTERMEDIATE SHAFT TYPICAL

PROJECT:
Mokelumne Aqueducts Delta Tunnel Study - TM3

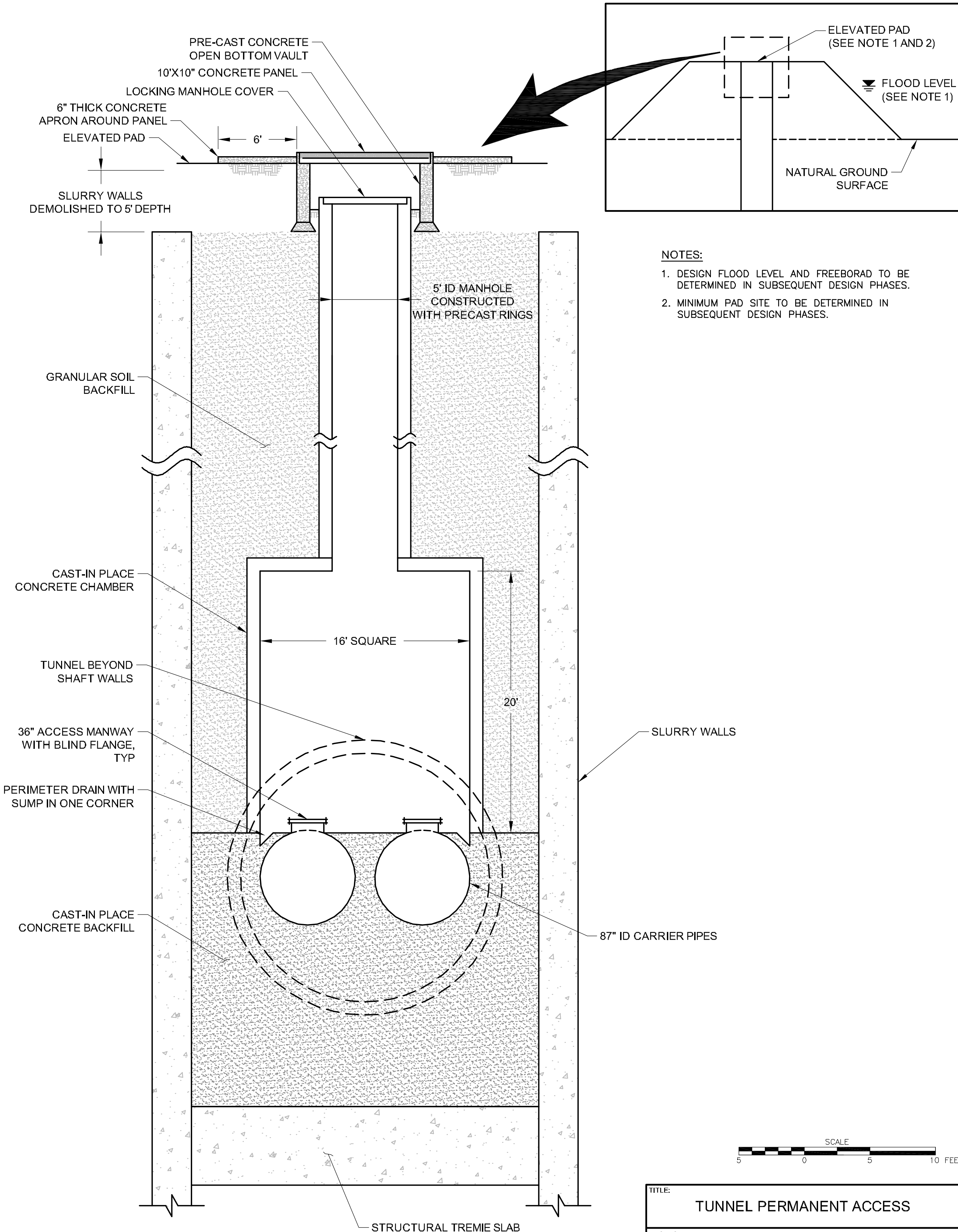
DATA REFERENCES:

EBMUD

MWH

FIGURE:
6-2

D:\pwdirectory jen\dms13808\10504305 Detail Sheet



NOTES:

1. DESIGN FLOOD LEVEL AND FREEBORAD TO BE DETERMINED IN SUBSEQUENT DESIGN PHASES.
2. MINIMUM PAD SITE TO BE DETERMINED IN SUBSEQUENT DESIGN PHASES.

TITLE: TUNNEL PERMANENT ACCESS

PROJECT: Mokelumne Aqueducts Delta Tunnel Study - TM3

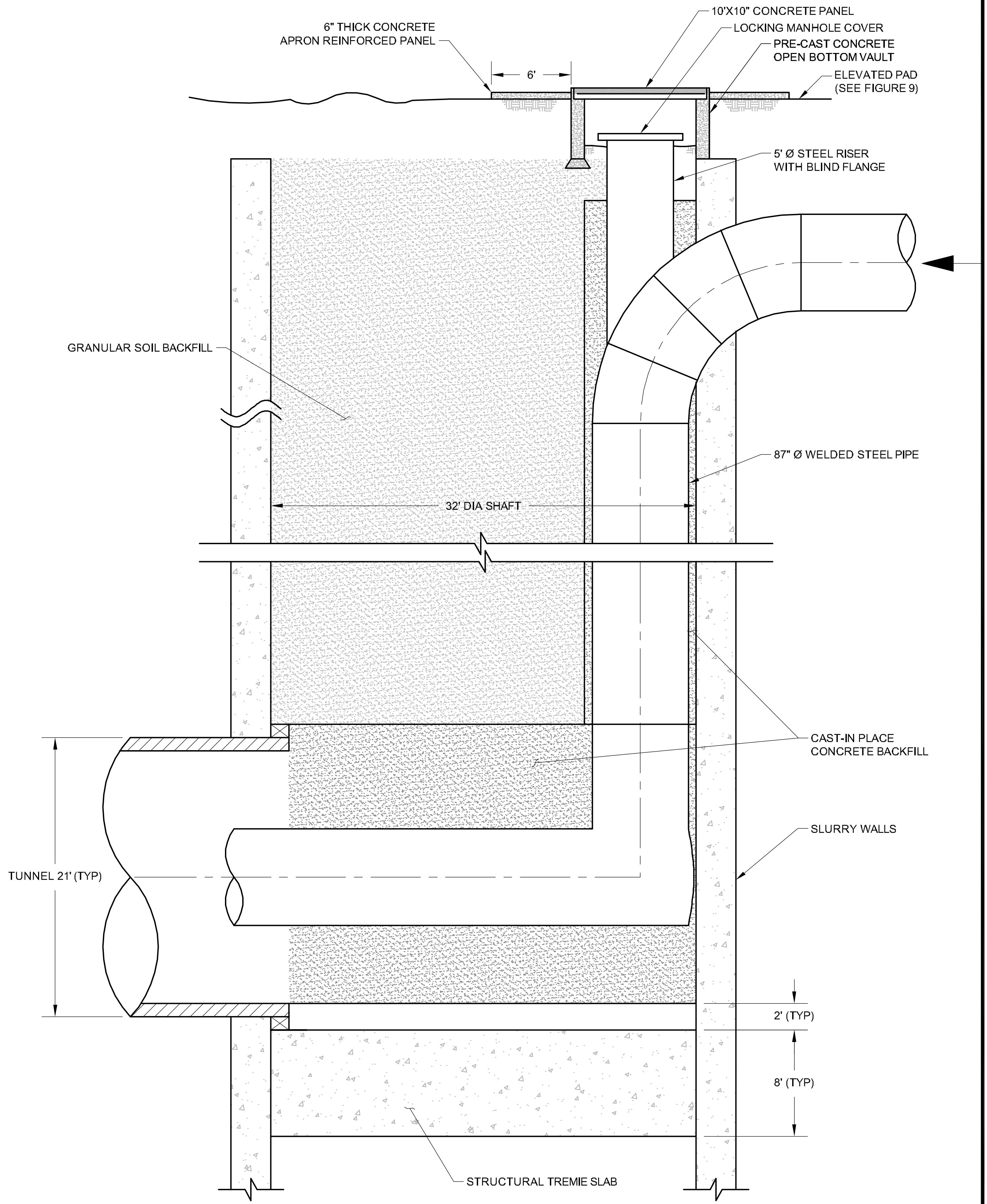
DATA REFERENCES:

EBMUD

MWH

FIGURE: 6-3

D:\pwdirectory_jen\dms13808\10504305 Detail Sheet



TITLE:

SHAFTS #1 AND #7 ELEVATION

PROJECT:

Mokelumne Aqueducts Delta Tunnel Study - TM3

DATA REFERENCES:

EBMUD

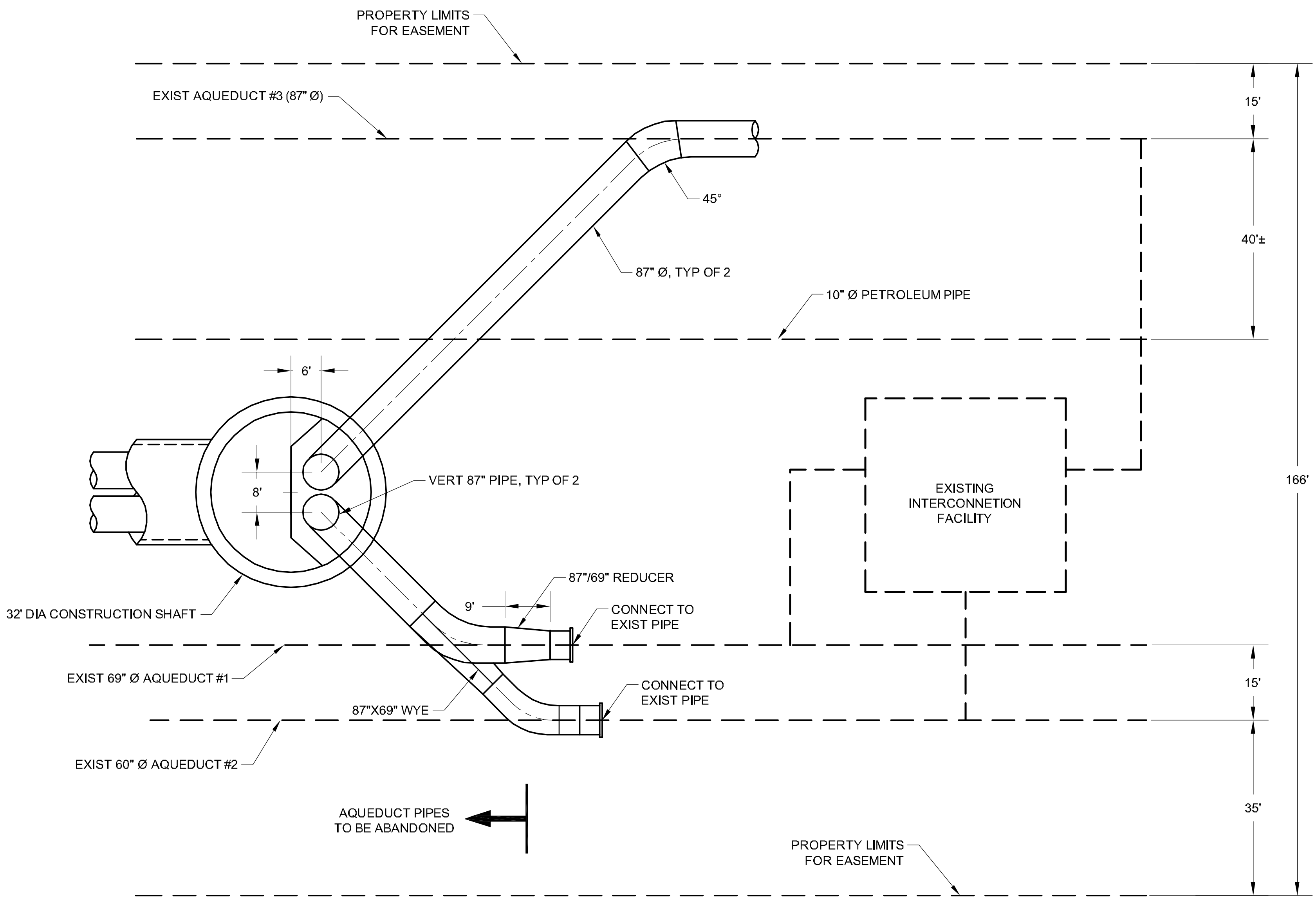
MWH

FIGURE:

7-1

D:\pwdirectory jen\dms13808\10504305 Detail Sheet

D:\pwdirectory jen\dms13808\10504305 Detail Sheet



TITLE:
SHAFT #1
PIPE CONNECTION LAYOUT -STOCKTON

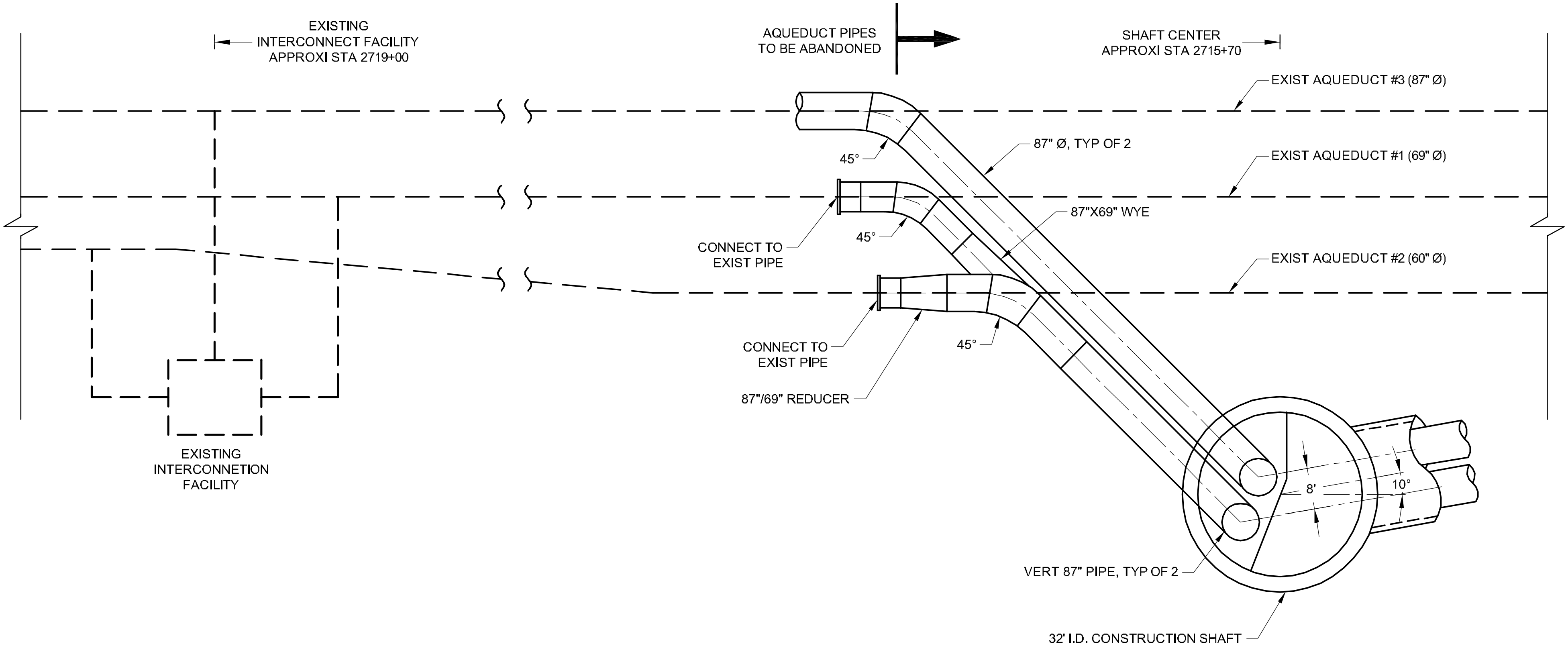
PROJECT:
Mokelumne Aqueducts Delta Tunnel Study - TM3

DATA REFERENCES:

EBMUD

MWH

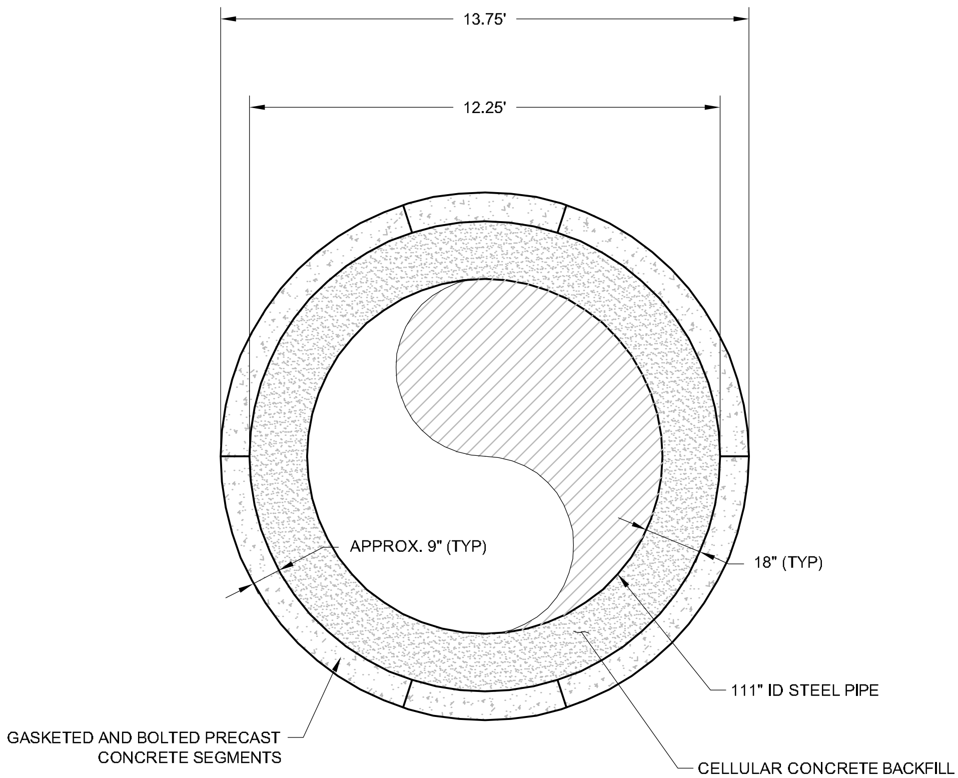
FIGURE:
7-2



NOTE:

1. SEE FIGURE 4, SHAFT 7 FOR SHAFT PLAN VIEW.

TITLE: SHAFT #7 PIPE CONNECTION LAYOUT - BIXLER	
PROJECT: Mokelumne Aqueducts Delta Tunnel Study - TM3	
DATA REFERENCES:	
EBMUD	MWH
	FIGURE: 7-3



NOTE:

1. FINAL DESIGN BY CONTRACTOR.

TITLE:
ALTERNATIVE TUNNEL CROSS SECTION
SINGLE PIPE

PROJECT:
Mokelumne Aqueducts Delta Tunnel Study - TM3

DATA REFERENCES:

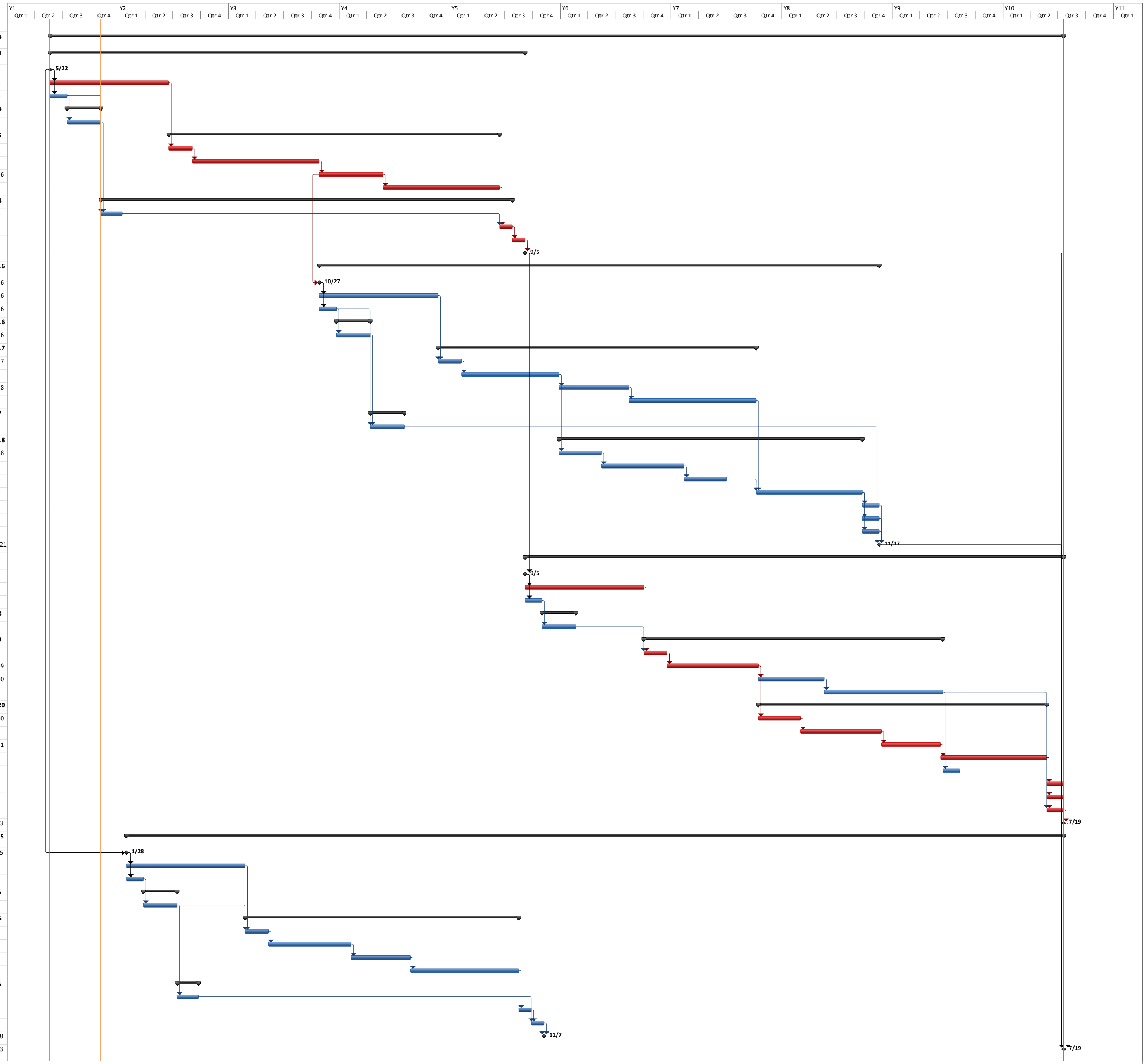
EBMUD

MWH

FIGURE: 5-2

D:\pwdirectory jen\dms13808\10504305 Detail Sheet

ID	Task Mode	Task Name	Duration	Start
1				
2		**MOKELUMNE DELTA TUNNEL Base Case**	**2390 days**	**Thu 5/22/14**
3		**CONTRACT A (EBMUD Mokelumne Delta Tunnel)**	**1120 days**	**Thu 5/22/14**
4		NTP CONTRACT A	0 days	Thu 5/22/14
5		TBM Order and Deliver	14 mons	Thu 5/22/14
6		Contract Mobilization & Submittals	2 mons	Thu 5/22/14
7		**Launch Shaft (Three Cells) Number 2**	**80 days**	**Thu 7/17/14**
8		Shaft Site Set Up/Construct Shaft 2	4 mons	Thu 7/17/14
9		**Reach 1 Tunnel Excavate 21 foot Diameter 14,925 lf**	**780 days**	**Thu 6/18/15**
10		Mobilization and Assemble TBM	11 wks	Thu 6/18/15
11		EBM Tunnel & Segment Installation	60 wks	Thu 9/3/15
12		Install 87 in T=.625 inch Steel Pipeline & Weld	30 wks	Thu 10/27/16
13		Place Cellular Concrete 7.35 cy/ft	55 wks	Thu 5/25/17
14		**Receiving Shaft Number 1 32 FT Finish**	**970 days**	**Thu 11/6/14**
15		Shaft Site Set Up/Construct Shaft 1	2.5 mons	Thu 11/6/14
16		Install Piping and Backfill Shaft 1	1.5 mons	Thu 6/14/18
17		**Testing & Demobilization**	1.5 mons	Thu 7/26/18
18		**Project Complete**	0 days	Wed 9/5/18
19		**CONTRACT B (EBMUD Mokelumne Delta Tunnel)**	**1320 days**	**Thu 10/27/16**
20		NTP CONTRACT B	0 days	Thu 10/27/16
21		TBM Order and Deliver	14 mons	Thu 10/27/16
22		Contract Mobilization & Submittals	2 mons	Thu 10/27/16
23		**Launch Shaft (Three Cells) Number 3**	**80 days**	**Thu 12/22/16**
24		Shaft Site Set Up/Construct Shaft 3	4 mons	Thu 12/22/16
25		**Reach 3 Tunnel Excavate 21 foot Diameter 16,250 lf**	**750 days**	**Thu 11/23/17**
26		Mobilization and Assemble TBM	11 wks	Thu 11/23/17
27		EBM Tunnel & Segment Installation	46 wks	Thu 2/8/18
28		Install 87 in T=.625 inch Steel Pipeline & Weld	33 wks	Thu 12/27/18
29		Place Cellular Concrete 7.35 cy/ft	60 wks	Thu 8/15/19
30		**Launch Shaft (Three Cells) Number 4**	**80 days**	**Thu 4/13/17**
31		Shaft Site Set Up/Construct Shaft 4	4 mons	Thu 4/13/17
32		**Reach 2 Tunnel Excavate 21 foot Diameter 13,600 lf**	**715 days**	**Thu 12/27/18**
33		Reset and Assemble TBM	20 wks	Thu 12/27/18
34		EBM Tunnel & Segment Installation	39 wks	Thu 5/16/19
35		Install 87 in T=.625 inch Steel Pipeline & Weld	20 wks	Thu 2/13/20
36		Place Cellular Concrete 7.35 cy/ft	50 wks	Thu 10/8/20
37		**Backfill Shaft 2**	2 mons	Thu 9/23/21
38		**Backfill Shaft 3**	2 mons	Thu 9/23/21
39		**Testing & Demobilization**	2 mons	Thu 9/23/21
40		**Project Complete**	0 days	Wed 11/17/21
41		**CONTRACT C (EBMUD Mokelumne Delta Tunnel)**	**1270 days**	**Wed 9/5/18**
42		NTP CONTRACT C	0 days	Wed 9/5/18
43		TBM Order and Deliver	14 mons	Thu 9/6/18
44		Contract Mobilization & Submittals	2 mons	Thu 9/6/18
45		**Launch Shaft (Three Cells) Number 5**	**80 days**	**Thu 11/1/18**
46		Shaft Site Set Up/Construct Shaft 5	4 mons	Thu 11/1/18
47		**Reach 4 Tunnel Excavate 21 foot Diameter 15175 lf**	**705 days**	**Thu 10/3/19**
48		Mobilization and Assemble TBM	11 wks	Thu 10/3/19
49		EBM Tunnel & Segment Installation	43 wks	Thu 12/19/19
50		Install 87 in T=.625 inch Steel Pipeline & Weld	31 wks	Thu 10/15/20
51		Place Cellular Concrete 7.35 cy/ft	56 wks	Thu 5/20/21
52		**Reach 5 Tunnel Excavate 21 foot Diameter 13,475 lf**	**680 days**	**Thu 10/15/20**
53		Reset and Assemble TBM	20 wks	Thu 10/15/20
54		EBM Tunnel & Segment Installation	38 wks	Thu 3/4/21
55		Install 87 in T=.625 inch Steel Pipeline & Weld	28 wks	Thu 11/25/21
56		Place Cellular Concrete 7.35 cy/ft	50 wks	Thu 6/9/22
57		**Backfill Shaft 4**	2 mons	Thu 6/16/22
58		**Backfill Shaft 5**	2 mons	Thu 5/25/23
59		**Backfill Shaft 6**	2 mons	Thu 5/25/23
60		**Testing & Demobilization**	2 mons	Thu 5/25/23
61		**Project Complete**	0 days	Wed 7/19/23
62		**CONTRACT D (EBMUD Mokelumne Delta Tunnel)**	**2210 days**	**Wed 1/28/15**
63		NTP CONTRACT D	0 days	Wed 1/28/15
64		TBM Order and Deliver	14 mons	Thu 1/29/15
65		Contract Mobilization & Submittals	2 mons	Thu 1/29/15
66		**Launch Shaft (Three Cells) Number 6**	**80 days**	**Thu 3/26/15**
67		Shaft Site Set Up/Construct Shaft 6	4 mons	Thu 3/26/15
68		**Reach 6 Tunnel Excavate 21 foot Diameter 13,720 lf**	**645 days**	**Thu 2/25/16**
69		Mobilization and Assemble TBM	11 wks	Thu 2/25/16
70		EBM Tunnel & Segment Installation	39 wks	Thu 5/12/16
71		Install 87 in T=.625 inch Steel Pipeline & Weld	28 wks	Thu 2/9/17
72		Place Cellular Concrete 7.35 cy/ft	51 wks	Thu 8/24/17
73		**Receiving Shaft Number 7**	**50 days**	**Thu 7/16/15**
74		Shaft Site Set Up/Construct Shaft 7	2.5 mons	Thu 7/16/15
75		**Install Piping and Backfill Shaft 7**	1.5 mons	Thu 8/16/18
76		**Testing & Demobilization**	1.5 mons	Thu 9/27/18
77		**Project Complete**	0 days	Wed 11/7/18
78		**Mokelumne Delta Tunnel Project Complete**	0 days	Wed 7/19/23



Project: MOK SCHEDULES NOV R
Date: Wed 11/5/14

Task	Milestone	Project Summary	External Milestone	Inactive Milestone	Manual Task	Manual Summary Rollup	Start-only	Deadline	Critical Split
Split	Summary	External Tasks	Inactive Task	Inactive Summary	Duration-only	Manual Summary	Finish-only	Critical	Progress

APPENDIX A – PRESSURIZED FACE TBM

1.0 GENERAL

TBM selection will be based on the need to control the risks associated with high groundwater inflows, excessive settlement, TBM cutterhead chamber access, wear to the TBM moving parts from abrasion and delays to the project schedule. Based on these risks a pressurized face TBM, either an EPB TBM or Slurry TBM would be required. A pressurized face TBM counterbalances the ground and water inflow at the face by maintaining a pressure on the excavated material. The following discussion describes each of the main type of pressurized TBMs. Note however, that composite or hybrid TBMs that can function as an EPB or slurry TBM have recently been manufactured.

2.0 EARTH PRESSURE BALANCE (EPB) TBM

EPB TBMs are designed to counterbalance the ground and water inflow at the face by maintaining a pressure on the excavated material in the cutterhead chamber. The machine and workers are protected in the shield and the initial support is erected in the tail of the shield and pushed out by a ring of hydraulic propulsion cylinders. The tail of the shield includes rows of greased wire-brushes, sealing the gap between the inside surface of the shield and the outside surface of the initial support to prevent the ingress of groundwater and soils into the tunnel. The muck loosened from the face migrates through openings in the cutterhead into the cutterhead chamber, and is discharged from the cutterhead chamber by a screw conveyor. The screw conveyor ideally has its entrance near the invert where the muck will migrate naturally. The screw conveyor consists of a tubular casing, auger, hydraulic drive unit, and discharge outlet that is elevated to discharge muck onto a belt conveyer or into muck cars. The rotational speed of the screw and the restriction of the discharge outlet influence the muck flow rate and pressure gradient along the screw conveyor. The cutterhead chamber pressure supporting the tunnel face is regulated by controlling the rate of soil discharge and the pressure dissipation along the screw conveyor. **Figure A1** shows basic elements of an EPB machine.

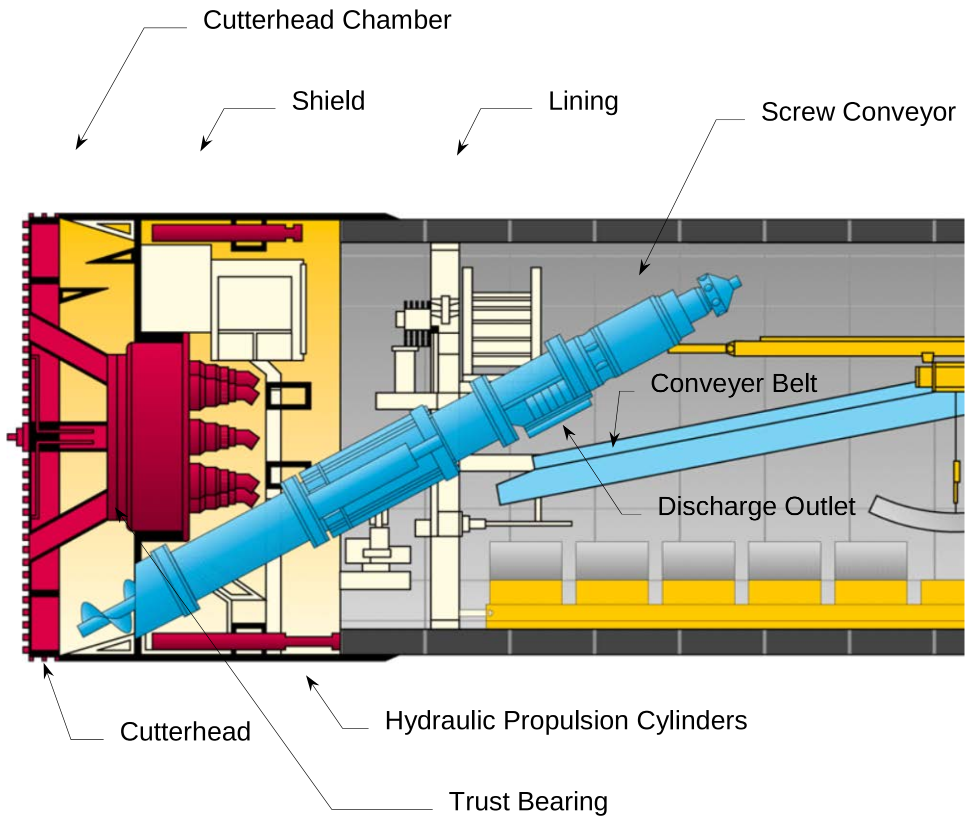


Figure A1. EPB TBM

An EPB machine can be employed for widely varying ground conditions. EPB machines rely on fines in the muck for water blocking and flow control in the screw conveyer. If clean sands or gravels are encountered, hydrophilic polymer slurry can be injected into the cutterhead chamber to absorb and block water flow, increase the fluidity of the muck, and facilitate the pressure-balancing function of the screw conveyer. If clays or dry soils are encountered, the cuttings can become sticky and tend to plug inside the cutterhead chamber. Foams, polymer bentonite and water mixes, collectively known as ground conditioners, can be injected to decrease stickiness and increase plasticity of the muck. The ground conditioning injection ports are located on the cutterhead, the bulkhead inside the cutterhead chamber, and the screw conveyer (**Figure A2**). In instances where boulders, mixed face, or hard rock conditions are encountered (this is not anticipated for the Delta Tunnel), the cutterhead can be configured with a mixed-ground cutterhead equipped with disc cutters as the primary cutting tools. EPB TBMs have similar advantages and disadvantages as shielded TBMs, except they offer better handling in fast raveling or flowing ground conditions or/and pressurized groundwater conditions.

Figure A2. EPB TBM Fitted with Disc Cutters (Brightwater BT-4)

Although EPB TBMs are used in predominantly soil conditions, they can be run in "open mode" (i.e., without face pressurization) for efficient excavation in soil or "closed" mode in the sections where very poor ground and/or groundwater conditions are encountered. It is anticipated that for the Delta Tunnel Project, the EPB TBM would be run in closed mode.

3.0 MIXED FACE OR SLURRY TBM

Mixed or slurry TBMs are designed to counterbalance the ground and water inflow at the face by maintaining a pressure with a bentonite slurry in the excavation chamber (**Figure A3**). The machine and workers are protected in the shield and the initial support (precast segmental lining) is erected in the tail of the shield and pushed out by a ring of hydraulic propulsion cylinders. The tail of the shield includes rows of greased wire-brushes, sealing the gap between the inside surface of the shield and the outside surface of the initial support to prevent the ingress of groundwater and soils into the tunnel.

The bentonite slurry forms a mud cake or membrane on the excavated tunnel face as excavation proceeds. The excavated material is mixed and suspended in slurry and pumped through piping from the plenum or excavation chamber to the separation plant on the surface (**Figure A4**), where the suspended soil material is removed from the slurry. The muck is disposed off-site while the slurry is reconditioned and recirculated back to the tunnel face. The finer the soil material the more complicated and expensive the separation of the muck and slurry becomes.

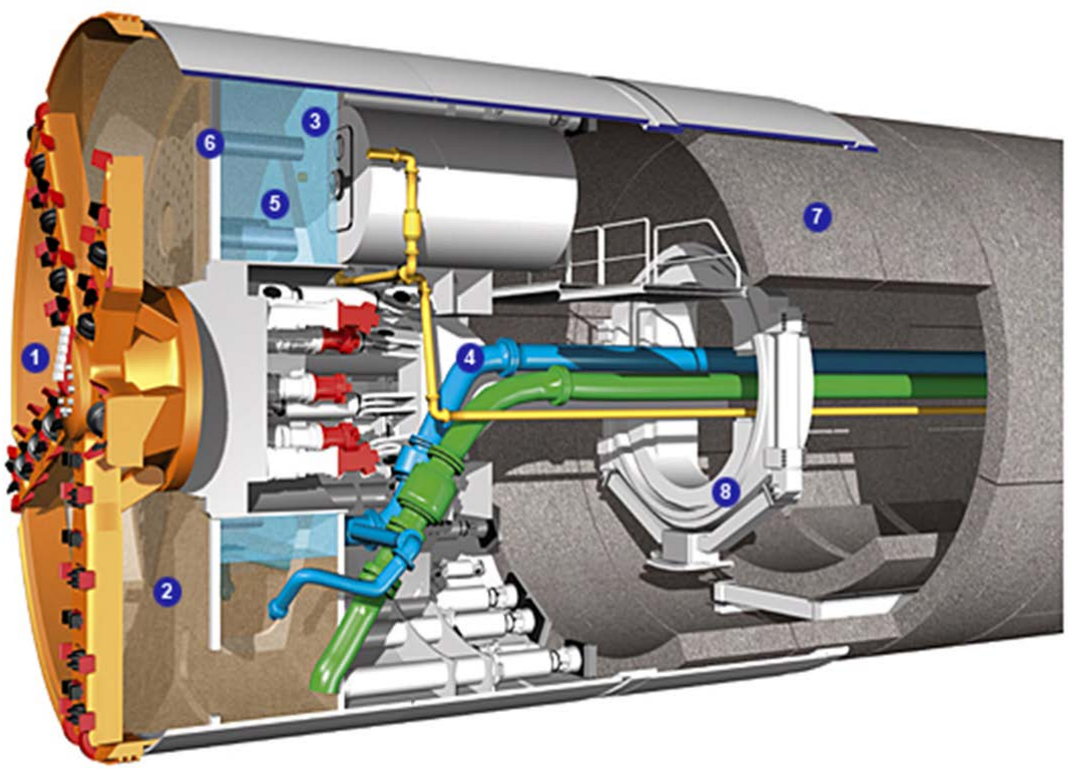


Figure A3. Mixed or Slurry TBM

Figure A4. Slurry Separation Plant (Brightwater BT2&3)

The slurry TBM has a partial bulkhead or buffer wall that separates the fluid-filled excavation chamber form a pressure chamber that contains an air cushion above the slurry surface. The air cushion system effectively eliminates large pressure fluctuations.

A slurry TBM can be used in a variety of ground conditions from coarse grained materials to weak rock.

Figure A5. Slurry TBM Fitted with Disc Cutters (Brightwater BT-3)

APPENDIX B – OPCC AND SCHEDULE

MOKELUMNE DELTA TUNNEL All Tunnel (Two Carrier Pipes) SUMMARY ALL CONTRACTS BASE ESTIMATE			
Currency: USD-United States			
Description	Quantity	Unit	Toatal Amount
Contract A	14,925	LF	$ 291,984,491
Contract B	29,850	LF	$ 556,354,848
Contract C	28,650	LF	$ 529,818,071
Contract D	13,720	LF	$ 273,738,954
Total All Contracts	87,145	LF	$ 1,651,896,364

MOKELUMNE DELTA TUNNEL All Tunnel (Smaller Tunnel ,One Carrier Pipe) SUMMARY ALL CONTRACTS SINGLE PIPE ALTERNATE			
Currency: USD-United States			
Description	Quantity	Unit	Toatal Amount
Contract A	14,925	LF	$ 224,867,049
Contract B	29,850	LF	$ 426,632,944
Contract C	28,650	LF	$ 403,167,683
Contract D	13,720	LF	$ 179,675,323
Total All Contracts	87,145	LF	$ 1,234,343,000

MWH DC 11/25/2014

MOKELUMNE DELTA TUNNEL

CONTRACT A (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 1 and Shaft Number 2

Currency: USD-United States

Grand Total Price:					$ 291,984,491	
Item	**Description**	**Quantity**	**UOM**	**Unit Price**	**Total Price**	**Comments**
	Launch Shaft (Three Cells) Number 2	142	VF	$78,442.74	**$11,138,868**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	includes work area pad
3	Shaft Starter Wall for Slurry Trench	50	CY	$700.00	$35,000	
4	Slurry Wall 3 ft Thick at Perimeter 31.11 cy/vf 172 ft deep	5,351	CY	$1,045.00	$5,591,795	ball park Quote
5	Excavate Three Cell Shaft 92.59 cy/vf	13,148	CY	$200.00	$2,629,556	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	741	CY	$500.00	$370,500	
7	Dispose of Excavated Material	18,101	CY	$20.00	$362,017	
8	Jet Grout Block 45 x 45 x 30; Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Receiving Shaft Number 1 32 FT Finish	142	VF	$42,599.89	**$6,049,184**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	includes work area pad
3	Shaft Starter Wall for Slurry Trench	25	CY	$500.00	$12,500	
4	Slurry Wall 3 ft Thick at Perimeter 12.21 cy/vf 172 ft deep	2,100	CY	$1,045.00	$2,194,500	ball park Quote
5	Excavate 32ft Finish Diameter Shaft 29.77 cy/vf	4,227	CY	$200.00	$845,468	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	238	CY	$400.00	$95,264	
7	Concrete Backfill	1,034	CY	$500.00	$516,990	
8	Concrete Leveling Slab 2ft Thick	60	CY	$300.00	$17,862	
9	Install Shaft Piping 87 inch Steel Pipe	284	VF	$75.00	$21,300	
10	Backfill Shaft Granular	2,068	CY	$19.50	$40,325	
11	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
12	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
13	Install Locking Manhole Cover	1	EA	$300.00	$300	
14	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
15	Concrete Apron 6in	7	CY	$550.00	$3,850	
16	Dispose of Excavated Material	6,145	CY	$20.00	$122,892	
17	Jet Grout Block 45 x 45 x 30; Tunnel Eye 1 Each	2,250	CY	$400.00	$900,000	
	Reach 1 Tunnel Excavate 21 foot Diameter	14,925	LF	$5,318.53	**$79,379,020**	
1	Purchase EPB TBM 21ft	1	LS	$10,000,000.00	$10,000,000	Robbins Ball Park Quote included parts
2	Mobilization and Assemble TBM	1	LS	$2,250,000.00	$2,250,000	
3	EPBM Tunnel Excavation & Lining Startup	300	LF	$6,500.00	$1,950,000	
4	EPBM Tunnel Excavation & Lining	14,625	LF	$2,000.00	$29,250,000	
5	Install 87 in T=.625 inch Steel Pipeline & Weld	29,850	LF	$250.00	$7,462,500	
6	Place Cellular Concrete 7.35 cy/ft	109,699	CY	$200.00	$21,939,750	
7	Dispose of Excavated Material 12.82 bcy /lf	191,339	BCY	$20.00	$3,826,770	
8	Jet Grout Block 45 x 45 x 45; Safe Havens, 2 Each	6,750	CY	$400.00	$2,700,000	
	Purchased Materials				**$59,038,861**	
1	Pipe Bedding Materials Land	60	CY	$15.00	$900	
2	Concrete Purchase	9,581	CY	$125.00	$1,197,585	
3	Granular Backfill in Shafts	2,068	CY	$12.00	$24,816	
4	87 in T=.625 inch Steel Pipeline	29,850	LF	$800.00	$23,880,000	
5	87 in T=.625 inch Steel Pipeline in shaft	284	LF	$800.00	$227,200	
6	87 in T=.625 inch Steel Pipeline Land	120	LF	$800.00	$96,000	
7	87 in T=.625 inch Steel Pipeline Elbows	6	EA	$12,000.00	$72,000	
8	87 in x 69 inch x 69 inch Wye T=.625 inch Steel Pipeline	1	EA	$30,000.00	$30,000	
9	87 in x 69 inch T=.625 inch Steel Pipeline Reducer	1	EA	$8,000.00	$8,000	
10	Tunnel Liner Concrete Precast Segments 12 in Thick	14,925	LF	$1,500.00	$22,387,500	ball park Quote
11	Cellular Concrete Tunnnel	111,032	CY	$100.00	$11,103,200	
12	Steel Riser Pipe 5 ft Diameter	12	LF	$480.00	$5,760	
13	Precast Open Bottom Vault	1	EA	$1,800.00	$1,800	
14	10ft x 10 ft Precast Concrete Panel	1	EA	$3,750.00	$3,750	
15	Locking Manhole Cover	1	EA	$350.00	$350	
	Tie in Land Work from Shaft Number 1				**$38,500**	
1	Excavate Lay & Backfill 87in Pipe	150	LF	$65.00	$9,750	
2	Weld 87 in T=.625 inch Pipeline	8	JT	$2,500.00	$18,750	
3	Weld 87 in x 69 inch Reducers Pipeline	4	JT	$2,500.00	$10,000	
				Running Subtotal:	**$155,644,433**	
	Mobilization/Field Oversight Expenses				**$ 38,911,108**	
1	Contractor General Conditions (Prime)	1	ls	25%	$ 38,911,108	
	Unlisted Items Cost Allowance				**$9,727,777**	
1	Unlisted Items Allowance	1	ls	5%	$9,727,777	
				Running Subtotal:	**$204,283,318**	
	Markups				**$ 39,037,091**	

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MOKELUMNE DELTA TUNNEL

CONTRACT A (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 1 and Shaft Number 2

Currency: USD-United States

Grand Total Price: $ 291,984,491

Item	Description	Quantity	UOM	Unit Price	Total Price	Comments
1	Prime Contractor OH&P	1	ls	15.0%	$ 30,642,498	
2	Contractor Insurance Program	1	ls	1.5%	$ 3,523,887	
3	Taxes on Matls	1	ls	8.25%	$ 4,870,706	
4	Escalation	1	ls	0.0%	$ -	not included
				Running Subtotal:	$243,320,409	
	Project Administration & Management				$48,664,082	
1	Construction Oversight & Mgt	1	ls	0%	$0	not included
2	Engineering	1	ls	0%	$0	not included
3	Permitting/Planning/Procurement	1	ls	0%	$0	not included
4	Scope Contingency/Market Conditions	1	ls	20%	$48,664,082	
5	Construction Contingency/Management Reserve	1	ls	0%	$0	not included
				Grand Total:	$291,984,491	Total w/ Contingency
			Cost Range:	$233,587,593	$379,579,839	Per AACE cost estimate guidelines
				20%	30%	

This OPCC is classified as a Class 5 cost estimate per AACE guidelines. Stated accuracy range = -15% to + 25%.

Pricing basis = 4th Qtr 2014, escalation to midpoint of construction is not included.

Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).

Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

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MOKELUMNE DELTA TUNNEL

CONTRACT B (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 2 and Shaft Number 4

Currency: USD-United States

Item	Description	Quantity	UOM	Unit Price	Total Price	Comments
Grand Total Price:					$ 556,354,848	
	Launch Shaft (Three Cells) Number 2	142	VF	$27,722.62	**$3,936,612**	
1	Concrete Backfill	1,593	CY	$500.00	$796,598	
2	Cast in Place Chamber Walls	2,689	CY	$750.00	$2,017,045	
3	Install Precast Manhole Rings	87	VF	$140.00	$12,180	
4	Backfill Shaft Granular	9,164	CY	$19.50	$178,705	
5	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
6	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
7	Install Locking Manhole Cover	1	EA	$300.00	$300	
8	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
9	Concrete Apron 6in	7	CY	$550.00	$3,850	
10	Jet Grout Block 45 x 45 x 30; Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Launch Shaft (Three Cells) Number 3	142	VF	$106,765.30	**$15,160,673**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	includes work area pad
3	Shaft Starter Wall for Slurry Trench	50	CY	$700.00	$35,000	
4	Slurry Wall 3 ft Thick at Perimeter 31.11 cy/vf 172 ft deep	5,351	CY	$1,045.00	$5,591,795	ball park Quote
5	Excavate Three Cell Shaft 92.59 cy/vf	13,574	CY	$200.00	$2,714,756	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	741	CY	$500.00	$370,500	
7	Concrete Backfill	1,593	CY	$500.00	$796,598	
8	Cast in Place Chamber Walls	2,689	CY	$750.00	$2,017,045	
9	Install Precast Manhole Rings	87	VF	$140.00	$12,180	
10	Backfill Shaft Granular	9,164	CY	$19.50	$178,698	
11	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
12	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
13	Install Locking Manhole Cover	1	EA	$300.00	$300	
14	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
15	Concrete Apron 6in	7	CY	$550.00	$3,850	
16	Dispose of Excavated Material	18,101	CY	$20.00	$362,017	
17	Jet Grout Block 45 x 45 x 30; Tunnel Eyes, 2 Each	4,500	CY	$400.00	$1,800,000	
	Launch Shaft (Three Cells) Number 4	142	VF	$78,442.74	**$11,138,868**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	includes work area pad
3	Shaft Starter Wall for Slurry Trench	50	CY	$700.00	$35,000	
4	Slurry Wall 3 ft Thick at Perimeter 31.11 cy/vf 172 ft deep	5,351	CY	$1,045.00	$5,591,795	ball park Quote
5	Excavate Three Cell Shaft 92.59 cy/vf	13,148	CY	$200.00	$2,629,556	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	741	CY	$500.00	$370,500	
7	Dispose of Excavated Material	18,101	CY	$20.00	$362,017	
8	Jet Grout Block 45 x 45 x 30, Tunnel Eyes, 1 Each	2,250	CY	$400.00	$900,000	
	Reach 2 Tunnel Excavate 21 foot Diameter	13,600	LF		**$73,779,040**	
1	Purchase EPB TBM 21ft	1	LS	$10,000,000.00	$10,000,000	Robbins Ball Park Quote included parts
2	Mobilization and Assemble TBM	1	LS	$2,250,000.00	$2,250,000	
3	EPBM Tunnel Excavation & Lining Startup	300	LF	$6,500.00	$1,950,000	
4	EPBM Tunnel Excavation & Lining	13,300	LF	$2,000.00	$26,600,000	
5	Install 87 in T=.625 inch Steel Pipeline & Weld	27,200	LF	$250.00	$6,800,000	
6	Place Cellular Concrete 7.35 cy/ft	99,960	CY	$200.00	$19,992,000	
7	Dispose of Excavated Material 12.82 bcy /lf	174,352	BCY	$20.00	$3,487,040	
8	Jet Grout Block 45 x 45 x 45, Safe Havens, 2 Each	6,750	CY	$400.00	$2,700,000	
	Reach 3 Tunnel Excavate 21 foot Diameter	16,250	LF		**$74,879,000**	
1	Reset and Assemble TBM	1	LS	$3,500,000.00	$3,500,000	
2	EPBM Tunnel & Segment Installation	16,250	LF	$2,000.00	$32,500,000	
3	Install 87 in T=.625 inch Steel Pipeline & Weld	32,500	LF	$250.00	$8,125,000	
4	Place Cellular Concrete 7.35 cy/ft	119,438	CY	$200.00	$23,887,500	
5	Dispose of Excavated Material 12.82 bcy /lf	208,325	BCY	$20.00	$4,166,500	
6	Jet Grout Block 45 x 45 x 45, Safe Haven, 2 Each	6,750	CY	$400.00	$2,700,000	
	Purchased Materials				**$117,410,038**	
1	Concrete Purchase	20,849	CY	$125.00	$2,606,148	
2	Granular Backfill in Shafts	18,328	CY	$12.00	$219,941	
3	87 in T=.625 inch Steel Pipeline	59,700	LF	$800.00	$47,760,000	
4	Tunnel Liner Concrete Precast Segments 12 in Thick	29,850	LF	$1,500.00	$44,775,000	ballpark quote
5	Cellular Concrete Tunnnel	219,398	CY	$100.00	$21,939,750	
6	Precast Open Bottom Vault	3	EA	$1,800.00	$5,400	
7	10ft x 10 ft Precast Concrete Panel	3	EA	$3,750.00	$11,250	
8	Locking Manhole Cover	3	EA	$350.00	$1,050	
9	Precast Manhole Rings	366	VF	$250.00	$91,500	
				Running Subtotal:	**$296,304,231**	
	Mobilization/Field Oversight Expenses				**$ 74,076,058**	

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MOKELUMNE DELTA TUNNEL

CONTRACT B (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 2 and Shaft Number 4

Currency: USD-United States

Grand Total Price:					$ 556,354,848	
Item	**Description**	**Quantity**	**UOM**	**Unit Price**	**Total Price**	**Comments**
1	Contractor General Conditions (Prime)	1	ls	25%	$ 74,076,058	
	Unlisted Items Cost Allowance				**$18,519,014**	
1	Unlisted Items Allowance	1	ls	5%	$18,519,014	
				Running Subtotal:	**$388,899,304**	
	Markups				**$ 74,729,737**	
1	Prime Contractor OH&P	1	ls	15.0%	**$ 58,334,896**	
2	Contractor Insurance Program	1	ls	1.5%	**$ 6,708,513**	
3	Taxes on Matls	1	ls	8.25%	**$ 9,686,328**	
4	Escalation	1	ls	0.0%	**$ -**	not included
				Running Subtotal:	**$463,629,040**	
	Project Administration & Management				**$92,725,808**	
1	Construction Oversight & Mgt	1	ls	0%	**$0**	not included
2	Engineering	1	ls	0%	**$0**	not included
3	Permitting/Planning/Procurement	1	ls	0%	**$0**	not included
4	Scope Contingency/Market Conditions	1	ls	20%	**$92,725,808**	
5	Construction Contingency/Management Reserve	1	ls	0%	**$0**	not included
				Grand Total:	**$556,354,848**	Total w/ Contingency
			Cost Range:	**$445,083,879**	**$723,261,303**	Per AACE cost estimate guidelines
				20%	**30%**	

This OPCC is classified as a Class 5 cost estimate per AACE guidelines. Stated accuracy range = -15% to + 25%.

Pricing basis = 4th Qtr 2014, escalation to midpoint of construction is not included.

Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).

Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

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MOKELUMNE DELTA TUNNEL

CONTRACT C (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 4 and Shaft Number 6

Currency: USD-United States

Grand Total Price: $ 529,818,071

Item	Description	Quantity	UOM	Unit Price	Total Price	Comments
	Launch Shaft (Three Cells) Number 4	142	VF	$27,722.62	**$3,936,612**	
1	Concrete Backfill	1,593	CY	$500.00	$796,598	
2	Cast in Place Chamber Walls	2,689	CY	$750.00	$2,017,045	
3	Install Precast Manhole Rings	87	VF	$140.00	$12,180	
4	Backfill Shaft Granular	9,164	CY	$19.50	$178,705	
5	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
6	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
7	Install Locking Manhole Cover	1	EA	$300.00	$300	
8	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
9	Concrete Apron 6in	7	CY	$550.00	$3,850	
10	Jet Grout Block 45 x 45 x 30; Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Launch Shaft (Three Cells) Number 5	142	VF	$104,090.04	**$14,780,786**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	includes work area pad
3	Shaft Starter Wall for Slurry Trench	50	CY	$700.00	$35,000	
4	Slurry Wall 3 ft Thick at Perimeter 31.11 cy/vf 172 ft deep	5,351	CY	$1,045.00	$5,591,795	ball park Quote
5	Excavate Three Cell Shaft 92.59 cy/vf	13,148	CY	$200.00	$2,629,556	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	741	CY	$500.00	$370,500	
7	Concrete Backfill	1,421	CY	$500.00	$710,480	
8	Cast in Place Chamber Walls	2,399	CY	$750.00	$1,798,986	
9	Install Precast Manhole Rings	103	VF	$140.00	$14,420	
10	Backfill Shaft Granular	9,595	CY	$19.50	$187,095	
11	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
12	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
13	Install Locking Manhole Cover	1	EA	$300.00	$300	
14	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
15	Concrete Apron 6in	7	CY	$550.00	$3,850	
16	Dispose of Excavated Material	18,044	CY	$20.00	$360,872	
17	Jet Grout Block 45 x 45 x 30, Tunnel Eyes 2 Each	4,500	CY	$400.00	$1,800,000	
	Launch Shaft (Three Cells) Number 6	142	VF	$25,655.38	**$3,643,063**	
1	Concrete Backfill	1,421	CY	$500.00	$710,480	
2	Cast in Place Chamber Walls	2,399	CY	$750.00	$1,798,986	
3	Install Precast Manhole Rings	103	VF	$140.00	$14,420	
4	Backfill Shaft Granular	9,595	CY	$19.50	$187,095	
5	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
6	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
7	Install Locking Manhole Cover	1	EA	$300.00	$300	
8	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
9	Concrete Apron 6in	7	CY	$550.00	$3,850	
10	Jet Grout Block 45 x 45 x 30; Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Reach 4 Tunnel Excavate 21 foot Diameter	15,175	LF		**$80,435,620**	
1	Purchase EPB TBM 21ft	1	LS	$10,000,000.00	$10,000,000	Robbins Ball Park Quote included parts
2	Mobilization and Assemble TBM	1	LS	$2,250,000.00	$2,250,000	
3	EPBM Tunnel Excavation & Lining Startup	300	LF	$6,500.00	$1,950,000	
4	EPBM Tunnel Excavation & Lining	14,875	LF	$2,000.00	$29,750,000	
5	Install 87 in T=.625 inch Steel Pipeline & Weld	30,350	LF	$250.00	$7,587,500	
6	Place Cellular Concrete 7.35 cy/ft	111,536	CY	$200.00	$22,307,250	
7	Dispose of Excavated Material 12.82 bcy /lf	194,544	BCY	$20.00	$3,890,870	
8	Jet Grout Block 45 x 45 x 45, Safe Havens, 2 Each	6,750	CY	$400.00	$2,700,000	
	Reach 5 Tunnel Excavate 21 foot Diameter	13,475	LF		**$66,750,740**	
1	Reset and Assemble TBM	1	LS	$3,500,000.00	$3,500,000	
2	Mobilization and Assemble TBM	1	LS	$2,250,000.00	$2,250,000	
3	EPBM Tunnel Excavation & Lining Startup	300	LF	$6,500.00	$1,950,000	
4	EPBM Tunnel & Segment Installation	13,175	LF	$2,000.00	$26,350,000	
5	Install 87 in T=.625 inch Steel Pipeline & Weld	26,950	LF	$250.00	$6,737,500	
6	Place Cellular Concrete 7.35 cy/ft	99,041	CY	$200.00	$19,808,250	
7	Dispose of Excavated Material 12.82 bcy /lf	172,750	BCY	$20.00	$3,454,990	
8	Jet Grout Block 45 x 45 x 45, Safe Haven, 2 Each	6,750	CY	$400.00	$2,700,000	
	Purchased Materials				**$112,582,794**	
1	Concrete Purchase	18,085	CY	$125.00	$2,260,601	
2	Granular Backfill in Shafts	28,354	CY	$12.00	$340,243	
3	87 in T=.625 inch Steel Pipeline	57,300	LF	$800.00	$45,840,000	
4	Tunnel Liner Concrete Precast Segments 12 in Thick	28,650	LF	$1,500.00	$42,975,000	ballpark quote
5	Cellular Concrete Tunnnel	210,578	CY	$100.00	$21,057,750	
6	Precast Open Bottom Vault	3	EA	$1,800.00	$5,400	
7	10ft x 10 ft Precast Concrete Panel	3	EA	$3,750.00	$11,250	
8	Locking Manhole Cover	3	EA	$350.00	$1,050	
9	Precast Manhole Rings	366	VF	$250.00	$91,500	
				Running Subtotal:	**$282,129,615**	

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MOKELUMNE DELTA TUNNEL

CONTRACT C (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 4 and Shaft Number 6

Currency: USD-United States

Grand Total Price:					$ 529,818,071	
Item	**Description**	**Quantity**	**UOM**	**Unit Price**	**Total Price**	**Comments**
	Mobilization/Field Oversight Expenses				**$ 70,532,404**	
1	Contractor General Conditions (Prime)	1	ls	25%	$ 70,532,404	
	Unlisted Items Cost Allowance				**$17,633,101**	
1	Unlisted Items Allowance	1	ls	5%	$17,633,101	
				Running Subtotal:	**$370,295,120**	
	Markups				**$ 71,219,939**	
1	Prime Contractor OH&P	1	ls	15.0%	**$ 55,544,268**	
2	Contractor Insurance Program	1	ls	1.5%	**$ 6,387,591**	
3	Taxes on Matls	1	ls	8.25%	**$ 9,288,080**	
4	Escalation	1	ls	0.0%	**$ -**	not included
				Running Subtotal:	**$441,515,059**	
	Project Administration & Management				**$88,303,012**	
1	Construction Oversight & Mgt	1	ls	0%	**$0**	not included
2	Engineering	1	ls	0%	**$0**	not included
3	Permitting/Planning/Procurement	1	ls	0%	**$0**	not included
4	Scope Contingency/Market Conditions	1	ls	20%	**$88,303,012**	
5	Construction Contingency/Management Reserve	1	ls	0%	**$0**	not included
				Grand Total:	**$529,818,071**	Total w/ Contingency
			Cost Range:	**$423,854,457**	**$688,763,492**	Per AACE cost estimate guidelines
				20%	**30%**	

This OPCC is classified as a Class 5 cost estimate per AACE guidelines. Stated accuracy range = -15% to + 25%.

Pricing basis = 4th Qtr 2014, escalation to midpoint of construction is not included.

Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).

Owner soft costs and project management expenses excluded.

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MOKELUMNE DELTA TUNNEL

CONTRACT D (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 6 and Shaft Number 7

Currency: USD-United States

Grand Total Price:					$ 273,738,954	
Item	**Description**	**Quantity**	**UOM**	**Unit Price**	**Total Price**	**Comments**
	Launch Shaft (Three Cells) Number 6	142	VF	$78,434.58	**$11,137,710**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	includes work area pad
3	Shaft Starter Wall for Slurry Trench	50	CY	$700.00	$35,000	
4	Slurry Wall 3 ft Thick at Perimeter 31.11 cy/vf 172 ft deep	5,351	CY	$1,045.00	$5,591,795	ball park Quote
5	Excavate Three Cell Shaft 92.59 cy/vf	13,148	CY	$200.00	$2,629,556	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	741	CY	$500.00	$370,500	
7	Dispose of Excavated Material	18,043	CY	$20.00	$360,859	
8	Jet Grout Block 45 x 45 x 30, Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Receiving Shaft Number 7 32 FT Finish	107	VF	$48,762.69	**$5,217,608**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	includes work area pad
3	Shaft Starter Wall for Slurry Trench	25	CY	$500.00	$12,500	
4	Slurry Wall 3 ft Thick at Perimeter 12.21 cy/vf 137 ft deep	1,673	CY	$1,045.00	$1,748,285	ball park Quote
5	Excavate 32ft Finish Diameter Shaft 29.77 cy/vf	3,185	CY	$200.00	$637,078	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	238	CY	$400.00	$95,264	
7	Concrete Backfill	772	CY	$500.00	$385,817	
8	Concrete Leveling Slab 2ft Thick	60	CY	$300.00	$17,862	
9	Install Shaft Piping 87 inch Steel Pipe	214	VF	$75.00	$16,050	
10	Backfill Shaft Granular	1,543	CY	$19.50	$30,094	
11	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
12	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
13	Install Locking Manhole Cover	1	EA	$300.00	$300	
14	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
15	Concrete Apron 6in	7	CY	$550.00	$3,850	
16	Dispose of Excavated Material	4,629	CY	$20.00	$92,576	
17	Jet Grout Block 45 x 45 x 30, Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Reach 6 Tunnel Excavate 21 foot Diameter	13,720	LF		**$74,286,208**	
1	Purchase EPB TBM 21ft	1	LS	$10,000,000.00	$10,000,000	Robbins Ball Park Quote included parts
2	Mobilization and Assemble TBM	1	LS	$2,250,000.00	$2,250,000	
3	EPBM Tunnel Excavation & Lining Startup	300	LF	$6,500.00	$1,950,000	
4	EPBM Tunnel Excavation & Lining	13,420	LF	$2,000.00	$26,840,000	
5	Install 87 in T=.625 inch Steel Pipeline & Weld	27,440	LF	$250.00	$6,860,000	
6	Place Cellular Concrete 7.35 cy/ft	100,842	CY	$200.00	$20,168,400	
7	Dispose of Excavated Material 12.82 bcy /lf	175,890	BCY	$20.00	$3,517,808	
8	Jet Grout Block 45 x 45 x 45, Safe Haven, 2 Each	6,750	CY	$400.00	$2,700,000	
	Purchased Materials				**$55,244,171**	
1	Pipe Bedding Materials Land	60	CY	$15.00	$900	
2	Concrete Purchase	8,916	CY	$125.00	$1,114,542	
3	Granular Backfill in Shafts	1,543	CY	$12.00	$18,519	
4	87 in T=.625 inch Steel Pipeline	27,440	LF	$800.00	$21,952,000	
5	87 in T=.625 inch Steel Pipeline in shaft	249	LF	$800.00	$199,200	
6	87 in T=.625 inch Steel Pipeline Land	120	LF	$800.00	$96,000	
7	87 in T=.625 inch Steel Pipeline Elbows	6	EA	$12,000.00	$72,000	
8	87 in x 69 inch x 69 inch Wye T=.625 inch Steel Pipeline	1	EA	$30,000.00	$30,000	
9	87 in x 69 inch T=.625 inch Steel Pipeline Reducer	1	EA	$8,000.00	$8,000	
10	Tunnel Liner Concrete Precast Segments 12 in Thick	13,720	LF	$1,500.00	$20,580,000	ball park Quote
11	Cellular Concrete Tunnnel	111,032	CY	$100.00	$11,103,200	
12	Steel Riser Pipe 5 ft Diameter	12	LF	$480.00	$5,760	
13	Precast Open Bottom Vault	2	EA	$1,800.00	$3,600	
14	10ft x 10 ft Precast Concrete Panel	2	EA	$3,750.00	$7,500	
15	Locking Manhole Cover	2	EA	$350.00	$700	
16	Precast Manhole Rings	209	VF	$250.00	$52,250	
	Tie in Land Work from Shaft Number 1				**$38,500**	
1	Excavate Lay & Backfill 87in Pipe	150	LF	$65.00	$9,750	
2	Weld 87 in T=.625 inch Pipeline	8	JT	$2,500.00	$18,750	
3	Weld 87 in x 69 inch Reducers Pipeline	4	JT	$2,500.00	$10,000	
				Running Subtotal:	**$145,924,198**	
	Mobilization/Field Oversight Expenses				**$ 36,481,049**	
1	Contractor General Conditions (Prime)	1	ls	25%	$ 36,481,049	
	Unlisted Items Cost Allowance				**$9,120,262**	
1	Unlisted Items Allowance	1	ls	5%	$9,120,262	
				Running Subtotal:	**$191,525,509**	
	Markups				**$ 36,590,286**	

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MOKELUMNE DELTA TUNNEL

CONTRACT D (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 6 and Shaft Number 7

Currency: USD-United States

Grand Total Price:					$ 273,738,954	
Item	**Description**	**Quantity**	**UOM**	**Unit Price**	**Total Price**	**Comments**
1	Prime Contractor OH&P	1	ls	15.0%	$ 28,728,826	
2	Contractor Insurance Program	1	ls	1.5%	$ 3,303,815	
3	Taxes on Matls	1	ls	8.25%	$ 4,557,644	
4	Escalation	1	ls	0.0%	$ -	not included
				Running Subtotal:	**$228,115,795**	
		MU Factor:				
	Project Administration & Management				**$45,623,159**	
1	Construction Oversight & Mgt	1	ls	0%	**$0**	not included
2	Engineering	1	ls	0%	**$0**	not included
3	Permitting/Planning/Procurement	1	ls	0%	**$0**	not included
4	Scope Contingency/Market Conditions	1	ls	20%	**$45,623,159**	
5	Construction Contingency/Management Reserve	1	ls	0%	**$0**	not included
				Grand Total:	**$273,738,954**	Total w/ Contingency
			Cost Range:	**$218,991,163**	**$355,860,640**	Per AACE cost estimate guidelines
				20%	**30%**	

This OPCC is classified as a Class 5 cost estimate per AACE guidelines. Stated accuracy range = -15% to + 25%.

Pricing basis = 4th Qtr 2014, escalation to midpoint of construction is not included.

Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).

Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

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MOKELUMNE DELTA TUNNEL
Single Tunnel and Single Pipe
CONTRACT A (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 1 and Shaft Number 2

Currency: USD-United States

Grand Total Price: $ 224,867,049

Item	Description	Quantity	UOM	Unit Price	Total Price	Comments
	Launch Shaft (Three Cells) Number 2	142	VF	$78,442.74	**$11,138,868**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	
3	Shaft Starter Wall for Slurry Trench	50	CY	$700.00	$35,000	
4	Slurry Wall 3 ft Thick at Perimeter 31.11 cy/vf 172 ft deep	5,351	CY	$1,045.00	$5,591,795	ballpark quote
5	Excavate Three Cell Shaft 92.59 cy/vf	13,148	CY	$200.00	$2,629,556	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	741	CY	$500.00	$370,500	
7	Dispose of Excavated Material	18,101	CY	$20.00	$362,017	
8	Jet Grout Block 45 x 45 x 30; Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Receiving Shaft Number 1 32 FT Finish	142	VF	$42,649.89	**$6,056,284**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	
3	Shaft Starter Wall for Slurry Trench	25	CY	$500.00	$12,500	
4	Slurry Wall 3 ft Thick at Perimeter 12.21 cy/vf 172 ft deep	2,100	CY	$1,045.00	$2,194,500	ballpark quote
5	Excavate 32ft Finish Diameter Shaft 29.77 cy/vf	4,227	CY	$200.00	$845,468	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	238	CY	$400.00	$95,264	
7	Concrete Backfill	1,034	CY	$500.00	$516,990	
8	Concrete Leveling Slab 2ft Thick	60	CY	$300.00	$17,862	
9	Install Shaft Piping 111 inch Steel Pipe	284	VF	$100.00	$28,400	
10	Backfill Shaft Granular	2,068	CY	$19.50	$40,325	
11	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
12	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
13	Install Locking Manhole Cover	1	EA	$300.00	$300	
14	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
15	Concrete Apron 6in	7	CY	$550.00	$3,850	
16	Dispose of Excavated Material	6,145	CY	$20.00	$122,892	
17	Jet Grout Block 45 x 45 x 30; Tunnel Eye 1 Each	2,250	CY	$400.00	$900,000	
	Reach 1 Tunnel Excavate 13.75 foot Diameter	14,925	LF		**$63,771,125**	
1	Purchase EPBM TBM 13.75 Ft	1	LS	$8,000,000.00	$8,000,000	Robbins Ball Park Quote included parts
2	Mobilization and Assemble TBM	1	LS	$2,250,000.00	$2,250,000	
3	EPBM Tunnel Excavation & Lining Startup	300	LF	$3,000.00	$900,000	
4	EPBM Tunnel & Segment Installation	14,625	LF	$2,000.00	$29,250,000	
5	Install 111in T=.8125 inch Steel Pipeline & Weld	14,925	LF	$900.00	$13,432,500	
6	Place Cellular Concrete 1.875 cy/ft	27,984	CY	$200.00	$5,596,875	
7	Dispose of Excavated Material 5.50 bcy /lf	82,088	BCY	$20.00	$1,641,750	
8	Jet Grout Block 45 x 45 x 45; Safe Havens, 2 Each	6,750	CY	$400.00	$2,700,000	
	Purchased Materials				**$39,122,423**	
1	Pipe Bedding Materials Land	60	CY	$15.00	$900	
2	Concrete Purchase	9,606	CY	$125.00	$1,200,710	
3	Granular Backfill in Shafts	2,068	CY	$12.00	$24,816	
4	111in T=.8125 inch Steel Pipeline	14,925	LF	$1,350.00	$20,148,750	
5	111 in T=.8125 inch Steel Pipeline in shaft	284	LF	$1,350.00	$383,400	
6	111 in T=.8125 inch Steel Pipeline Land	120	LF	$1,350.00	$162,000	
7	111 in T=..8125 inch Steel Pipeline Elbows	6	EA	$20,000.00	$120,000	
8	111 in x 69 inch x 69 inch Wye T=..8125 inch Steel Pipeline	1	EA	$75,000.00	$75,000	
9	111 in x 69 inch T=..8125 inch Steel Pipeline Reducer	1	EA	$18,000.00	$18,000	
10	Tunnel Liner Concrete Precast Segments 9 in Thick	14,925	LF	$950.00	$14,178,750	
11	Cellular Concrete Tunnnel	27,984	CY	$100.00	$2,798,438	
12	Steel Riser Pipe 5 ft Diameter	12	LF	$480.00	$5,760	
13	Precast Open Bottom Vault	1	EA	$1,800.00	$1,800	
14	10ft x 10 ft Precast Concrete Panel	1	EA	$3,750.00	$3,750	
15	Locking Manhole Cover	1	EA	$350.00	$350	
	Tie in Land Work from Shaft Number 1				**$120,000**	
1	Excavate Lay & Backfill 111in Pipe	150	LF	$200.00	$30,000	
2	Weld 111 in T=.8125 inch Pipeline	8	JT	$8,000.00	$60,000	
3	Weld 111 in x 69 inch Reducers Pipeline	4	JT	$7,500.00	$30,000	
				Running Subtotal:	**$120,208,701**	
	Mobilization/Field Oversight Expenses				**$ 30,052,175**	
1	Contractor General Conditions (Prime)	1	ls	25%	$ 30,052,175	
	Unlisted Items Cost Allowance				**$7,513,044**	
1	Unlisted Items Allowance	1	ls	5%	$7,513,044	
				Running Subtotal:	**$157,773,919**	
	Markups				**$ 29,615,288**	
1	Prime Contractor OH&P	1	ls	15.0%	**$ 23,666,088**	

MOKELUMNE DELTA TUNNEL
Single Tunnel and Single Pipe
CONTRACT A (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 1 and Shaft Number 2

Currency: USD-United States

Grand Total Price:					$ 224,867,049	
Item	**Description**	**Quantity**	**UOM**	**Unit Price**	**Total Price**	**Comments**
2	Contractor Insurance Program	1	ls	1.5%	$ 2,721,600	
3	Taxes on Matls	1	ls	8.25%	$ 3,227,600	
4	Escalation	1	ls	0.0%	$ -	not included
				Running Subtotal:	**$187,389,207**	
	Project Administration & Management				**$37,477,841**	
1	Construction Oversight & Mgt	1	ls	0%	**$0**	not included
2	Engineering	1	ls	0%	**$0**	not included
3	Permitting/Planning/Procurement	1	ls	0%	**$0**	not included
4	Scope Contingency/Market Conditions	1	ls	20%	**$37,477,841**	
5	Construction Contingency/Management Reserve	1	ls	0%	**$0**	not included
				Grand Total:	**$224,867,049**	Total w/ Contingency
			Cost Range:	**$179,893,639**	**$292,327,164**	Per AACE cost estimate guidelines
				20%	**30%**	

This OPCC is classified as a Class 5 cost estimate per AACE guidelines. Stated accuracy range = -15% to + 25%.

Pricing basis = 4th Qtr 2014, escalation to midpoint of construction is not included.

Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).

Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

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MOKELUMNE DELTA TUNNEL
Single Tunnel and Single Pipe
CONTRACT B (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 2 and Shaft Number 4

Currency: USD-United States

Grand Total Price: $ 426,632,944

Item	Description	Quantity	UOM	Unit Price	Total Price	Comments
	Launch Shaft (Three Cells) Number 2	142	VF	$27,722.62	**$3,936,612**	
1	Concrete Backfill	1,593	CY	$500.00	$796,598	
2	Cast in Place Chamber Walls	2,689	CY	$750.00	$2,017,045	
3	Install Precast Manhole Rings	87	VF	$140.00	$12,180	
4	Backfill Shaft Granular	9,164	CY	$19.50	$178,705	
5	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
6	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
7	Install Locking Manhole Cover	1	EA	$300.00	$300	
8	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
9	Concrete Apron 6in	7	CY	$550.00	$3,850	
10	Jet Grout Block 45 x 45 x 30; Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Launch Shaft (Three Cells) Number 3	142	VF	$106,765.30	**$15,160,673**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	
3	Shaft Starter Wall for Slurry Trench	50	CY	$700.00	$35,000	
4	Slurry Wall 3 ft Thick at Perimeter 31.11 cy/vf 172 ft deep	5,351	CY	$1,045.00	$5,591,795	ballpark quote
5	Excavate Three Cell Shaft 92.59 cy/vf	13,574	CY	$200.00	$2,714,756	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	741	CY	$500.00	$370,500	
7	Concrete Backfill	1,593	CY	$500.00	$796,598	
8	Cast in Place Chamber Walls	2,689	CY	$750.00	$2,017,045	
9	Install Precast Manhole Rings	87	VF	$140.00	$12,180	
10	Backfill Shaft Granular	9,164	CY	$19.50	$178,698	
11	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
12	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
13	Install Locking Manhole Cover	1	EA	$300.00	$300	
14	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
15	Concrete Apron 6in	7	CY	$550.00	$3,850	
16	Dispose of Excavated Material	18,101	CY	$20.00	$362,017	
17	Jet Grout Block 45 x 45 x 30; Tunnel Eyes, 2 Each	4,500	CY	$400.00	$1,800,000	
	Launch Shaft (Three Cells) Number 4	142	VF	$78,442.74	**$11,138,868**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	
3	Shaft Starter Wall for Slurry Trench	50	CY	$700.00	$35,000	
4	Slurry Wall 3 ft Thick at Perimeter 31.11 cy/vf 148ft deep	5,351	CY	$1,045.00	$5,591,795	ballpark quote
5	Excavate Three Cell Shaft 92.59 cy/vf	13,148	CY	$200.00	$2,629,556	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	741	CY	$500.00	$370,500	
7	Dispose of Excavated Material	18,101	CY	$20.00	$362,017	
8	Jet Grout Block 45 x 45 x 30, Tunnel Eyes, 1 Each	2,250	CY	$400.00	$900,000	
	Reach 2 Tunnel Excavate 13.75 foot Diameter	13,600	LF		**$59,286,000**	
1	Purchase EPBM TBM 13.75 Ft	1	LS	$8,000,000.00	$8,000,000	Robbins Ball Park Quote included parts
2	Mobilization and Assemble TBM	1	LS	$2,250,000.00	$2,250,000	
3	EPBM Tunnel Excavation & Lining Startup	300	LF	$3,000.00	$900,000	
4	EPBM Tunnel & Segment Installation	13,300	LF	$2,000.00	$26,600,000	
5	Install 111in T=.8125 inch Steel Pipeline & Weld	13,600	LF	$900.00	$12,240,000	
6	Place Cellular Concrete 1.875 cy/ft	25,500	CY	$200.00	$5,100,000	
7	Dispose of Excavated Material 5.50 bcy /lf	74,800	BCY	$20.00	$1,496,000	
8	Jet Grout Block 45 x 45 x 45, Safe Havens, 2 Each	6,750	CY	$400.00	$2,700,000	
	Reach 3 Tunnel Excavate 13.75 foot Diameter	16,250	LF		**$61,206,250**	
1	Reset and Assemble TBM	1	LS	$3,500,000.00	$3,500,000	
2	EPBM Tunnel & Segment Installation	16,250	LF	$2,000.00	$32,500,000	
3	Install 111in T=.8125 inch Steel Pipeline & Weld	16,250	LF	$900.00	$14,625,000	
4	Place Cellular Concrete 1.875 cy/ft	30,469	CY	$200.00	$6,093,750	
5	Dispose of Excavated Material 5.50 bcy /lf	89,375	CY	$20.00	$1,787,500	
6	Jet Grout Block 45 x 45 x 45, Safe Haven, 2 Each	6,750	CY	$400.00	$2,700,000	
	Purchased Materials				**$77,180,538**	
1	Concrete Purchase	20,856	CY	$125.00	$2,607,023	
2	Granular Backfill in Shafts	18,328	CY	$12.00	$219,941	
3	111in T=.8125 inch Steel Pipeline	29,850	LF	$1,350.00	$40,297,500	
4	Tunnel Liner Concrete Precast Segments 9 in Thick	29,850	LF	$950.00	$28,357,500	ballpark quote
5	Cellular Concrete Tunnnel	55,969	CY	$100.00	$5,596,875	
6	Precast Open Bottom Vault	3	EA	$1,800.00	$5,400	
7	10ft x 10 ft Precast Concrete Panel	3	EA	$3,750.00	$11,250	
8	Locking Manhole Cover	3	EA	$350.00	$1,050	
9	Precast Manhole Rings	336	VF	$250.00	$84,000	
				Running Subtotal:	**$227,908,941**	
	Mobilization/Field Oversight Expenses				$ 56,977,235	

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MOKELUMNE DELTA TUNNEL
Single Tunnel and Single Pipe
CONTRACT B (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 2 and Shaft Number 4

Currency: USD-United States

Grand Total Price: $ 426,632,944

Item	Description	Quantity	UOM	Unit Price	Total Price	Comments
1	Contractor General Conditions (Prime)	1	ls	25%	$ 56,977,235	
	Unlisted Items Cost Allowance				**$14,244,309**	
1	Unlisted Items Allowance	1	ls	5%	$14,244,309	
				Running Subtotal:	**$299,130,485**	
	Markups				**$ 56,396,968**	
1	Prime Contractor OH&P	1	ls	15.0%	**$ 44,869,573**	
2	Contractor Insurance Program	1	ls	1.5%	**$ 5,160,001**	
3	Taxes on Matls	1	ls	8.25%	**$ 6,367,394**	
4	Escalation	1	ls	0.0%	**$ -**	not included
				Running Subtotal:	**$355,527,454**	
		MU Factor:				
	Project Administration & Management				**$71,105,491**	
1	Construction Oversight & Mgt	1	ls	0%	**$0**	not included
2	Engineering	1	ls	0%	**$0**	not included
3	Permitting/Planning/Procurement	1	ls	0%	**$0**	not included
4	Scope Contingency/Market Conditions	1	ls	20%	**$71,105,491**	
5	Construction Contingency/Management Reserve	1	ls	0%	**$0**	not included
				Grand Total:	**$426,632,944**	Total w/ Contingency
			Cost Range:	**$341,306,355**	**$554,622,828**	Per AACE cost estimate guidelines
				20%	**30%**	

This OPCC is classified as a Class 5 cost estimate per AACE guidelines. Stated accuracy range = -15% to + 25%.

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Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).

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MWH DC
11/25/2014

MOKELUMNE DELTA TUNNEL
Single Tunnel and Single Pipe
CONTRACT C (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 4 and Shaft Number 6

Currency: USD-United States

Grand Total Price: $ 403,167,683

Item	Description	Quantity	UOM	Unit Price	Total Price	Comments
	Launch Shaft (Three Cells) Number 4	142	VF	$27,722.62	**$3,936,612**	
1	Concrete Backfill	1,593	CY	$500.00	$796,598	
2	Cast in Place Chamber Walls	2,689	CY	$750.00	$2,017,045	
3	Install Precast Manhole Rings	87	VF	$140.00	$12,180	
4	Backfill Shaft Granular	9,164	CY	$19.50	$178,705	
5	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
6	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
7	Install Locking Manhole Cover	1	EA	$300.00	$300	
8	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
9	Concrete Apron 6in	7	CY	$550.00	$3,850	
10	Jet Grout Block 45 x 45 x 30; Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Launch Shaft (Three Cells) Number 5	142	VF	$104,090.04	**$14,780,786**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	
3	Shaft Starter Wall for Slurry Trench	50	CY	$700.00	$35,000	
4	Slurry Wall 3 ft Thick at Perimeter 31.11 cy/vf 172 ft deep	5,351	CY	$1,045.00	$5,591,795	ball park Quote
5	Excavate Three Cell Shaft 92.59 cy/vf	13,148	CY	$200.00	$2,629,556	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	741	CY	$500.00	$370,500	
7	Concrete Backfill	1,421	CY	$500.00	$710,480	
8	Cast in Place Chamber Walls	2,399	CY	$750.00	$1,798,986	
9	Install Precast Manhole Rings	103	VF	$140.00	$14,420	
10	Backfill Shaft Granular	9,595	CY	$19.50	$187,095	
11	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
12	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
13	Install Locking Manhole Cover	1	EA	$300.00	$300	
14	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
15	Concrete Apron 6in	7	CY	$550.00	$3,850	
16	Dispose of Excavated Material	18,044	CY	$20.00	$360,872	
17	Jet Grout Block 45 x 45 x 30, Tunnel Eyes 2 Each	4,500	CY	$400.00	$1,800,000	
	Launch Shaft (Three Cells) Number 6	142	VF	$25,655.38	**$3,643,063**	
1	Concrete Backfill	1,421	CY	$500.00	$710,480	
2	Cast in Place Chamber Walls	2,399	CY	$750.00	$1,798,986	
3	Install Precast Manhole Rings	103	VF	$140.00	$14,420	
4	Backfill Shaft Granular	9,595	CY	$19.50	$187,095	
5	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
6	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
7	Install Locking Manhole Cover	1	EA	$300.00	$300	
8	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
9	Concrete Apron 6in	7	CY	$550.00	$3,850	
10	Jet Grout Block 45 x 45 x 30; Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Reach 4 Tunnel Excavate 13.75 foot Diameter	15,175	LF		**$64,617,375**	
1	Purchase EPBM TBM 13.75 Ft	1	LS	$8,000,000.00	$8,000,000	Robbins Ball Park Quote included parts
2	Mobilization and Assemble TBM	1	LS	$2,250,000.00	$2,250,000	
3	EPBM Tunnel Excavation & Lining Startup	300	LF	$3,000.00	$900,000	
4	EPBM Tunnel Excavation & Lining	14,875	LF	$2,000.00	$29,750,000	
5	Install 111in T=.8125 inch Steel Pipeline & Weld	15,175	LF	$900.00	$13,657,500	
6	Place Cellular Concrete 1.875 cy/ft	28,453	CY	$200.00	$5,690,625	
7	Dispose of Excavated Material 5.50 bcy /lf	83,463	BCY	$20.00	$1,669,250	
8	Jet Grout Block 45 x 45 x 45, Safe Havens, 2 Each	6,750	CY	$400.00	$2,700,000	
	Reach 5 Tunnel Excavate 13.75 foot Diameter	13,475	LF		**$54,362,875**	
1	Reset and Assemble TBM	1	LS	$3,500,000.00	$3,500,000	
2	Mobilization and Assemble TBM	1	LS	$2,250,000.00	$2,250,000	
3	Starter Tunnel	300	LF	$3,000.00	$900,000	
4	EPBM Tunnel Excavation & Lining	13,175	LF	$2,000.00	$26,350,000	
5	Install 111in T=.8125 inch Steel Pipeline & Weld	13,475	LF	$900.00	$12,127,500	
6	Place Cellular Concrete 1.875 cy/ft	25,266	CY	$200.00	$5,053,125	
7	Dispose of Excavated Material 5.50 bcy /lf	74,113	CY	$20.00	$1,482,250	
8	Jet Grout Block 45 x 45 x 45, Safe Haven, 2 Each	6,750	CY	$400.00	$2,700,000	
	Purchased Materials				**$73,976,919**	
1	Concrete Purchase	18,085	CY	$125.00	$2,260,601	
2	Granular Backfill in Shafts	28,354	CY	$12.00	$340,243	
3	111in T=.8125 inch Steel Pipeline	28,650	LF	$1,350.00	$38,677,500	
4	Tunnel Liner Concrete Precast Segments 9 in Thick	28,650	LF	$950.00	$27,217,500	ballpark quote
5	Cellular Concrete Tunnnel	53,719	CY	$100.00	$5,371,875	
6	Precast Open Bottom Vault	3	EA	$1,800.00	$5,400	
7	10ft x 10 ft Precast Concrete Panel	3	EA	$3,750.00	$11,250	
8	Locking Manhole Cover	3	EA	$350.00	$1,050	
9	Precast Manhole Rings	366	VF	$250.00	$91,500	
				Running Subtotal:	**$215,317,630**	

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11/25/2014

MOKELUMNE DELTA TUNNEL
Single Tunnel and Single Pipe
CONTRACT C (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 4 and Shaft Number 6

Currency: USD-United States

Grand Total Price:					$ 403,167,683	
Item	**Description**	**Quantity**	**UOM**	**Unit Price**	**Total Price**	**Comments**
	Mobilization/Field Oversight Expenses				**$ 53,829,408**	
1	Contractor General Conditions (Prime)	1	ls	25%	$ 53,829,408	
	Unlisted Items Cost Allowance				**$13,457,352**	
1	Unlisted Items Allowance	1	ls	5%	$13,457,352	
				Running Subtotal:	**$282,604,389**	
	Markups				**$ 53,368,680**	
1	Prime Contractor OH&P	1	ls	15.0%	**$ 42,390,658**	
2	Contractor Insurance Program	1	ls	1.5%	**$ 4,874,926**	
3	Taxes on Matls	1	ls	8.25%	**$ 6,103,096**	
4	Escalation	1	ls	0.0%	**$ -**	not included
				Running Subtotal:	**$335,973,069**	
	Project Administration & Management				**$67,194,614**	
1	Construction Oversight & Mgt	1	ls	0%	**$0**	not included
2	Engineering	1	ls	0%	**$0**	not included
3	Permitting/Planning/Procurement	1	ls	0%	**$0**	not included
4	Scope Contingency/Market Conditions	1	ls	20%	**$67,194,614**	
5	Construction Contingency/Management Reserve	1	ls	0%	**$0**	not included
				Grand Total:	**$403,167,683**	Total w/ Contingency
			Cost Range:	**$322,534,147**	**$524,117,988**	Per AACE cost estimate guidelines
				20%	**30%**	

This OPCC is classified as a Class 5 cost estimate per AACE guidelines. Stated accuracy range = -15% to + 25%.

Pricing basis = 4th Qtr 2014, escalation to midpoint of construction is not included.

Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).

Owner soft costs and project management expenses excluded.

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MWH DC
11/25/2014

MOKELUMNE DELTA TUNNEL
Single Tunnel and Single Pipe
CONTRACT D (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 6 and Shaft Number 7

Currency: USD-United States

Grand Total Price: $ 179,675,323

Item	Description	Quantity	UOM	Unit Price	Total Price	Comments
	Launch Shaft (Three Cells) Number 6	142	VF	$78,434.58	**$11,137,710**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	
3	Shaft Starter Wall for Slurry Trench	50	CY	$700.00	$35,000	
4	Slurry Wall 3 ft Thick at Perimeter 31.11 cy/vf 164ft deep	5,351	CY	$1,045.00	$5,591,795	ball park Quote
5	Excavate Three Cell Shaft 92.59 cy/vf	13,148	CY	$200.00	$2,629,556	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	741	CY	$500.00	$370,500	
7	Dispose of Excavated Material	18,043	CY	$20.00	$360,859	
8	Jet Grout Block 45 x 45 x 30, Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Receiving Shaft Number 7 32 FT Finish	107	VF	$48,762.69	**$5,217,608**	
1	Water Control for Shaft & Tunnel Construction	1	LS	$800,000.00	$800,000	
2	Shaft Site Set Up	1	LS	$450,000.00	$450,000	
3	Shaft Starter Wall for Slurry Trench	25	CY	$500.00	$12,500	
4	Slurry Wall 3 ft Thick at Perimeter 12.21 cy/vf 120ft deep	1,673	CY	$1,045.00	$1,748,285	ball park Quote
5	Excavate 32ft Finish Diameter Shaft 29.77 cy/vf	3,185	CY	$200.00	$637,078	
6	Concrete Tremie Slab Shaft Base Concrete 8ft Thickness	238	CY	$400.00	$95,264	
7	Concrete Backfill	772	CY	$500.00	$385,817	
8	Concrete Leveling Slab 2ft Thick	60	CY	$300.00	$17,862	
9	Install Shaft Piping 87 inch Steel Pipe	214	VF	$75.00	$16,050	
10	Backfill Shaft Granular	1,543	CY	$19.50	$30,094	
11	Install Precast Open Bottom Vault	1	EA	$4,000.00	$4,000	
12	Install 10ft x 10 ft Precast Concrete Panel	1	EA	$600.00	$600	
13	Install Locking Manhole Cover	1	EA	$300.00	$300	
14	Demolish 5ft of Slurry Wall	156	CY	$150.00	$23,333	
15	Concrete Apron 6in	7	CY	$550.00	$3,850	
16	Dispose of Excavated Material	4,629	CY	$20.00	$92,576	
17	Jet Grout Block 45 x 45 x 30, Tunnel Eye, 1 Each	2,250	CY	$400.00	$900,000	
	Reach 6 Tunnel Excavate 13.75 foot Diameter	13,720	LF		**$52,332,200**	
1	Purchase EPBM TBM 13.75 Ft	1	LS	$800,000.00	$640,000	Robbins Ball Park Quote included parts
2	Mobilization and Assemble TBM	1	LS	$2,250,000.00	$2,250,000	
3	EPBM Tunnel Excavation & Lining Startup	300	LF	$3,000.00	$900,000	
4	EPBM Tunnel Excavation & Lining	13,420	LF	$2,000.00	$26,840,000	
5	Install 111in T=.8125 inch Steel Pipeline & Weld	13,720	LF	$900.00	$12,348,000	
6	Place Cellular Concrete 1.875 cy/ft	25,725	CY	$200.00	$5,145,000	
7	Dispose of Excavated Material 5.50 bcy /lf	75,460	BCY	$20.00	$1,509,200	
8	Jet Grout Block 45 x 45 x 45, Safe Haven, 2 Each	6,750	CY	$400.00	$2,700,000	
	Purchased Materials				**$27,448,011**	
1	Pipe Bedding Materials Land	60	CY	$15.00	$900	
2	Concrete Purchase	8,916	CY	$125.00	$1,114,542	
3	Granular Backfill in Shafts	1,543	CY	$12.00	$18,519	
4	111in T=.8125 inch Steel Pipeline	13,720	LF	$1,350.00	$18,522,000	
5	111 in T=.8125 inch Steel Pipeline in shaft	249	LF	$1,350.00	$336,150	
6	111 in T=.8125 inch Steel Pipeline Land	150	LF	$1,350.00	$202,500	
7	111 in T=..8125 inch Steel Pipeline Elbows	6	EA	$20,000.00	$120,000	
8	111 in x 69 inch x 69 inch Wye T=..8125 inch Steel Pipeline	1	EA	$75,000.00	$75,000	
9	111 in x 69 inch T=..8125 inch Steel Pipeline Reducer	1	EA	$18,000.00	$18,000	
10	Tunnel Liner Concrete Precast Segments 9 in Thick	4,629	LF	$950.00	$4,397,340	ball park Quote
11	Cellular Concrete Tunnnel	25,725	CY	$100.00	$2,572,500	
12	Steel Riser Pipe 5 ft Diameter	12	LF	$480.00	$5,760	
13	Precast Open Bottom Vault	2	EA	$1,800.00	$3,600	
14	10ft x 10 ft Precast Concrete Panel	2	EA	$3,750.00	$7,500	
15	Locking Manhole Cover	2	EA	$350.00	$700	
16	Precast Manhole Rings	212	VF	$250.00	$53,000	
	Tie in Land Work from Shaft Number 1				**$120,000**	
1	Excavate Lay & Backfill 111in Pipe	150	LF	$200.00	$30,000	
2	Weld 111 in T=.8.125 inch Pipeline	8	JT	$8,000.00	$60,000	
3	Weld 111 in x 69 inch Reducers Pipeline	4	JT	$7,500.00	$30,000	
				Running Subtotal:	**$96,255,530**	
	Mobilization/Field Oversight Expenses				**$ 24,063,882**	
1	Contractor General Conditions (Prime)	1	ls	25%	$ 24,063,882	
	Unlisted Items Cost Allowance				**$6,015,971**	
1	Unlisted Items Allowance	1	ls	5%	$6,015,971	
				Running Subtotal:	**$126,335,383**	
	Markups				**$ 23,394,054**	

MWH DC

11/25/2014

MOKELUMNE DELTA TUNNEL
Single Tunnel and Single Pipe
CONTRACT D (EBMUD Mokelumne Delta Tunnel)
Between Shaft Number 6 and Shaft Number 7

Currency: USD-United States

Grand Total Price:					$ 179,675,323	
Item	**Description**	**Quantity**	**UOM**	**Unit Price**	**Total Price**	**Comments**
1	Prime Contractor OH&P	1	ls	15.0%	$ 18,950,307	
2	Contractor Insurance Program	1	ls	1.5%	$ 2,179,285	
3	Taxes on Matls	1	ls	8.25%	$ 2,264,461	
4	Escalation	1	ls	0.0%	$ -	not included
				Running Subtotal:	**$149,729,436**	
		MU Factor:				
	Project Administration & Management				**$29,945,887**	
1	Construction Oversight & Mgt	1	ls	0%	**$0**	not included
2	Engineering	1	ls	0%	**$0**	not included
3	Permitting/Planning/Procurement	1	ls	0%	**$0**	not included
4	Scope Contingency/Market Conditions	1	ls	20%	**$29,945,887**	
5	Construction Contingency/Management Reserve	1	ls	0%	**$0**	not included
				Grand Total:	**$179,675,323**	Total w/ Contingency
			Cost Range:	**$143,740,259**	**$233,577,921**	Per AACE cost estimate guidelines
				20%	**30%**	

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Pricing basis = 4th Qtr 2014, escalation to midpoint of construction is not included.

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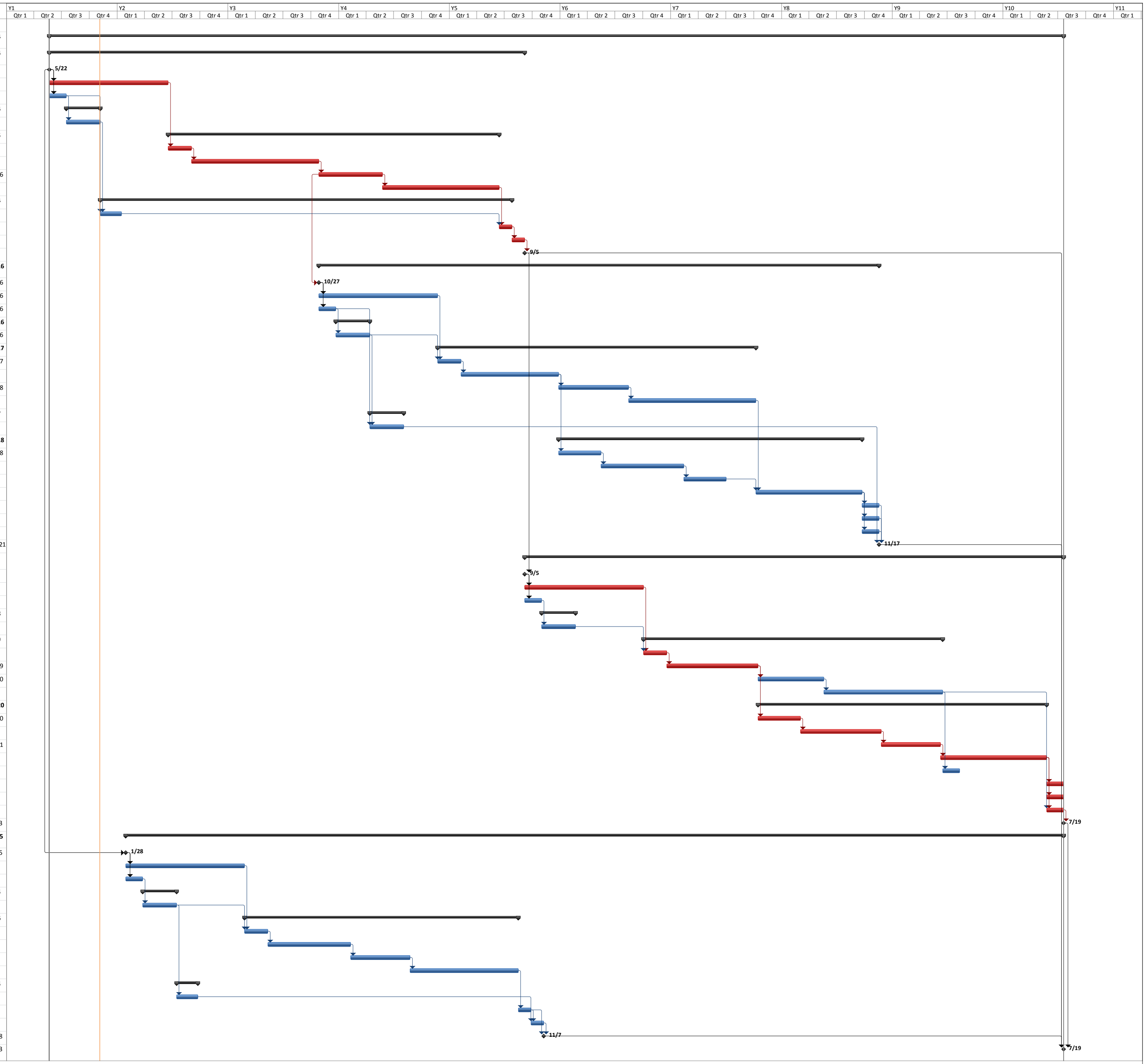
ID	Task Mode	Task Name	Duration	Start
1				
2		**MOKELUMNE DELTA TUNNEL Base Case**	**2390 days**	**Thu 5/22/14**
3		**CONTRACT A (EBMUD Mokelumne Delta Tunnel)**	**1120 days**	**Thu 5/22/14**
4		NTP CONTRACT A	0 days	Thu 5/22/14
5		TBM Order and Deliver	14 mons	Thu 5/22/14
6		Contract Mobilization & Submittals	2 mons	Thu 5/22/14
7		**Launch Shaft (Three Cells) Number 2**	**80 days**	**Thu 7/17/14**
8		Shaft Site Set Up/Construct Shaft 2	4 mons	Thu 7/17/14
9		**Reach 1 Tunnel Excavate 21 foot Diameter 14,925 lf**	**780 days**	**Thu 6/18/15**
10		Mobilization and Assemble TBM	11 wks	Thu 6/18/15
11		EBM Tunnel & Segment Installation	60 wks	Thu 9/3/15
12		Install 87 in T=.625 inch Steel Pipeline & Weld	30 wks	Thu 10/27/16
13		Place Cellular Concrete 7.35 cy/ft	55 wks	Thu 5/25/17
14		**Receiving Shaft Number 1 32 FT Finish**	**970 days**	**Thu 11/6/14**
15		Shaft Site Set Up/Construct Shaft 1	2.5 mons	Thu 11/6/14
16		Install Piping and Backfill Shaft 1	1.5 mons	Thu 6/14/18
17		**Testing & Demobilization**	1.5 mons	Thu 7/26/18
18		**Project Complete**	0 days	Wed 9/5/18
19		**CONTRACT B (EBMUD Mokelumne Delta Tunnel)**	**1320 days**	**Thu 10/27/16**
20		NTP CONTRACT B	0 days	Thu 10/27/16
21		TBM Order and Deliver	14 mons	Thu 10/27/16
22		Contract Mobilization & Submittals	2 mons	Thu 10/27/16
23		**Launch Shaft (Three Cells) Number 3**	**80 days**	**Thu 12/22/16**
24		Shaft Site Set Up/Construct Shaft 3	4 mons	Thu 12/22/16
25		**Reach 3 Tunnel Excavate 21 foot Diameter 16,250 lf**	**750 days**	**Thu 11/23/17**
26		Mobilization and Assemble TBM	11 wks	Thu 11/23/17
27		EBM Tunnel & Segment Installation	46 wks	Thu 2/8/18
28		Install 87 in T=.625 inch Steel Pipeline & Weld	33 wks	Thu 12/27/18
29		Place Cellular Concrete 7.35 cy/ft	60 wks	Thu 8/15/19
30		**Launch Shaft (Three Cells) Number 4**	**80 days**	**Thu 4/13/17**
31		Shaft Site Set Up/Construct Shaft 4	4 mons	Thu 4/13/17
32		**Reach 2 Tunnel Excavate 21 foot Diameter 13,600 lf**	**715 days**	**Thu 12/27/18**
33		Reset and Assemble TBM	20 wks	Thu 12/27/18
34		EBM Tunnel & Segment Installation	39 wks	Thu 5/16/19
35		Install 87 in T=.625 inch Steel Pipeline & Weld	20 wks	Thu 2/13/20
36		Place Cellular Concrete 7.35 cy/ft	50 wks	Thu 10/8/20
37		**Backfill Shaft 2**	2 mons	Thu 9/23/21
38		**Backfill Shaft 3**	2 mons	Thu 9/23/21
39		**Testing & Demobilization**	2 mons	Thu 9/23/21
40		**Project Complete**	0 days	Wed 11/17/21
41		**CONTRACT C (EBMUD Mokelumne Delta Tunnel)**	**1270 days**	**Wed 9/5/18**
42		NTP CONTRACT C	0 days	Wed 9/5/18
43		TBM Order and Deliver	14 mons	Thu 9/6/18
44		Contract Mobilization & Submittals	2 mons	Thu 9/6/18
45		**Launch Shaft (Three Cells) Number 5**	**80 days**	**Thu 11/1/18**
46		Shaft Site Set Up/Construct Shaft 5	4 mons	Thu 11/1/18
47		**Reach 4 Tunnel Excavate 21 foot Diameter 15175 lf**	**705 days**	**Thu 10/3/19**
48		Mobilization and Assemble TBM	11 wks	Thu 10/3/19
49		EBM Tunnel & Segment Installation	43 wks	Thu 12/19/19
50		Install 87 in T=.625 inch Steel Pipeline & Weld	31 wks	Thu 10/15/20
51		Place Cellular Concrete 7.35 cy/ft	56 wks	Thu 5/20/21
52		**Reach 5 Tunnel Excavate 21 foot Diameter 13,475 lf**	**680 days**	**Thu 10/15/20**
53		Reset and Assemble TBM	20 wks	Thu 10/15/20
54		EBM Tunnel & Segment Installation	38 wks	Thu 3/4/21
55		Install 87 in T=.625 inch Steel Pipeline & Weld	28 wks	Thu 11/25/21
56		Place Cellular Concrete 7.35 cy/ft	50 wks	Thu 6/9/22
57		**Backfill Shaft 4**	2 mons	Thu 6/16/22
58		**Backfill Shaft 5**	2 mons	Thu 5/25/23
59		**Backfill Shaft 6**	2 mons	Thu 5/25/23
60		**Testing & Demobilization**	2 mons	Thu 5/25/23
61		**Project Complete**	0 days	Wed 7/19/23
62		**CONTRACT D (EBMUD Mokelumne Delta Tunnel)**	**2210 days**	**Wed 1/28/15**
63		NTP CONTRACT D	0 days	Wed 1/28/15
64		TBM Order and Deliver	14 mons	Thu 1/29/15
65		Contract Mobilization & Submittals	2 mons	Thu 1/29/15
66		**Launch Shaft (Three Cells) Number 6**	**80 days**	**Thu 3/26/15**
67		Shaft Site Set Up/Construct Shaft 6	4 mons	Thu 3/26/15
68		**Reach 6 Tunnel Excavate 21 foot Diameter 13,720 lf**	**645 days**	**Thu 2/25/16**
69		Mobilization and Assemble TBM	11 wks	Thu 2/25/16
70		EBM Tunnel & Segment Installation	39 wks	Thu 5/12/16
71		Install 87 in T=.625 inch Steel Pipeline & Weld	28 wks	Thu 2/9/17
72		Place Cellular Concrete 7.35 cy/ft	51 wks	Thu 8/24/17
73		**Receiving Shaft Number 7**	**50 days**	**Thu 7/16/15**
74		Shaft Site Set Up/Construct Shaft 7	2.5 mons	Thu 7/16/15
75		**Install Piping and Backfill Shaft 7**	1.5 mons	Thu 8/16/18
76		**Testing & Demobilization**	1.5 mons	Thu 9/27/18
77		**Project Complete**	0 days	Wed 11/7/18
78		**Mokelumne Delta Tunnel Project Complete**	0 days	Wed 7/19/23



Project: MOK SCHEDULES NOV R
Date: Wed 11/5/14

Task · Split · Milestone · Summary · Project Summary · External Tasks · External Milestone · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · Deadline · Critical · Critical Split · Progress