Appendix C6. Reusable Tunnel Material (Final Draft)

1. Introduction and Purpose

The purpose of this technical memorandum (TM) is to address soil material that would be removed from the ground during tunneling for the Delta Conveyance Project (Project) and is planned for use elsewhere within the Project footprint to reduce reliance on imported materials. This material is referred to as reusable tunnel material (RTM). Based on the tunnel diameter and length, the excavated volume of RTM from tunnel construction would be approximately 14.4 million cubic yards.

The purpose of this TM is to evaluate the properties of the RTM, to calculate the expected quantity of RTM, understand the requirements for processing the RTM, estimate the area required for temporary and permanent storage of RTM, determine where the RTM will be generated and where the RTM could be used. The TM also describes potential health and environmental conditions associated with the extracting, processing, storing, moving and reuse of RTM.

The TM describes the assumptions and approach used to develop the conclusions. The RTM generation quantities, locations, and schedule described in this TM were also used in a Project-wide soil balance, which accounts for surface borrow and shaft excavation quantities as described in the Concept Engineering Report (CER) Appendix G4 *Soil Balance*. Note, this information is considered preliminary and will be subject to change as the Project develops.

1.1 Organization

This TM is organized as follows:

- Introduction and Purpose
- Anticipated Geotechnical Conditions in the Tunnel Zone
- Tunneling
- Engineering Properties of Reusable Tunnel Material
- Environmental Properties of RTM
- Health, Environment, and Ecology
- Reusable Tunnel Materials Quantities
- Reusable Tunnel Material Processing
- Reusable Tunnel Material Usage and Disposal
- Conclusions
- References
- Attachment 1 – Bethany Reservoir Alignment
- Attachment 2 – Table of Inputs and Assumptions
- Attachment 3 – Determination of Geotechnical Factors
- Attachment 4 – RTM Calculations for Bethany Reservoir Alignment

2. Anticipated Geotechnical Conditions in the Tunnel Zone

The Delta forms part of the San Francisco Bay estuary that extends into the Central Valley. The Central Valley is a sedimentary basin, approximately 435 miles long and up to 62 miles wide, which lies between the Sierra Nevada mountain range to the east and the Coast Ranges to the west.

2.1 Geomorphology and Geology

The Delta's geomorphology and surficial geology have been shaped by the landward spread of tidal environments resulting from sea level rise after the last glacial period. During the last glacial period, approximately 15,000 years ago, the Pacific Coast was at least 6 miles west of its current position, the relative sea level was approximately 300 feet lower than present-day sea level, and the location of the present-day Delta was an arid alluvial floodplain. As a consequence, alluvial and eolian sand deposits underlie most of the late Holocene Delta soils (less than 11,000 years-old). Between 10,000 and 5,000 years ago, relative sea level rise was rapid, resulting in the landward transgression of the ocean through the Carquinez Strait and into the Central Valley, forming the Suisun Bay and the Delta. This period saw the widespread deposition of organic silt and clay across the former alluvial floodplain surface. Approximately 5,000 years ago, relative sea level rise slowed, and the deltaic environment remained in approximately its present position, with slow relative sea level rise balanced by vertical marsh growth through biomass accumulation and sediment deposition.

2.2 Tunnel Horizon Soils

The tunnel horizon is expected to be in the range of approximately 100 to 170 feet below the current ground surface and is anticipated to be excavated in the older soils of the former alluvial floodplain. Groundwater is typically 5 feet below ground surface and is controlled, over much of the area of the tunnel corridors, by farming activities, including irrigation and pumping to maintain groundwater levels below the root zones of cultivated crops.

Given their depth, their depositional history, and the shallow groundwater level, the soils are anticipated to be saturated mixtures of sands, silts and clays interfingering as the corridor passes from buried stream channels into old stream banks and overbank deposits.

2.3 Prior Reusable Tunnel Material Testing

During soils investigations for the prior California Waterfix project, soil samples from the tunnel horizon obtained from 19 boreholes were blended to generate a baseline sample of anticipated RTM. The blended sample was generally characterized as 44 percent sands and 56 percent clay and silt fines and was subjected to strength and environmental testing in its blended form as well as when mixed with three typical soil conditioners. The goal of the testing, the results from which were reported in the Reusable Tunnel Material Testing Report (URS, 2014), was to assess the effect of the soil conditioners on the suitability of the RTM for beneficial reuse. The evaluation included laboratory testing for strength, permeability and toxicity. This information was based on a limited number of borings from a corridor that differs from the present one and the geology is expected to vary over the length of the corridor.

2.4 Bulking, Drying and Compacting

Excavated RTM would be in a less compact state than it is in the ground and with the addition of water and conditioners during the tunneling process, could be expected to occupy a greater volume. To account for this, a bulking factor is applied to the in-situ volume to estimate the excavated volume to appropriately account for the space required for processing and stockpiling the RTM. For the material expected to be excavated from the Project area, a bulking factor of 1.3 has been applied based on published data for similar ground conditions.

Wet Excavated Volume = 1.3 x In Situ Volume

Assuming the wet RTM was then dried prior to storage or use, a volume loss could be expected during the drying process. For the expected material and planned reduction in moisture content, the volume loss has been estimated to be 5 percent of the wet excavated volume.

Dry Excavated Volume Loss= (5%) x Wet Excavated Volume

Similarly, if the RTM was compacted, for example, for long-term storage or for use in embankments, the volume would be further reduced. To account for this, a compaction factor is applied to the dry excavated volume which is necessary to calculate the area required for storage and other usage. For the material expected to be excavated from the Project area, a compaction factor of 0.8 has been estimated for structural use.

Dry Fully Compacted Volume = 0.8 x Dry Excavated Volume

3. Tunneling

3.1 Tunnel Dimensions

The Bethany Reservoir Alignment tunnel internal diameter is 36-foot to provide the Project design flow capacity of 6,000 cfs.

The external diameter of the tunnel is a function of the required thickness of the tunnel lining which is directly related to the internal diameter. The lining thickness has been determined to be 18 inches based on experience with similar diameter tunnel projects in similar ground conditions and explained in further detail in the CER Appendix C2 *Conceptual Tunnel Lining Evaluation*. In addition to the tunnel lining thickness, the tunnel boring machine (TBM) shield thickness and radial overcut, needs to be accounted for to determine the excavated volume. Based on experience, these are assumed to be 3.5 inches each.

The assumptions and resulting cutterhead/excavated area for the tunnel is presented in Table 1 below.

Table 1 Tunnel Lining and TBM Dimensions and Resulting Excavated Area

Criteria	Dimension
Tunnel lining ID (ft)	36.0
Lining thickness (in)	18.0
Tunnel lining external diameter (ft)	39.0
TBM tail can thickness (in)	3.5
Cutterhead offset (in)	3.5
TBM cutterhead diameter (ft)	40.2
TBM cutterhead (excavated area) (yd2)	141

Notes:
in = inch(es)
ft = foot (feet)
yd^2 = square yard(s)

3.2 Tunnel Alignment

The Bethany Reservoir Alignment tunnel would extend from Intake C-E-3 roughly southwest down through Glanville Tract, where it takes a more southerly route through New Hope Tract, Canal Ranch Tract, Brack Tract, Terminous Tract, King Island, and Rindge Tract to Lower Roberts Island. From here the alignment turns southwest through Lower Roberts Island, Lower and Upper Jones Tracts, Victoria Island, Kings Island, Union Island, and Coney Island to the Surge Basin reception shaft at the Bethany Complex. The tunnel alignment is approximately 45 miles in length.

3.3 Shafts

Along the tunnel sections, there are a number of shafts. Three different types of shafts would be constructed as part of the Project, each serving a different purpose to support tunneling activities:

- Launch shafts – At these shafts, the TBM would be lowered into the ground and begin excavation. All of the RTM associated with a tunnel reach would be extracted and brought to the surface at the respective launch site.
- Maintenance shafts – These shafts are located between the launch and reception shafts that the TBMs would pass through. These provide an opportunity to inspect and carry out maintenance and repairs to the cutterhead at the front of the TBM as well as the main bearing and other components that would otherwise be difficult to access during excavation.
- Reception shafts – At these shafts, the TBMs would complete excavation and be extracted from the ground.

Table 2 summarizes each tunnel reach for the whole alignment, listing the shaft name, shaft type, tunnel reach, tunnel reach direction (indicated by an arrow) and tunnel reach length. The table omits the maintenance shafts for simplicity.

Table 2. Details of Bethany Reservoir Alignment Tunnel

Structure	Shaft Type and Tunnel Reach Direction	Reach Length
Intake C-E-3 Shaft	Reception	not applicable
Tunnel Reach 1	**North**	8.2 mi
Twin Cities Shaft	Launch	not applicable
Tunnel Reach 2	**South**	12.7 mi
Terminous Tract Shaft	Reception	not applicable
Tunnel Reach 3	**North**	9.5 mi
Lower Roberts Island Shaft	Launch	not applicable
Tunnel Reach 4	**South**	14.4 mi
Surge Basin Shaft	Reception	not applicable
Total		**44.8 mi**

Notes:
mi = mile(s)

3.4 Tunnel Boring Machines

The tunnels would be excavated using four TBMs, one for each reach and for the known ground conditions along the corridors, the most appropriate type of TBM would be either an Earth Pressure Balance (EPB) TBM or a Slurry TBM. Typically, the contractor would make the final decision as to which type of machine to use and it is possible that both types would be employed across the Project. The TBM selection would depend on the type of materials expected to be encountered during tunnel excavation and would be determined following additional geotechnical investigations.

3.4.1 Earth Pressure Balance Tunnel Boring Machine

With an EPB TBM, excavated material discharges from the TBM cutterhead chamber through a screw auger conveyor onto a belt conveyor, which transports the RTM back along the completed length of tunnel to the launch shaft. At the launch shaft, the RTM is lifted to the surface, typically by a vertical conveyor. EPB TBMs maintain pressure at the cutterhead by varying the speed at which the TBM is advanced in conjunction with the rate at which RTM is withdrawn from the cutterhead chamber by the screw auger. The soils within the screw auger are therefore a critical part of the ability to maintain a positive pressure at the cutterhead and soil conditioners may be added at the tunnel face and screw auger to achieve and promote uniform consistency of the soil within the auger and for their ability to avoid washing out of the auger.

3.4.2 Slurry Tunnel Boring Machines

With a slurry TBM, bentonite is mixed with water to create a slurry which is pumped to the tunnel face and held at pressure to support the ground. As material is excavated, it is mixed with the bentonite slurry in the cutterhead chamber to a consistency that allows the mixture to be pumped from the chamber back along the completed length of tunnel to the launch shaft and up to the ground surface within an enclosed pipe. Once at the surface, the excavated material would pass through a slurry screening plant to separate the RTM from the bentonite slurry, which would be reused in the excavation process.

4. Engineering Properties of Reusable Tunnel Material

Geotechnical tests were conducted on the baseline and conditioned soil samples, the results of which were presented in URS (2014). These samples were consistent with RTM expected to be generated from an EPB TBM. The purpose of these tests was to evaluate the strength, compressibility and constructability of conditioned soils for use as structural fill. The following tests were performed in accordance with ASTM International (ASTM) standards:

- Moisture content (ASTM D2216), Atterberg limits (ASTM D4318), gradation and hydrometer (ASTM D422)
- Optimum moisture content and maximum dry density (ASTM D698)
- Remolded unconsolidated undrained triaxial shear strength (ASTM D2850)
- Remolded consolidated undrained triaxial shear strength with pore pressure measurements (ASTM D4767)
- Remolded consolidation (ASTM D2435) and permeability (ASTM D5084)

Remolded specimens were compacted to 95 percent of maximum dry density at optimum moisture content determined in accordance with ASTM D698. It should be noted that conditioners were intentionally added to the soil samples at quantities beyond what would be typical for RTM so that the effects would be exaggerated in the laboratory testing.

4.1 Physical and Index Properties

While the total percent fines (silt and clay) remained relatively constant between the baseline and conditioned soil samples, the percent of silt size particles decreased and the percent of clay size particles increased in the conditioned soil samples. This was attributed to the soil conditioners' dispersive effects. This also affected the Atterberg limits, with the conditioners reporting higher liquid limits and plastic limits.

4.1.1 Shaft material

This TM does not consider the material excavated during shaft construction in the volume calculations. At launch shafts, suitable material excavated from shaft construction would be used to fill any local borrow excavations, while unsuitable material (i.e. peat, topsoil) would be stockpiled onsite. At shafts where RTM would not be generated, material excavated from the shaft would be stockpiled locally. Soil generated from shaft excavation, shallow borrow and surface stripping is captured in the CER Appendix G4. Shaft construction is addressed separately in CER Appendix C4 *Shaft Conceptual Design*.

4.2 Strength and Compressibility

The results indicated a slight increase in compressibility and slight decrease in undrained shear strength for the conditioned soil samples that were also attributed to the soil conditioners' dispersive effects, which reduced inter-particle bonds. The changes were not considered significant.

4.3 Permeability

The hydraulic conductivity (vertical permeability) of the conditioned soil samples was substantially lower than the baseline samples, also attributed to the soil conditioners' dispersive effects that increased the percent of clay size particles and reduced the effective pore diameter.

4.4 Conclusions

The soil conditioner application rates used in the 2014 RTM testing program (URS, 2014) were stated to be purposefully greater than industry typical values. As a result, the observed effects of adding conditioners to the soil's geotechnical properties were likely magnified over what might be expected for RTM. Even with increased rates of conditioner application, the report noted that the testing indicated conditioned soil samples tested met current levee fill requirements. URS (2014) did recommend pinhole dispersion tests to evaluate the dispersive effects of the soil conditioners to confirm they were not erodible. Further, the RTM is generally anticipated to be suitable for use in the construction of water-holding embankments. If the soils are found to be erodible, a zoned embankment core or a cutoff wall could be incorporated into the embankment design.

URS (2014) did note that the RTM will be saturated and significantly exceed the moisture content range necessary to meet compaction requirements. The conditioned soil samples from the testing program were approximately 20 to 25 percent greater than the optimum moisture content for compaction.

5. Environmental Properties of RTM

URS (2014) presented the results of environmental testing performed on composite samples of soil in both the conditioned and unconditioned states. The purpose of the 2014 environmental testing was to assess the effect of the conditioner on the leachability of naturally occurring soil constituents and to assess the nature of the conditioners themselves.

The primary source of existing environmental data for the native soil and groundwater was the Environmental Sampling Report – Phase 1 Geotechnical Investigations (DWR, 2010), which presents the analytical results from soil and water samples collected during previous geotechnical investigations from a full range of depths.

Additional environmental sampling was performed as part of the Fiscal Year 2020-2021 (FY20-21) field investigation program (DCA, 2021).

This section summarizes the environmental testing on composite samples and the findings of the environmental sampling from the two geotechnical investigations.

5.1 Key Findings

Environmental specialists reviewed the three sources of data with specific reference to background levels of naturally occurring metals in the US (USGS, 2013) and with regard to human health and ecological risks associated with the extracting, processing, storing, moving and reuse of the anticipated RTM. They noted the following:

- Petroleum hydrocarbons and pesticide residues were not detected in soil samples from the corridor.
- Metals and inorganic elements were detected throughout the soil profile resembling naturally occurring levels with the exception of cadmium.
- Cadmium was detected at concentrations greater than naturally occurring levels (DWR, 2010) but far below environmental screening levels for health or ecological impacts. It was noted that cadmium levels often track with zinc levels in the soil, and zinc was not detected at levels above those considered to be background.
- Arsenic concentrations detected in the soil pose no greater risk to human health and the environment than those present in native soils and the addition of conditioners does not affect the concentrations of arsenic.
- Total chromium analyzed was indistinguishable from naturally occurring levels.
- Mercury concentration detected was below naturally occurring levels.
- The limited analytical results suggest that odor impacts associated with volatile sulfides in soil are unlikely to pose an impact to humans.
- When blended with native soil in tunneling, the soil conditioners do not pose a health hazard to humans or the environment.
- The extracting, handling, storing and reuse of soils could likely result in emissions of dust. An analysis of the potential impacts is needed to identify appropriate mitigation measures.
- Following excavation, RTM would be tested in accordance with the requirements of the Central Valley Regional Water Quality Control Board and the Department of Toxic Substance Control.

5.2 Reusable Tunnel Material Chemical Constituents

As noted above, metals and inorganic elements were detected throughout the soil profile resembling naturally occurring levels. Certain metals and inorganic elements in soil are of interest because of specific concerns about toxicity or mobility. These include arsenic, chromium and mercury, which are discussed in further detail below.

5.2.1 Cadmium

Cadmium was reported to be detected in all samples at concentrations ranging from 2.8 to 10 milligrams per kilogram (mg/kg) (DWR, 2010). While the analytical results have been validated, they are considered anomalous when compared with typical background levels which, in soil, do not exceed 0.3 mg/kg. Cadmium was futher analyzed in soil samples collected in the FY20-21 field investigation program and was not detected at a concentration greater than 1 mg/kg in any soil sample (DCA, 2021). Though the earlier results are considered anomalous, the values as reported in the environmental sampling report do not appear to represent a health or ecological impact when compared with environmental screening levels. All results fall below the Tier 1 Environmental Screening Level (ESL) (RWQCB, 2019) for cadmium of 78 mg/kg in soil.

5.2.2 Arsenic

Arsenic poses human health and environmental hazards with high levels of exposure in the in soil. Arsenic is naturally occurring in the environment, in many cases at levels well below those posing human health and ecological risks. Naturally occurring levels of arsenic in soil in the United States (U.S.) average about 6.4 mg/kg though concentrations in soil upwards of 100 mg/kg have been reported in the USGS's sampling data. Cleanup decisions for arsenic to protect human health at contaminated sites are generally based on concentrations of 30 to 100 mg/kg and above in soil (Davis et al, 2001). Arsenic concentrations detected in the soil as reported in the environmental sampling report range from <1.0 to 4.7 mg/kg (DWR, 2010). Arsenic concentrations detected during the FY20-21 field investigation program range from <1.0 to 23.4 mg/kg (DCA, 2021). Therefore, human health and environmental risks from arsenic in RTM would be no different from the risk of arsenic in native soils. The results from testing conditioned soil showed that the addition of soil conditioners does not appear to affect the concentrations of arsenic.

5.2.3 Chromium

Chromium in the environment is present in multiple oxidation states with different levels of toxicity. Most chromium in soil is in the form of insoluble, low-toxicity trivalent chromium. A fraction of the chromium in soil might be present as soluble, higher-toxicity hexavalent chromium depending on the soil chemistry. Lower pH conditions, coupled with elevated manganese in soil, promotes the oxidation of trivalent chromium to the hexavalent species. Similarly, higher pH conditions, coupled with elevated iron in soil, promotes the reduction of hexavalent to lower-toxicity trivalent chromium. Chromium in solution detected in water is considered hexavalent as this is the soluble species. Total chromium analyzed in soil in the environmental sampling report is indistinguishable from background levels. The environmental sampling report did not analyze manganese, iron, hexavalent chromium nor pH in soil or water samples and therefore does not provide additional information about the potential for forming hexavalent chromium in soil.

Hexavalent chromium was not analyzed in the environmental sampling report (DWR, 2010). Hexavalent chromium was not detected in soil during the FY20-21 field investigation program with a detection limit of 0.005 mg/kg (DCA, 2021). The RTM testing report analyzed the pH for both native soil and soil treated with soil conditioners and found a range from pH of 8 to 9 (URS, 2014). This is generally considered a neutral range and not the low pH values at which hexavalent chromium might form in soil. The available information suggests that chromium in soil is most likely present as low-toxicity trivalent chromium.

5.2.4 Mercury

Mercury concentration detected in soil during environmental sampling typically ranged from <0.01 to 0.045 mg/kg (DWR, 2010). Mercury was not detected in approximately half of the soil samples collected. Similarly, mercury was not detected in soil during the FY20-21 field investigation program with a reporting limit of <0.5 mg/kg (DCA, 2021). The analytical reporting limits differed between the investigations but the findings of both are lower than the Tier 1 ESL of 13 mg/kg. The average mercury concentration in U.S. soils is 0.05 mg/kg (USGS, 2013). In flooded environments, such as wetlands, inorganic mercury can be metabolized by anaerobic microbes to methylmercury, which is more toxic and bioaccumulates readily into aquatic organisms. While soils deep below the ground surface, such as the tunneling depth, may be anoxic, the biological activity in deep soils is very low and may not support the metabolism of inorganic mercury to methyl mercury. The introduction of soil conditioners increases soil moisture content and whilst this might further depress the oxygen content in soil, it is not likely that the addition of soil conditioners would increase the potential formation of methylmercury in soil.

Methylmercury was not analyzed in the environmental sampling report (DWR, 2010). Methylmercury was detected in a few samples with estimated concentrations up to 0.245 ng/g (DCA, 2021). All the detected concentrations are considered very low, as these are less than the reporting limit for methylmercury (<0.4 ng/g). No background level in soil has been estimated for methylmercury. However, all concentrations detected fell below a risk-based screening level in soil based on a residential exposure scenario, the Tier 1 Environmental Screening Level (ESL) (RWQCB, 2019).

5.2.5 Organic Substances

Organochlorine pesticides (dichlorodiphenyltrichloroethane (DDT) and dieldrin) were detected in a few soil samples in the FY20-21 field investigation program. These are residual levels from historical use of organochlorine pesticides which ended in the 1970s. Detected concentrations of DDT ranged from 9.75 to 24.1 ug/kg, compared with a Tier 1 ESL of 1.1 ug/kg for a hypothetical residential scenario. Detected concentrations of dieldrin ranged from 4.8 to 216 ug/kg compared with a Tier 1 ESL of 0.46ug/kg for residential land use.

Polycyclic Aromatic Hydrocarbons (PAHs) were also detected in some soil samples. The PAH naphthalene was detected at a concentration of 51 ug/kg in one sample, compared with the residential Tier 1 ESL of 42 ug/kg.

Some of the concentrations of organochlorine pesticides and PAHs detected were higher than their respective Tier 1 ESLs based on a hypothetical residential scenario. However, a hypothetical residential exposure scenario uses the conservative assumption that an individual is exposed to contaminants in soil daily over their lifetime. Actual contact by humans with RTM is likely to be at a much lower frequency, duration and intensity, with corresponding risks from contact with these substances in soil also being much lower.

5.2.6 Sulfides

Volatile reduced sulfur compounds, when emitted into the air, can produce objectionable odors for example, the characteristic 'rotten-egg' odor associated with hydrogen sulfide. Hydrogen sulfide results from the anaerobic metabolism by soil microbes in flooded or waterlogged soils. Reduced sulfur compounds are a feature in estuarine or riparian soils and represent conditions that differ from the soil conditions expected to be encountered in the Project corridor at the tunnel depth. Though limited sampling and analytical data for sulfide is available from the Project corridor, it is consistent with literature findings.

From a total of eight leachate samples collected (water samples), sulfide was not detected in four. The remaining four results were rejected because the holding times had been exceeded. The limited analytical results, along with literature information, suggests odor impacts associated with volatile sulfides in soil are unlikely to pose a nuisance impact to humans. In addition, hydrogen sulfide produces detectable odors that are below the levels that produce adverse health effects in humans. Therefore, hydrogen sulfide levels in the air not detectable by odor also are not likely to pose a human health hazard. Volatile reduced sulfide compounds in air or soil also are not likely to represent a hazard to wildlife.

5.2.7 Conditioners

The soil conditioning agents are liquid formulations containing mixtures of long-chained fatty acids or glycosides with acid, alcohol or ether functional groups that provide good surfactant properties. The liquid formulations, when handled by workers, pose eye and skin irritation hazards and recommendations for the use of personal protective equipment should be provided in the Safety Data Sheets (SDS). Spills from the liquid formulation that runoff to surface water may pose a hazard to aquatic organisms. When blended with native soil after use in a TBM, the soil conditioners do not pose a health hazard to humans or the environment.

The soil conditioners consist of slightly ionized organic molecules, which would not affect soil pH. As noted, soil pH levels measured in native and conditioned soils were within a range of pH 8 to 9, or relatively neutral levels. While the pH effects in soil would not affect the leachability of metals from treated soil, the soil conditioning agents might act as chelating agents, which could mobilize metals in soil. The leachability of metals from both native and conditioned soil was tested in URS (2014). The results from the testing report showed that leachable concentrations from soil, both in native and conditioned soils, were very limited and far less than state leachability standards for hazardous wastes. Additional soil sampling and testing in the future would confirm the leachability of conditioned soils.

Ultimately, the contractor would be required to verify, by certification of the supplier, that the additives used for soil conditioning during tunneling operations were inert, biodegradable and nontoxic to prevent contamination of the surrounding ground and the RTM.

6. Health, Environment and Ecology

6.1 Overview

This section discusses the results of the existing data evaluation to assess the potential impacts to human health, wildlife and the environment associated with extracting, handling, storing and reuse of RTM.

6.2 Health and Environmental Hazards

Potential hazards to human health, wildlife and the environment associated with RTM include metals and inorganic elements normally present in soil, organic compounds introduced to surface soil (such as agricultural pesticides), improper release of hazardous materials or petroleum products and potential chemical additives included in soil conditioners used during tunneling.

As discussed, a review of prior environmental test results performed on native soils and conditioned soils concluded that metals and inorganic elements detected throughout the soil profile resemble naturally occurring levels, apart from cadmium. The addition of commercial soil conditioners did not increase the leachability of the naturally occurring constituents, nor did they present a human or ecological health risk.

The process of extracting, handling, storing and reuse of RTM, as with any soil materials, may emit particulate matter into the air which potentially represents a respiratory health hazard to humans and wildlife. These hazards may be present if there are potentially complete exposure pathways from RTM to humans and wildlife. Additionally, leachate from the RTM may come into contact with groundwater or surface water, which may present additional pathways to humans and wildlife.

6.2.1 Dust

As is common with earth moving projects, the potential air quality impacts would be analyzed as part of the regulatory process to identify appropriate mitigation measures to control dust emissions into the air and meet regulatory requirements.

6.2.2 Water

As is common with earth moving projects, the potential water quality impacts would be analyzed as part of the regulatory process to identify appropriate mitigation measures to control potential impacts of runoff and seepage into surface water and groundwater from stored RTM. Leachability testing reported in URS (2014) indicates that the addition of soil conditioners does not increase the mobility of metals in stored material. Drying the RTM would further reduce the leachability.

The results from the RTM testing report (URS, 2014) also indicate that leachate would be below the regulatory thresholds for treatment and disposal.

If quick lime is employed as a drying agent to the RTM, any water captured during processing or storage of the RTM should be tested for pH to determine if neutralization, by addition of acid, to lower the pH, is needed before disposal. pH testing can be performed in a laboratory with a typical turnaround time of 1 to 2 weeks or for efficiency, on-site testing kits could be used to provide reliable real time results.

6.2.3 Testing

As RTM is excavated, it would need to be stockpiled in a temporary holding area. A sample from the stockpile would be tested in accordance with the requirements of the Central Valley Regional Water Quality Control Board and the Department of Toxic Substance Control. Similarly, leachate collected from the temporary holding area would be subjected to the same testing before it is used or released to surface waterways.

The RTM would be tested for the presence of hazardous materials at concentrations exceeding regulatory threshold criteria to confirm the interpretation of the environmental testing data presented herein. If identified as hazardous, the entire temporary stockpile would be transported to a licensed disposal location for those constituents. If the RTM is not found to be hazardous, it would be released to be processed as described later in this TM.

7. Reusable Tunnel Material Quantities

7.1 Reusable Tunnel Material Volumes

As discussed in Section 3.3, RTM would be generated at the TBM launch shafts. The volume of RTM generated at these shafts would be a function of the tunnel diameter and length equating to 6.7 million cubic yards and 7.7 million cubic yards at Twin Cities Complex and Lower Roberts Island respectively for a total of 14.4 million cubic yards.

7.2 Rate of Excavation

The rate at which RTM would be generated at each launch shaft site would depend on the linear distance the TBM could be expected to travel over a given time period. Typically, the advance rate would be slower to begin with as the TBM is fully assembled and the tunneling crew become familiar with the machine. Following this start up period, the TBM would typically advance at an average rate for the rest of the reach although it will vary day to day to allow time for inspection, maintenance and extending the TBM equipment as the tunnel length increases.

The average excavation rate assumed for the 36-foot ID tunnel is 40 feet/day and was estimated based on experience of other similar size tunnels in similar ground conditions.

At times, the TBM's can be expected to operate at a peak excavation rate which is estimated to be double the average excavation rate. Again, this is estimated based on experience of other similar size tunnels in similar ground conditions. It is estimated the peak excavation rate can be sustained for a maximum of 20 straight working days or 1 month out of every 6 months without interruption for inspection, maintenance and extending the TBM equipment. This is a practical limit as when a TBM advances it will need to stop periodically in order to extend the temporary rail lines, power supply, lighting, ventilation system, conveyors etc.

8. Reusable Tunnel Material Processing

This section describes the process involved for natural drying of RTM excavated by EPB TBM. For a slurry TBM, the excavated material would be pre-processed in the slurry separation plant and thus the requirement to further dry the RTM would be less.

8.1 Moisture Content

The naturally occurring moisture content of the ground in the tunnel zones is expected to average 31 percent (URS, 2014). With the addition of conditioners and water used in the tunneling process, the excavated material can be expected to have a moisture content varying from 38 percent to 45 percent (URS, 2014). An average value of 41.5 percent moisture content has been assumed for the excavated material.

To stockpile the RTM it has been determined that the moisture content would have to be reduced to an optimum range of between 17 percent and 21 percent (for clay-rich soils) and the maximum allowable moisture content should be no more than 3 percent above optimum being 20 percent to 24 percent. This range represents typical values for embankment fill and is consistent with the previously conducted compaction test results (URS, 2014). Based on this, a target moisture content of 22 percent has been assumed.

8.2 Natural Drying

Natural Drying provides a reasonable method to manage and stockpile the RTM at the launch shaft sites. The process for testing, spreading, and drying the RTM would follow the flowchart shown on Figure 1 and described below.

The excavated material would be transferred from the shaft by conveyor to a temporary wet stockpile area where it would be piled up to a maximum of 10 feet in height by bulldozers. The temporary wet stockpiles would be designed to accommodate one week's worth of RTM at peak excavation rate. Once a week's worth (or other amount to be determined by the contractor) of RTM is placed in the temporary wet stockpile area, it would be isolated whilst a sample is taken and tested for hazardous materials. Meanwhile, stockpiling would continue in a second and subsequent temporary wet stockpile areas. Filling of the temporary stockpiles would occur whenever a TBM advances and hence is expected to be a 20 hour/day operation. Any leachate or runoff from the temporary wet stockpiles would be collected and tested before being used or released.

Once the test results have been received, the temporary wet stockpile can be emptied with the use of bulldozers pushing the RTM into central conveyor pits. It is anticipated that it would take two weeks to empty a full wet stockpile area based on a 10 hour working day and as such a total of four temporary wet stockpile areas would be required with one being filled, one being tested and two being emptied at any one time. Additionally, it is recommended that a further two contingency stockpiles of the same size are provided to accommodate any unforeseen delays.

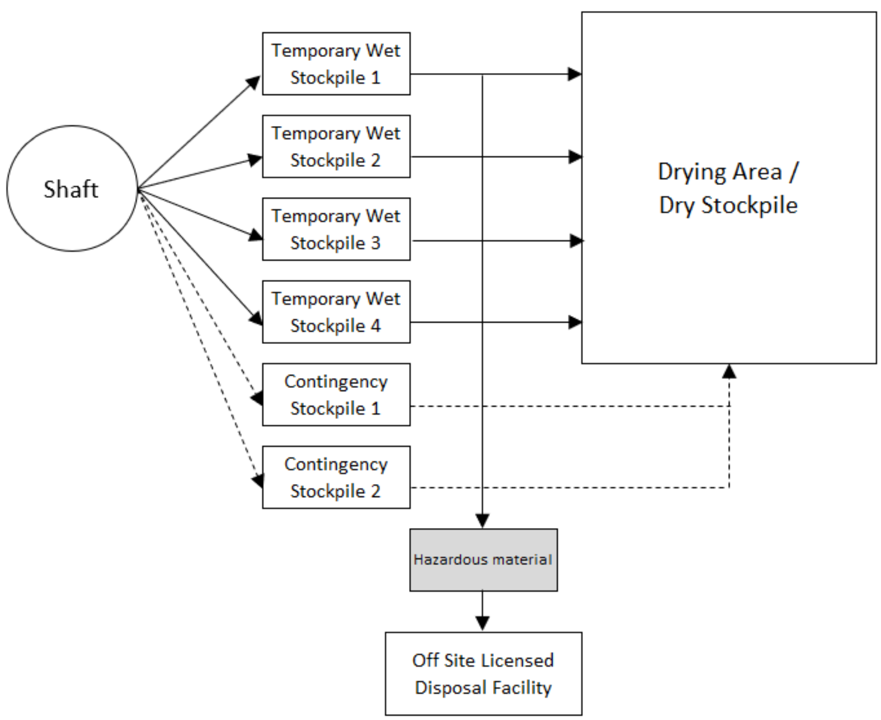

Figure 1. Natural Drying Flowchart

If the test results suggest that a sample was hazardous, all of the RTM from that stockpile would be removed from site and taken to a licensed disposal facility. If the test results deem the sample as non-hazardous, the RTM would be transferred by wheel loader, or other method to be determined by the contractor, to a specific cell within the drying area. During the wet season the RTM will be piled up within the drying cell until the dry season. At the beginning of the dry season the RTM piles and any subsequent RTM generated would be spread out by bulldozers within its respective cell to a depth of 18 inches and allowed to dry for a minimum of three weeks with no additional effort applied to accelerate the drying process since the soil is not needed for structural fill as part of the Project. This duration was calculated based on an average volume of water that would need to be extracted of 1.65 gallons per cubic foot of soil and an evaporation rate of 0.21 inch per day over a given area, estimated from the California Irrigation Management Information System data for the period of April 2019 until March 2020. Once dry, at the end of the third week, a compactor would roll over the RTM to compact it in place, preparing the ground for the next lift. Each cell will be designed to hold one week's worth of RTM at 18 inches high. The wet season is conservatively estimated to last 7 months of the year and as such, a total of 37 cells will be required with 15 of those being used twice within an annual cycle.

8.3 Quicklime

High calcium quicklime could be added to the RTM to expedite drying. Quicklime and hydrated lime are highly effective at drying wet clays and silty soils. Typically, 3 to 5 percent of the weight of soil is required. The use of quicklime however, presents notable health and safety hazards for workers in the form of eye, skin and respiratory tract irritation. Safe handling practices and personal protective equipment are required as per the safety data sheet for the product. URS (2014) showed that RTM treated with quicklime measured approximately pH13, which would make it unsuitable for plant growth.

8.4 Temporary Stockpile

The process described above would continue as tunnel excavation advances with a total area required for the temporary stockpile for each tunnel reach of 196 acres based on the same assumed average excavation rate. The final height of the temporary stockpiles would be a function of the total volume and hence specific to each tunnel reach ranging from 5.8 feet to 10.5 feet.

8.5 Permanent Stockpile

For the Project it is assumed that upon completion of tunneling, the surplus RTM for each of the two tunnel reaches at each of the double launch shaft sites will be consolidated into a single permanent stockpile. The size of the permanent stockpiles were developed in conjunction with the projectwide soil balance, as described in the CER Appendix G4, which considers onsite borrow, other onsite material sources, fill needs across the Project and at Twin Cities, includes the demolished ring levee material that will be added to the stockpile.

It is assumed that the borrow material at both launch shaft sites would be replaced by RTM with the surplus RTM being stockpiled to a maximum height of 15 feet based on a review of geotechnical conditions using available information and would be subject to revision based on collection of site-specific subsurface data, testing, geotechnical analyses and consideration of other site factors that may pose restrictions. This resulted in a permanent stockpile area of 214 acres at the Twin Cities Complex and 189 acres at Lower Roberts.

These areas include a 5 percent allowance for working space and vehicle maneuvering; the RTM would be placed with side slopes similar to the soil's natural angle of repose or as recommended by the Project geotechnical engineers. For simplicity, side slopes are not accounted for in the calculations directly and would only have a negligible effect on volume and area calculations for such large quantities with comparatively small heights. Any difference in volume resulting from side slopes is more than accounted for in the 5 percent allowance for working space and vehicle maneuvering. Areas designated for the permanent storage of RTM that were not previously prepared would be stripped of topsoil prior to placement of the RTM. Stripped topsoil would be stockpiled and re-spread over these areas after the RTM was placed and the stockpiles would be planted with erosion control grasses.

8.6 Processing Equipment

The equipment used in the processing, as well as the power requirement of that equipment, is directly related to the excavation rate and tunnel diameter.

Table 3 shows the estimated earth-moving equipment required, and the estimated range of hours and power per tunnel reach.

Table 3. Earth-moving Equipment Required Per Tunnel Reach

Equipment, Hours, Power and Cost	Value
Bulldozers	12
Wheel Loaders	2
Compactor	1
Capital Cost	$2.8M
Annual Working Hours	15,200
Power Requirements (MWh/yr)	3,000
Annual Operating Cost	$1.6M

Notes:
MWh/yr = megawatt-hour(s) per year
M = Million

8.7 Site Preparation

Consideration should be given to each of the RTM processing areas to confirm the ground is sufficiently prepared for all loading and operations that are expected. The temporary wet stockpiles are expected to be concrete structures with walls on three sides at least 3 ft above the designed stockpile height. They are also expected to have two centrally located conveyor pits into which the RTM can be pushed by bulldozer and underground channels for the conveyors to transport the RTM away from the temporary stockpiles to be moved to the drying area. For the wet temporary stockpiles, drainage should be incorporated into the floor design to catch run off and leachate for testing, treatment or both. The surface area of the temporary wet stockpiles would be 196 acres at both Twin Cities Complex and Lower Roberts Island.

At Twin Cities Complex and Lower Roberts Island, the maximum height of the permanent stockpiles would be 15 feet and the surface area would be 214 and 189 acres, respectively.

8.8 Settlement

A preliminary settlement analysis should be conducted at each proposed storage site to understand the potential impacts, which would depend on the site-specific geotechnical conditions. Additional geotechnical analyses should be performed upon completion of supplemental site-specific geotechnical exploration and testing. Furthermore, at Lower Roberts Island, RTM stored permanently is expected to sink by as much as 20 percent and that which has sunk would become unusable for future use, although this is likely to take a number of years and have negligible effect outside of the stockpile footprint. When such settlements occur, the height of the stockpiles would be reduced approximately the same amount as the settlements.

9. Reusable Tunnel Material Usage and Disposal

At this time, the geotechnical and environmental properties of the anticipated RTM have been evaluated and deemed suitable for use in earthwork construction, subject to identified additional sampling and testing and confirmatory testing during RTM generation. The following sections discuss potential beneficial uses of RTM.

9.1 Shaft Pads

At this time, it is expected that shaft pads would be primarily built with soils borrowed from shallow excavation within the Project, however, if RTM generation timing allows, pads may also be built from RTM. This would apply only to shaft pads constructed after the tunnel excavation has begun and would therefore represent only a small proportion of total shaft locations. The RTM volume anticipated for shaft pads would be negligible.

9.2 Intakes

At this time, no RTM is anticipated to be required at the intake structures.

9.3 Other Uses

At this time, it is anticipated that RTM would be used on the Project to the greatest extent possible to reduce the need for imported fill. It is anticipated that approximately 13 million cubic yards of suitable fill is required for levee maintenance within the Delta to upgrade the current levee system to comply with PL 84-99 Delta-Specific Geometry Standards (Arcadis, 2017). The majority of this fill is needed in the northwest and southeast portions of the Delta. Depending on project needs and timing, this fill could be made available to the Local Maintaining Agencies (LMA’s) for levee maintenance and enhancements, subject to the environmental permitting requirements unique to those projects.

Other possible uses include:

- Fill material for construction of embankments or building pads to prevent flooding
- Fill material for habitat restoration projects
- Fill material for roadway projects
- Material for flood response
- Material to fill Project-related borrow areas

An assessment of the suitability of RTM for these or any other application would be required to determine the feasibility taking into account transportation and environmental factors among others.

9.4 Disposal

If the RTM could not all be used for other purposes on the Project and the surplus could not be stockpiled at the launch shaft site where it was generated, the RTM would need to be removed to a site(s) where it could be stockpiled, including Delta islands, aggregate suppliers, soil brokers or landfills.

10. Conclusions

The following conclusions can be drawn from this evaluation:

- For a 36-foot ID tunnel, the volume of excavated RTM would be 14.4 million cubic yards.
- Findings of the preliminary environmental assessment (DWR,2010) and the FY20-21 field investigation program (DCA, 2021) suggest there is no risk to human health, wildlife or the environment from extracting, handling, storing and reuse of RTM, provided standard procedures are followed.
- The use of soil conditioners in the tunneling process does not pose a risk to human health, wildlife or the environment provided standard procedures are followed.
- Following excavation, RTM would be tested in accordance with the requirements of the Central Valley Regional Water Quality Control Board and the Department of Toxic Substance Control for the presence of hazardous materials at concentrations exceeding regulatory threshold criteria, to confirm the interpretation of the environmental testing data.
- The extracting, handling, storing and reuse of soils may result in dust emissions that would impact air quality. An analysis of the potential impacts is needed to identify appropriate mitigation measures.
- Natural drying is the recommended method for the Project since the RTM would not be used as fill elsewhere on the Project and it provides a reasonable method to manage and stockpile the RTM at the launch shaft sites. Settlement analysis and a study to understand the potential limitation on future land use should be conducted at each proposed RTM storage site to understand the potential impacts.

11. References

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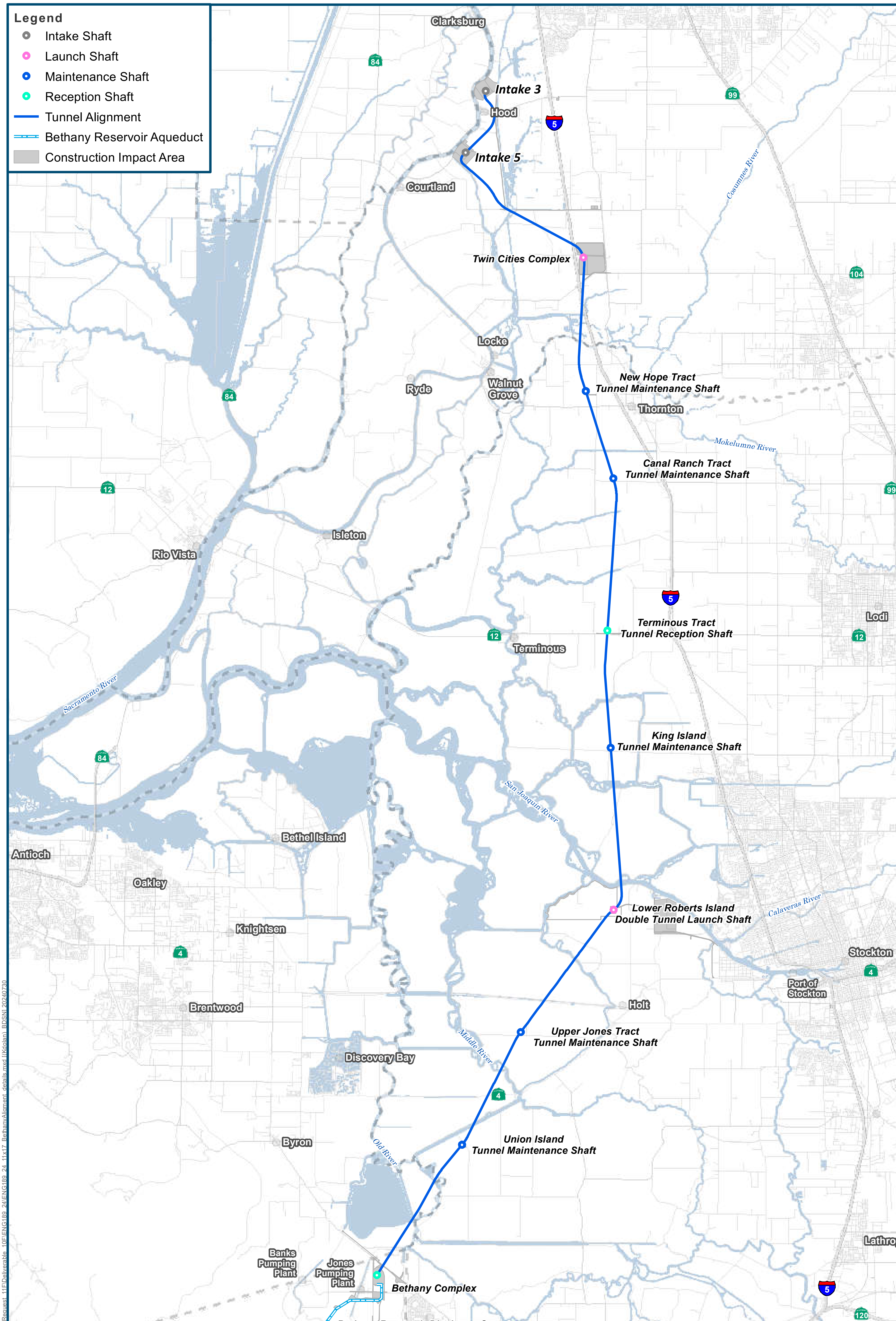
Attachment 1
Bethany Reservoir Alignment



DCA DELTA CONVEYANCE DESIGN & CONSTRUCTION AUTHORITY

For Illustration Purposes Only

N 0 1.5 3 Miles

Bethany Reservoir Alignment

Data Source: DCA, DWR

Attachment 2
Table of Inputs and Assumptions

CA Delta Conveyance Tunnel - RTM Calculations

Inputs and Assumptions

Input		Value	Unit
Tunnel Lining Dimensions			
6,000 cfs	Tunnel Lining ID	36.00	ft
	Tunnel Lining Thickness	18.00	in
TBM Dimensions			
TBM tailcan thickness		3.50	in
Cutterhead offset		3.50	in
Tunnel Excavation Rates			
Start up advance rate		30.00	ft / day
Tunnels average advance rate		40.00	ft / day
Estimated percentage of excavation at peak rate		16.67	%

TBM Utilization		
Tunnelling hours per day	20	hours
Tunnelling days per week	5	days / wk
Tunnelling weeks per year	51	wks / yr

Geotechnical Factors		
Unit weight of in-situ RTM	120.00	lb/ft3
Unit weight of wet excavated RTM	99.70	lb/ft3
Unit weight of dry excavated RTM	95.00	lb/ft3
Bulking factor	1.30	
Volume loss during drying	5.00	%
Volume of water extracted during drying	1.65	gal/ft3
Full compaction factor	0.80	

Drying RTM		
Average moisture content of excavated RTM	41.50	%
Desired optimum moisture content	22.00	%
Height of stockpile during drying	18.00	in
Working space / buffer for drying	20.00	%

Storing RTM		
Temporary stockpile working space/buffer	50.00	%
Temporary working space / buffer	20.00	%
Permanent working space / buffer	5.00	%
Max. height of temporary short term dry stockpiles	10.00	ft
Max. height of temporary short term wet stockpiles	10.00	ft
Max. height of temporary long term wet stockpiles	5.00	ft
Max. height of dry stockpile at Twin Cities	25.00	ft
Max. height of dry stockpile at Bouldin Island / Lower Roberts Island	8.00	ft

Transporting RTM		
Road capacity by volume based on one truck per trip	18	yd3 / trip
Road capacity by weight (semi-end dump trucks)	18	tons / trip
Road capacity by weight (bottom dump trucks)	20	tons / trip
Rail capacity based on 60yd3 per car, 20 cars per train	1,200	yd3 / trip

Alignment and Shaft Locations	
Shaft locations	As shown on dwg
Corridor options	As shown on dwg
Launch/reception shaft designation	As shown on dwg

Attachment 3
Determination of Geotechnical Factors

Project: Delta Conveyance
Subject: RTM Volume Reduction due to Drying
By: Myra Au/Andrew Finney
Checked: Dean Harris
Date: 04/21/2020 rev2

Assume

In-situ soil total unit weight
(avg total unit weight from depth 100 to 200ft) $\gamma_t := 120\text{pcf}$

In-situ soil water content (WC) $w_{in\_situ} := 0.31$

RTM moisture content (URS, 2014)
(conditioner and water added during tunneling) $w_{exc} := 0.415$

RTM optium moisture content (URS, 2014) $w_{opt} := 0.22$

RTM optimum dry unit weight (URS, 2014) $\gamma_{max} := 103\text{pcf}$

Bulking factor (no account for change in WC) $BF := 1.3$

Soil specific gravity $G_s := 2.7$

Unit weight of water $\gamma_w := 62.4\text{pcf}$

Soil Unit Weight Calculation

In-situ soil dry unit weight $\gamma_d := \dfrac{\gamma_t}{(1 + w_{in\_situ})} = 91.6 \times \text{pcf}$

This is the weight of the solids in 1 cubic foot of in-situ soil. Now add water and bulk to get RTM properties

RTM total unit weight $\gamma_{t\_exc} := \dfrac{\gamma_d \times (1 + w_{exc})}{BF} = 99.7 \times \text{pcf}$

RTM dry unit weight $\gamma_{d\_exc} := \dfrac{\gamma_{t\_exc}}{(1 + w_{exc})} = 70.5 \times \text{pcf}$

RTM - Soil Phase Relationship (on the basis of $1ft^3$ total volume)

Total volume $Vol_{total} := 1ft^3$

Mass of soil solids $Mass_{exc\_solid} := \gamma_{d\_exc} \times 1ft^3 = 70.46 \times lbf$

Volume of soil solid $Vol_{exc\_solid} := \frac{Mass_{exc\_solid}}{G_s \times \gamma_w} = 0.42 \times ft^3$

Volume of water $Vol_{exc\_water} := \frac{\gamma_{d\_exc} \times w_{exc}}{\gamma_w} \times 1ft^3 = 0.47 \times ft^3$

Volume of air $Vol_{exc\_air} := Vol_{total} - Vol_{exc\_solid} - Vol_{exc\_water}$

$Vol_{exc\_air} = 0.11 \times ft^3$

Volume of void $Vol_{exc\_void} := 1ft^3 - Vol_{exc\_solid} = 0.58 \times ft^3$

RTM Dried to Optium Water Content - Soil Phase Relationship (on the basis of $1ft^3$ total volume)

RTM total unit weight (pcf) at optimum moisture content (after drying)

$$\gamma_{t\_exc\_opt} := \gamma_{d\_exc} \times (1 + w_{opt}) = 85.97 \times pcf$$

Total volume (ft^3)

$$Vol_{total} := 1ft^3$$

Mass of soil solids (lb)

$$Mass_{exc\_dry\_solid} := \gamma_{d\_exc} \times 1ft^3 = 70.46 \times lbf$$

Volume of soil solid

$$Vol_{exc\_dry\_solid} := \frac{Mass_{exc\_dry\_solid}}{G_s \times \gamma_w} = 0.42 \times ft^3$$

Volume of water

$$Vol_{exc\_dry\_water} := \frac{\gamma_{d\_exc} \times w_{opt}}{\gamma_w} \times 1ft^3 = 0.25 \times ft^3$$

Volume of air

$$Vol_{exc\_dry\_air} := Vol_{total} - Vol_{exc\_dry\_solid} - Vol_{exc\_dry\_water}$$

$$Vol_{exc\_dry\_air} = 0.33 \times ft^3$$

Volume of void

$$Vol_{exc\_dry\_void} := Vol_{total} - Vol_{exc\_dry\_solid} = 0.58 \times ft^3$$

<u>Unit Volume of Water Reduction during Drying</u>
(From RTM to "dried" RTM)

$$Vol_{water\_red} := \frac{(Vol_{exc\_water} - Vol_{exc\_dry\_water})}{1 \times ft^3} = 1.65 \times \frac{gal}{ft^3}$$

<u>Percent Volume Reduction</u>
(As the RTM in the thermal dryer gets dried, more soil solids and water will fill the increased air void. Assume the total unit weight of the RTM after drying in the thermal dryer to be 95pcf)

On the basis of $1ft^3$ of soil volume in the thermal dryer after the RTM has been dried to optimum water content:

RTM total unit weight (pcf)

$$\gamma_{t\_dried} := 95 \times pcf$$

Optimum water content

$$w_{opt} = 0.22$$

RTM dry unit weight (pcf) $$\gamma_{d\_dried} := \frac{\gamma_{t\_dried}}{1 + w_{opt}} = 77.87 \cdot pcf$$

Mass of RTM soil solids $$M_{d\_dried} := \gamma_{d\_dried} \cdot ft^3 = 77.87 \cdot lbf$$

Volume of soil solids in RTM $$V_{s\_dried} := \frac{M_{d\_dried}}{G_s \cdot \gamma_w} = 0.46 \cdot ft^3$$

Mass of water in RTM $$M_{w\_dried} := M_{d\_dried} \cdot w_{opt} = 17.13 \cdot lbf$$

Volume of water in RTM $$V_{w\_dried} := \frac{M_{w\_dried}}{\gamma_w} = 0.27 \cdot ft^3$$

Volume of air in RTM $$V_{a\_dried} := 1ft^3 - V_{w\_dried} - V_{s\_dried} = 0.26 \cdot ft^3$$

$$Vol_{collapse} := \frac{\gamma_{t\_dried}}{\gamma_{t\_exc}} \cdot 100\% = 95 \cdot \%$$

So after drying the RTM occupys 95% of the former wet RTM volume.

Percent Volume Reduction in place at 95% compaction

$$\gamma_{d\_95\_compacted} := 0.95 \cdot \gamma_{max} = 97.8 \cdot pcf$$

$$\gamma_{t\_95\_compacted} := \gamma_{d\_95\_compacted} \cdot (1 + w_{opt}) = 119.38 \cdot pcf$$

$$SF_{inplace} := \frac{\gamma_{t\_dried}}{\gamma_{t\_95\_compacted}} = 0.80$$

Attachment 4
RTM Calculations for Bethany Reservoir Alignment

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **RTM Volumes**

Column Inputs	Internal Diameter	Tunnelling days / week	Tunnelling weeks / year	TBM Cutterhead Area	Bulking factor	Volume reduction due to drying	Compaction factor	TBM Cutterhead Area	Bulking factor	Volume reduction due to drying	Compaction factor
Northern tunnels ID	36.0 ft	5 days	51 wks	141 yd2	1.30	5.00 %	0.80	141 yd2	1.30	5.00 %	0.80
Main tunnels ID	36.0 ft	5 days	51 wks	141 yd2				141 yd2			
Southern tunnels ID	36.0 ft	5 days	51 wks	141 yd2				141 yd2			

			Drive Options				RTM Volume / Tunnel Length				RTM Volume / Shaft				RTM Volume / Tunnel Drive	
Option	Element	Tunnel Length	Tunnel Drive	Drive Length	Drive Duration	TBM's	In-Situ RTM Volume / Tunnel Length	Wet Excavated RTM Volume / Tunnel Length	Dry Excavated RTM Volume / Tunnel Length	Dry Compacted RTM Volume / Tunnel Length	Wet In-situ RTM Volume / Shaft	Wet Excavated RTM Volume / Shaft	Dry Excavated RTM Volume / Shaft	Dry Compacted RTM Volume / Shaft	Dry Compacted RTM Volume / Tunnel Drive	Ave. Quarterly Excavated Dry Compacted RTM Volume / Tunnel Drive
BETHANY		0.000 mi					- yd3	- yd3	- yd3	- yd3						
	Intake No. 3 Shaft		R													
	Northern Tunnel	2.550 mi	↑	8.190 mi	4.2 yrs		631,876 yd3	821,439 yd3	780,366.76 yd3	624,293 yd3					2,005,084 yd3	120,055 yd3
	Intake No. 5 Shaft		M													
	Northern Tunnel	5.640 mi	↑				1,397,561 yd3	1,816,829 yd3	1,725,988 yd3	1,380,790 yd3						
	Twin Cities Shaft		L			2					5,173,949 yd3	6,726,133 yd3	6,389,827 yd3	5,111,861 yd3		
	Main Tunnel	4.580 mi	↓				1,134,899 yd3	1,475,368 yd3	1,401,600 yd3	1,121,280 yd3						
	New Hope Shaft		M													
	Main Tunnel	3.000 mi	↓	12.690 mi	6.3 yrs		743,383 yd3	966,398 yd3	918,079 yd3	734,463 yd3					3,106,778 yd3	122,937 yd3
	Canal Ranch		M													
	Main Tunnel	5.110 mi	↓				1,266,230 yd3	1,646,099 yd3	1,563,794 yd3	1,251,035 yd3						
	Terminous Tract Shaft		R													
	Main Tunnel	3.940 mi	↑				976,310 yd3	1,269,203 yd3	1,205,743 yd3	964,595 yd3						
	King Island Shaft		M	9.500 mi	4.8 yrs										2,325,799 yd3	120,448 yd3
	Main Tunnel	5.560 mi	↑				1,377,737 yd3	1,791,058 yd3	1,701,506 yd3	1,361,204 yd3						
	Lower Roberts Island Shaft		L			2					5,922,288 yd3	7,698,974 yd3	7,314,026 yd3	5,851,221 yd3		
	Southern Tunnels	5.130 mi	↓				1,271,186 yd3	1,652,541 yd3	1,569,914 yd3	1,255,931 yd3						
	Upper Jones Tract Shaft		M													
	Southern Tunnels	4.240 mi	↓	14.400 mi	6.9 yrs		1,050,649 yd3	1,365,843 yd3	1,297,551 yd3	1,038,041 yd3					3,525,422 yd3	128,114 yd3
	Union Island Shaft		M													
	Southern Tunnels	5.030 mi	↓				1,246,406 yd3	1,620,328 yd3	1,539,312 yd3	1,231,449 yd3						
	Surge Basin Shaft		R													
	Total	44.78 mi	2	44.78 mi		4	11,096,237 yd3	14,425,108 yd3	13,703,852 yd3	10,963,082 yd3	11,096,237 yd3	14,425,108 yd3	13,703,852 yd3	10,963,082 yd3	10,963,082 yd3	491,554 yd3

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **RTM Volumes**

Column Inputs	Internal Diameter	Tunnelling days / week	Tunnelling weeks / year
Northern tunnels ID	36.0 ft	5 days	51 wks
Main tunnels ID	36.0 ft	5 days	51 wks
Southern tunnels ID	36.0 ft	5 days	51 wks

Option	Element	Tunnel Length	Drive Options: Tunnel Drive	Drive Length	Drive Duration	TBM's
BETHANY		0.000 mi				
	Intake No. 3 Shaft		R			
	Northern Tunnel	2.550 mi	↑	8.190 mi	4.2 yrs	
	Intake No. 5 Shaft		M			
	Northern Tunnel	5.640 mi	↑			
	Twin Cities Shaft		L			2
	Main Tunnel	4.580 mi	↓			
	New Hope Shaft		M			
	Main Tunnel	3.000 mi	↓	12.690 mi	6.3 yrs	
	Canal Ranch		M			
	Main Tunnel	5.110 mi	↓			
	Terminous Tract Shaft		R			
	Main Tunnel	3.940 mi	↑			
	King Island Shaft		M	9.500 mi	4.8 yrs	
	Main Tunnel	5.560 mi	↑			
	Lower Roberts Island Shaft		L			2
	Southern Tunnels	5.130 mi	↓			
	Upper Jones Tract Shaft		M			
	Southern Tunnels	4.240 mi	↓	14.400 mi	6.9 yrs	
	Union Island Shaft		M			
	Southern Tunnels	5.030 mi	↓			
	Surge Basin Shaft		R			
	Total	44.78 mi	2	44.78 mi		4

Quarterly Dry Compacted RTM Volume Generated by Tunnel Drive (m yd3)

Start	HIDE	Y1				Y2				Y3				Y4			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quarterly		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Start	Y5				Y6				Y7				Y8			
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
20	0.00	0.00	0.00	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
17	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
22	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
20	0.00	0.00	0.00	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Quarterly	0.12	0.12	0.12	0.37	0.37	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Total	0.12	0.25	0.37	0.74	1.11	1.60	2.09	2.59	3.08	3.57	4.06	4.55	5.04	5.54	6.03	6.52

Start	Y9				Y10				Y11				Y12			
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
20	0.12	0.12	0.12	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.03	0.00	0.00	0.00	0.00	0.00	0.00
22	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.07	0.00
Quarterly	0.49	0.49	0.49	0.46	0.37	0.37	0.37	0.37	0.29	0.16	0.13	0.13	0.13	0.13	0.07	0.00
Total	7.01	7.50	7.99	8.45	8.82	9.19	9.56	9.93	10.22	10.38	10.51	10.64	10.77	10.90	10.96	10.96

Start	Y13				Y14			
	49	50	51	52	53	54	55	56
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quarterly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.96	10.96	10.96	10.96	10.96	10.96	10.96	10.96

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **RTM Volumes**

Column Inputs	Internal Diameter	Tunnelling days / week	Tunnelling weeks / year
Northern tunnels ID	36.0 ft	5 days	51 wks
Main tunnels ID	36.0 ft	5 days	51 wks
Southern tunnels ID	36.0 ft	5 days	51 wks

Drive Options

Option	Element	Tunnel Length	Tunnel Drive	Drive Length	Drive Duration	TBM's	Start
BETHANY		0.000 mi					
	Intake No. 3 Shaft		R				
	Northern Tunnel	2.550 mi	↑	8.190 mi	4.2 yrs		20
	Intake No. 5 Shaft		M				
	Northern Tunnel	5.640 mi	↑				
	Twin Cities Shaft		L			2	
	Main Tunnel	4.580 mi	↓				
	New Hope Shaft		M				
	Main Tunnel	3.000 mi	↓	12.690 mi	6.3 yrs		17
	Canal Ranch		M				
	Main Tunnel	5.110 mi	↓				
	Terminous Tract Shaft		R				
	Main Tunnel	3.940 mi	↑				
	King Island Shaft		M	9.500 mi	4.8 yrs		22
	Main Tunnel	5.560 mi	↑				
	Lower Roberts Island Shaft		L			2	
	Southern Tunnels	5.130 mi	↓				
	Upper Jones Tract Shaft		M				
	Southern Tunnels	4.240 mi	↓	14.400 mi	6.9 yrs		20
	Union Island Shaft		M				
	Southern Tunnels	5.030 mi	↓				
	Surge Basin Shaft		R				
	Total	44.78 mi	2	44.78 mi		4	

Quarterly Dry Compacted RTM Volume Generated at Each Shaft (m yd3)

	Y1				Y2				Y3				Y4				Y5				Y6				Y7			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Twin Cities Shaft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Lower Roberts Island Shaft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Quarterly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.37	0.37	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.25	0.37	0.74	1.11	1.60	2.09	2.59	3.08	3.57	4.06	4.55

	Y8				Y9				Y10				Y11				Y12				Y13				Y14			
	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Twin Cities Shaft	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.21	0.12	0.12	0.12	0.12	0.12	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Roberts Island Shaft	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.17	0.13	0.13	0.13	0.13	0.13	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quarterly	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.46	0.37	0.37	0.37	0.37	0.29	0.16	0.13	0.13	0.13	0.13	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	5.04	5.54	6.03	6.52	7.01	7.50	7.99	8.45	8.82	9.19	9.56	9.93	10.22	10.38	10.51	10.64	10.77	10.90	10.96	10.96	10.96	10.96	10.96	10.96	10.96	10.96	10.96	10.96

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Stockpiles**

Maximum allowable stockpile heights

Max. permanent stockpile height at Twin Cities	15	ft	above grade
Max. permanent stockpile height at Lower Roberts	15	ft	above grade
Contingency	5	%	

Temporary stockpiles (All RTM)

Bethany	Vol. of RTM to stockpile (yd3)	Area of temp. stockpile (acres)	Height of temp. stockpile (ft)	Resulting individual lift (in)
Twin Cities North	1,828,519	196	5.8	18.0
Twin Cities South	2,833,200	196	9.0	18.0
Lower Roberts North	2,198,745	196	7.0	18.0
Lower Roberts South	3,332,834	196	10.5	18.0

Temporary stockpile notes

Twin Cities

- < 7,500 cfs, area based on drying method
- 7,500 cfs uses same area as for 6,000 cfs

Lower Roberts

- Area based on drying method
- Max. available area 196 acres / tunnel drive
- See 'No Drying Annual Process' sheet.

Permanent stockpiles (Surplus RTM)

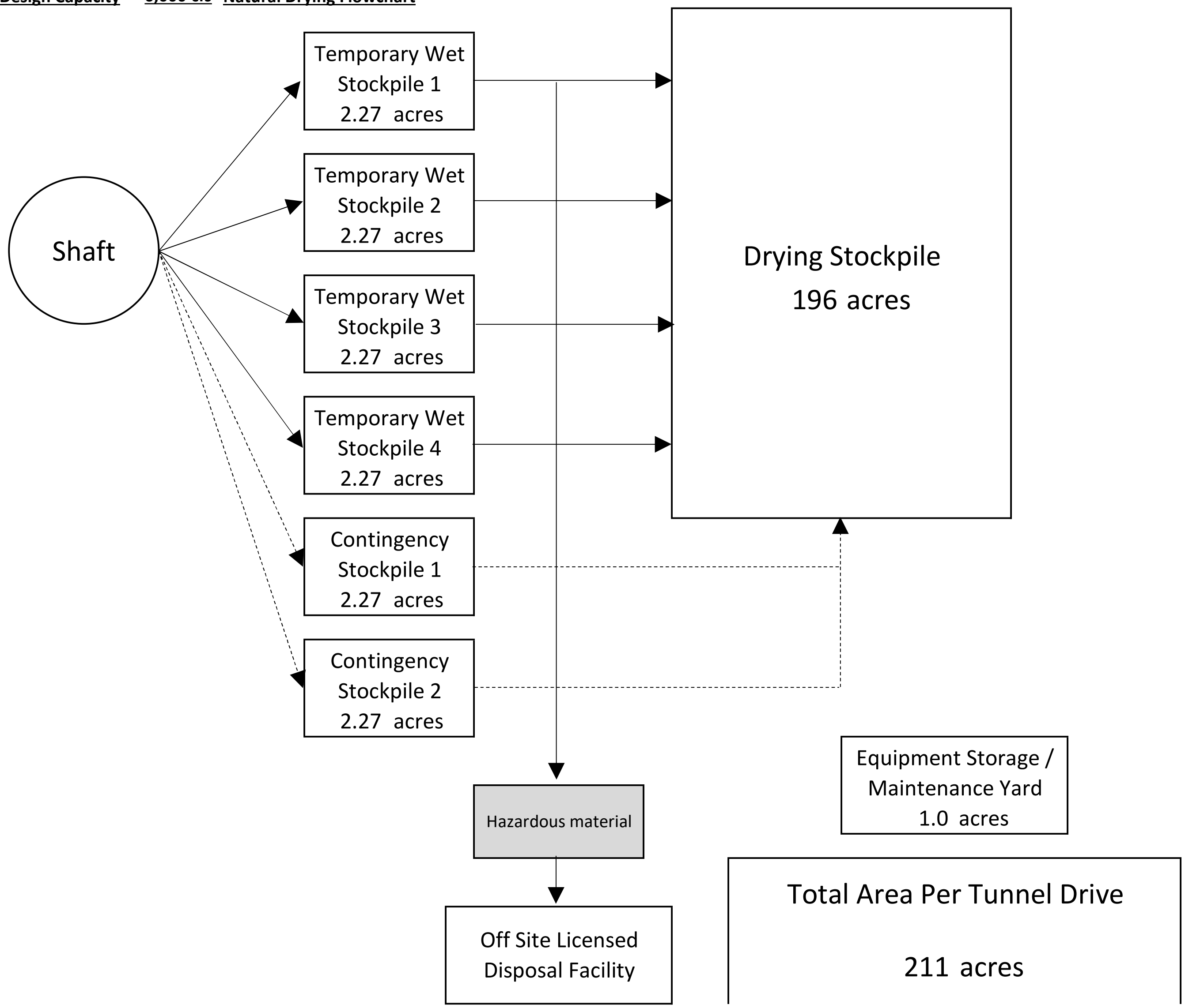
		Based on max. height	
Bethany	Vol. of RTM to stockpile (yd3)	Area of perm. stockpile (acres)	Height of perm. stockpile (acres)
Twin Cities	4,924,578	214	15
Lower Roberts	4,361,335	189	15

Permanent stockpile notes

Both sites consolidated into one stockpile
Area calculated based on 15ft height
At TC volume includes ring levee degradation
Surplus volumes account for filling borrow pit

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Natural Drying Flowchart**



CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Natural Drying Annual Process**

Drying stockpile height per lift	18	in
Drying stockpile contingency	5	%
Tunnelling days / week	5	days / week
Tunnelling weeks / year	51	weeks / year
Wet season	7	months / year
Wet season	30	weeks / year
Number of drying cells	37	

Per Tunnel Drive Season	Cell >	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37		
	Area→ Week↓	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	Spreading	Compacting
Wet	1	Hold	Hold	Hold	Fill	< wet season begins with 3 full cells from previous drying season																																	0	0
Wet	2	Hold	Hold	Hold	Hold	Fill																																	0	0
Wet	3	Hold	Hold	Hold	Hold	Hold	Fill																																0	0
Wet	4	Hold	Hold	Hold	Hold	Hold	Hold	Fill																															0	0
Wet	5	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																														0	0
Wet	6	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																													0	0
Wet	7	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																												0	0
Wet	8	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																											0	0
Wet	9	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																										0	0
Wet	10	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																									0	0
Wet	11	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																								0	0
Wet	12	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																							0	0
Wet	13	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																						0	0
Wet	14	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																					0	0
Wet	15	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																				0	0
Wet	16	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																			0	0
Wet	17	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																		0	0
Wet	18	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																	0	0
Wet	19	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																0	0
Wet	20	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill															0	0
Wet	21	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill														0	0
Wet	22	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill													0	0
Wet	23	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill												0	0
Wet	24	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill											0	0
Wet	25	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill										0	0
Wet	26	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill									0	0
Wet	27	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill								0	0
Wet	28	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill							0	0
Wet	29	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill						0	0
Wet	30	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill					0	0
Dry	31	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill + Spread				3	0
Dry	32	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Fill + Spread			3	0
Dry	33	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Dry	Fill + Spread		3	0
Dry	34	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry + Compact	Dry	Dry	Fill + Spread	3	3
Dry	35	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold		Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold		Dry + Compact	Dry	Dry	3	3
Dry	36	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold			Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold			Dry + Compact	Dry	3	3
Dry	37	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold				Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold				Dry + Compact	3	3
Dry	38	Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold					Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold					3	3
Dry	39		Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold						Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold					3	3
Dry	40			Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold							Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold					3	3
Dry	41				Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold								Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold					3	3
Dry	42					Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold									Dry + Compact	Dry	Dry	Spread	Hold	Hold					3	3
Dry	43						Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold										Dry + Compact	Dry	Dry	Spread	Hold					3	3
Dry	44							Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold											Dry + Compact	Dry	Dry	Spread					3	3
Dry	45								Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold												Dry + Compact	Dry	Dry					2	3
Dry	46									Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold													Dry + Compact	Dry					2	3
Dry	47										Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold														Dry + Compact					2	3
Dry	48											Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold																			2	2
Dry	49												Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread																			2	2
Dry	50	Fill												Dry + Compact	Dry	Dry		Dry + Compact	Dry	Dry																			0	2
Dry	51	Hold	Fill												Dry + Compact	Dry			Dry + Compact	Dry																			0	2
Dry	52	Hold	Hold	Fill												Dry + Compact				Dry + Compact																			0	2

Permanent stockpile per site

Shaft site	Total vol. of RTM (yd3)	Stockpile area (acres)	Final height of stockpile (ft)	Equivalent annual lift (in)
Twin Cities	4,924,578	392	7.8	24
Lower Roberts	4,361,335	392	6.9	24

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Natural Drying Areas**

Excavation Rates per tunnel drive

Tunnel lining ID	36	ft
TBM cutterhead area	1,267	ft2
TBM advance rate (ave.)	40	ft / day
TBM advance rate (peak)	80	ft / day
Daily in-situ rate of excavation per tunnel (ave.)	1,877	yd3 / day
Daily in-situ rate of excavation per tunnel (peak)	3,754	yd3 / day
Bulking factor	1.30	
Daily excavated volume per tunnel (ave.)	2,440	yd3 / day
Daily excavated volume per tunnel (peak)	4,881	yd3 / day
Estimated duration of peak excavation	21	days
Volume loss due to drying	5	%
Equivalent daily dry excavated volume per tunnel (ave.)	2,318	yd3 / day
Equivalent daily dry excavated volume per tunnel (peak.)	4,637	yd3 / day

Temporary Wet Stockpile Area per tunnel drive

No. of days storage	5	days	assuming 5 days of peak excavation in a 7 day cycle
Volume of RTM to stockpile at peak excavation rate	24,404	yd3	per stockpile
Height of stockpile	10	ft	short term
Contingency	50	%	includes allowance for conveyor pits
Area required at peak excavation rate	2.27	acres	per stockpile = 314 x 314 ft or equivalent
No. of temporary stockpiles	6.0		
Total area of temporary stockpiles	13.6	acres	

Equipment Storage / Maintenance Yard per tunnel drive

Area required for equipment storage / maintenance yard	1.0	acres

Drying Stockpile

Contingency	5	%

Natural Drying Area Summary

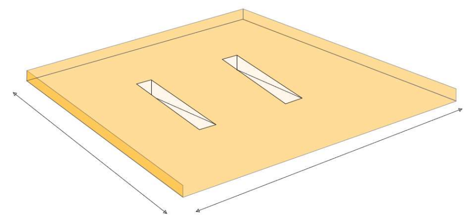
Alignment	Site	Tunnel Drive	Compacted RTM to store above grade	Temporary Wet Stockpile 10 ft high	Equipment / Maintenance Yard	Dry Stockpile (height varies)	Total RTM Area	Total RTM Area
Bethany	Twin Cities	North	1.8 m yd3	13.6 acres	1 acres	196 acres	211 acres	421 acres
		South	2.8 m yd3	13.6 acres	1 acres	196 acres	211 acres	
	Lower Roberts Island	North	2.2 m yd3	13.6 acres	1 acres	196 acres	211 acres	421 acres
		South	3.3 m yd3	13.6 acres	1 acres	196 acres	211 acres	

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Natural Drying Equipment**

Temporary Wet Stockpile Filling per tunnel drive

Volume of RTM to stockpile at peak excavation rate	24,404	yd3	per stockpile as for Natural Drying
Bulldozer capacity	14.50	yd3 / bulldozer	
Target time for filling temporary stockpile	5	days	
Working hours per day	20	hours	
Average cycle time per shove	5	mins	
Efficiency	80	%	
Number of bulldozers required	2	bulldozers	
Total hours at peak excavation rate per day	34.9	hours / day	
Total hours at average excavation rate per day	17.4	hours / day	
Total hours for operation per year	4,448	hours / year	



Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Temporary Wet Stockpile Emptying per tunnel drive

Assume two conveyor pits in the centre of the temporary stockpile each to be loaded from both sides.

Volume of RTM to stockpile at peak excavation rate	24,404	yd3	per stockpile as for Natural Drying
Bulldozer capacity	14.50	yd3 / bulldozer	
Target time for emptying temporary stockpile	10	days	
Working hours per day	10	hours	
Average cycle time per shove	5	mins	
Efficiency	81	%	
Number of bulldozers required	2	bulldozers	
Total hours at peak excavation rate per day	34.6	hours / day	
Total hours at average excavation rate per day	17.3	hours / day	2 stockpiles emptied at any one time
Total hours for operation per year	4,415	hours / year	

Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Drying Stockpile Moving per tunnel drive

Daily excavated volume per tunnel (peak)	2,440	yd3 / day	to be moved per day
Wheel Loader capacity	19.50	yd3 / wheel loader	
Working hours per day	10	hours	
Average cycle time	5	mins	
Efficiency	81	%	
Number of wheel loaders	2	wheel loaders	
Total hours at peak excavation rate per day	12.9	hours / day	
Total hours at average excavation rate per day	6.4	hours / day	
Total hours for operation per year	1,642	hours / year	

Example: Caterpillar, 990K, Capacity = 19.5yd3 (see equipment schedule for details)

Drying Area / Dry Stockpile Spreading per tunnel drive

Volume of RTM to be spread per cell (ave.)	12,202	yd3 / cell
Bulldozer capacity	14.50	yd3 / bulldozer
Working hours per week	50	hours / week / cell
Average cycle time per shove	5	mins
Efficiency	81	%
Number of bulldozers required	2	bulldozers / cell
Max. number of cells to spread in one week	3	cells
Number of bulldozers required	6	bulldozers
Total hours per cell (ave.)	86.6	hours / cell
Number of cells to spread per year	52	cells / year
Total hours for operation per year	4,502	hours / year

Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Drying Stockpile Compacting   per tunnel drive

Roller width	84	in	
Roller width	2.33	yd	
Area per cell	5.3	acres	per site (ie. two tunnel drives)
Area per cell	25,624	yd2	
Speed	6.8	mph	
Speed	11,968	yd/hr	
Area/hr	27,925	yd2/hr	
Working hours per day	10	hours	
Efficiency	50	%	
No. of passes	2	passes	
Time to compact one cell	3.7	hrs	
Max. number of cells to compact in one week	3	cells / week	
Number of compactors required	1	compactors	
Number of cells to compact per year	52	cells / year	
Total hours for operation per year	191	hours / year	

Example: Caterpillar, CS54B, Capacity = 84in roller at 6.8mph (see equipment schedule for details)

CA Delta Conveyance Tunnel - RTM Calculations

24 Jun 2021

Project Design Capacity **6,000 cfs** **Natural Drying Equipment Schedule**

Working Hours / Year

Day shift only

Hours / day	10	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	2550	hours

Day and night shift

Hours / day	20	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	5100	hours

Equipment Schedule (per tunnel drive)

Operation	Equipment	Manufacturer	Model	Power	Power	Hours / Year / Operation	Hourly Operating Cost	Capital Cost	Average Excavation Rate: Total Hours / Year	Average Excavation Rate: Total Power / Year	Average Excavation Rate: Total Annual Operating Cost	Peak Excavation Rate: Quantity	Peak Excavation Rate: Total Capital Cost
Temporary Wet Stockpiles Filling	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	4448 hrs	$ 105	$ 196,000	4448 hrs	720 MWh	$ 467,073	2	$ 392,000
Temporary Wet Stockpiles Testing													
Temporary Wet Stockpiles Emptying	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	4415 hrs	$ 105	$ 196,000	4415 hrs	714 MWh	$ 463,614	4	$ 784,000
Drying Stockpile Moving	Wheel Loaders	Caterpillar	990K	699 hp	521 kW	1642 hrs	$ 120	$ 180,000	1642 hrs	856 MWh	$ 196,993	2	$ 360,000
Drying Stockpile Spreading	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	4502 hrs	$ 105	$ 196,000	4502 hrs	728 MWh	$ 472,704	6	$ 1,176,000
Drying Stockpile Compacting	Compactor	Caterpillar	CS54B	131 hp	98 kW	191 hrs	$ 55	$ 73,100	191 hrs	19 MWh	$ 10,497	1	$ 73,100

Equipment utilization 20%

	Total Hours / Year	Total Power / Year	Total Annual Operating Cost	Quantity	Total Capital Cost
Total Electrical	- hrs	- MWh	$ -	0	$ -
Total Gas/Diesel	15,198 hrs	3,037 MWh	$ 1,610,882	15	$ 2,785,100
Total	15,198 hrs	3,037 MWh	$ 1,610,882	15	$ 2,785,100

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Equipment Schedule Summary**

Working Hours

Day shift only

Hours / day	10	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	2550	hours

Day and night shift

Hours / day	20	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	5100	hours

Equipment Schedule

No Drying - (per tunnel drive)			Annual usage		
Operation	Equipment	Power	Quantity required	Total Hours / Year	Notes
Temporary Wet Stockpiles Filling	Bulldozers	217 hp	2	4,448 hrs	Day and night shift, 12mths/yr
Temporary Wet Stockpiles Testing		hp		hrs	No activity
Temporary Wet Stockpiles Emptying	Bulldozers	217 hp	4	4,415 hrs	Day shift only, 12mths/yr
Drying Stockpile Moving	Wheel Loaders	699 hp	2	1,642 hrs	Day shift only, 12mths/yr
Drying Stockpile Spreading	Bulldozers	217 hp	6	4,502 hrs	Day shift only, 12mths/yr
Drying Stockpile Compacting	Compactor	131 hp	1	191 hrs	Two passes over each drying cell / yr

Total Electrical	0	- hrs
Total Gas/Diesel	15	15,198 hrs
Total	15	15,198 hrs