Appendix D5. Conceptual Development of Aqueduct and Discharge Structure (Final Draft)

1. Introduction and Purpose

The purpose of the Technical Memorandum (TM) is to summarize design concepts and considerations, anticipated construction methodology and sequencing, and operation and maintenance requirements for the Bethany Reservoir Aqueduct (aqueduct) portion of the Delta Conveyance Project (DCP), which would operate between the Bethany Reservoir Pumping Plant (BRPP) and the Bethany Reservoir Discharge Structure at the reservoir.

1.1 Organization

This TM is organized as follows:

- Introduction and Purpose
- Aqueduct System Configuration
- Anticipated Construction Methodology and Sequencing
- Operation and Maintenance Requirements
- References

1.2 Background and Overview

The overall Delta Conveyance Project – Bethany Reservoir Alignment would receive water from the Sacramento River and deliver it through deep tunnels to the new BRPP and surge basin just south of Clifton Court Forebay and Byron Highway. The BRPP would then lift the water to a hydraulic gradeline (HGL) sufficient for delivery of Project flows to Bethany Reservoir downstream of Banks Pumping Plant. That delivery would be accomplished through an aqueduct consisting of four parallel 180-inch diameter welded steel pipelines.

Figure 1 is a schematic of the Bethany Reservoir Alignment. The Aqueduct and Discharge Structure portions are identified on Figure 2 and serve as the basis for the remainder of this TM.

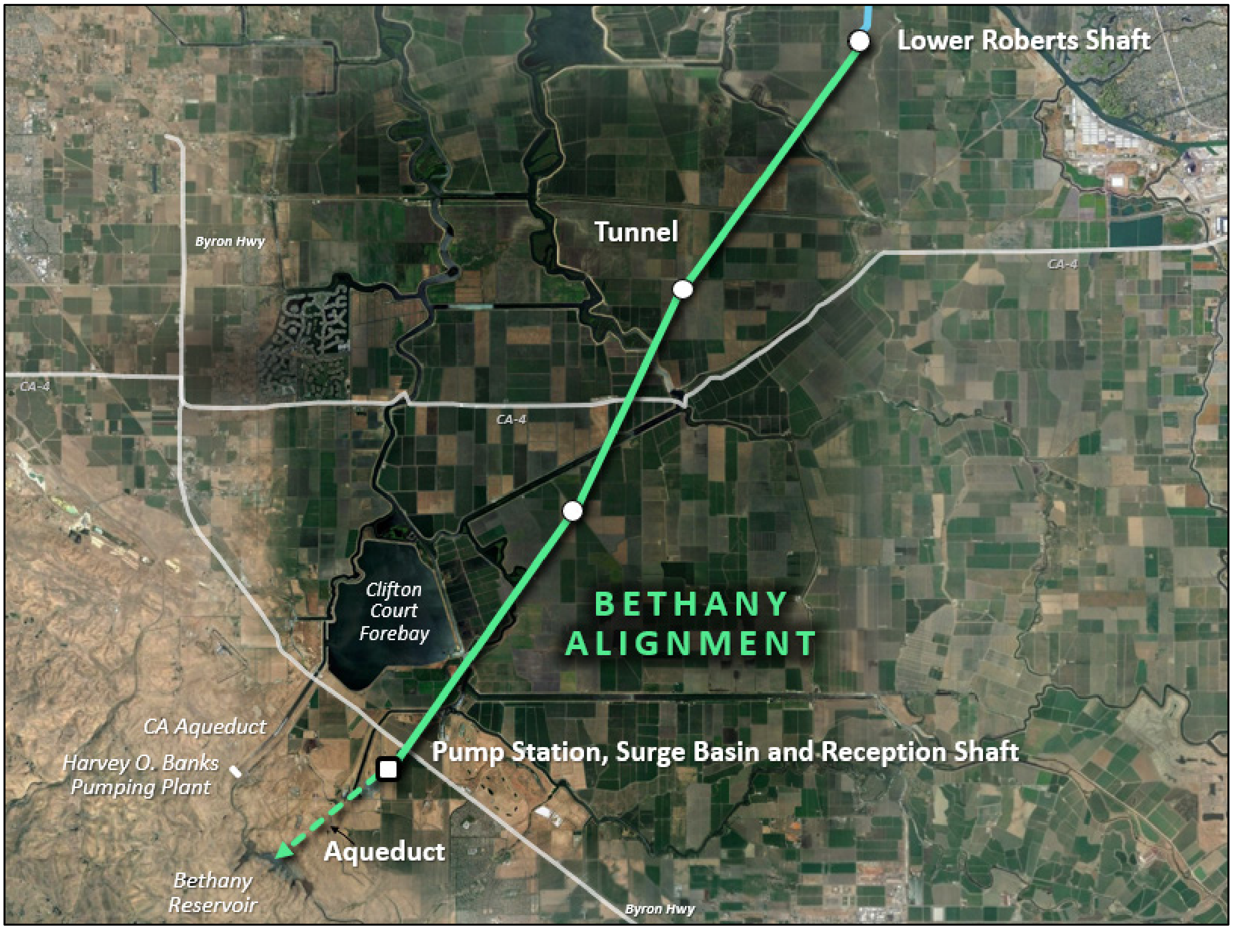

Figure 1. Delta Conveyance Project, Bethany Reservoir Alignment Schematic, South of Lower Roberts Shaft

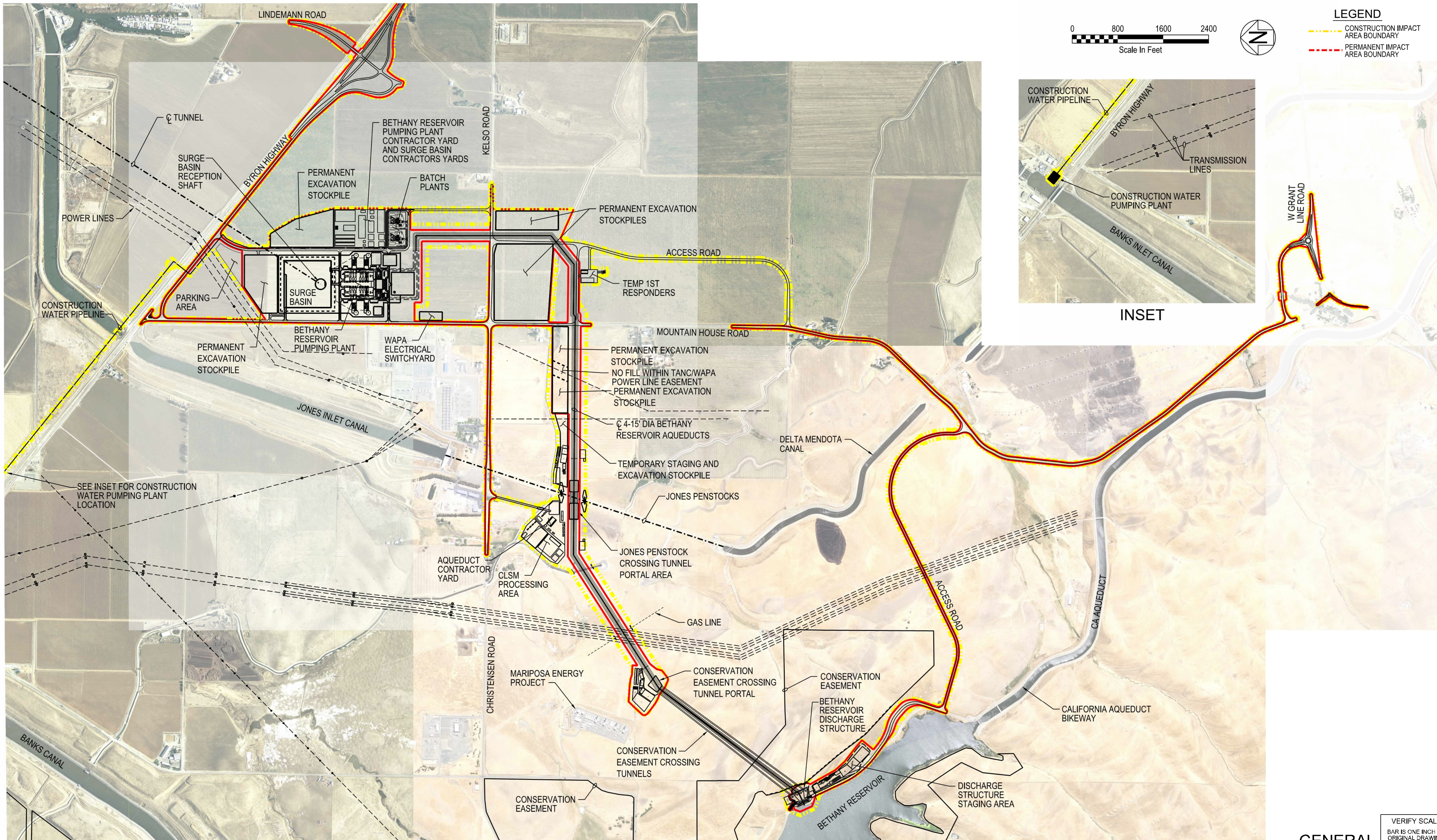

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Figure 2

BETHANY COMPLEX IMPACT AREA LIMITS

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1.3 Aqueduct System Capacity and Hydraulics

The DCP's maximum design diversion capacity from the Sacramento River to BRPP and to the Bethany Reservoir is 6,000 cfs. Flow is delivered in four 180-inch diameter pipelines from the BRPP to the Bethany Reservoir. Each pipeline would carry up to 1,500 cfs and would operate at working pressures up to about 100 psi and transient pressures under surge conditions of up to about 180 psi. More details on the hydraulics of the system are provided in the Concept Engineering Report (CER)Appendix A2 *Hydraulic Analysis of Delta Conveyance Options*.

2. Aqueduct System Configuration

For the purposes of this TM, the aqueduct system would comprise the following components, generally listed in direction of flow.

- Aqueduct pipelines and appurtenances
- Permanent patrol road along aqueduct
- Aqueduct tunnels, including portals and shafts (to carry portions of the pipelines under surface features that cannot be disturbed)
- Bethany Reservoir Discharge Structure

Each of these facilites is further described in the following subsections.

2.1 Bethany Reservoir Pumping Plant to Bethany Reservoir

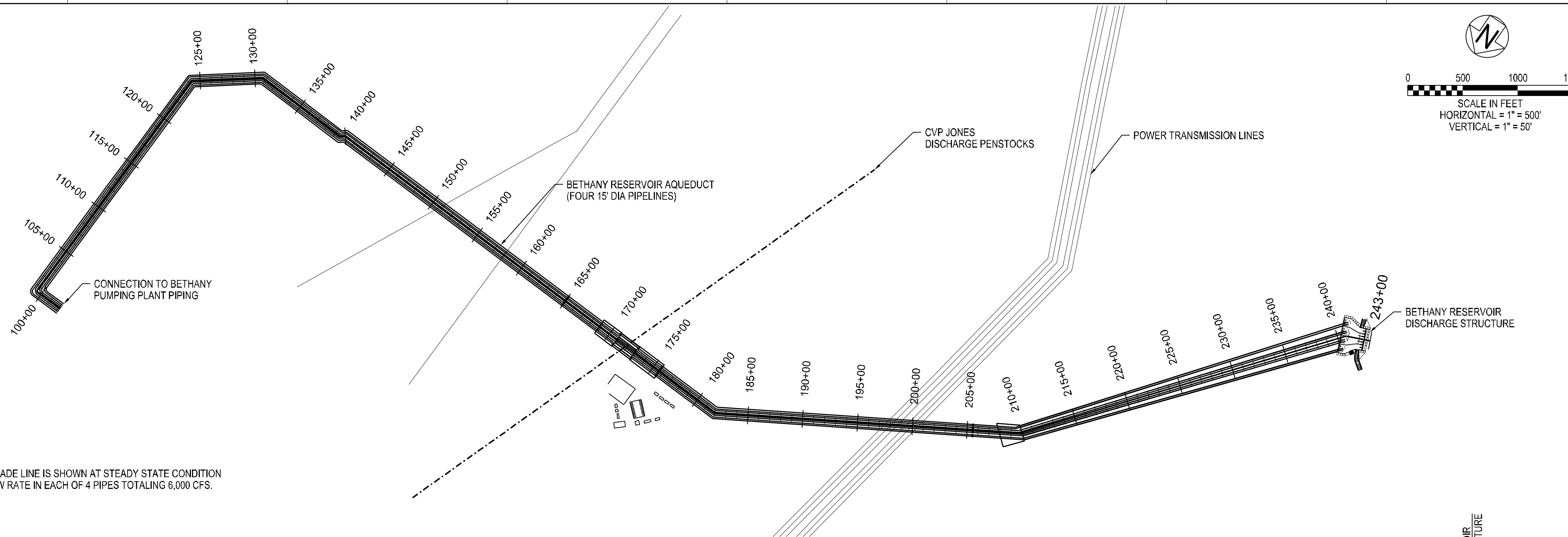
2.1.1 Aqueduct Pipelines and Appurtenances

The aqueduct from the BRPP to Bethany Reservoir would begin where multiple discharge pipelines emerge from both sides of the BRPP and converge into a parallel alignment. Following the horizontal alignment shown in Figure 2, the aqueduct would cross under the following surface features, in the direction of flow:

- Kelso Road
- Byron-Bethany Irrigation District (BBID) canal (first crossing)
- Mountain House Road
- CVP Jones Pumping Plant penstocks
- BBID canal (second crossing)
- A pair of petroleum pipelines (26-inch and 36-inch diameter)
- The Bethany Reservoir Conservation Easement
- A 16-inch diameter petroleum pipeline
- California Aqueduct Bikeway (SWP access road)

Figure 3 illustrates the aqueduct profile between the BRPP and Bethany Reservoir.

PLAN



NOTE:

1. THE HYDRAULIC GRADE LINE IS SHOWN AT STEADY STATE CONDITION FOR 1,500 CFS FLOW RATE IN EACH OF 4 PIPES TOTALING 6,000 CFS.

PROFILE

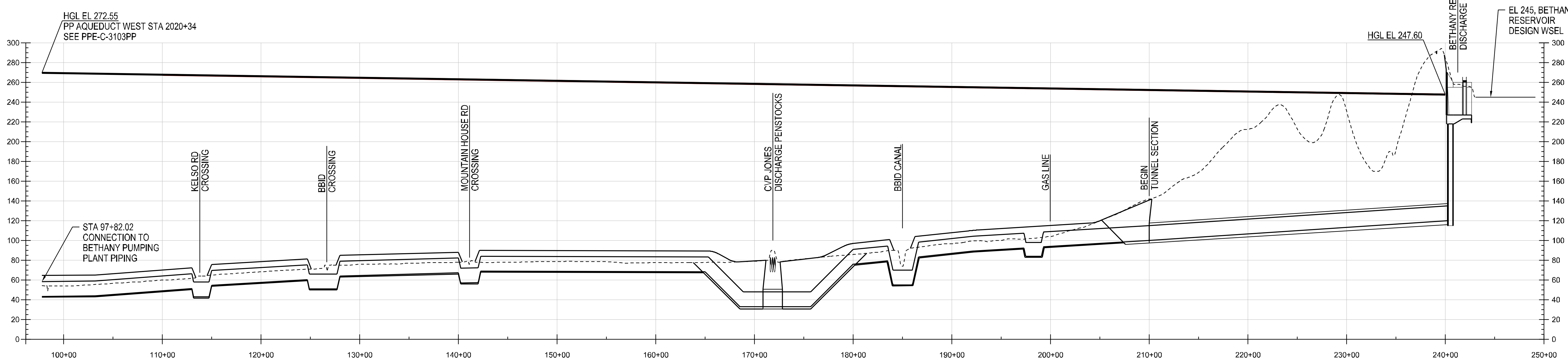


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Figure 3 OVERALL HYDRAULIC PLAN AND PROFILE - AQUEDUCT

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The aqueduct would consist of 4 welded steel pipelines, 180-inches in diameter. The pipelines would be constructed 30 feet on center, with pipe inverts set at a depth of 0.7 times the diameter (0.7D, or 10.5 feet in this case) below original ground in all reaches not affected by the undercrossings listed above. The portion of the pipe trench below original ground would be backfilled with Controlled Low Strength Material (CLSM). CLSM is a low strength mixture of cement, on-site excavated soil, and water. The exposed portion of the pipes would be backfilled by mounding fill over the top of the pipes using compacted soil to a depth of 0.7 (10.5 feet) above original ground or about 6 feet over the top of pipe. The 0.7 times the diameter bury depth was established to ensure suitable structural support for the pipeline from the CLSM pipe zone material. Similarly, the separation by one diameter between each parallel pipeline would provide appropriate width for CLSM structural support.

An illustration of the typical finished pipeline trench for four parallel pipelines is depicted in Figure 4 below.

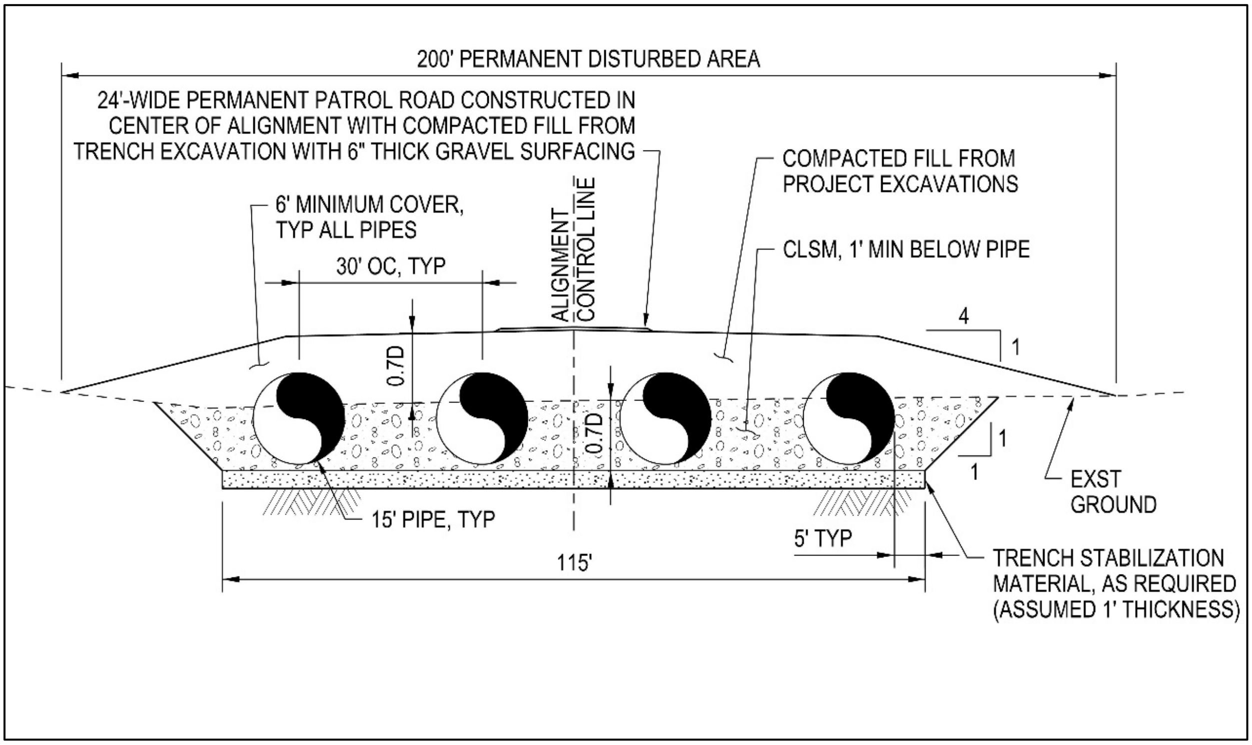


Figure 4. Typical Pipeline Trench between BRPP and Bethany Reservoir

A preliminary analysis was conducted in accordance with AWWA M11 to determine the conceptual steel cylinder thickness for the pipelines. The analysis considered handling, buckling, internal pressure, and deflection. The analysis suggested that a thickness of 0.750 inches would be sufficient, based on the following:

- Operating and surge pressures of 100 psi and 180 psi, respectively
- E’ modulus of soil reaction of 3,000 psi (based on CLSM backfill to 0.7D on the pipe)
- Allowable design stress (50% of minimum yield point) of 18 to 21 ksi, assuming 36 to 42 ksi yield steel (to be determined during final design).
- Cover material density of 120 lb/cubic foot

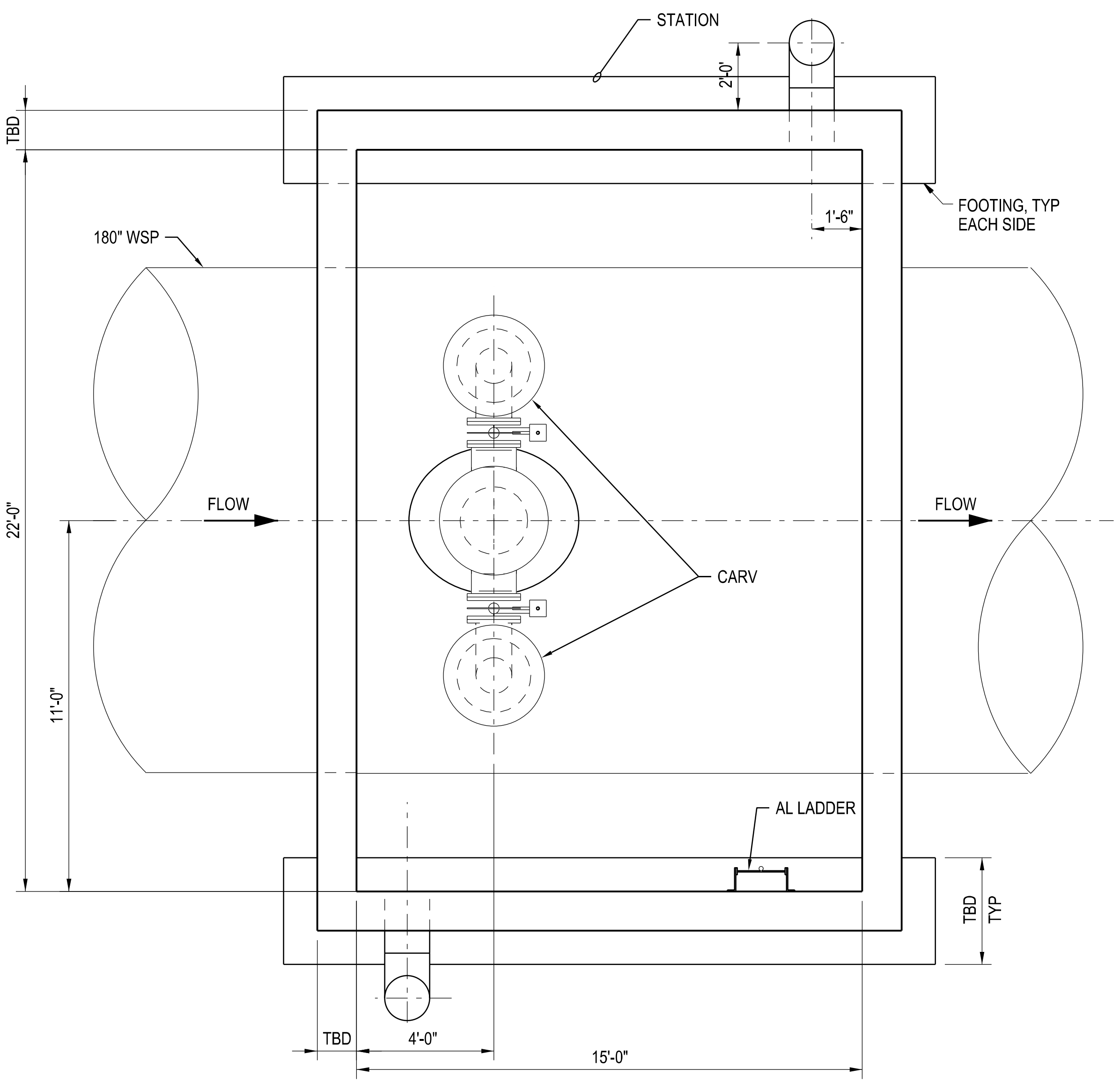
- AASHTO live load of 32,000 lbs for an HS-20 Single Truck
- Allowable deflection for lining/coating not to exceed 2.25 percent

While the pipe is not expected to operate under vacuum conditions, at a thickness of 0.750 inch it would withstand a full vacuum without buckling (including a 2:1 safety factor) for the conceptual design configuration depicted on the engineering concept drawings. It is anticipated that the pipelines would be internally lined with field-applied cement mortar and externally coated with polyethylene tape or polyurethane, and that corrosion would be further controlled with an impressed-current cathodic protection system with air-cooled or oil-cooled rectifiers installed at the pumping plant site.

The aqueduct would include pipeline appurtenances such as air and vacuum valves, access manways, and pipelines drains (blowoffs), as follows:

- Combination air and vacuum valves (CARVs) would be located at each high point in the alignment, especially at many of the undercrossings where the pipe would dive down to go under surface features. CARVs would release accumulating air (through smaller outlet orifices) and help mitigate surge and vacuum conditions (through larger inlet orifices).
- One additional larger CARV would be provided just prior to the tunnel portal, upstream of the by the Conservation Easement, to further facilitate surge mitigation.
- 30- to 36-inch access manways would be provided as part of the CARV facilities described above to provide for entry into the pipelines for inspection and maintenance.
- Blow-offs in vaults would be provided at each low point (same undercrossings listed above) for occasional draining of the low spots along the pipelines for maintenance.

Figure 5 depicts a typical CARV/Manway configuration.



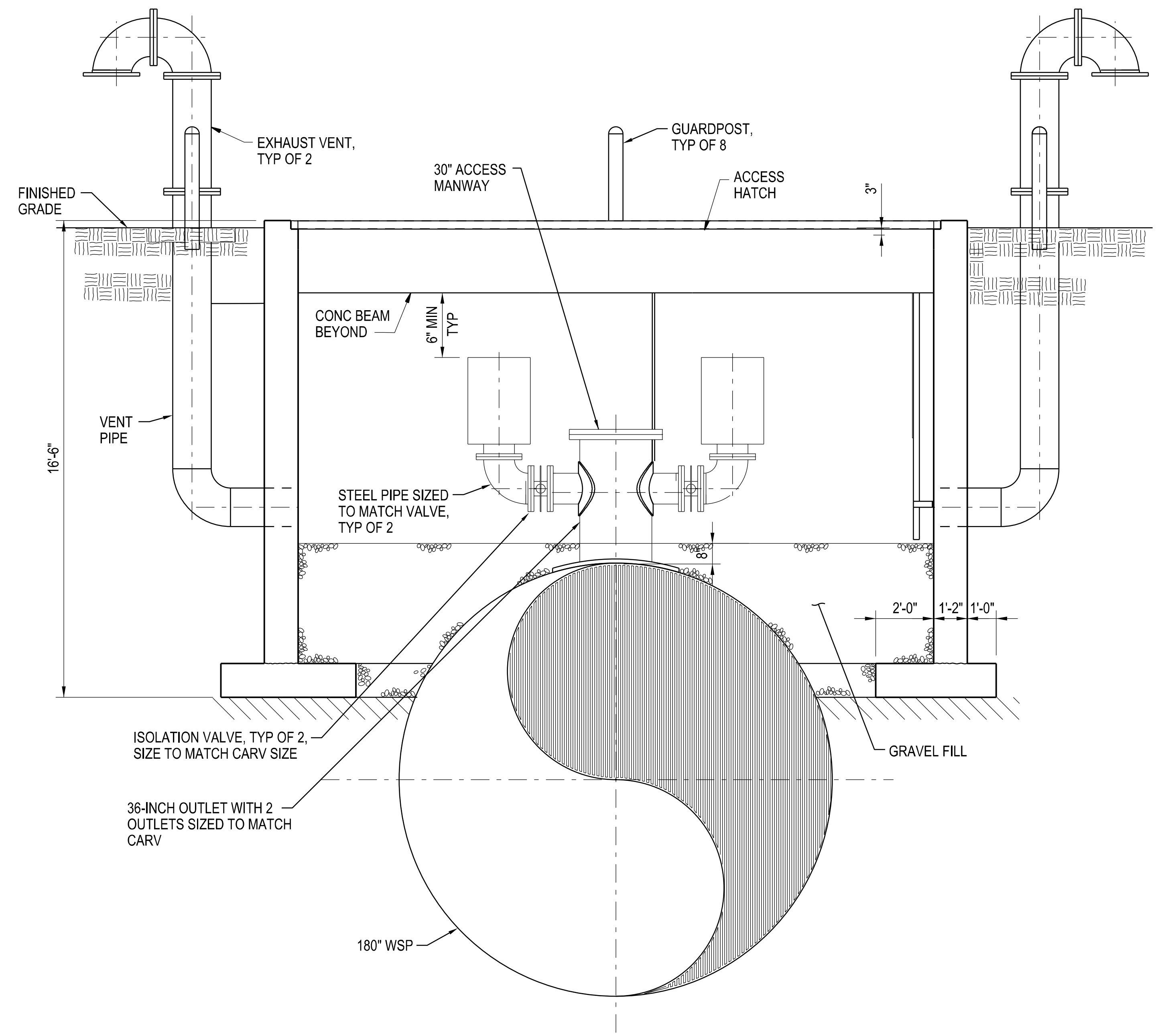


FIGURE 5 :
TYPICAL CARV/MANWAY PLAN AND SECTION

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2.1.2 Patrol Road

As depicted in Figure 4, a 24-foot-wide gravel patrol road would be constructed over the pipe trench on compacted fill. The road would provide permanent access to the aqueduct system for operation and maintenance activities. Although generally centered over the pipelines and within the 200-foot-wide permanent easement, the road would veer off this alignment at many of the various undercrossings listed above. In these locations, new permanent bridges would be installed (at petroleum line, penstock, and canal crossings) or existing roads would be used (road crossings) for continuity of the patrol road, with “shoefly” or similar alignment variations on a case-by-case basis. The patrol road would end at the upstream portal to the aqueduct tunnel that extends beneath the Bethany Reservoir Conservation Easement. No surface features would be provided, or required, above this aqueduct tunnel.

Access to the Bethany Reservoir Discharge Structure would use existing roads to the reservoir plus one new road south of the easement used for heavy construction equipment access during construction.

2.1.3 Tunnels

The following two reaches of the aqueduct would be constructed utilizing tunnel excavation methods, because open trenching and surface disturbance would be impractical and/or not permitted:

- Jones Penstock Crossing – At this location, three existing 180-inch diameter steel pipes carry water from the CVP Jones Pumping Plant to the upper section of the Delta-Mendota Canal. The new DCP aqueduct pipelines would cross underneath the existing pipes inside 200-foot-long tunnels, one for each pipeline, with a clearance of approximately one to two tunnel diameters (to be determined during final design, drawings show one diameter of clearance).
- Bethany Reservoir Conservation Easement – Surface disturbance would not be allowed through this easement due to the terms and conditions used to establish it. Further, the terrain adjacent to the easement would require extremely deep and costly excavations for open trenching or if installed on the surface as the remaining of the aqueduct, the pipes would have to be installed in a steep and challenging terrain. Therefore, each aqueduct pipeline would be installed within a separate tunnel, that would be approximately 3,000 feet in length each. Also, the 16-inch petroleum pipeline listed above would be crossed some 140 feet below within this tunneled reach which will not have an impact of the petroleum pipeline.

Figure 3 shows these two tunneled reaches in profile along the aqueduct alignment. In each case, the 15-foot (180 inch) diameter pipelines would be installed inside tunnels approximately 20 feet in diameter. The design is based on installing the pipelines through the tunnels, rather than using pressure tunnels, since the high operational and surge pressure would require a robust, expensive, and potentially infeasible tunnel lining system that could leak over time.

Figure 6 illustrates two ground support concepts for the tunnels that vary based on ground conditions. The configuration would be refined during final design based on data from subsurface explorations such as rock strength and quality.

For both tunnel locations, cuts would be required to establish tunnel portals at ends of the tunnel. Tunnel portals are large excavated areas at the ends of the tunnel and are used to support excavation operations, manage excavated material, allow ingress and egress into the tunnel, and allow the pipelines to be installed in the tunnels. Tunnel portals are generally backfilled after construction.

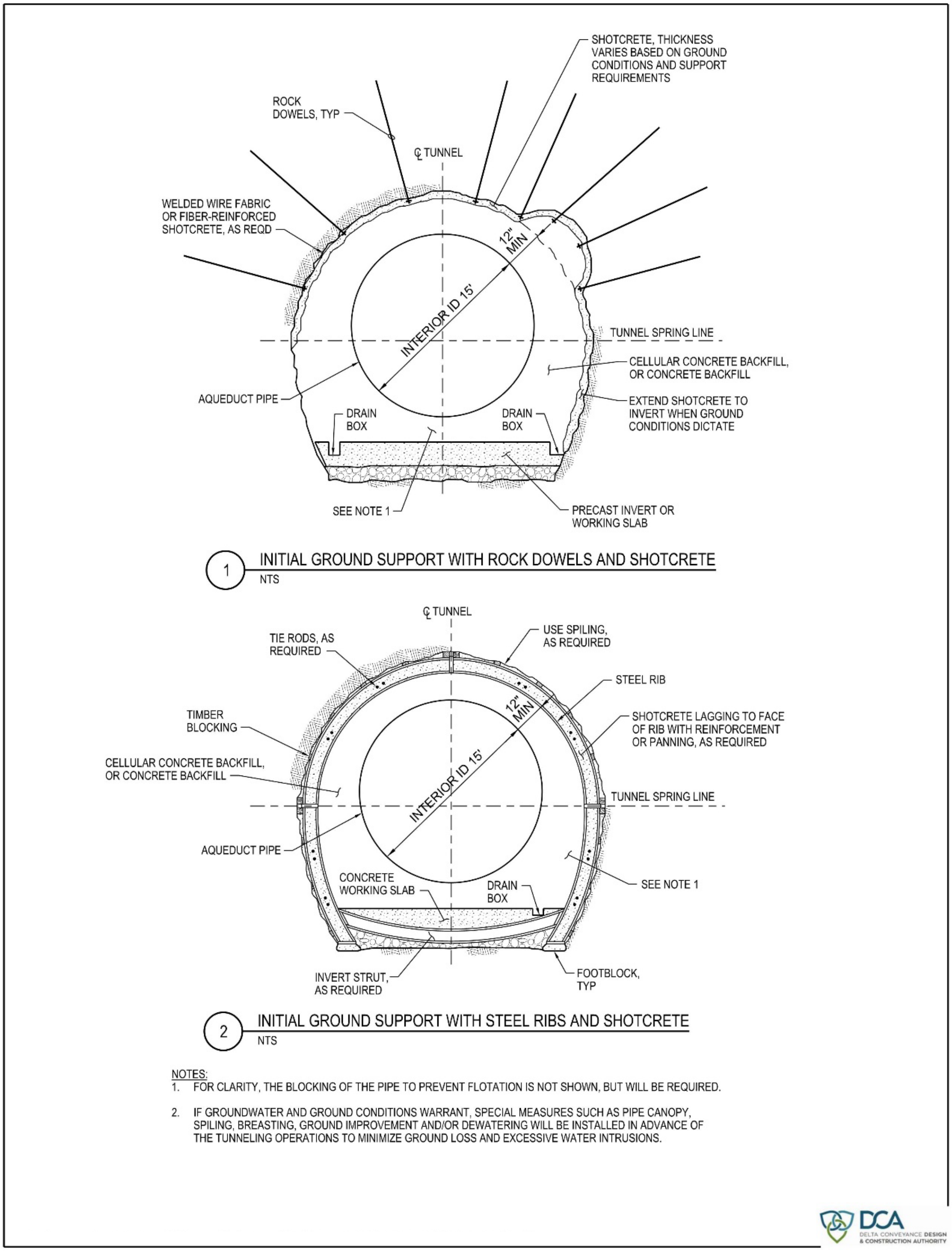


Figure 6. Potential Aqueduct Tunnel Configurations

The 180-inch diameter pipelines housed in the tunnels would be welded in place and the annular space between the tunnel walls and the pipelines would be backfilled with grout typically called Low Density Cellular Concrete (LDCC). This LDCC is grout (cement and water) with foaming agent to yield an approximate density of 80 pounds per cubic foot, however once set it has sufficient strength to adequately keep the pipe in place.

The tunnels for the Jones Penstock Crossing would be excavated 40 feet on center (i.e. parallel) over their entire length and have an excavated portal on each end.

The Conservation Easement Crossing tunnels would also be spaced at 40 feet on center on the upstream end and excavation would commence at an excavated portal located at approximate Station 210+00 on the aqueduct alignment. This location is approximately 0.4 miles north and east of the conservation easement boundary because the topography and tunnel depth are better suited to a portal at this location. In lieu of a portal, these tunnels would terminate on the downstream end in 55-foot diameter deep shafts (one for each tunnel). The tunnels and shafts would be constructed at a spacing of 80 feet on center. Therefore, the tunnels would gradually diverge from each other over their length. The shafts would extend up into the Bethany Reservoir Discharge Structure just beyond the boundary of the easement. The 180-inch diameter pipelines housed in the shafts would be welded in place and connect to pipe installed in the tunnels with 90-degree bends at the bottom of the shafts. The pipes would terminate at the bottom of the concrete channel in the discharge structure that connects to the Bethany Reservoir (see Section 2.1.4). The annular space between the shaft walls and the pipeline would be backfilled with CLSM and concrete up to the Bethany Reservoir Discharge Structure floor. Each tunnel crossing underneath the Bethany Reservoir Conservation Easement would have an excavated diameter of approximately 20 feet in a horseshoe shape and a length of 3,060 feet, and would be constructed with a 0.6 percent upward gradient from the portal to the shaft

2.1.4 Bethany Reservoir Discharge Structure

2.1.4.1 Structure Location

The Bethany Reservoir Discharge Structure would be a large concrete structure connecting the aqueduct system to the reservoir. It would be located on a relatively narrow strip of land between the conservation easement and the edge of the reservoir. Site selection for the structure was based on two primary factors:

1) Terrain – A suitable location would be of sufficient size (say 2.5 to 3 acres), on reasonably flat ground that is above the reservoir water levels, and not adjacent to sections of the reservoir rim formed by dams. Approximately one-third of the north and east side of the reservoir are formed by dams or embankments. It is not desirable (nor is it likely to be permittable) to connect to the reservoir through these structures.
2) Water Quality in the Reservoir – For reasonable mixing and circulation of the reservoir, it would be desirable to locate the discharge as close to its “upstream” end as possible (i.e. at the existing Banks Pumping Plant discharge). Otherwise, if water from the new conveyance system was discharged near the downstream end of the reservoir in a future condition with reduced or eliminated contributions from the Banks facility, upstream portions of the reservoir could have less flow-through and possibly create water quality issues.

The site that was ultimately selected is at the approximate mid-point of the reservoir. This location is the upstream-most portion of the reservoir not rimmed by a dam section, and a mid-point discharge was assumed to be sufficient for mixing and circulation. The terrain is suitably above the water level and most of it is relatively flat. However, a portion of the site (0.5 to 1 acre) is on steep, hilly terrain and would require grading to build the structure. A 10-foot wide buffer would be left between the conservation easement and site disturbance, including the required grading.

2.1.4.2 Structure Configuration

The structure would be divided into a number of separate channels equal to the number of aqueduct pipelines described above. The discharge structure width at the location the 55-foot diameter shafts enter from below would be dictated by the required 80-foot center-to-center spacing of the shafts. From the shafts to the reservoir, these separate channels would gradually narrow to approximately half of their original width and be divided into two subchannels each. The subchannel width of 21 feet would be sufficient to keep flow velocity below 2 feet per second for a full reservoir at water surface elevation of 245, or 3.25 feet per second for a low reservoir level at water surface elevation of 238 feet. The channels would be flat from the shafts to the reservoir bank at an elevation (227.0 - nominally selected to match the floor of DWR's existing discharge structure from the Banks Pumping Plant at the northwest corner of the reservoir). With the reservoir water surface operating between elevations of about 238 and 245, depth of water in the channels would vary from 11 to 18 feet.

Structure side walls would rise to elevation 260.0 feet for grade conformance and walls dividing the channels to 255.0 feet, providing significant freeboard over the maximum water level of 245. The height of the outer walls and external soil load would require the structure to include concrete counterforts around the perimeter. The counterforts along the back wall would be founded, in part, on the backfilled shafts.

Near the reservoir, the structure would be crossed by an existing road (the California Aqueduct Bikeway), so a 32-foot wide bridge would span the structure and the discharge channels. To provide isolation of the aqueduct system from the reservoir, each 21-foot wide subchannel would have the following:

- Radial (or Tainter) gates 21 feet wide and 18-20 feet high, facing the reservoir.
- Two rows of stoplog guides, one on each side of the radial gate, to isolate the gate for maintenance. These stoplogs could also be used to isolate the aqueduct from the reservoir.

Radial gates would be held completely out of the water during aqueduct system operation, and the position of the gates would be controlled by hoists situated mid-span on concrete beams spanning each channel. Access to the hoists would be provided by a 12-foot wide maintenance bridge next to the beam supporting the hoists. Trunnions on the other end of the gates would be mounted above high water level on beams forming part of the bridge structure. A standby engine generator would be located at the site for emergency operation of the gates in the event of a power failure.

Stoplogs would be large aluminum or steel stackable panels designed to span the 21-foot width and the hydraulic load under full reservoir head. The bikeway bridge would include openings situated above the upstream-most stoplog slot for stoplog installation/removal, with the openings typically covered with traffic-rated hatches. Downstream stoplogs would be immediately adjacent to the maintenance bridge, on the opposite side of the hoists. It is expected that these stoplogs would be installed and removed by a crane parked on either side of the overall structure, but personnel could assist from the maintenance bridge as needed. This will be discussed further in Section 4.

The concrete floor of the discharge structure would end near the reservoir bank, and a layer of large riprap would be placed beyond the structure to help stabilize and protect the bank and bed of the reservoir from turbulence that may be generated as the water is discharged. At the design discharge velocity, turbulence and erosive forces are expected to be minor, and flow velocity should dissipate quickly in the lake conditions.

Figures 7 and 8 depict the design concept for the Discharge Structure.

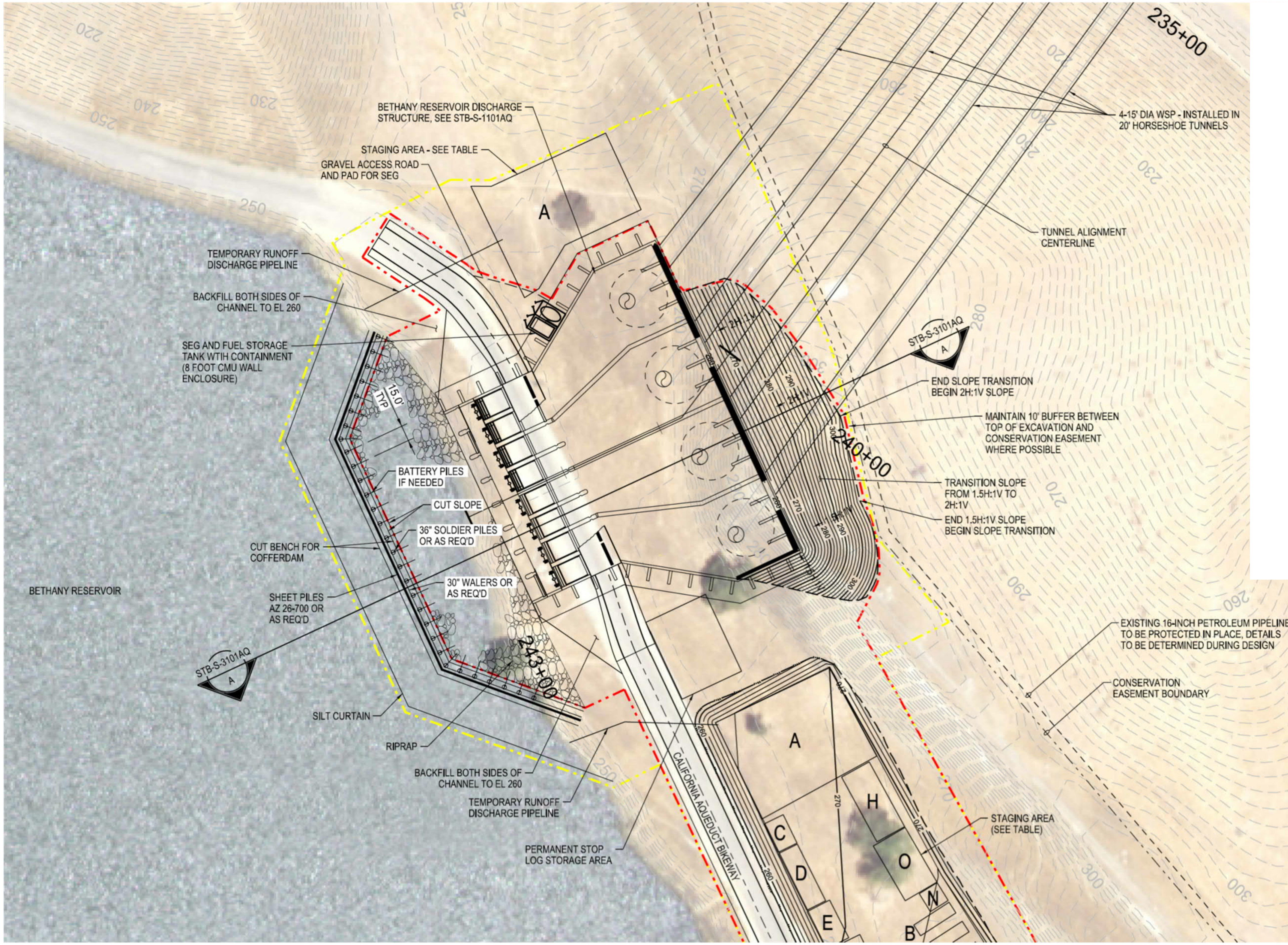
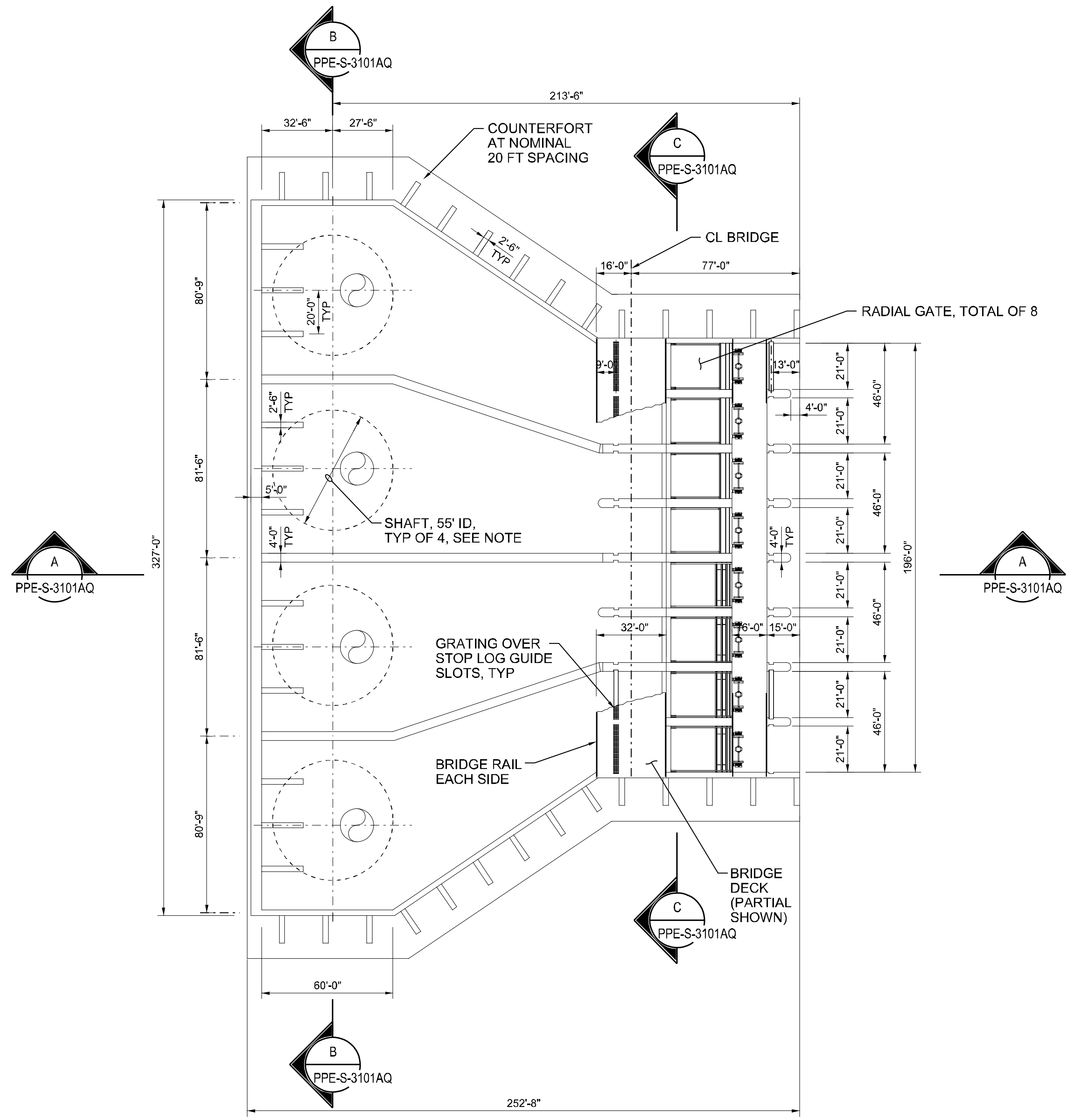


FIGURE 7 :
BETHANY RESERVOIR DISCHARGE STRUCTURE -
SITE PLAN AND GRADING



NOTE:
SHAFT SIZE DEPENDENT ON ELBOW CONFIGURATION, ACTUAL SIZE TO BE DETERMINED DURING FINAL DESIGN.

DISCHARGE STRUCTURE PLAN

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CHECKED: K PARIS

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Figure 8 STRUCTURAL PLAN
BETHANY RESERVOIR DISCHARGE STRUCTURE

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3. Anticipated Construction Methodology and Sequencing

This section describes anticipated methodology and sequencing of construction, including earthwork, tunneling, staging, cofferdamming and dewatering, pipeline and structure installation, backfill, and demobilization. Material will be presented separately according to the two primary construction locations for the Aqueduct system (aqueduct pipelines and Bethany Reservoir Discharge Structure).

3.1 Aqueduct Pipeline Construction

The aqueduct pipelines would mostly be constructed by open cut and backfill methods. However, two tunnels within the aqueduct reach would be needed to carry the pipelines under an existing surface feature and a conservation easement (as described in Section 2.1.3). The material below describes construction methodology and sequencing separately for the open cut and tunneled reaches.

3.1.1 Open-Trenched Reaches

Just under 10,000 lineal feet (LF) of each aqueduct pipeline from the BRPP to Bethany Reservoir would be constructed using open cut (“cut-cover”) methods.

3.1.1.1 Construction Area and Temporary Limits of Disturbance (LOD)

The aqueduct construction corridor (temporary LOD) in the open cut sections of BRPP-to-Bethany Reservoir reach would be 400 feet wide. This width was established based on the following:

- Trench width 115 feet wide at the bottom, to accommodate 4 pipes at 180-inches in diameter and 30 feet on center
- Trench excavated to a depth of about 0.7 times pipe diameter (0.7D), plus 1 foot for pipe bedding and another 1 foot or more for trench stabilization material, where needed
- Trench side slopes 1:1 (assumed, actual slope would be as required for OSHA conformance and contractor’s trench safety means and methods)
- A work area 20 feet in width on each side of trench excavation
- An 80-foot-wide strip on each side of trench, beyond the 20-foot wide work area, allocated to serve as a staging area, primarily for temporary storage of excavated material and pipe segments not yet installed in the trench
- Adjacent to the 80-foot-wide staging area, an additional 20-foot wide strip allocated on each side of the trench to serve as a temporary access road for construction travel along the edges of the aqueduct corridor

Figure 9 illustrates the construction condition for open cut aqueduct installation.

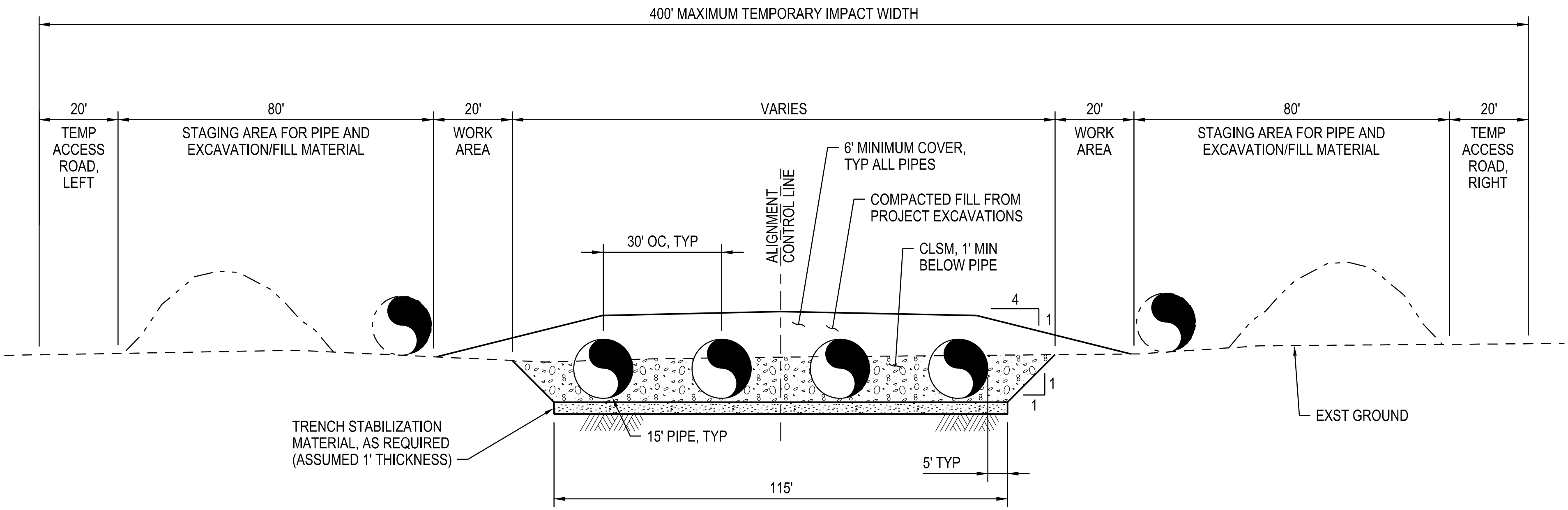

FIGURE 9:
TYPICAL CONSTRUCTION CONDITION FOR AQUEDUCT INSTALLATION - BRPP TO BETHANY RESERVOIR

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In specific reaches, the available work area would extend beyond the 400-foot width. Specifically, between the BRPP and the second crossing of the BBID canal (approximate STA 185+00), the work area west and north of the aqueduct will extend to Mountain House Road and to the BBID canal to provide space for batch plants and other contractor facilities and to utilize space otherwise isolated between the canal and the pipeline construction work. It is generally expected that this additional width would be used for soil stockpiles as part of the overall management of excavated materials for the Bethany Alignment. For additional information, see CER Appendix C6 *Reusable Tunnel Material* and Section 3.1.1.7 below.

Between the BBID Canal and the existing powerline (approximate stations 185+00 to 200+00), the work area would be reduced as much as possible to help avoid impacts to vernal pools and wetlands. It is expected that about 80-100 feet of work area width reduction could be achieved in this area. The actual amount depends on the actual limits of the vernal pools and wetlands and final pipeline profile. The work area reduction is not shown on the engineering concept drawings, but would be defined during design.

3.1.1.2 Logistics within Pipeline Construction Corridor

As described in Section 3.1.1.1, a portion of the construction corridor would be allocated to vehicle travel and equipment transport on each side of the trench for most of the length of the BRPP to Bethany Reservoir reach. At crossings of the two BBID canals, the Jones Penstocks, and the existing petroleum line, temporary bridges would be installed near the edge of the temporary LOD in general alignment with these temporary access roads on both sides of the trench.

Additionally, as the pipelines are advanced and backfilled and the permanent patrol road (see Section 2.1.2) is constructed on top of the trench, it would provide a secondary means for travel within the corridor. Bridges would be constructed to support the permanent access road at most of the same locations where bridges would be required during construction.

3.1.1.3 Main Contractor's Yard

The contractor's main yard for aqueduct construction would be located at the southwest corner of the intersection of Kelso Road and Mountain House Road (see Figure 2). This parcel of land is relatively flat and wouldn't require significant grading for this purpose. It is anticipated that a yard of about 5 acres would be established to provide space for construction trailers, employee parking, maintenance shop, tool and equipment storage, fuel storage and containment, water tanks, and miscellaneous material storage. Most of the pipe and backfill material for aqueduct construction would be stored at other locations (see Sections 3.1.1.1 and 3.1.1.4).

3.1.1.4 CLSM Processing Area

Aqueduct construction would require from 160,000 to 330,000 cubic yards of CLSM backfill. A CLSM processing area would be established at the approximate mid-point of the aqueduct, in a roughly 13-acre triangular area bounded by two BBID canals and the aqueduct alignment (see Figure 2). The area would include two CLSM batch plants that will mix soils excavated from the pipeline trench with cement, fly ash (potentially), and water to generate CLSM. Other facilities at this site would include offices, a soils storage area, cement/fly ash storage silos, water tanks, a steel building for miscellaneous material storage, an area for conveying and loading equipment, and parking spaces for Redi-Mix trucks and employees. The area is relatively flat and would not require significant grading.

3.1.1.5 Drainage

Construction work in the aqueduct corridor and the associated trench, work areas, staging areas, access roads, and Contractor's yard would in some locations affect local drainage patterns for stormwater. The

Contractor would be required to preserve natural drainage paths through and across the site as needed. Specific drainage features, including culverts and ditches, would be developed during final design to preserve drain flow across the top of the backfilled aqueduct. Construction contractors would be required to collect, treat, and discharge stormwater on the work areas in accordance with an approved Stormwater Pollution Protection Plan (SWPPP) and construction phase permits.

3.1.1.6 Special Measures at Special Crossings

Open-trenched crossings of BBID canals, the petroleum lines, roads, and powerlines would require special design and construction measures, including support and safety systems to protect the existing facilities and workers during construction and operations.

It is anticipated that the BBID canals would be crossed outside the irrigation season and pipelines would be concrete encased beneath the canals. Working outside the irrigation season would allow the canals to be disturbed and replaced in kind, possibly with canal lining improvements and possibly requiring bypass pumping from small off-season flows in the canal. Details of BBID canal crossings are subject to coordination with BBID and would require additional design development during the design phase.

The petroleum lines would need to be kept in continuous service and would be carefully supported and protected in-place throughout aqueduct construction. Details of the petroleum line crossings are subject to coordination with the utility owner and would require additional design development during the design phase.

Road crossings would take several days to weeks each and would require temporary bypasses for traffic, traffic control, and potential restrictions on work hours. Details of road crossings are subject to coordination with the county, conformance with associate permits. and would require additional design development during the design phase.

Work under powerlines would require excavation offsets from tower foundations and special grounding of pipe and equipment. Details of powerline crossings are subject to coordination with the utility owner and would require additional design development during the design phase.

3.1.1.7 Excavation and Soil Handling

Material excavated from the pipeline trench would have four possible temporary destinations:

- Sidecast to the staging areas adjacent to the trench, as shown on Figure 10, for later reuse as backfill
- Transported to the CLSM processing area for use in generating CLSM for backfill
- Transported to other stockpile areas for temporary or permanent storage

Most of the excavated material would be reused either as part of CLSM backfill along the pipelines, or as part of mounding and patrol road backfill over the pipelines. It is expected that only 10-20 percent of the excavated material would remain to be hauled to stockpile areas for other Project uses or permanent storage.

Additional information and more comprehensive discussion about soil handling is provided in the CER Appendix C6.

3.1.1.8 Dewatering

Prior to pipeline installation, portions of the excavated trench may need to be dewatered to allow for proper placement of bedding and backfill materials. At this conceptual stage of design, little information is available as to the existing groundwater table or the volume of water that would be involved, so the type of dewatering system to be used along the aqueduct corridor would need to be evaluated during final design. However, it is expected that pipeline construction would use sumping for shallower trench's and well points and sumping for deeper trenches (typically at the crossings).

Water removed from the trench by sumping would be pumped to the surface, treated, and either reused for construction water needs or land applied within the aqueduct construction area (subject to applicable permits). Water collected in well points could also be used for dust mitigation, CLSM production, or (if permitted) discharged to BBID canals nearby.

3.1.1.9 Pipe Delivery, Staging, and Installation

As shown in Figure 9, it is anticipated that individual pieces of pipe (about 30-40 feet in length) would be delivered directly from the plant to the aqueduct corridor, cradled, and strung out adjacent to the trench. From there, they would be lifted directly into the trench by large cranes in the work area between the pipe and trench. It is anticipated that during a typical workday, up to about four pieces could be installed and welded. This means that for a four-pipe trench, the aqueduct would advance by one piece of pipe (about 30-40 feet) per day. Other activities, including the excavation and backfill, would be expected to advance at about the same rate, before and after pipe installation.

Installation of pipe inside tunneled segments is covered in Section 3.1.2.

3.1.1.10 Leakage Testing

Since the pipelines are planned as welded joint welded steel pipe, no leakage would be allowed from the completed pipeline system. All pipe (including pipe installed by open cut methods or installed in the aqueduct tunnels) would be pressure tested at a pressure about 25 percent greater than the maximum operational working pressure. No leakage would be allowed. Note that such a requirement is common in the industry and readily achievable.

3.1.2 Aqueduct Tunnel Construction

Tunnels will be required for installation of the aqueduct under the Jones Penstocks and under the Bethany Reservoir Conservation Easement, as described in Section 2.1.3. These reaches total just over 3,000 feet, and each parallel pipeline would have its own separate tunnel, meaning that a total of about 12,000 feet of tunnel would be excavated.

3.1.2.1 Tunneling Contractor's Temporary Facilities

For each tunnel reach, 4-5 acre temporary yards would be established at the portal areas for the tunneling contractor's mobile cranes, shops and offices, parking, material laydown and erection areas, equipment staging, tunnel ventilation system housing, temporary electrical substation, portable sanitary facilities, and storage for topsoil stripping. The area at the Jones Penstock tunnel site is relatively flat adjacent to the excavated portal area and wouldn't require significant grading for these purposes (see Figure 10). The area adjacent to the portal excavation for the Conservation Easement tunnel is on a hillside and would need significant grading (mostly excavation, see Figure 11). It is anticipated that the temporary yard graded for the Conservation Easement portal would be left in the "as graded" condition upon completion of the work and not backfilled to original grade. Some sculpted backfills could be placed for aesthetic reasons, if desired.

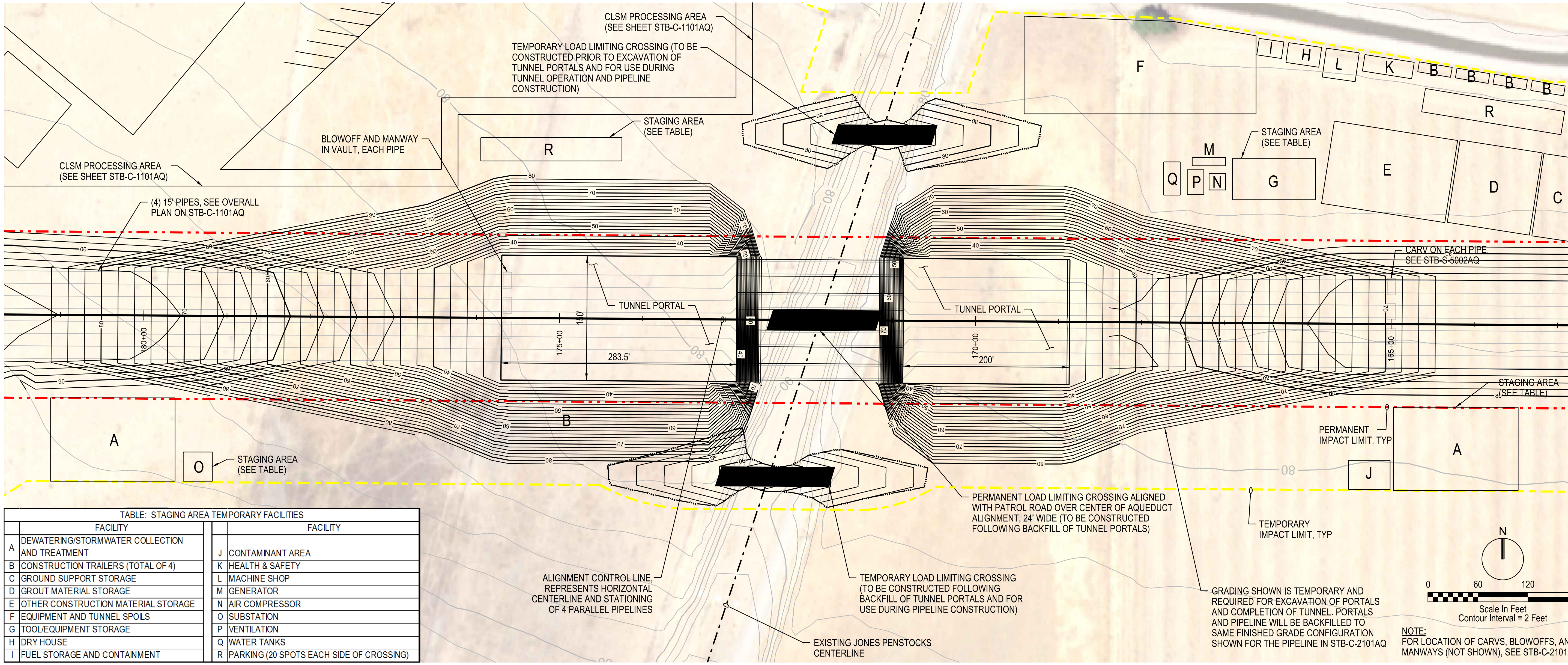

TABLE: STAGING AREA TEMPORARY FACILITIES

	FACILITY		FACILITY
A	DEWATERING/STORMWATER COLLECTION AND TREATMENT	J	CONTAMINANT AREA
B	CONSTRUCTION TRAILERS (TOTAL OF 4)	K	HEALTH & SAFETY
C	GROUND SUPPORT STORAGE	L	MACHINE SHOP
D	GROUT MATERIAL STORAGE	M	GENERATOR
E	OTHER CONSTRUCTION MATERIAL STORAGE	N	AIR COMPRESSOR
F	EQUIPMENT AND TUNNEL SPOILS	O	SUBSTATION
G	TOOL/EQUIPMENT STORAGE	P	VENTILATION
H	DRY HOUSE	Q	WATER TANKS
I	FUEL STORAGE AND CONTAINMENT	R	PARKING (20 SPOTS EACH SIDE OF CROSSING)

FIGURE 10:
JONES PENSTOCK TUNNEL PORTAL AND TEMPORARY FACILITY YARD

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TABLE: STAGING AREA TEMPORARY FACILITIES	
	FACILITY
A	DEWATERING/STORMWATER COLLECTION AND TREATMENT
B	CONSTRUCTION TRAILERS
C	GROUND SUPPORT STORAGE
D	GROUT MATERIAL STORAGE
E	OTHER CONSTRUCTION MATERIAL STORAGE
F	EQUIPMENT AND TUNNEL SPOILS
G	TOOL/EQUIPMENT STORAGE
H	DRY HOUSE
I	FUEL STORAGE AND CONTAINMENT
J	CONTAMINANT AREA
K	HEALTH & SAFETY
L	MACHINE SHOP
M	GENERATOR
N	AIR COMPRESSOR
O	SUBSTATION
P	VENTILATION
Q	WATER TANKS
R	PARKING

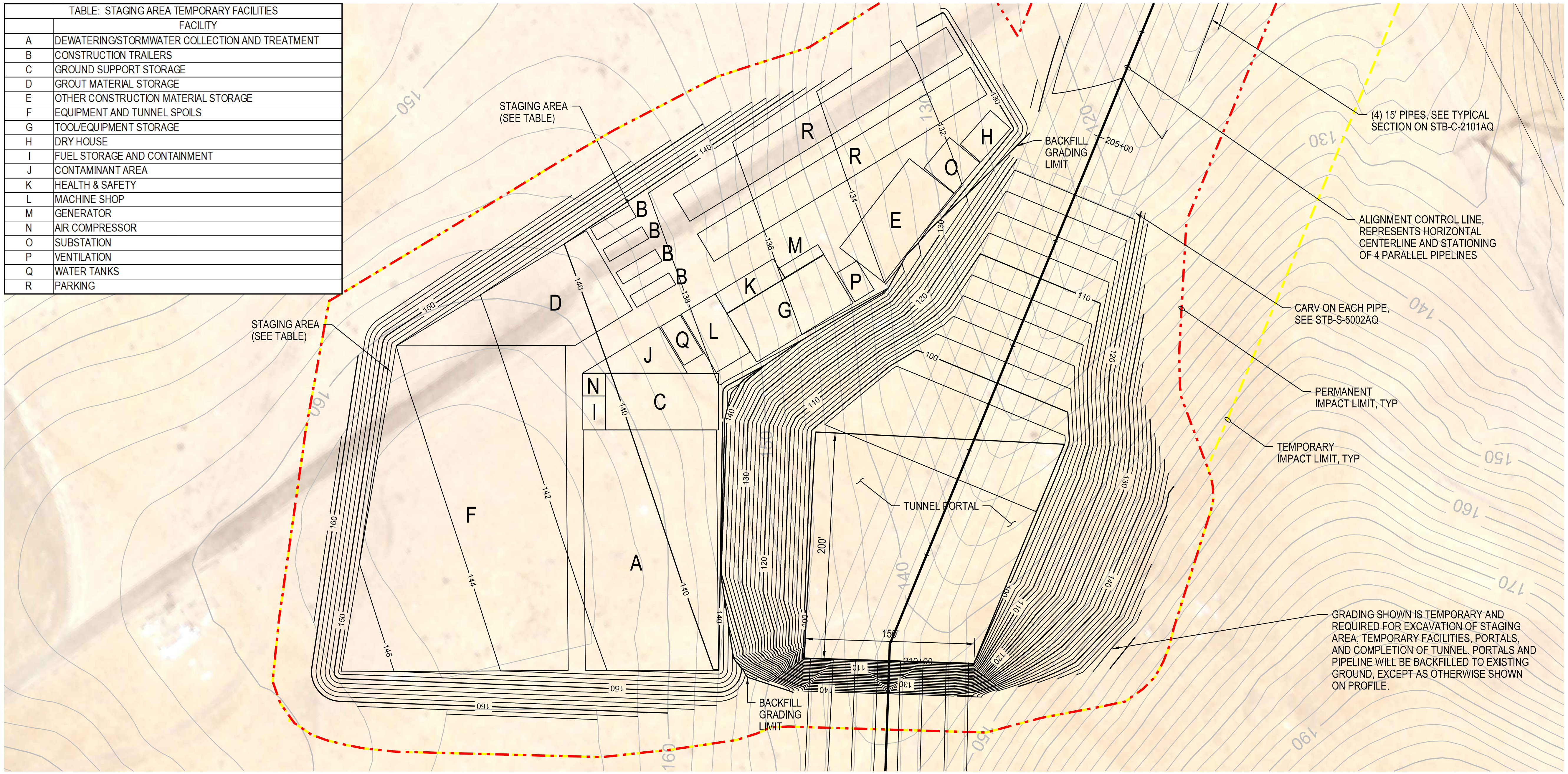

FIGURE 11:
CONSERVATION EASEMENT TUNNEL LAUNCH PORTAL AND TEMPORARY FACILITY YARD

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3.1.2.2 Portals – Excavation and Soil Handling

At each tunnel, a temporary portal would be excavated to create a work area for the tunneling equipment. Portals would be about 200 feet long, 150 feet wide, and 25 to 40 feet deep. The 150-foot width for the four-tunnel option would be reduced for three- and two-tunnel options.

Material removed from the portals would be placed in nearby temporary stockpiles (in staging and pipeline alignment areas) if it is required to backfill the portal and pipe trench area. Excess excavated material that would not be replaced in the areas would be hauled to the permanent stockpile areas.

Material removed from the tunnels would be combined with portal material and handled as part of the overall soil handling strategy described above and in CER Appendix C6.

3.1.2.3 Tunnel Sequencing Relative to Connected Work Sequencing

Excavation of the portals and tunnels would be expected to be completed well in advance of nearby open-trench pipeline construction, and as such would be among the first work activities initiated for the aqueduct system. This sequencing supports continuous installation and testing of the steel pipe with delays for portions of the work. The excavation of the 55-foot diameter shafts at the Bethany Reservoir Discharge Structure would be initiated at the same time. These shafts could be completed before the Conservation Easement tunnels are completed, or alternatively the tunnels could be completed first.

3.1.2.4 Tunnel Pipeline Installation

It is anticipated that after the tunnels are completed, individual pipe pieces would be transported into position within the tunnel utilizing a specialized pipe carrier. Then the pipe would be supported in place and welded to the adjacent piece of pipe. Following leakage testing (see Section 3.1.1.10) and appropriate blocking to prevent floatation, the annular space between the tunnel wall and the pipe would be filled with grout (LDCC). Then, pieces pipe would be installed on the portal floor on each side of the tunnel, welded, and backfilled similar to open cut pipe including restoring the portal areas to original and required grades, as applicable.

3.1.2.5 Considerations for Tunneling under the Jones Penstocks

The tunnel underneath the Jones Penstocks could be constructed in alluvial soils, which may be highly permeable and have a high groundwater inflow potential. The tunnel is considered too short to use a TBM; however, based on the expected ground conditions, a digger shield with an excavator arm mounted inside would appear to be the most suitable excavation method. Digger shields are used mainly to excavate soft ground tunnels with short lengths. To support unstable portions of the face, digger shields can be outfitted with breast tables or breasting doors to provide face support while continuing excavation in other areas of the face. The breasting typically consists of several hydraulically actuated doors or louvers that are pushed into the face. As with all tunnel shields, the shield is advanced forward by pushing off an initial support system consisting of segmental lining or steel ribs and lagging. The initial support is assembled in the tail of the shield. Pre-excavation ground modification (including but not limited to dewatering and/or permeation grouting) would also likely be needed to improve the stability of the ground along the alignment of the new tunnel. Such ground modifications in advance of the tunneling would also reduce the water inflow rates at the tunnel face.

3.1.2.6 Considerations for Tunneling under the Conservation Easement

A construction portal would be used on the north end of the Conservation Easement Tunnel for access to complete the following tasks:

- Excavate the tunnels.
- Remove the excavated material from the tunnel.
- Provide ventilation.
- Install the tunnel temporary support
- Install the final welded steel pipe and grout the annulus.
- Provide access for work crews during construction and maintenance crews during operations.

a minimum tunnel spacing of one tunnel diameter would be maintained between each of the tunnels at the portal locations. It is well understood that as the distance from the tunnel opening increases, the influence of the opening upon the stresses in the rock decreases. Based on basic rock mechanic principles at r =3a (where a = radius, r = distance to stresses at a point) the ratio of induced to applied stress is very close to unity (Hoek, 1980). This means that one tunnel diameter spacing is large enough to allow adequate clearance so that stresses generated by the first tunnel excavation would not affect the structural stability of the adjacent tunnel.

The one tunnel diameter spacing also allows adequate room at the portal to allow equipment access without creating conflicts and enables concurrent tunnel excavation sequences to reduce the potential likelihood of any construction impacts from occurring. At the southern end of the tunnel alignments the spacing between the tunnels increases to 50 feet at the connection to the Bethany Discharge Structure shafts to accommodate conservative riser shaft dimensions. The spacing of the tunnels could be refined in future design phases, if needed, once additional geotechnical information becomes available and the riser shaft design is further developed. Tunnel Excavation and Initial Ground Support Methods

The tunnels underneath the conservation area would encounter highly variable ground conditions, ranging from recent alluvial deposits to sedimentary rocks consisting of interbedded shales, sandstones, and siltstones with occasional hard calcareous boulder concretions within the sandstone beds. It is expected that majority of the alignment would be excavated beneath the groundwater table, and groundwater pressures would be expected to increase for the last 500 feet of the tunnel excavation due to proximity to the reservoir.

Several tunnel excavation methods are feasible to excavate the tunnels underneath the conservation easement:

- A crawler-mounted roadheader could be used to excavate the tunnels in weak to moderately strong rocks. The advantages of roadheader include flexibility to adjust to variable ground support requirements and good access to the tunnel face for installation of initial support. Roadheaders also provide the ability to increase the tunnel section in localized areas where heavier supports are needed. Roadheaders are generally a very economical method for excavating sedimentary rock and have been used on another nearby project in similar ground conditions.

- A TBM is feasible; however, the short lengths of each tunnel, the variability of ground conditions and the logistical challenges associated with retrieving the TBM at the end of each drive and relaunching the TBM make it unlikely that a TBM would be considered as a preferred excavation method. Depending on the ground conditions, a larger-diameter starter tunnel could be needed for the first few hundred feet of tunnel before the TBMs would be launched. Alternatively, if the ground conditions are favorable, the TBM could be launched from the portal with the trailing gear attached for a more efficient operation.

- Drill-and -blast excavation methods are considered feasible for the portion of tunnels excavated in the sedimentary deposits. Drill-and-blast methods would require controlled, smooth-wall blasting techniques to minimize overbreak and prevent excessive loosening, damage, or deterioration of the rock mass bordering the excavation. However, due to the rock formation's low compressive strength, mechanized excavation methods should be used in lieu of blasting methods to the greatest extent practicable so that higher production rates can be achieved under safer working conditions.

Rock reinforcement is considered to be a feasible and cost-effective initial support method for tunnel excavation in the sedimentary rock, except where weathered or highly fractured rock is encountered. In weathered rock or highly fractured rock, sections of the tunnel steel ribs (or lattice girders) and shotcrete would be needed for initial support. Face support measures could also be necessary in the weaker ground. Depending on the excavation method used, examples of face support could include breasting tables or plates, forepoling, and shotcrete with or without fiberglass rock dowels. Similar to the Jones Penstock tunnel crossing, ground improvements would also be needed in certain sections to improve the tunnel's stability.

Within 200 feet of areas that are likely to contain high accumulations of water, probe holes would be drilled and maintained so at least 20 feet of tested ground would remain in place beyond the face at all times in accordance with California Division of Occupational Safety and Health (Cal OSHA) Tunnel Safety Orders (CCR 2018). To reduce and control water inflows into the tunnel excavation, one or two probe holes could be continuously drilled ahead of the face and pre-excavation grouting would be performed only when a specified water inflow criterion was exceeded. Probe holes are typically drilled 120 feet ahead of the tunnel face at a 45-degree angle relative to the face, to intersect potentially water-producing features that could trend parallel to the tunnel axis. If a predetermined water inflow criteria were exceeded, additional grout holes would be drilled to initiate grouting operations. Once the water inflow criteria were satisfied, tunnel excavation could resume for no more than 100 feet and repeat the probing and grouting cycle.

3.2 Bethany Reservoir Discharge Structure

3.2.1 Sequencing of the Work

Due to the terrain, limited space, and multiple phases and types of construction work, the Bethany Reservoir Discharge Structure would be a congested construction site requiring compact work areas and efficient supply logistics. The sequence of construction is anticipated to be as follows:

- Initial grading of the site and shoring near tunnel outlet shafts
- Setting up shaft contractor's temporary facilities
- Pre-excavation grouting and/or curtain grouting at the shafts.
- Excavating the shafts
- Completion of tunnels under Conservation Easement into the shafts
- Placement of pipe inside tunnel
- Installing and backfilling pipe and fittings in the shafts
- Cofferdamming and dewatering (would be concurrent to work above such that this activity is complete about the same time as backfilling the pipe in the shafts)

- Conducting grouting in the rock matrix beneath the site to minimize water inflow into the excavation from Bethany Reservoir
- Additional excavation and grading between shafts and reservoir (now protected by a cofferdam)
- Forming and pouring the structure
- Installing gates and other features
- Placing riprap
- Backfilling the structure
- Complete electrical/mechanical/SCADA work
- Commissioning and demobilizing

These steps would not in all cases run as “finish-to-start”, because the site would be large enough to allow (for example) grading work to continue in some other areas while the shafts are being excavated. Further, it is expected that the work will involve two to four separate and distinct construction crews (and possibly separate contractors) that specialize in earthwork, shaft excavation, cofferdamming/in-water work, and structure construction. The subsections below (3.2.1.1. through 3.2.1.10) provide additional discussion of construction considerations and anticipated methodology.

3.2.1.1 Initial Grading of the Site and Shoring Near Shafts

The terrain associated with this structure varies considerably in elevation and would require significant grading to create workspace for excavating the shafts, forming and pouring concrete, and establish the contractor’s yard. This grading would need to accommodate a 10-foot wide buffer left between the conservation easement and site disturbance. However, it is anticipated that only portions of the grading needed to develop the work area and begin shaft excavation would be completed initially. Because the shaft pad and the overall structure would be 25-30 feet below reservoir level, it is assumed that most of the ground adjacent to the reservoir would be left unchanged to serve as a “plug” during the 12-18 months of shaft excavation.

The finished floor of the structure itself would be at elevation 227.0. Accounting for the thickness of the slab, the area would need to be excavated down to elevations ranging from 217 to 222, whereas the terrain varies from elevation 250 to over 300 feet. Because of the nearby conservation easement and buffer noted above, the excavation could not be sloped or laid back for portions of the site. The eastern edge of the structure, adjacent to the shafts, and particularly the southeast corner, would need to be shored to address roughly half of this vertical difference. Above elevation 260, the slope could be laid back at 1.5:1 or 2:1 while still providing the required buffer. This sloped area would be a permanent feature, as shown in Figure 7. Other portions of the structure’s perimeter would have finished walls roughly at existing grade, so the initial grading for this deep excavation would be backfilled against these walls.

Note that geotechnical information at this site had not been collected prior to the preparation of this TM. As such, it may be possible that the presence of rock could simplify shoring and slope requirements.

The area allocated for the contractor’s yard is similarly on uneven terrain and would require significant grading to create an area for the facilities to be described in the next section. This would include cutting a sidehill road to provide more than one means of ingress/egress into this long and narrow area. It is anticipated that this grading work (as shown in Figure 12) would be left generally as shown and not regraded to original conditions. Some sculpted backfills could be placed for aesthetic reasons, if desired.

FIGURE 12:
TYPICAL CONSTRUCTION CONDITION FOR AQUEDUCT INSTALLATION - BRPP TO BETHANY RESERVOIR

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3.2.1.2 Contractor's Temporary Facilities

As described in Section 3.2.1, the site would likely require multiple contractors (or subcontractors) with multiple specialties. It is expected that after initial grading work and shoring the hillside on the east/southeast edge of the structure, the primary activity onsite would be excavation of the 55-foot diameter shafts. This work would be expected to take 1 to 1.5 years to complete, during which time the shaft contractor would occupy most/all of the area allocated for temporary facilities, including:

- Offices
- Health and safety and quality building
- Equipment storage buildings (including ventilation equipment storage)
- Shaft ventilation fan housing
- Maintenance shops
- Grout material storage
- Ground support storage
- Shaft spoils storage
- Water tank
- Air compressor
- Standby engine generator
- Vehicle parking
- Electrical substation

Following completion of the shafts and the shaft contractor leaves the site, the area allocated for temporary facilities would likely be re-purposed for materials and equipment associated with additional earthwork, cofferdamming, and concrete structures. Some of the facilities brought in by the shaft contractor could remain, and the site would be expected to include the following:

- Offices
- Dry house
- Health and safety and quality building
- Construction material storage
- Excavated material temporary storage/staging
- General tool equipment storage
- Fuel storage and containment
- Concrete washdown
- Contaminant area
- Water treatment/discharge facilities
- Construction and dust suppression water storage
- Air Compressor
- Vehicle parking
- Electrical substation

3.2.1.3 Excavating the Shafts

The four shafts (Project design capacity of 6,000-cfs) located at the Bethany Reservoir Discharge Structure would have an excavated diameter of approximately 55 feet and a depth of approximately 115 feet. Each shaft would intersect a 20-foot-diameter (horseshoe shaped) tunnel that would cross beneath the Conservation Easement, as described in Section 4.2. The shafts would connect to the base of the Reservoir Discharge Structure that would be constructed after the shafts were completed.

This excavation would be against the hillside at the back of the structure and could be protected by a cofferdam placed in the reservoir to form a work area from which to construct the shafts. The upper portion of the shaft would be excavated in recent alluvium consisting of fat clay and sandy clay with lenses of sand and gravel. Beneath the alluvium, the shaft excavation would encounter sedimentary rock deposits consisting of shale and sandstones with varying degrees of weathering. The groundwater table could be high due to the proximity of the Bethany Reservoir, which could result in groundwater heads of approximately 100 feet at the shaft invert.

Key issues in the selection of shaft excavation and support methods include the shaft depth, stability of the soil/rock formation, and groundwater level. Feasible shaft excavation methods could include roadheader/backhoe, drill-and-blast, and slurry diaphragm wall excavation with hydro-mill.

Based on limited geotechnical information, in poorer ground conditions the shaft excavation could be supported using steel ring beams with either liner plates, shotcrete, or timber lagging. Where the rock was less weathered and fractured, rock reinforcement consisting of pattern bolting and reinforced shotcrete could be used. Using a roadheader/backhoe combination appears to be the most feasible excavation method for the expected ground conditions. The excavation method and support of the shaft would be confirmed in the future once results from the geotechnical exploration program became available.

Given the proximity of the shafts to the reservoir, there is the potential for large water inflows if open joints are present within the rock mass. To minimize the potential for large water inflows, pre-excavation grouting and/or curtain grouting could be performed at the shaft. Such grouting programs are conducted from the surface at the periphery of the shaft prior to shaft excavation.

It is anticipated that the shafts would be excavated with roadheader equipment. Vertical shafts would be excavated to a bottom elevation of 115.0, a total depth of about 112 feet with a finished surface elevation of about 227.0. However, because the ground would be graded to a surface of about 217 to account for slab thickness, the actual shaft depth to achieve with the roadheader would be about 102 feet. The material removed could be placed temporarily at the nearby facilities yard, or hauled directly to the stockpile areas described in the CER Appendix C6.

3.2.1.4 Completion of Tunnels under Conservation Easement and Placement of Pipe inside Tunnel

As described in Section 3.1.2.4, the tunnels under the Conservation Easement could be completed before or after the shafts have been excavated. Following completion of the shafts and the tunnels, the pipeline through the tunnels would be installed, welded, and leakage tested. Grouting of the annular space could be completed to within a short distance of the shafts, or postponed until the pipelines are placed and welded within the shafts.

3.2.1.5 Installation and Backfill of Pipe in the Shafts

The 180-inch diameter 90-degree bends would be lowered into the shafts and welded to the pipelines at or near the ends of the tunnels. A robust temporary system would need to be designed and installed by the Contractor to install the bend and support them during welding, and during installation of the adjoining straight 180-inch diameter pipe segments running up to the top of the shafts. Once the bends and straight segments are installed and welded, leakage testing would be completed and then the annular space would be filled with concrete (near the bottom) and CLSM. This CLSM would form the subgrade for portions of the main structure slab, and for parts of each counterfort on the high back wall of the structure.

3.2.1.6 Cofferdamming and Dewatering

With shaft work complete and construction shifting to the large concrete structure, the next step would be to construct a cofferdam in Bethany Reservoir. All of the concrete work would be on shore, but portions would be 25 to 30 feet below the reservoir's water surface. Riprap designated to be placed beyond the end of the structure would also be in an otherwise-inundated area. For both these reasons, a cofferdam would be needed to isolate the work from the reservoir and provide a dry work area.

It is envisioned that the cofferdam would consist of sheet piles attached to a series of drilled piles and walers. Circular piles would be drilled into the lake bottom on a predetermined spacing. Sheet piles would then be installed between the circular piles. To minimize vibration at this site within 200-300 feet of a section of dam forming the reservoir bank, the sheet pile would likely not be driven, but rather vibrated into place or pre-excavated into soft rock and backfilled with tremie concrete to help form a water seal at the bottom. Supports would be installed on the dry side of the cofferdam and supported against the lake bottom. The cofferdam and all components would be removed at the completion of the work. If portions of the cofferdam cannot be pulled up from the lake bottom, they would be cut off below grade by divers and any remaining portions covered with small riprap material.

Up to 50 feet beyond the cofferdam (further into the reservoir), a silt curtain would be installed to help contain turbidity from construction activity. The silt curtain would be anchored on the shore and held in place within the reservoir by temporary anchor weights.

On the dry side of the cofferdam, a dewatering system of trenches, pumps, and well points would be required to capture leakage and/or water "subbing" up through the reservoir bottom material and pipe it to shore for treatment and discharge back to the reservoir outside the silt curtain.

3.2.1.7 Additional Excavation and Grading

With the cofferdam and dewatering facilities in place, the remainder of the excavation could occur between the shafts and the edge of the reservoir. Portions of the material removed from the site would be retained in the nearby construction yard for later backfilling, but the remainder would be hauled directly to the stockpile areas described in a separate TM, CER Appendix C6.

It is anticipated that portions of the deep excavation not bounded by the Conservation Easement would be sloped back rather than shored. However, the contractor's access to various parts of the site could be changed and would be developed further during design.

3.2.1.8 Forming and Pouring the Structure

The structure would involve placement of up to 29,000 cubic yards of concrete. The structure would be relatively complex because of its shape and combination of multiple slab thickness, interior and exterior walls, counterforts on three sides, piers, stoplog slots, gate features, and bridge decking.

3.2.1.9 Riprap

Riprap as described above would be placed in the area between the end of the structure and the cofferdam. This would be a relatively simple operation on a combination of flat, excavated ground and the sloping reservoir bed. Generally, the riprap would be placed on top of existing grade except for a transition area at the end of the structure. It would also be keyed into the native material at the toe along the cofferdam. The size of the rip rap would be determined during the design phase of the Project.

3.2.1.10 Backfill and Demobilization

After placing the riprap and adequate time to cure the concrete, the structure would be backfilled, and the dewatering systems would be removed. At that time, the cofferdam and silt curtain would be removed from the reservoir. The piles and walers would be disassembled and it is expected that most of the structure could be removed with ease, but portions drilled and tremied into the reservoir bed may need to be cut off just below the original ground surface using divers.

3.2.2 Logistics

The terrain would make access around the site during construction challenging in some areas. The large and deep excavation for the structure, the Conservation Easement, and Bethany Reservoir would limit available space for roads and entry points for materials and equipment. Access to the site for most construction loads and deliveries would be from the south along a new access road to the reservoir starting on Mountain House Road south of the Conservation Easement. The existing California Aqueduct Bikeway would be widened for construction traffic from a location near the south end of the reservoir up to the structure site. Smaller vehicle access could also access the site from the north via Christensen Road, through the fishing access park, and over one of the perimeter dams to the site.

Though not shown in Figures 7 and 12, the contractor would likely need to install temporary bridges, ramps, additional shoring, or other means for his access around and through the site. It is anticipated that the California Aqueduct Bikeway would be closed to public use throughout the work.

The long and narrow area allocated for the contractor’s temporary facilities could be accessed in two locations and would be directly connected to the construction site, but as described in Section 3.2.1.1, this area would be graded to make the area suitable for buildings and equipment. The contractor would therefore need to construct ramps and carefully plan the layout of facilities to make the best use of the space and optimize ingress and egress.

3.2.3 Temporary Limits of Disturbance (LOD)

The temporary LOD for the Bethany Reservoir Discharge Structure site are shown in Figure 12. Rather than being established based on a specific width or offset distance, they generally encompass the area needed to complete temporary and permanent grading, provide construction access to all areas, allocate space for temporary facilities, and enclose the silt curtain in the reservoir.

3.2.4 Drainage

Construction work for the discharge structure, and even for the contractor’s yard, would affect local drainage patterns for stormwater. The Contractor would be required to collect, treat, and discharge stormwater in accordance with an approved SWPPP and applicable permits. Finished site grading would allow existing drainage patterns to be maintained after construction.

4. Operation and Maintenance Requirements

4.1 System Operation

4.1.1 Filling

The aqueduct system would be filled by pumping from the BRPP into each aqueduct pipeline using a single pump at its lowest speed. Prior to filling, crews would need to ensure that all personnel and equipment are out of the pipe, all manways are closed, valves at blowoffs are closed, CARVs are open and functional, and gates at the Bethany Reservoir Discharge Structure are fully open.

During start up, the fluid velocity within the system should be limited to that generated by one pump at minimum flow (assumed to be about 250 cfs or 1.4 feet per second) while filling or until all air has been flushed out and the pressure brought up to operating conditions. At the beginning of filling, it is assumed that the water level at the discharging side of the BRPP pumps would be essentially at the wet well water level. Since the initial pumping head is low, control valves on the discharging pipes would be used to throttle the flow so the pumps could be operated within acceptable ranges.

4.1.2 Draining

Should the system need to be drained for maintenance or repairs in the aqueduct pipelines or portions of the BRPP, the following steps would need to be taken:

- Shut off the pumps at the BRPP.
- Close the radial gates at the Bethany Reservoir Discharge Structure (also install stoplogs on one or both side of the gates depending on whether work is needed inside the pipelines or on the gates or channels between the stoplogs).
- Operate dewatering flow control facility within the BRPP to allow water to be drained back into the pumping plant wet well.
- Open valves at blowoffs to allow sections of pipe that do not drain by gravity at the BRPP to be pumped out, as applicable. This step is not needed unless work is required at that location or movement of people or air is needed. To drain, drop in portable pumps at the blowoffs, and discharge the water to the nearest gravity-draining portion of the aqueduct through temporarily-opened manways (or, discharge to a nearby water course following permitted practices).

4.1.3 CARVs

The combination air and vacuum valves as described in Section 2.1.1 would work automatically to release accumulating air (from outlet orifices) and help mitigate surge and vacuum conditions (through inlet orifices). The isolation valves would be set in the open position. The CARVs are a duplex, fully-redundant design, so one valve could be removed for servicing. At least one valve would need to be in place and operable at all times.

4.1.4 Emergency Shutdown/Isolation (Discharge Structure)

Should a pipe break or other circumstance occur that requires an immediate aqueduct system shutdown, the radial gates at the Bethany Reservoir Discharge Structure would close. Some closures related to loss of pressure would be automatic, preventing the reservoir from draining back through aqueduct. Other closures could be initiated by the system operators from the applicable operations control center, the BRPP, or locally. The control system for the gates would be set such that if any pipeline shows an unexpected pressure drop, all gates for that pipeline would be signaled to close. It is expected that the gates would be fully closed within 5 to 20 minutes. Due to the critical control nature of this facility, a standby engine generator would be provided for backup power in case of a power outage.

4.2 System Maintenance

Elements of the aqueduct system would vary greatly in terms of the types and frequency of required maintenance. The primary elements requiring maintenance and brief descriptions of the maintenance actions are described below.

4.2.1 Pipelines

Corrosion protection for the pipelines will be provided by the cathodic impressed-current cathodic protection system with air-cooled or oil-cooled rectifiers as described in Section 2.1.1. Maintenance of the CP system would consist of the following:

- Inspect the electrical performance of rectifiers and sacrificial anodes or impressed current anode outputs. This typically is performed monthly.
- Make repairs as needed from monthly inspections.
- Corrosion test stations or test points (accessible aboveground appurtenances such as riser or accessible valve in vault), as well as, any aboveground anode junction boxes with anode wires are checked annually.

All data would be stored as a system of record for the life of the CP system. Inspections, troubleshooting and repairs would be performed by a corrosion engineer.

The pipeline's cement mortar lining would need to be inspected after about 1 year of operation and then every 2 to 3 years by accessing the pipeline though the manways. Visual inspections would typically be performed. Magnetic flux leakage (MFL) testing may be warranted as the system ages. Field repairs of any problem areas found would need to be made immediately to protect pipeline integrity.

Equipment at the CARV's and blowoffs would also need to be tested annually for proper function, leakage, or other operational issues. Valves would need to be exercised as part of this process.

4.2.2 Patrol Roads

Patrol roads along the aqueduct would need intermittent maintenance to maintain a good driving surface. Grading and recompaction of the gravel surface could be needed at least annually, and rutting and potholes from rain and runoff after larger storms could require intermittent or spot repairs several times each year.

4.2.3 Bethany Reservoir Discharge Structure

Maintenance activities at this structure would mostly consist of cleaning the channels of any accumulated debris or sediment, and cleaning, lubricating, and inspecting the radial gates including hoists and related mechanisms. Radial gate corrosion protection anodes would be inspected annually and replaced as needed. Work on the gate hoists could occur at any time since they would be above the water level, but work on the trunions or debris/sediment cleaning would require isolation of a given channel using the gates and stoplogs. Stoplogs would be stored on the site for use as needed. It is anticipated that when isolation is needed, a mobile crane would be brought to the site to lift the hatches (upstream row of stoplogs only) and install the stoplogs. The isolated bay(s) could then be pumped out for maintenance or repairs. The on-site standby engine generator would be tested for proper operation monthly.

Upstream of the stoplogs, in the section between the bridge and the vertical shafts, any given channel could only be dewatered for cleaning if the associated pipeline and pump back at the BPRR were shut off and partially drained. However, very little debris or sediment is expected to collect in these portions of the structure because of the constant flow of water and the relatively clean water source.

5. References

California Department of Water Resources (DWR). 2023. *Delta Conveyance Project Final Environmental Impact Report*. SCH# 2020010227. December 2023.