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GEOTECHNICAL ENGINEERING DESIGN MEMORANDUM

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From:	Andy Kositsky, GE
Subject:	Canyon Tunnel – Geotechnical Engineering Design
Project No.	1055-24-002/10
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DATE SIGNED 1-28-2025

INTRODUCTION

This Geotechnical Engineering Design Memorandum (Memo) presents geotechnical engineering discussion, conclusions, and design criteria by Provost & Pritchard Consulting Group (P&P) for the Canyon Tunnel Project. It presents discussion and conclusions on expected ground conditions at excavations for the tunnel, retaining walls, foundations and subgrades.

P&P's drawings show the proposed work. The Geologic Data Report (GDR) presents the data.

Note that the Geotechnical Baseline Report (GBR) is the contract document that defines ground and groundwater conditions at excavations. This Memo presents discussion to support the developed design criteria, and it is available to the contractors for information.

Note that portions of the structures at the intake are under jurisdiction of the California Division of Safety of Dams (DSOD).

GEOTECHNICAL ENGINEERING DISCUSSION, CONCLUSIONS AND DESIGN

P&P estimated ground conditions and developed design criteria for the following improvement areas:

- Boat ramp and landing at Goodwin Reservoir
- Intake (for the North Coffer Dam**,** shotcrete retaining walls supporting cuts, footing-supported/cast-in-place retaining walls supporting fill, dowels in ground for the concrete cap, the existing intake, excavations for/improvements for the intake, and the intake niche)
- Tunnel
- Outlet (for shotcrete retaining walls supporting cuts, cutslopes, and the flume)

This Memo references engineering unit designations defined in the GBR (Unit 0, Unit 1, etc.). P&P notes that for soil, we used the Unified Soil Classification System for classifications and commonly used consistency descriptions. P&P notes that the GBR contains geologic cross sections and profiles that show ground conditions described in this Memo.

P&P's analyses for developing design criteria involved rock mass rating analysis for shotcrete retaining walls (shotcrete walls), applying soil mechanics/rock mechanics/foundation engineering principles for foundations and retaining walls, applying the attached Geologic Strength Index (GSI) chart, reviewing/applying typical values, and applying our experience.

P&P developed site classes for seismic design for structures not under DSOD jurisdiction from our review and evaluation of GDR data. We developed seismic design criteria by determining site coordinates and using a computer tool for inputting site class and site coordinates. We also summarize our method for developing seismic design criteria for structures under DSOD jurisdiction.

P&P documents structural engineering and ground support design evaluations and calculations separately. The ground support design evaluations and calculations show the idealized subsurface profiles and phreatic surfaces that we modeled for analyses (based on our data evaluation) and the total stress ratios that we used for finite element analyses.

The subsections that follow present geotechnical engineering discussion, conclusions, and developed design criteria for each improvement area.

BOAT RAMP AND LANDING

P&P expects that the south ramp will be underlain by up to about 15 feet of fill (a fill slope). Subgrade preparation by design will consist of removing vegetation, loose rock clasts and blocks, and recent/soft sediment to an expected depth of up to 1.5 feet to expose dense/relatively incompressible ground. The Engineer shall verify the required depth and extent of overexcavation needed during construction, by design. P&P expects that the ground beneath the prepared subgrade at the upslope/south side will consist of up to about 11.5 feet of adequately dense/relatively incompressible existing fill over natural ground and that the downslope side will consist of natural ground. We expect that the existing fill consists of dense/relatively incompressible gravel to boulder-sized clasts of greenstone rock (originating from excavations in the Gopher Ridge formation). We expect that the natural ground consists of up to about 3 feet of dense/relatively incompressible sand with silt and gravel over greenstone rock of the Gopher Ridge formation. We expect that the top 3 feet (or less) of rock is highly weathered and that the rock beneath is moderately to less weathered. We expect that the groundwater level is near elevation 364.5 feet (at the Goodwin pool water surface elevation).

P&P expects that the north landing will be underlain by a prepared soil subgrade in an excavation over natural ground at the north/upslope side of the landing. We expect that the Contractor will need to overexcavate up to 1.5 feet to remove soft sediment to expose firm natural ground and backfill the overexcavations, by design. Therefore, the subgrade will consist of either prepared/compacted natural ground or up to 1.5 feet of compacted engineered fill over natural ground. We expect that the natural ground will mostly be slightly weathered to fresh Gopher Ridge rock (Unit 2). We expect that the overexcavation backfill material will consist of lean clay with sand and gravel generated from excavations in colluvium (after the Contractor removes cobbles and boulders from the excavated ground as required by design). We expect that the groundwater level is near elevation 364.5 feet (at the Goodwin pool water surface elevation). Note that the Engineer shall verify the required extent and depths of overexcavations during construction, by design.

P&P designed the ramp pavement as 8 inches of reinforced concrete over 6 inches of compacted Class 2 aggregate base (AB). Based on our experience and considering the expected ground conditions beneath the ramp subgrade, we conclude that such pavement is adequate for the expected ramp service life and occasional traffic by equipment and vehicles that the Owner transports on boats.

INTAKE

P&P expects that the cutslope for intake access, to be supported with a shotcrete shoring wall, will expose colluvium (Unit 0) over rock and that the contact between the colluvium and the rock will occur within about 5 feet of the bottom of the excavation. We expect that the colluvium will consist of very stiff to hard lean clay with fine sand, with coarse and rounded to subangular gravel, and with cobble to boulders up to 18 inches in size. We expect that the rock will consist of pyroclastic rock of the Mehrten Formation (Unit 4).

P&P expects that excavations for the footing supporting the retaining wall along the outslope side of the intake access road will encounter weathered rock of the Gopher Ridge Formation (Unit 1). We expect that the compacted engineered fill that the wall will retain will consist of lean clay with sand and gravel generated from excavations in colluvium (after the Contractor removes cobbles and boulders from the excavated ground).

P&P expects that slightly weathered to fresh rock of the Gopher Ridge Formation (Unit 2) lies beneath the existing intake. We expect that the existing ground behind the existing intake retaining walls consists of up to about 5 feet of weathered rock of Unit 1 over slightly weathered to fresh rock of Unit 2.

P&P expects that the excavation between the existing retaining wall that the Contractor will demolish and the outslope end of the intake niche will encounter Mehrten pyroclastic rock (Unit 4) over weathered Gopher Ridge Rock (Unit 1) over slightly weathered to fresh Gopher Ridge Rock (Unit 2). We expect that the excavation from the outslope end of the intake niche to the intake niche headwall will encounter colluvium (Unit 0) with varying thickness over Mehrten pyroclastic rock (Unit 4) over weathered Gopher Ridge Rock (Unit 1) over slightly weathered to fresh Gopher Ridge Rock (Unit 2). We expect that the colluvium will consist of very stiff to hard lean clay with fine sand, coarse and rounded to subangular gravel, and cobble and boulders up to 18 inches in size.

P&P expects that soldier piles for the North Coffer Dam will extend through up to 5 feet of Unit 1 over Unit 2. We expect that the footings supporting the ends of the waler will be in Unit 1.

P&P expects that dowels that connect the intake concrete cap to the shotcrete liners/ground behind the liners will extend into Unit 4 and Unit 1.

P&P expects that fill behind tops of retaining walls that support the cushion layer over the concrete cap will consist of compacted lean clay with sand and gravel generated from excavations in colluvium (after the Contractor removes cobbles and boulders from the excavated ground).

P&P expects that the groundwater level occurs beneath the foundation level of the intake but that excavations may encounter seepage of groundwater originating from Goodwin pool (from leaks around the coffer dam). In addition, we expect that there may be minor seepage of perched groundwater originating from precipitation and minor groundwater in rock fractures originating from precipitation.

The following presents the geotechnical engineering design criteria that P&P developed for the intake improvements.

Seismic Design – 2022 California Building Code (CBC – not applicable to shotcrete shoring wall and structures under DSOD jurisdiction)

- Site Class = B (estimated)
- S_S = 0.406 g (where g is acceleration from gravity)
- S_1 = 0.199
- S_{MS} = 0.406
- S_{DS} = 0.271
- S_{D1} = 0.133

Seismic Design for Structures under DSOD Jurisdiction

P&P developed a short duration spectral response acceleration for calculating design seismic base shear for the intake by:

- Following DSOD site seismicity guidelines (Inspection and Reevaluation Protocols – 2019)
- Applying typical relationships between peak ground accelerations and short duration spectral response accelerations

P&P applied criteria for the “minimum earthquake” considering the site location is in the western slope of the Sierra Nevada Mountains/Central Valley – an area with “low seismic activity.” In addition, we applied criteria for a “high consequence” project.

Such guidelines call for 84-percent deterministic ground motion from a 6¼-magnitude-earthquake at a (iterated) distance from the site that causes a peak ground acceleration of 0.25 g at the site. We developed a value for S_{DS} (to calculate base shear according to the equivalent lateral force procedure of the CBC – for 5 percent damped) by applying a 2.5-amplification factor to the PGA (for short-period 5 percent damped spectral acceleration). We developed an S_{DS} value of 0.625 g accordingly.

Shotcrete Walls for North Landing and Intake

- Site Class = C
- Colluvium (Unit 0) and Weathered Gopher Ridge Rock (Unit 1)
  - Unit weight = 125 pcf
  - Internal friction angle = 32 degrees
  - Cohesion = 350 psf
  - Ultimate bond stress = 15 pounds per square inch (psi; maximum)
- Mehrten Pyroclastic Rock (Unit 4)
  - Unit weight = 120 pcf
  - Internal friction angle = 48 degrees
  - Cohesion = 3,000 psf

  - Ultimate bond stress = 150 psi (maximum)
- Moderately to Less Weathered Gopher Ridge Rock (Unit 2)
  - Unit weight = 175 pcf
  - Internal friction angle = 48 degrees
  - Cohesion = 3,000 psf
  - Ultimate bond stress = 150 psi (maximum)

<u>North Coffer Dam</u>

- Omit resistance from friction between the existing mat foundation and ground (conservative approach)
- Omit resistance from the weight of ground between the excavation line and the back of the existing retaining wall (conservative approach)
- System of piles, Unit 1 over Unit 2 ground, and existing retaining wall provides adequate arching between piles with spacing of 4 pile diameters – no other lagging needed
- Passive resistance for soldier piles along east/west-aligned segment (in Unit 2): 1,900 psf acting over 2 pile diameters
- Passive resistance for soldier piles along north/south-aligned segment (in Unit 1): 11,000 psf acting over 2 pile diameters
- Passive resistance for footings supporting ends of waler: 11,000 psf
  - Start passive resistance at a depth of at least 1 foot beneath the ground surface

<u>Lateral Earth Loads for Retaining Walls that Support Fill</u>

- Calculate using an equivalent fluid unit weight of 35 pcf (for unrestrained conditions and drained conditions with a subdrain by design)
- Added lateral earth pressure from traffic surcharge: 125 psf (uniform)
- Extend equivalent fluid unit weight and added lateral earth pressure from the retained ground surface to the bottom of the footing heel
- No seismic analyses needed – static conditions govern design considering the low acceleration potential and the low wall height

<u>Lateral Earth Loads for Retaining Walls that Support Existing Ground beneath the Concrete Cap</u>

- Calculate using an equivalent fluid unit weight of 40 pcf (for restrained conditions)
- Extend equivalent fluid unit weight from the retained ground surface to the bottom of the footing heel
- No seismic analyses needed – static conditions govern design considering the low acceleration potential and the low wall height

<u>Footing Supporting the Retaining Wall – Outslope Side of the North Landing</u>

- Depth of footing toe and heel: at least 12 inches below the lowest adjacent soil subgrade
- Allowable bearing capacity for dead plus normal duration live loads = 20,000 psf

  - P&P based this value on a safety factor of 2 and increased it by one-third for total loads
- Resistance to lateral loads
  - Base friction
    - Calculate using an ultimate base friction = 0.55
  - Passive resistance: calculate using equivalent fluid unit weight of 600 pcf
    - P&P reduced this value by a 1.5-factor from the estimated ultimate to reduce the footing movement required to fully mobilize passive resistance
    - Discount the passive resistance from the ground surface in-front of the footing to 6 inches beneath the ground surface
  - P&P calculated/combined base friction resistance and passive resistance using these values without reductions

<u>Existing Mat and New Mat for the Intake</u>

- Allowable bearing capacity for dead plus normal duration live loads = 60,000 psf
  - P&P based this value on a safety factor of 2 and increased it by one-third for total loads
- Subgrade reaction modulus
  - k_s (pounds per cubic inch – pci) = k1*(1+B/2L)/1.5/B
    - Where
      - k_1 = coefficient of subgrade reaction for a 1-foot-square plate = 30,000 pci
      - B = width of deflected mat in feet in the shorter dimension
      - L = length of deflected mat in feet in the longer direction
  - Iterate B and L (and the calculated ks value from iterated B and L values) until the iterated B and L are consistent with B and L yielded from analysis
- Resistance to lateral loads
  - Ultimate base friction = 0.55

<u>Laterally Loaded Dowels at Concrete Cap/Intake Niche Liner</u>

- Apply CBC equation 8-1 or 8-2 using a uniform passive resistance of 8,000 psf acting over 3 times the drillhole diameter (so apply the equations using b = drillhole diameter * 3 and $S_1 = S_3$ = 8,000 psf)
- This allowable passive resistance starts at the joint between the cast-in-place concrete wall and the shotcrete wall

TUNNEL

The GBR presents information on the expected ground conditions at tunnel excavations. P&P developed geotechnical engineering design criteria for our tunnel ground support analyses – finite element analyses using the Mohr-Coulomb/plastic constitutive model for soil and the generalized Hoek-Brown failure criterion (plastic)/generalized Hoek-Diederichs constitutive model for rock.

The following presents the criteria that we developed for ground support analyses.

Colluvium (Soil – Unit 0)

- Total unit weight = 125 pcf
- Poisson's ratio = 0.3
- Young's Modulus = 15,000 psi
- Peak tensile strength = 0
- Peak friction angle = 32 degrees
- Peak cohesion = 200 psf
- Residual friction angle = 30 degrees
- Residual cohesion = 200 psf
- Dilation angle = 0 degrees

Weathered Gopher Ridge rock (Unit 1)

- Total unit weight = 130 pcf
- Poisson's ratio = 0.25
- Intact uniaxial compressive strength = 1,500 psi
- GSI = 40
- Intact rock constant = 25
- Disturbance factor = 0
- Modulus ratio = 350
- Residual Mb = 0.5 (Mb)
- Residual S = 0
- Residual a = a
- Dilation = 0.15 (Residual Mb)

Slightly weathered to fresh Gopher Ridge rock (Unit 2)

- Total unit weight = 175 pcf
- Poisson's ratio = 0.25
- Intact uniaxial compressive strength = 10,000 psi
- GSI = 55
- Intact rock constant = 25
- Disturbance factor = 0
- Modulus ratio = 350
- Residual Mb = 1.5
- Residual S = 0

- Residual a = a
- Dilation = 0.3 Residual Mb

<u>Mehrten sandstone and conglomerate (Unit 3)</u>

- Total unit weight = 130 pcf
- Poisson's ratio = 0.25
- Intact uniaxial compressive strength = 400 psi
- GSI = 75
- Intact rock constant = 17
- Disturbance factor = 0
- Modulus ratio = 350
- Residual Mb = 1
- Residual S = 0
- Residual a = a
- Dilation = 0

<u>Mehrten pyroclastic rock (Unit 4)</u>

- Total unit weight = 120 pcf
- Poisson's ratio = 0.25
- Intact uniaxial compressive strength = 3,500 psi
- GSI = 80
- Intact rock constant = 17
- Disturbance factor = 0
- Modulus ratio = 350
- Residual Mb = 1
- Residual S = 0
- Residual a = a
- Dilation = 0

OUTLET

P&P expects that the excavation for the shotcrete wall at the tunnel portal will expose mostly natural soil and weathered Gopher Ridge rock (Unit 0 and Unit 1) over slightly weathered to fresh Gopher Ridge Rock (Unit 2). We expect that the excavation for the shotcrete wall along the southeast side of the portal access road (and the cutslope above the top of this wall) will mostly encounter Unit 2 material. P&P expects that minor groundwater occurs in this ground as perched water and minor groundwater in rock fractures that originates from precipitation.

P&P expects that the ground exposed at excavations for the flume (below the top of the flume) will mostly be weathered Gopher Ridge Rock (Unit 1) over slightly weathered to fresh Gopher

Ridge Rock (Unit 2). We expect that the exposed ground at the floor subgrade and ground encountered in drilled pile foundations will be Unit 2 material.

P&P expects that the groundwater table occurs beneath the bottoms of walls and the intake mat but that excavations may encounter minor perched groundwater originating from precipitation and minor groundwater in rock fractures originating from precipitation.

P&P developed the design criteria that follows:

Seismic Design – 2022 California Building Code

- Site Class = B (estimated)
- S_S = 0.42 g (where g is acceleration from gravity)
- S_1 = 0.202
- S_{MS} = 0.42
- S_{DS} = 0.28
- S_{D1} = 0.135

Shotcrete Walls

- Colluvium/weathered Gopher Ridge rock (Unit 0 and Unit 1)
  - Unit weight = 130 pcf
  - Internal friction angle = 28 degrees
  - Cohesion = 250 psf
  - Ultimate bond stress = 10 psi (maximum)

Finite Element Analysis

- Colluvium (Unit 0)
  - Total unit weight = 130 pcf
  - Poisson’s ratio = 0.3
  - Young’s Modulus = 10,000 psi
  - Peak tensile strength = 0
  - Peak friction angle = 30 degrees
  - Peak cohesion = 250 psf
  - Residual friction angle = 30 degrees
  - Residual cohesion = 250 psf
  - Dilation angle = 0 degrees
- Slightly weathered to fresh Gopher Ridge rock (Unit 2)
  - Total unit weight = 175 pcf
  - Poisson’s ratio = 0.2
  - Intact uniaxial compressive strength = 10,000 psi

- GSI = 45
- Intact rock constant = 10
- Disturbance factor = 0.7
- Modulus ratio = 450
- Residual Mb = 0.5 Mb
- Residual S = 0
- Residual a = a
- Dilation = 0.1 residual M_b

Lateral Earth Loads for Flume Retaining Walls

- Calculate using an equivalent fluid unit weight of 80 pcf (for unrestrained conditions)
- Extend equivalent fluid unit weight and added lateral earth pressure from the retained ground surface to the bottom of the footing heel
- No seismic analyses needed – static conditions govern design considering the low acceleration potential and the low wall height

Flume Drilled Piles

- Minimum spacing: center-to-center of at least 3 pile diameters
- Minimum depth: 5 feet
- Resistance to axial compression loads: allowable skin friction of 15,000 psf
- Resistance to vertical loads
  - Use the 2022 CBC "pole formula" (equations 18-1 or 18-2)
  - Use a uniform pressure of 50,000 psf acting over 3 times the drillhole diameter – apply the equations using b = drillhole diameter * 3 and $S_1 = S_3$ = 50,000 psf

CLOSURE

P&P incorporated the geotechnical engineering design criteria presented in this Memo in our structural engineering and ground support analyses. The ground support analysis/calculation report for shotcrete walls and tunnels presents other information pertinent to geotechnical engineering such as idealized subsurface profiles and total stress ratios.

Attachment
Geologic Strength Index Chart – Jointed Rock

WEATHERING

SEVERELY WEATHERED: Minerals decomposed to soil, but rock fabric and structure are preserved.
HIGHLY WEATHERED: Abundant fractures coated with oxides, carbonates, sulphates, mud, etc. thorough discoloration, rock disintegration, mineral decomposition.
MODERATELY WEATHERED: Some fracture coating, moderate or localized discoloration, little to no effect on cementation, slight mineral decomposition.
SLIGHTLY WEATHERED: A few stained fractures, slight discoloration, little or no effect on cementation, no mineral decomposition.
FRESH: Unaffected by weathering agents: no appreciable change with depth.

FRACTURE, JOINT, OR SHEAR SPACING

(Spacing in Inches)

CRUSHED	Less than 0.5
INTENSELY FRACTURED	0.5 to 1.25
CLOSELY FRACTURED	1.25 to 6
MODERATELY FRACTURED	6 to 12
OCCASIONALLY FRACTURED	12 to 48
VERY LITTLE FRACTURED	Greater than 48

THICKNESS OF SEDIMENTARY ROCK BEDS

(Thickness in Inches)

THINLY LAMINATED	Less than 0.25
LAMINATED	0.25 to 0.75
VERY THINLY BEDDED	0.75 to 2.5
THINLY BEDDED	2.5 to 8
MEDIUM BEDDED	8 to 24
THICKLY BEDDED	24 to 72
VERY THICKLY BEDDED	Greater than 72

FRACTURE OR LAYER SEPARATION

(Thickness of Separations in Millimeters)

VERY WIDE	> 10
OPEN	2.5 to 10
MODERATELY OPEN	0.5 to 2.5
TIGHT	0.1 to 0.5
VERY TIGHT	<0.1

FRACTURE OR LAYER ROUGHNESS

SOFT GOUGE: Open and continuous with soft gouge
SLICKENSIDED: Open and continuous with gouge
SLIGHTLY ROUGH AND SOFT: Soft joint rock wall
SLIGHTLY ROUGH: Hard joint rock wall
VERY ROUGH: Non-continuous, Hard joint rock wall

STRUCTURE

LAMINATED/SHEARED: Lack of blockiness due to close spacing of shear planes.
DISINTEGRATED: Poorly interlocked, heavily broken, mix of angular and rounded rock pieces.
DISTURBED/SEAMY: Folded with angular blocks, formed by many intersecting joint sets, persistence of bedding planes or schistosity.
VERY BLOCKY: Interlocked, partially disturbed, with multi-faceted angular blocks formed by 4 or more joint sets.
BLOCKY: Well interlocked, undisturbed rock mass, consisting of cubical blocks formed by three intersecting joint sets.
INTACT/MASSIVE: Intact rock specimens with few widely spaced discontinuities.

HARDNESS

SOFT: Can be readily indented, grooved or gouged with fingernail.
LOW HARDNESS: Can be gouged deeply or carved easily with a knife blade
MODERATELY HARD: Can be readily scratched by a knife blade; scratch leaves a heavy trace of dust and is readily visible after the powder has been blown away.
HARD: Can be scratched with difficulty; scratch produced a little powder and is often faintly visible.
VERY HARD: Cannot be scratched with a knife blade; leaves a metallic streak.

STRENGTH (ISRM STANDARDS)*

GRADE	FIELD IDENTIFICATION	APPROXIMATE RANGE ON UNIAXIAL COMPRESSIVE STRENGTH (psi)
R0	EXTREMELY WEAK: Indented by thumbnail	40-150
R1	VERY WEAK: Crumbles under firm blows with point of geological hammer	150-730
R2	WEAK: Shallow indentations can be made by firm blow with point of geological hammer	730-3,600
R3	MEDIUM STRONG: Can be fractured with single firm blow of geological hammer	3,600-7,300
R4	STRONG: Requires more than one blow of geological hammer to fracture it	7,300-14,500
R5	VERY STRONG: Requires many blows of geological hammer to fracture it	14,500-36,300
R6	EXTREMELY STRONG: Can be chipped by geological hammer	+36,300

GROUND WATER

FLOWING
DRIPPING
WET
DAMP
DRY

NOTE

* STRENGTH GRADE, FIELD IDENTIFICATION, AND RANGE OF UNIAXIAL COMPRESSIVE STRENGTHS FROM INTERNATIONAL SOCIETY FOR ROCK MECHANICS COMMISSION ON STANDARDIZATION OF LABORATORY AND FIELD TESTS, 1978. UNIAXIAL COMPRESSIVE STRENGTH VALUES ARE CONVERTED FROM METRIC UNITS AND ROUNDED.

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