Chamberlain Creek
Coho Passage Design Project
100% Basis of Design Memorandum

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1 CERTIFICATION AND LIMITATIONS

The report entitled *"Chamberlain Creek Coho Passage Design Project"* was prepared by or under the direction and oversight of a professional environmental/hydraulic engineer and a professional geologist at Pacific Watershed Associates (PWA). All information herein is based on data and information collected by PWA staff. The interpretations and conclusions presented in this report are based on a study of inherently limited scope. Observations range from qualitative to quantitative and are confined to surface expressions of limited extent and shallow investigations of subsurface materials and groundwater conditions. Interpretations of problematic geologic, hydrologic and geomorphic features (such as surface and subsurface water table, stratigraphy and bedrock) and their impact on local fluvial processes are based on the information available at the time of the study and on the nature and distribution of existing features.

The conclusions and recommendations contained in this report are professional opinions derived in accordance with current standards of professional practice and are valid as of the submittal date. No other warranty, expressed or implied, is made. PWA is not responsible for changes in the conditions of the property with the passage of time, whether due to natural processes, the works of man, or changing conditions on adjacent areas. Furthermore, to be consistent with existing conditions, information contained in the report should be reevaluated after a period of no more than three years, and it is the responsibility of the landowner to ensure that all recommendations in the report are reviewed and implemented according to the conditions existing at the time of construction. Finally, PWA is not responsible for changes in applicable or appropriate standards beyond our control, such as those arising from changes in legislation or the broadening of knowledge, which may invalidate any of our findings.

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2 INTRODUCTION AND PROJECT SUMMARY

2.1 Project Background and Location

The Mendocino Land Trust (MLT) coordinates restoration projects throughout Northern California and has been actively conducting restoration projects in the Chamberlain Creek watershed for several years. In partnership with Pacific Watershed Associates (PWA) these activities have included removing a concrete splash dam, 2 failing log stringer bridges, as well as installing large woody debris (LWD) to enhance stream complexity. In 2021, MLT received a grant from the California Department of Fish and Wildlife (CDFW) to develop 100% engineering design plans to restore passage beyond a fish barrier in the mainstem Chamberlain Creek watershed, Mendocino County, California. This 100% basis of design (BOD) memorandum summarizes the results of the field investigations, alternatives evaluation, and proposed design for that project. The engineered construction sheets (Design Plans) can be found in Appendix A.

Chamberlain Creek is an important watershed for coho production and recovery in the North Fork Big River watershed. The highest priority recovery actions in the watershed include remediating fish barriers, increasing large woody debris, boulders, or other instream structure and restoring natural channel form and function (CDFG 2011).

The legacy of historic timber harvest in Chamberlain Creek has left the stream channel and its tributaries in a less-than-fully-functional state and has consequently contributed to a significant decline in coho populations within the watershed. The entire Chamberlain Creek watershed is located within Jackson Demonstration State Forest and is currently managed by CAL FIRE. The construction of logging, access, and other associated spur roads, along with more recent land management, have contributed to geomorphic simplification of mainstem Chamberlain Creek and tributaries including barriers to fish passage and incision of the channel.

A single stream crossing is the focus of this design project to remove or remediate this anadromous fish barrier. The barrier is a failing multi-plate corrugated pipe arch culvert that is 8’ tall x 13.5’ wide x 81’ long. This culvert has been identified in the California Fish Passage Assessment Database (PAD) as barrier #736913.

To access the proposed project site, take Highway 20 from the town of Willits, CA and drive west. Follow the highway for approximately 16 miles to the intersection with Road 200 just before the Chamberlain Creek bridge and Camp 20 recreation area. Turn north on Road 200 and follow it for approximately 2.75 miles to the culverted stream crossing (Appendix A, Sheet 1).

2.2 Purpose and Objectives

The primary purpose of the *Chamberlain Creek Culvert Removal and Fish Passage Design Project* is to restore access for all life stages of salmonids to 1.6 miles of upstream habitat beyond the existing creek-road crossing. Restoration of this crossing must also increase the flood resilience of Main Chamberlain Creek Road to ensure year-round access to the road network beyond the crossing.

Objectives that helped achieve that goal included the development of a variety of design options for the crossing and a thorough evaluation of those options with the Technical Advisory Committee (TAC) during a 30%, 65%, 90%, and 100% review process.

2.3 Current Design

The preferred design replaces the existing pipe arch with a partially filled, 26' diameter, round culvert that establishes year-round fish passage and complies with other design constraints. One (1) bank-based wood structure is proposed just downstream of the culvert on creek left to stabilize the bank and provide aquatic habitat. Design methodology closely follows criteria outlined in the California Salmonid Stream Habitat Restoration Manual (CDFG 2010) and the Stream Simulation guide for stream-road crossings (USFS 2008).

3 WATERSHED SETTING

3.1 Regional Geology

The geology encompassing the Chamberlain Creek watershed contains diverse rock groups ranging from recent alluvial and colluvial deposits to older sheared and potentially unstable rocks of the Coastal Belt Franciscan Complex (KJfs). In the project vicinity, the KJfs consist of highly fractured sandstones and argillite (siltstone); (Kilbourne 1982). Poorly consolidated sedimentary and sheared metamorphic rocks that are particularly susceptible to fluvial erosion and mass wasting during periods of sustained or heavy rainfall are exposed throughout the stream corridor and include recent (Holocene to present) alluvial deposits as well as discontinuous fragments of Quaternary river terrace deposits commonly found in the lowland settings of valley floors. Field observations of exposed materials within the project area are consistent with the published mapping. Chamberlain Creek roughly follows a N-S trending alignment. There are no mapped faults in the immediate vicinity, but the project area sits almost equidistant between two major northwest-southeast trending right-lateral slip faults: the Maacama Fault to the east, and the San Andreas Fault to the west. The Maacama Fault has a recurrence interval of approximately 370 to 500 years (Hart and Bryant 2001), while the northern San Andreas Fault has a recurrence interval of approximately 200-400 years (Prentice 1989). The long recurrence intervals of these faults should not be considered a constraint on the design or performance of this project.

3.2 Local Geology

Local geologic conditions are generally consistent with published mapping by CGS and USGS. Outcrops of bedrock are observed as fractured Franciscan sandstone throughout the project area (Appendix B). Most rock outcrops were observed along the banks of the creek or in road/skid cuts into the hillside. The fractured rock tends to break into relatively solid pieces ranging between 1 foot and 1 inch. The hillside soils in the area have undergone significant levels of disturbance as a result of tractor logging but range between 1 foot and 4 feet thick depending on the steepness of the hillside they were observed on.

3.2.1 Landslides

PWA geologists observed several landslides near the project area. These landslides range from shallow fill and hillside failures associated with road and skid trail construction to large deep-seated landslides that encompass acres of ground. The observed landslides are characterized individually in the following paragraphs and can be found on the map presented in Appendix C.

Landslide A is a rotational debris slide located on the left bank of Chamberlain Creek, just downstream from the culvert that is the primary focus of this design project. The landslide includes both native hillside and a long-ago abandoned skid road. The slide is approximately 45' wide x 20' long x 12' deep. Most of the slide is still composed of a single block of material except for the portion that is directly adjacent to the creek. That portion has since been eroded by fluvial scour. Currently the toe of the slide that is in the creek is stable, but the existing culvert outlet projects directly at this toe. Unless the culvert is realigned, further destabilization of this scarp under high flow conditions can be expected. There are both pistol-butted and straight trees observed growing within the rotated slide block.

The cause of landslide A is pretty clear. Fluvial scour at the toe of the slide area from the culvert is being directed into the channel margin and has reduced the bulk resistive forces keeping the lower hillside stable. This resulted in a localized landslide developing in the undercut area. PWA geologists traversed the hillside area above the landslide and did not observe any features indicating the slide is part of a larger slide or has/is propagating uphill. The fact that there are straight mature trees on the landslide mass is a strong indicator that the slide has not rotated since its initial slope failure.

Landslide B is a shallow fill failure on the outboard fill slope of an existing skid road. The slide is irregular in shape but has general dimensions of 15' wide x 25' long x 1' deep. The slide is completely vegetated and appears stable under current conditions. Given the location and vegetation cover, this slide probably formed soon after skid trail construction and has since stabilized.

Landslide C is a shallow hillside failure that has developed within a cut-slope associated with past skid road construction. The slide is approximately 20' wide x 45' long x 1' deep. The landslide is mostly vegetated with small brush, grass and herbs and exhibits no signs of recent surface erosion. Given the location and vegetation cover, this slide probably formed soon after skid trail construction and has since stabilized.

Landslide D has formed where intensive skid trial construction interacted with an ephemeral stream system. The slide includes both native hillside and skid trail fill material. The erosion appears more as fluvial scour than displaced hillside. The scarps on the erosion feature are 3-6 feet high and are bare in many areas, particularly near the creek alignment. Given its configuration and existing conditions, this feature is likely still actively eroding. Eroded sediment from this feature enters an ephemeral class III stream which flows approximately 150' until it is diverted into a roadside ditch on Main Chamberlain Creek Road.

Landslide E is a large hillside landslide located on the right bank of Chamberlain Creek, upstream of the main Chamberlain culvert slated for replacement. The slide is approximately

200’ wide x 350’ long x 10’-20’ deep. The depth of the landslide is an estimate based on the existing morphology of the hillside. The landslide has relatively discrete margins and rounded / vegetated scarps in the upper portions of the slide. There are two skid roads and a truck road that traverse the landslide. Since neither of them exhibits significant displacement of the road alignment, it can be inferred that the landslide has not been active since construction of the infrastructure. The stream channel at the base of the slide exhibits an increased number of boulders in the channel indicating that past movement of the slide has entered the creek and all the material washed away except for the largest rocks which make up the existing lag deposit.

3.2.2 Landslide risk analysis and mitigation recommendations

Since landslides have significant potential to impact the performance of any given project, it is prudent to identify any potential impacts they may pose and address them in the planning phase of a restoration project. After PWA geologists identified and characterized the existing landslides within the project area, it was determined that only Landslide A poses any potential impact to the culvert replacement design. Recommended mitigation focuses on realigning the channel and directing flows away from the rotated toe. In addition to reducing the likelihood of future rotation, the final designs utilize an oversized crossing structure that could accommodate the 100-year flow even if Landslide A were to reactivate and raise the thalweg elevation a few feet.

Landslides B and C represent localized small landslides that developed in relation to skid trail construction. These slides appear stable, localized, and present no potential impacts to the culvert replacement. Landslide D is more of a gully erosion feature than a mass wasting feature. Even though it is partly active, this feature is far enough away from the proposed culvert replacement that its likelihood of impacting the upgraded crossing is low. Although Landslide D has a low likelihood of impacting this project, it should probably be treated in the future as part of a sediment reduction project. Landslide E is the large hillside landslide, and this feature appears recently stable as indicated by the un-displaced skid and road networks that cross it. Because the slide is so large, relatively stable, and outside the immediate project area, we do not recommend any mitigation measures for Landslide E as part of this design project. It may be prudent to closely examine and develop mitigation plans for this landslide if any future timber harvests are proposed. The most relevant impact from this slide is its contribution of large boulders to the portion of the creek upstream of the culvert crossing beneath Main Chamberlain Road.

3.3 Local Hydrology

Chamberlain Creek feeds into the North Fork Big River immediately east of the Camp 20 Recreation Area just after the creek crosses State Route 20, also known as the Fort Bragg-Willits Road. The project area lies about 2.8 miles upstream of the confluence and the contributing watershed above the crossing happens to also be 2.8 square miles. Elevations in the contributing basin range from 526 feet to 1984 feet, and the mean annual precipitation is 49.6 inches (Appendix D). Excepting the rarest of occasions, Chamberlain Creek receives its precipitation as rainfall. Land-use in this watershed is mixed; the entire watershed resides in CAL FIRE’s Jackson Demonstration State Forest where the forested land is broken up by mostly unpaved roads that are maintained for timber production, fire suppression, research, and recreation.

3.4 Historic and Present-Day Land Use

The Chamberlain Creek watershed has, and will continue to be, predominantly used for industrial scale logging. The property is currently managed by CAL FIRE, and despite continuing the legacy of timber harvesting in these forests, logging occurs at a significantly diminished rate and has significantly decreased its disturbance. Most of the recent harvest plans specified cable yarding - where logs are removed from the landscape by suspending them in the air to minimize ground disturbance. Past timber harvest operations were conducted using bull dozers to "skid" the downed trees to centralized log landings where they were loaded onto trucks and taken to the mill. The legacies of these tractor logging operations are observed as "skid roads" that were cut across the hillside and stream corridors with reckless abandonment. Near the project area, these skid roads have resulted in shallow landslides, diverted stream crossings, and excessive road related sediment delivery to the fish bearing streams. It is prudent to note that the largest ecosystem impacts within Chamberlain Creek were associated with past land use activities, and on a relative scale, the current activities contribute very little to environmental degradation. As such, there is a lot of valuable work such as replacing ageing culverts and rebuilding in-stream geomorphic landforms that could be done to help the forest recover from historical disturbances. Ecological, climatological, and economic benefits aside, restoring the health of Jackson Demonstration State Forest (JDSF) is a public priority because CAL FIRE is increasingly incorporating research and recreation into JDSF's management practices. To continue to do this, JDSF needs to present itself as the premier example of a multi-use forest.

3.5 Stream Geomorphology and Dominant Fluvial Processes

The geomorphic conditions observed within Chamberlain Creek and adjacent to the project area reflect the legacy of historic land use within the watershed. Past anthropogenic activities such as logging, road construction, riparian conversion, and stream clearing have significantly altered the magnitude and timing of surface water runoff as well as the ability of the stream to naturally regulate the rate of water and sediment flux through its various channel reaches. These disturbances have resulted in an uneven distribution of large wood and sediment in some sections of the creek, while other stream reaches exhibit signs of extreme channel incision. It is uncertain whether the portion of Chamberlain Creek within the project area would have as much exposed bedrock as it does now if those anthropogenic disturbances had never occurred, but once the failing crossing is corrected, it is fortunate that the slope gradient of the bedrock-controlled channel section is low enough to allow for year-round fish passage. With this barrier addressed, 1.6 miles of upstream habitat will be available to salmonids and a major disruption to the natural geomorphic processes that regulate Chamberlain Creek will be rectified.

In general, the channel can be subdivided into 4 reaches that internally exhibit similar characteristics: the upstream riffle-pool system, the boulder chute and step pools, the area close to the culvert, and the downstream riffle-pool system. These four reaches have distinct channel morphologies, and while not explicitly defined in the plans, they are all shown on Sheet 3 of Appendix A:

(1) The upstream reach, above landslide E, exhibits greater floodplain access, slightly higher wood structure density, more creek meander, and a wider variety of habitat including pools, riffles, and glides. For simplicity, this section of Chamberlain Creek is referred to

as Reach 1. Average channel grades within this section fluctuate between 1% and 2%. Bankfull widths have a large range, but an appropriate average for discussion is ~28'.

(2) Downstream of Reach 1, but still upstream of the culvert inlet, is Reach 2. This reach exhibits more large boulders and boulder clusters than other reaches. As stated in Section 3.2.1, these boulders appear to be delivered to the stream by Landslide E. Those boulders allow for some energy dissipation, which in turn enables minor amounts of channel substrate to remain in the channel. This partially confined boulder and bedrock step system extends from a bedrock induced pinch point 150 feet upstream of the existing pipe arch all the way down to the culvert's outlet. This section of the creek exhibits a much higher average channel grade of 3.9% when compared to the reaches outside the confined bedrock system. The average bankfull width is ~19' and floodplain access is limited. Habitat complexity is restricted to a few pools near large wood and the boulder/bedrock steps. Reach 2 was selected as an appropriate reference reach because this boulder step system dominates the section of the creek just upstream of the road crossing. Of particular interest is the transitional area at the top of Reach 2 that connects to Reach 1. Mimicking native geomorphology is important using a Stream Simulation approach and using the transitional area between an unconfined system with floodplain access (Reach 1) to a partially confined system with boulder and bedrock steps (Reach 2) helped PWA design the new crossing along Chamberlain Creek in such a way that it will act as the transition from a boulder and bedrock chute back to a relatively unconfined system.

(3) The geomorphology of Reach 3 is controlled by the existing culvert. Poor culvert alignment during the original installation has significantly impacted channel morphology. As such, channel flow is required to make a hard left turn prior to entering the culvert and flows from the outlet are directed straight into the left bank of the channel downstream. At the inlet, the hard turn has caused minor scour damage to the right bank and has resulted in small fluvial-geomorphic landforms unique to misaligned stream orientations. At the outlet, the directivity of the stream into the left bank has caused a small landslide to form (Landslide A) and resulted in minor widening of the channel. In addition, the undersized culvert accelerates flow to such a degree that it has hydraulically mined the channel substrate just beyond the outlet. These sections of the channel bottom are dominated by regolith and bedrock. A few patches of gravel distributed in isolated pockets remain in the channel. A secondary consequence of blowing out the channel substrate downstream of the culvert, is that the removal of channel substrate allowed stream flow to winnow out channel bed material beneath the majority of the culvert. The culvert bottom directly abuts bedrock now, and the development of large holes in the bottom of the culvert have caused almost complete failure of the existing infrastructure. The torn apart and sharp bottom of the culvert, as well as the jump height caused by overconcentrated and accelerated flow velocities, have resulted in a temporal and treacherous fish barrier.

(4) Reach 4 is outside the influence of the culvert and is observed to have a relatively simplified channel with only pockets of suitable substrate. It is flanked by generally steep channel banks and is bereft of effective large woody debris that would naturally govern water and sediment flux through the channel reach. The combination of these characteristics gives the impression of an incised channel with little to no attributes consistent with undisturbed channel conditions. The fish in this reach tend to use the

shallow pools for meager habitat, but the lack of substrate and complex fluvial-geomorphic features makes this reach relatively sterile from an ecological perspective.

3.6 Fish Habitat and Watershed Use

3.6.1 Anadromous Species

The Chamberlain Creek watershed hosts native populations of coho salmon (*Oncorhynchus. kisutch*), and steelhead trout (*O. mykiss*) (CDFW Stream Inventory Report for Chamberlain Creek 2011). These species are either protected under the California State or Federal Endangered Species Act or listed as a sensitive species of concern and considered to be at-risk of extinction.

A Level II Habitat survey was conducted to assess the current habitat conditions with respect to the culverted crossing (Appendix E). The results from this survey show the culverted crossing to be a temporal barrier for adult salmonids seeking access to spawning habitats above and a complete barrier for juvenile salmonids upstream movement. This crossing was described in the 2011 Stream Inventory Report as having a 0.7-foot plunge at the outlet with some holes in the culvert bottom and coho juveniles were observed above the crossing in the 2011 Stream Inventory Report. However, none were observed above the crossing by PWA biologists in the 2021 survey. The 2021 survey conducted by PWA biologists show that the culverts condition had degraded over the last 10 years and nearly all the stream flow was being transported through the rusted bottom and under the culvert. Chamberlain Creek does provide habitat that would support coho above the crossing. There is a boulder and bedrock dominated section in Reach 2 that could provide step-run and pocket water habitats which were not present elsewhere in the survey. In streams that have areas with gradients exceeding 2% these habitat types allow for upstream navigation and provide resting areas with more heterogeneous micro habitats. This short reach would serve as an optimal reference for channel reconstruction for upgrading the failing culvert and ensuring passage for juveniles under all flow regimes.

3.6.2 Predation

Predation on salmonids is this area is limited to native avian, mammalian, and aquatic amphibians and reptiles. There are no known non-native or invasive predators in the Chamberlain Creek watershed.

4 SITE INVESTIGATION & DATA COLLECTION

4.1 Topographic Surveying

Using a total station (Topcon TDS 2R) and galvanized nails, a control network was established from the top to the bottom of the Chamberlain Creek project area. Including the control stations, 681 points were shot along existing stream channels, crossings, and adjacent areas to develop site topography for modeling and design purposes. It should be noted that during the field surveys, which took place in August of 2021, no horizontal or vertical NGS benchmarks were located or surveyed to, therefore all northing (N), easting (E), and elevation (Z) coordinates generated for the survey are relative and not absolute.

Using the point data, surface contours depicting site topography were generated via the following process. First, northing, easting, and elevation (NEZ) coordinate data for all points were imported from the total station into SurveyPro, where the data was aggregated into a single CSV file. The data was then exported to MS Excel for further analysis. After any necessary cleaning was performed in Excel, the survey data was imported into AutoCAD Civil 3D (C3D) to produce a topographic surface. The point data was used to create a Triangulated Irregular Network (TIN), a surface generated by connecting each point with two nearby points to form a triangle. From the TIN, surface contours were generated to form a general overview of the site's topography.

4.2 Bankfull Measurements

From the detailed topographic surface created in AutoCAD Civil 3D, bankfull measurements were estimated for the two geomorphic systems described in Section 3.5. These approximations were checked against field measurements to ensure that the C3D estimations were within reason.

Bankfull estimations for the boulder step reach (Reach 2) ranged from 15'-25', with the vast majority between 17'-22'. The sections of Chamberlain Creek upstream and downstream of the boulder chute had bankfull measurements ranging from 21'-38'. Most of these values were around 25'-32'. For this report, approximate bankfull values of 19' for the reference reach and 28' for areas outside the influence of the existing culvert are used for discussion and analysis.

4.3 Streambed and Bank Materials

Overlying soils in the project area have been mapped and described by the USDA Natural Resource Conservation Service (NRCS) as gravelly loam to extremely gravelly loam of the *Yellowhound soils,* and gravelly loam to extremely gravelly clay loam of the *Kibesillah complex* (Appendix B). Aside from several small (<100ft^2) exposures of Franciscan Complex bedrock knockers, including the stream bed at the inlet and outlet of the current culvert, field observations suggest primarily fine to coarse grained alluvial deposits exposed within the project reach streambed and banks in Chamberlain Creek. Generally, stream bank exposures in the Chamberlain Creek stream reach include silty to sandy gravels.

Two sets of pebble counts were conducted to characterize streambed material composition within the project area. One pebble count was conducted outside the hydraulic influence of the culvert, approximately 500 ft upstream from the Chamberlain Creek stream crossing in Reach 1 (Table 1). A second pebble count was conducted approximately 75 ft upstream of the Chamberlain Creek stream crossing, where the first pool exists within the boulder chute in Reach 2 (Table 2).

Table 1. Pebble count results for Chamberlain Creek at upstream end of survey

Size Class	Size percent finer than (mm)	Size percent finer than (in)	Material
D5	8	0.31	Medium Gravel
D16	16	0.63	Coarse Gravel
D50	32	1.26	Very Coarse Gravel
D84	90	3.54	Small Cobble
D95	180	7.09	Large Cobble

Table 2. Pebble count results for Chamberlain Creek at upstream end of boulder chute

Size Class	Size percent finer than (mm)	Size percent finer than (in)	Material
D5	5.7	0.22	Fine Gravel
D16	11.3	0.44	Medium Gravel
D50	22.6	0.89	Coarse Gravel
D84	45	1.77	Very Coarse Gravel
D95	128	5.04	Small Cobble

4.4 Reference Reach

The reference reach selected for the Chamberlain Creek crossing is in the uppermost third of the boulder step-pool system upstream of the existing crossing in Reach 2. This reach represents a transitional zone that links the two geomorphically distinct reaches (Reach 1 and 2) discussed in Section 3.5. It transforms Chamberlain Creek from a channel with floodplain access into a boulder chute and step pool system. The design reach occupies the downstream portion of the boulder chute and could function well as the transitional zone that restores Chamberlain Creek back into a stream with semi-connected floodplains. By mimicking characteristics of the reference reach, the design reach will blend in seamlessly with the overall profile and habitat types naturally available in Chamberlain Creek.

Figure 1. Reference Reach

4.5 Subsurface Investigations and Borehole Data

Five boreholes were advanced across and in-line with the proposed alignment of the new crossing structure to inform the project team about the subsurface geologic conditions that the new structure will be emplaced on and to help the design team determine any constraints that may influence the appropriate structure to install (Appendix F). The boreholes were drilled along the existing road alignment where it crosses the current culvert. Boreholes were advanced by Fisch Drilling using a light track mounted Geoprobe 6600 with a boring diameter of 6”. The holes were advanced using the hollow stem auger and intermittent samples were collected in the form of standard penetration tests (SPT) and Shelby tube sampling. Boreholes were advanced until refusal was noted to understand the depth to bedrock. Drilling was continued in some boreholes to evaluate the friability of bedrock in the project area.

The results of the on-site characterization of the observed geologic conditions as well as the SPT and laboratory results are plotted on the individual core logs in Appendix F. The plots of the boring logs demonstrate the approximate location of the depth to bedrock which we use to define the original channel alignment are also in Appendix F. From these observations, it appears that the original centerline of the channel is approximately located in line with borings 2 and 3. This is consistent with our field observations and suggests there was a more natural turn in the channel just downstream of the existing culvert alignment location.

Geologic materials observed and sampled in the 5 boreholes indicate the overall stratigraphy is generally homogenous in the upper sections but indicated some heterogeneity in the lower portions of the cores. Bedrock depths ranged from 10 to 30 feet below ground surface with the deepest bedrock encountered along the proposed realignment of the channel. The shallow bedrock observations were documented on the outer margins of the core transect indicating our transect traversed the historic channel alignment. The upper portions of the borings tended to be composed of silty and sandy gravel deposits which ranged in thickness from 5 to 20 feet. Below these units, the geologic material varied from boring to boring (Appendix F). This heterogeneity makes interpretation of the stratigraphy challenging and uncertain.

In general, our interpretation of the stratigraphy surmises that earthen fill was placed over either a hillside composed of regolith with minor soil development or filled channel deposits. At both ends of our boring transect (borings 1, 4, and 5) the stratigraphy appears to represent fill placed directly on top of regolith and bedrock with minor soil development. At borings 2 and 3 we interpret the stratigraphy as representing all fill material in the channel. It is permissible that the poorly graded gravel in boring #2 reflects original channel substrate but this interpretation has some uncertainty associated with it.

Overall, the materials encountered in the borings indicate heterogeneity in the subsurface geology. Much of this material will be unsuitable for load bearing and will need to be excavated and replaced with engineered material if it is to support focused loads like logging trucks. Despite the fact that borings were closely spaced, the exact extent of any given geologic unit (except the upper fill material) is unknown and could be encountered anywhere. Because of this uncertainty, the contractor should plan on importing any load bearing materials needed to support the structure.

Importantly, it seems that the geologic material encountered in our borings along the proposed culvert alignment will allow for over excavation and embedment of a culvert. There has been some mapping of potential bedrock exposures along the right bank upstream of the culvert inlet, but it is unknown if this material is in-place bedrock or large boulders associated with the hillside landslide deposit on the right bank upstream of the culvert inlet. Regardless of the nature of the observed rock, the construction budget should include adequate contingency if more challenging digging conditions are encountered. Additional adaptative measures have been considered, and could be employed, if the proposed culvert inlet needs to be shifted towards channel left away from the harder geologic material observed on the right bank just above the existing pipe arch.

5 HYDRAULIC MODEL SET-UP

To characterize flows through the project reach, PWA conducted a hydraulic analysis using HEC-RAS. Once model set-up was complete, results from this model were used to evaluate the hydraulic performance of the existing culvert. To inform the selection of a preferred crossing structure, multiple proposed crossing geometries were tested by modifying the existing conditions model. Once the preferred crossing structure was confirmed, a more robust proposed conditions model was created to accurately measure the performance of the designed crossing. Section 7 discusses model results for the existing crossing and Section 8 discusses model results of the proposed design.

5.1 Cross Section Selection and Development

To form the geometric basis of the model, cross sections were taken from the Civil 3D TIN Surface (see Section 4.1) in locations corresponding to riffle crests, changes in grade, channel expansion and contraction, change in meander direction, and the upstream and downstream locations of the culverted stream crossing. There are 26 cross sections that make up the model. Plan view representations of the existing and proposed models for Chamberlain Creek were pulled from HEC-RAS to create Figure 2 and Figure 3, respectively. It is worth noting that HEC-RAS does not always accurately portray crossing geometry, but the data inside the model is accurate. While the crossing geometries are very different for each model, the only visible difference between Figure 2 and Figure 3 is the stationing along the thalwegs. The proposed crossing corrects the unnatural skew imposed on Chamberlain Creek when the original crossing was built, and as such, has a slightly shorter thalweg length.

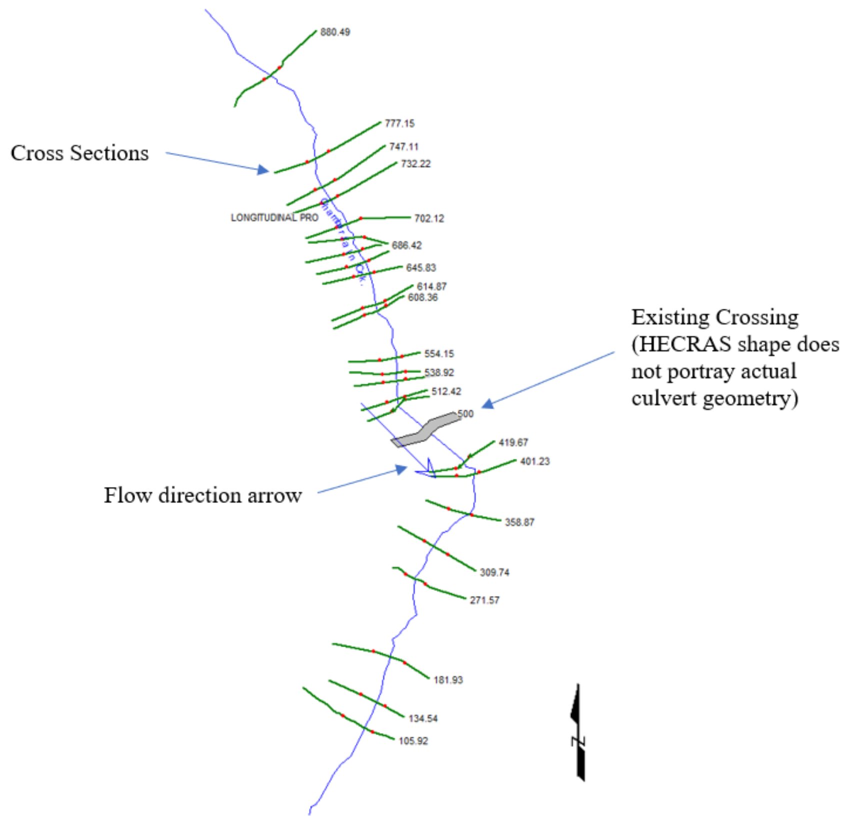

Figure 2. HEC-RAS cross sections for existing conditions along Chamberlain Creek

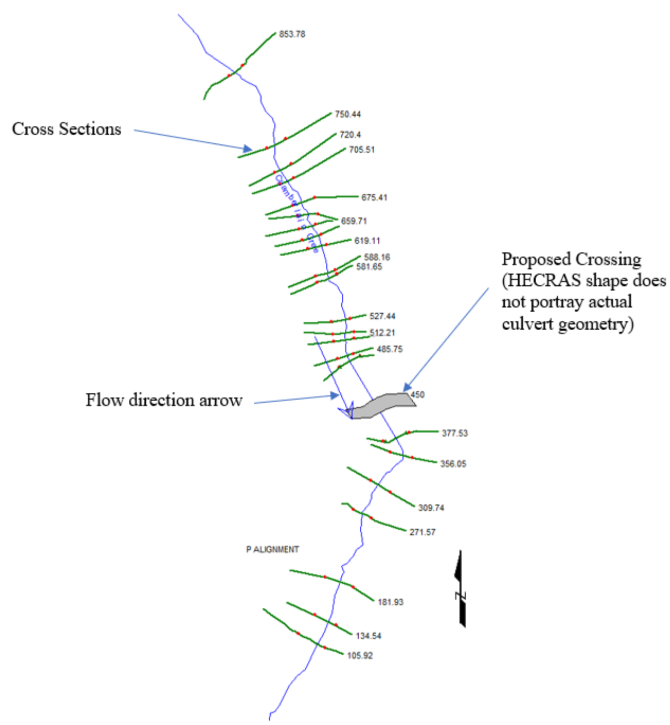

Figure 3. HEC-RAS cross sections for proposed conditions along Chamberlain Creek

5.2 Manning's Roughness

As mentioned in Section 3.5 when describing the local geomorphology, there are three distinct reaches with two unique channel classifications. The surveyed reaches downstream of the culverted crossing (Reach 4) and the portion of the creek more than 170 ft upstream of the culverted crossing (Reach 1) were determined to be pool-riffle systems; however, immediately upstream of the culvert the channel to Reach 1 can clearly be described as a step-pool system (Reach 2). Therefore, two roughness analyses were conducted, one for the pool-riffle reaches and one for the step-pool system.

For both channel types, roughness values were estimated using the method of Arcement and Schneider (1989), which accounts for channel substrate, hydraulic roughness, vegetation, variations in cross sections, flow obstructions, and channel meander. Channel substrate was classified based on pebble counts that were taken in the step-pool and pool-riffle reaches. Hydraulic roughness, vegetation type and density, cross section variation, flow obstructions and channel meander were all determined by direct on-site observations taken during a walkthrough of the surveyed extent of the channel.

The Arcement-Schneider roughness analysis yielded unique roughness values for the channel and overbanks in both the pool-riffle and step-pool reaches. The main channel roughness values were 0.067 and 0.097 for the pool-riffle and step-pool reaches, respectively. The overbank roughness values were 0.128 and 0.155 for the pool-riffle and the step-pool reaches.

HEC-RAS allows the user to select two roughness parameters for culverts, top and bottom, so a different material roughness such as ESM can be specified if desired. The roughness for the existing and proposed culverts were selected based on their conditions from documented roughness values in the HEC-RAS Hydraulic Reference Manual (Brunner 2021). As the existing culvert is devoid of substrate, it received the roughness value for corrugated metal culverts, 0.028, for both the top and bottom parameters. The proposed culvert also used a roughness of 0.028 for portions of the culvert that are not embedded. For the bottom portion filled with ESM, the main channel roughness of 0.067 discussed above was used.

5.3 Hydrologic Data

The USGS Streamflow Statistics (StreamStats) program is a map-based internet application that allows users to easily obtain streamflow statistics, basin characteristics, and other information for user-selected locations. The application relies on the data collected at U.S. Geological Survey streamflow-gauging stations, computer-aided computations of drainage-basin characteristics, and published regression equations for specific geographic regions comprising the United States.

5.3.1 Peak Flows

Peak flows are of particular interest when evaluating the stability of structures placed in salmonid streams. StreamStats evaluates basin characteristics to provide peak-flow statistics with annual exceedance probabilities of 50, 20, 10, 4, 2, 1, 0.5, and 0.2 percent for watersheds. These peak flows have recurrence intervals of 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year floods (Table 3). The report by Gotvald et al. (2012) presents streamflow regression equations that are applicable for California watersheds where developed land represents less than 10% of the contributing area. The generated StreamStats report can be found in Appendix D.

Table 3. Chamberlain Creek peak-flow statistics, Mendocino, CA from USGS StreamStats

Return Period	Q (cfs)	90% Prediction Interval (cfs)	
		Min	Max
2-yr	214	87.5	523
5-yr	412	197	864
10-yr	554	274	1,120
25-yr	742	379	1,450
50-yr	886	451	1,740
100-yr	1,040	517	2,090
200-yr	1,180	585	2,380
500-yr	1,370	663	2,830

5.3.2 Fish Passage Flows

Establishing bidirectional fish passage is the primary concern when implementing a successful fish passage project. Minimizing jump height, defining suitable fish passage flows, and analyzing useful metrics like water depth and flow velocities at potential barriers within the project reach are important factors to consider during the design phase. Following guidelines set forth in the California Salmonid Stream Habitat Restoration Manual, adult and juvenile fish passage high flows were set at 50% and 10% of the 2-year peak flow for the system, and the low flow passage for adults and juveniles were set to 3 cfs and 1 cfs (CDFG 2010, Part IX-A-7).

Table 4. Design flows for fish passage

Salmonid Lifestage	High Flow (cfs)	Low Flow (cfs)
Adult salmonids (>6”)	107	3
Juvenile salmonids (<6”)	21	1

5.4 Boundary Conditions

The hydraulic boundary conditions used by HEC-RAS to simulate flood elevations were set using the normal depth of flow into and out of the project area. Average channel slopes correspond to the normal depth of flow, and for Chamberlain Creek, the channel slopes for the upstream and downstream boundaries are 0.026 ft/ft and 0.015 ft/ft respectively.

6 DESIGN APPROACH

6.1 General Guidelines

Artificial barriers on a stream, such as culverts or bridges, can often be temporal or complete barriers to fish passage for both adult and juvenile salmonids. Resource agencies have identified culvert crossings as structures that can significantly contribute to the decline of coho salmon

populations if the culvert inhibits access to historic spawning and rearing habitats. The purpose of this project is to upgrade the Chamberlain Creek crossing so that it allows for year-round access to 1.6 miles of upstream habitat for juvenile and adult coho salmon.
Project methodology follows the stream simulation design process general guidelines presented in the CDFW Restoration Manual (CDFG 2010) and the USFS Stream Simulation manual (USFS 2008). Both manuals present methods for designing and implementing road-stream crossings intended to mimic the slope, structure, and material of the natural streambed to permit free and unrestricted movement of aquatic species.

6.2 Project Constraints and Risk Assessment

The design team considered each of the following limitations to ensure project viability and performance. Some of these constraints are typical of road stream crossing design projects, while others are directly related to this specific project and have been identified by the design team as mandatory to address. To varying degrees, each of these project constraints were considered and addressed in the proposed alternatives.

6.2.1 Fish Passage

Fish passage under or through road crossings is typically dependent on multiple factors, including species, size, age (juvenile or adult), channel depth, water velocity, leaping pool depths, and step height. Table 5 provides general salmonid performance data including, burst and prolonged swimming speeds, swim mode duration, and maximum leap speed, all of which can be used as baselines to develop fish passage criteria (CDFG 2010).

Table 5. Swimming & leaping performance of salmonids (CDFG 2010, Part IX-42)

Salmonid Lifestage	Minimum Water Depth	Prolonged Swimming Mode		Burst Swimming Mode		
		Maximum Swim Speed	Time to Exhaustion	Maximum Swim Speed	Time to Exhaustion	Maximum Leap Speed
Adult salmonids (>6”)	0.8 ft	6.0 ft/sec	30 minutes	10.0 ft/sec	5 seconds	15.0 ft/sec
Juvenile salmonids (<6”)	0.3 ft	1.5 ft/sec	30 minutes	3.0 ft/sec	5 seconds	4.0 ft/sec

When assessing fish passage, it is also important to note how fish move through a channel under natural conditions. Native, ‘undisturbed,’ rivers have large amounts of in-stream roughness elements that create turbulent flow and eddies which result in spatially varying water velocities that fish can use as they see fit. Fish in these conditions can use this variability to aid their upstream movements by swimming against fast flowing sections for short bursts and stopping by at resting pools as they work their way upstream. Flood conditions also alter flow depth, velocity, and barrier hydraulics, which can create passable conditions at varying flows. As such, fish passage criteria should favor designs that simulate the native channel and reference reaches.

6.2.2 Road Width, Height, and Orientation

This project was always going to preserve vehicular access along Main Chamberlain Road, but additional conversations with CAL FIRE have brought up a few preferred specifications. If financially and ecologically feasible, CAL FIRE would like to have a crossing that maintains a 14-16 foot road surface width between break in slope at the tops of the fill prism and has a safe and convenient turning radius for logging trucks making their way uphill or downhill on the eastern side of the crossing. Logging trucks can handle a wide range of acceptable grades and the road slope is unlikely to restrict project design.

6.2.3 Landowner Access

The entire project is taking place in the Jackson Demonstration State Forest on property owned and managed by CAL FIRE. All access to the project area will be on roads managed by CAL FIRE. We do not anticipate any other access issues arising from the development or eventual implementation of our proposed designs.

6.2.4 Flooding and Backwatering

The existing culvert is undersized and severely damaged. As such, the Chamberlain Creek crossing is artificially prone to backwater and flood conditions during large magnitude storm events. This potential risk was analyzed in detail using multiple iterations of the hydraulic model to maintain very low HW/D ratio while passing the 100-yr flow to accommodate any associated debris or changes in the flow regime down the line.

6.2.5 Floodplain Functions

The high energy, mid watershed floodplain functions within the project area will not be affected by the completion of this project. Once implemented, these designs will increase the habitat value of the project area and restore balance to local geomorphic processes.

6.2.6 Subsurface Earth Materials

Perhaps the largest geologic constraint is the depth to bedrock at the Chamberlain Creek stream crossing. As discussed in Section 4.3, subsurface investigations have heavily influenced the crossing's orientation, elevation, and foundation. The unsuitable foundation material discovered in borehole 3 will need to be thoroughly investigated during construction. It is likely that the western side of the crossing can be over-excavated and backfilled, but a complete understanding of the impacts from the material found in borehole 3 will not be known until construction is under way. The rock exposed on the right bank of the channel above the inlet may be bedrock or a large boulder associated with the hillside landslide upstream of the culvert. Regardless, it represents a larger hard feature that could present a challenge during construction. The project team is prepared for difficult excavation on the right bank and the possible eventuality of using adaptive management strategies to align the structure and ensure its function.

6.2.7 Existing Scarp and Unstable Hillslope

The topographic survey characterized the entirety of the scarp on river left just downstream of the existing culvert (Landslide A). Impacts to this hillslope from hydraulic forces resulting from flood events and proposed conditions were considered for every proposed alternative. The channel orientation will be adjusted to minimize the stream's ability to destabilize and reactivate this rotational slide. If the scarp were to destabilize down the line and raised the thalweg elevation back through the proposed culvert, the deliberately oversized structure would be able to accommodate a couple feet of aggradation and still pass the 100-year flow with freeboard.

6.2.8 Failure of Proposed Engineered Log Jam

Without adequate consideration of hydraulic forces such as shear, buoyancy, and scour, engineered log jams (ELJs) placed in riparian areas that experience flows have the potential to break apart, float away, and affect downstream infrastructure. ELJs also have the potential to function differently than intended, but that is not always a bad thing. A structure that becomes stranded outside the influence of the channel for a few years may come back into play when large flows move the main channel over to that area years after construction. While the goal is to add wood that has immediate and beneficial impacts for salmonids, downed and buried wood boost habitat heterogeneity throughout the riparian and are beneficial to the entire ecosystem. Depending on the project objectives, failure of an ELJ can mean a variety of different things. For this project, failure will be defined as the loss of a structure within the project area and its potential to float away and impact downstream infrastructure.

This project is only proposing a single bank-based structure, relatively small and uncomplex, that will be placed downstream of the proposed crossing (Section 8.5). To minimize the risk of failure, the structural stability of the proposed ELJ was analyzed using results from the proposed hydraulic model and Rafferty's *Large Wood Structure Stability Analysis* spreadsheet tool, see Appendix G (Rafferty 2016). The modeled 100-year flows were used as the design flow, and a minimum factor of safety of 1.5 was applied to the structure stability calculations to ensure the longevity of the structure for a variety of hydraulic and flow conditions. It is important to note that ELJs always have some fit in the field aspects since site conditions are never completely known until construction. The calculations performed in Appendix G were used to understand the general anchoring requirements for the proposed structure and create specific recommendations for the structure orientation, ballast, and embeddedness depths detailed in the Final Plans (Appendix A). Since those calculations may not represent the exact orientation, ballast, or embeddedness of the placed structure after construction, an experienced engineer will oversee the ELJ placement during construction as an added risk minimization measure. In the unlikely event of structure failure, debris from the failed wood structure poses very little risk to the upstream crossing. Floating debris from the failed structure also pose little risk to downstream infrastructure. The downstream bridges are 2+ miles away and are large structures with massive concrete wingwalls poured directly into bedrock. They appear relatively unscathed despite having endured large flood events for at least 50 years and will be able to pass any large wood that may leave this project site.

6.2.9 Existing Infrastructure (Structures, Pipelines, and Overhead Utilities)

There are no existing utility lines, underground pipes, or structures that will be impacted by the design and implementation of this project. There are multiple bridges 2+ miles downstream that are well outside of the project influence and are highly unlikely to be impacted in the event of any structural failure.

6.2.10 Potential Climate Change Impacts

As California's climate adapts to its dramatically altered chemistry, Mendocino forests are likely to experience more frequent and extended dry periods as well as less frequent, but more intense, rainfall events. Vegetation dieback will increase the susceptibility of the land to forest fire, and once burned, the land will be more prone to landslides and increased run-off speeds. Flashier flood events with increased amounts of debris are highly likely to come rushing down Chamberlain Creek in the near future. Over-sizing this crossing is one of the best proactive methods to prepare for this eventuality, but future projects to retain large woody debris, decrease the speed that water moves through the watershed, and capture sediment to stabilize grade and sort for spawning gravels are other achievable and extremely valuable goals to maintain basic ecosystem function and preserve the health of Jackson Demonstration State Forest.

6.3 Design Criteria

Every design solution strikes a different balance between project priorities. The following criteria was used to measure the overall success of the proposed alternatives but if new insights from the TAC or important information comes from future site investigations then these metrics will be updated accordingly. The primary design criteria are as follows:

- Maximize flood resilience of the crossing to increase project effectiveness and longevity.
  - The proposed crossing structure will meet a 0.67 HW/D ratio during the Q100.
- Minimize the frequency and severity of water velocities that exceed the swimming capabilities of salmonids to maximize conditions suitable for fish passage.
  - 10 ft/s and 3 ft/s metrics will be met for adult and juvenile fish passage flows at the designed crossing.
- Maximize floodplain connectivity and restore riparian processes as much as possible.
  - Bank stability of ESM will be ensured up to the 100-yr flood, but substrate mobilized from higher up in the watershed will be expected to replenish incidental bedload loss once natural sediment fluxes of the main channel are reconnected in the system.
- Maximize bathymetric variability while ensuring that the severity of jumps and steps remains low in order to prevent accidental creation of temporal fish barriers.
  - Jump heights shall not exceed 1 foot for rock steps and 6 inches for log steps.
- Maximize channel connectivity under low flow conditions.
  - Adult (3 cfs) and juvenile (1 cfs) fish passage flows will be included in the hydrologic model to ensure adequate flow depths of 0.8 ft and 0.3 ft are achieved.
- Minimize construction disturbance to retain existing ecosystem services.
  - Shade trees and adjacent vegetation will be preserved where possible.
- Minimize cost without significantly compromising design performance.
  - Road height, width and orientation will be adjusted to balance performance with cost of materials and stable fill.

7 EXISTING CONDITIONS ANALYSIS AND MODEL RESULTS

7.1 Multiplate Pipe Arch

The existing multiplate pipe arch is 8’ tall x 13.5’ wide x 81’ long and has a maximum conveyance area of approximately 90 square feet. The bottom of the culvert is completely destroyed and has jagged and broken pieces of steel everywhere. There is no substrate covering the jagged metal, lower flows simply drop down below the surface of the pipe, and the perched outlet serves as a temporal barrier to fish passage. The existing crossing is a major concern both structurally and biologically.

As previously discussed, the existing conditions at the project site, including culvert hydraulics, were modeled using HEC-RAS. All of the flows mentioned in Section 5.3 were modelled, but for discussion and image clarity purposes, only a few targeted flows are shown in the following figures. The 100-year, 10-year, 2-year, high and low fish passage flows for adults and juveniles are shown below. A profile of the project reach, including the water surface elevation for various flows through the existing culvert, is shown in Figure 4.

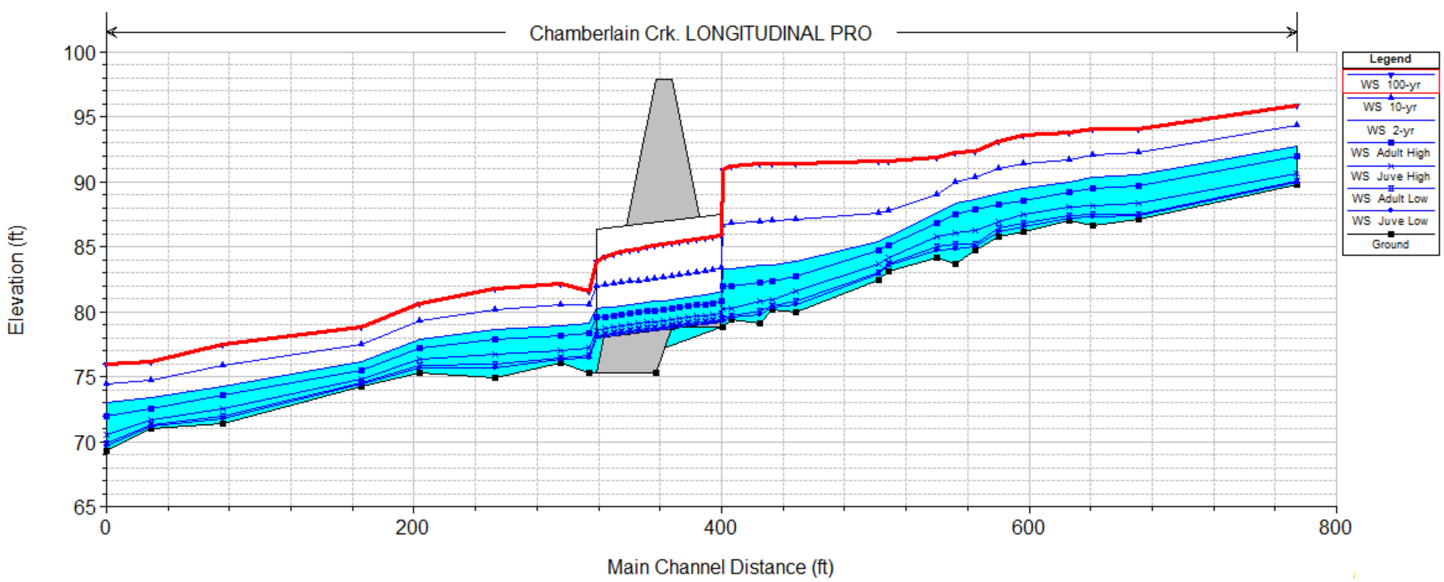

Figure 4. HEC-RAS profile of existing flows along Chamberlain Creek

For reference, the 2-year flood is filled in with light blue, the 100-year flood is the red line, and all of the other flows have different markers along the dark blue profile lines. Looking at the elevation of the 100-year flood as it approaches the culvert, and then as it moves through the culvert, it is clear that the culvert hydraulically constrains Chamberlain Creek. In fact, floods equal to the 10-year flow or greater approach the culvert with a higher water surface elevation than the culvert can support without acceleration and compression. As evidenced in Figure 4, it is also easy to see that most of the flows entering the culvert show a decrease in water surface elevation. The coincidental increases in velocities (and details for other hydraulic parameters) are listed in Table 6 and Table 7.

Table 6. Hydraulic results for upstream cross section and the existing culvert inlet

		Upstream of Culvert (Station 6+15)			**Culvert Invert**	
	Flow (cfs)	Velocity (ft/s)	Depth (ft)	Shear Stress (lb/sq ft)	Velocity (ft/s)	Depth (ft)
100-year Flow	1040	5.78	8.49	4.68	13.78	6.70
50-year Flow	886	5.95	7.23	5.39	13.22	5.79
25-year Flow	742	6.13	6.11	6.11	12.69	4.96
10-year Flow	554	6.54	4.62	7.76	11.18	4.17
2-year Flow	214	5.32	2.66	6.26	8.02	2.39
Adult High Flow	107	4.16	1.95	4.32	6.54	1.61
Juvenile High Flow	21	2.62	1.01	2.37	3.73	0.69
Adult Low Flow	3	1.34	0.58	0.76	1.75	0.21
Juvenile Low Flow	1	0.97	0.42	0.44	1.15	0.11

Table 7. Hydraulic results for the existing culvert outlet and downstream cross section

		Culvert Outlet		**Downstream of Culvert (Station 3+10)**		
	Flow (cfs)	Velocity (ft/s)	Depth (ft)	Velocity (ft/s)	Depth (ft)	Shear Stress (lb/sq ft)
100-year Flow	1040	15.36	5.85	8.50	5.40	5.62
50-year Flow	886	14.06	5.39	8.01	4.99	5.15
25-year Flow	742	12.84	4.90	7.47	4.58	4.64
10-year Flow	554	11.72	4.00	6.46	3.99	3.93
2-year Flow	214	8.68	2.23	4.62	2.61	2.28
Adult High Flow	107	6.87	1.54	3.63	1.94	1.59
Juvenile High Flow	21	4.35	0.59	2.00	1.11	0.63
Adult Low Flow	3	2.27	0.16	1.12	0.55	0.24
Juvenile Low Flow	1	1.58	0.08	0.84	0.36	0.16

The existing and proposed culverts are longer than what salmonids can be expected to traverse using Burst Swimming Mode, so comparisons were made to the values for Prolonged Swimming Mode (Table 5). The red cells in Table 6 and Table 7 indicate parameters during fish passage flows that do not meet the listed thresholds for fish passage. Cross sections at Station 6+15 and Station 3+10 were selected for comparison because they are far from the culvert invert/outlet and have similar characteristics to parameters found in the Reference Reach used to inform the Proposed Design. It is clear to see that at the high fish passage flows, velocities through the culvert are the limiting factors, while at the low fish passage flows, water depths are the primary limiting factor. Those trends also apply to a few parameters in the sections of Chamberlain Creek outside the influence of the culvert. However, the magnitude of the velocity and depth issues outside the culvert is much less egregious than values that appear near the existing culvert. These results provide more evidence to confirm that the existing crossing is a temporal barrier to fish passage.

Not only is fish passage impeded, but the fluvial geomorphic processes that would normally be at play in Chamberlain Creek are dramatically altered. The acceleration of flow during peak flood events is rather extreme. Using the 25-year flood event as an example, velocities approach the culvert at 6.13 ft/s. That flow accelerates to 12.69 ft/s to pass through the culvert, and then blasts out the downstream end at 12.84 ft/s. It will be apparent when comparisons are made between these tables and the proposed tables later, but even 140 feet upstream of the culvert entrance at Station 6+15, backwater (and the resultant downstream firehose) conditions are created for all flows greater than the 2-year event. These results leave little wonder as to why there is no substrate in the existing culvert and provide an obvious answer as to why the downstream left bank has collapsed into the creek. Reducing the flow constriction caused by this crossing will reduce the firehose effect currently happening on Chamberlain Creek and restore natural fluvial processes like sediment transport and increase the cross-sectional variability of flow. The results of the modeled existing conditions reinforce the need to replace the failing crossing.

7.2 Channel Alignment

In the first field visit, observations were made by PWA and the TAC that the existing crossing alignment is not in line with the expected natural flow path of Chamberlain Creek. In what appears to have been a compromise made between the shortest culvert path and where the creek ideally would flow, the existing culvert is skewed in such a way that it pushes water into the toe of the unstable hillslope just downstream of the outlet (Figure 5). This misalignment is very apparent in the topographic survey and the proposed design will restore a more natural flow path to Chamberlain Creek and reduce erosional and hydraulic pressure on the downstream scarp. As previously discussed, there is exposed bedrock or a very large boulder buried on the right side of the channel at the culvert inlet. If this hard material can’t be excavated and adequate embeddedness depths cannot be achieved as a result of its presence, then it is possible that the culvert inlet might need to be shifted a few feet west. If this minor fit in the field modification is necessary, all other culvert elevations and channel characteristics will remain the same.

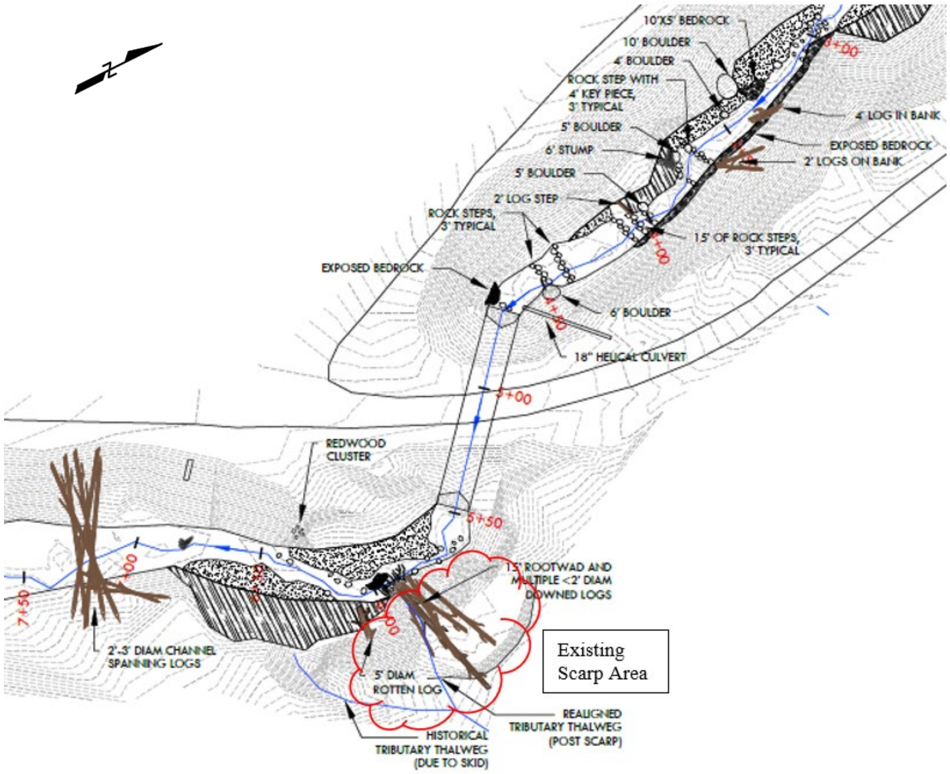

Figure 5. Existing Culvert Alignment (Appendix A, Sheet 3)

7.3 Longitudinal Profile

As discussed in Section 4.1, 974 feet of the Chamberlain Creek channel thalweg was captured in the topographic survey. That thalweg data was subsequently imported into AutoCAD Civil 3D where a centerline alignment and longitudinal profile were created. Channel slopes and channel stationing were developed using that profile, and a Vertical Adjustment Profile (VAP) analysis of the data is presented in Figure 6.

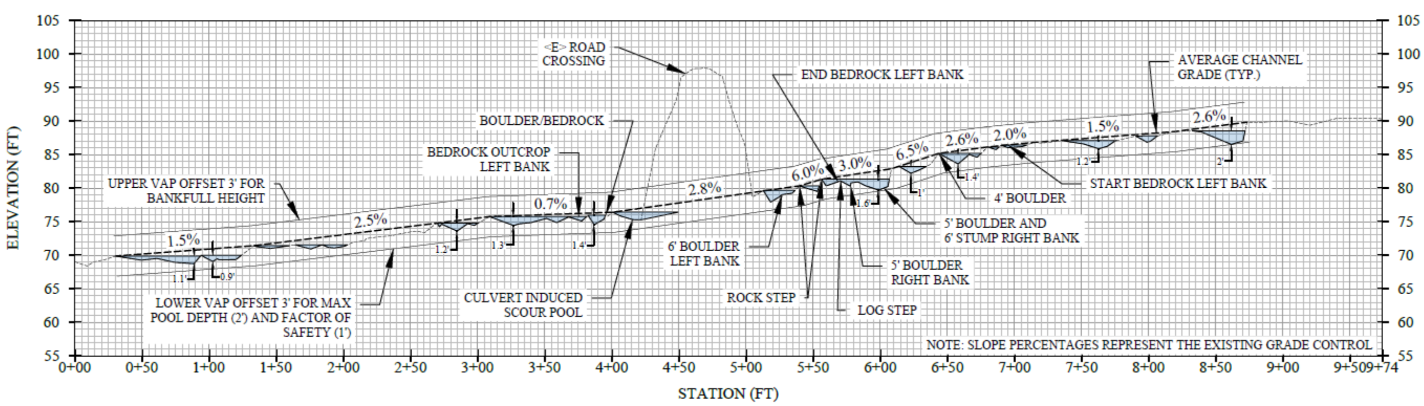

Figure 6. Chamberlain Creek longitudinal profile, vertically exaggerated x5 (Appendix A, Sheet 5)

The average channel slope in the bedrock chute varies, but the overall slope is approximately 3.9%. This is significantly steeper than the other reaches. The approximate slope through the existing crossing is 2.8%. Average channel slopes measured using riffle crests for the 974-ft channel length range between 0.7% and 2.6%. These sequences of pools and riffles are demonstrated in the profile shown above.

The lower VAP line was developed by offsetting the average channel profile by the maximum residual pool depth (2') and adding on a factor of safety (1') related to the anticipated scour from extreme flood events. It is worth mentioning that bedrock/boulder constraints, both above and below the existing culvert, indicate that major scour is unlikely to occur even if key grade control features were destabilized during any such flood events in the future. The upper VAP line was created by adding the average top of bank elevation to the general channel slope. Top of bank elevations represent the maximum ability of racked debris to aggrade a channel before the stream would reroute itself to create a new flow path. In short, the lower and upper VAP lines represent the maximum expected scour and aggradation that could possibly occur in Chamberlain Creek over the redesigned crossing's lifetime.

8 PROPOSED ALTERNATIVES, PREFERRED DESIGN, AND MODEL RESULTS

8.1 Initial Structure Alternatives

After completing the preliminary analysis and testing solutions based on the design criteria, four potential crossing structures would be able to satisfy project objectives and allow year-round passage to 1.6 miles of previously unavailable habitat for salmonids for all life cycle stages: a round culvert, a pipe arch, an open bottom culvert, and a clear spanning bridge.

Setting the crossing structure below grade (culvert or footings) and backfilling it with ESM is critical to securing low-flow fish passage for juveniles, interstitial flows for other aquatic organisms, and limiting scour and high flow velocities during higher flows for adult passage. Grade control structures installed throughout the crossing structure would ensure fish passage and could also break up high velocity flows to provide heterogeneous habitat and small resting eddies. Each structure comes with its own benefits and drawbacks; each also has its own compromises. Table 8 uses the sizing criteria discussed in Section 6.3 to estimate structure geometry, and trade-offs are further discussed in the individual sections for each structure type.

Table 8. Minimum Metrics Used to Size Design Alternatives

Design Metric	Minimum to be Met	Alternative 1 - 22' Dia. Round Culvert[1]	Theoretical Alternative 2 - 22' x 16' Pipe Arch Culvert[2]	Alternative 2 - 20.5' x 13.2' Pipe Arch Culvert[3]	Alternative 3 - Open Bottom Culvert	Alternative 4 - 25' Clear Span Bridge
Structure Material Cost	N/A	~$190,000	N/A	~$109,000	~$111,000 + Footings	N/A[4]
Structure Length (including road prism)	Varies with road elevation and skew	90-100 ft	80-90 ft	80-90 ft	75-85 ft	70-80 ft
Bankfull Width	19 feet	19 ft (21 ft VAP)	22 ft (22 ft VAP)	20.5 ft (20 ft) VAP	If semi-circle, 30 ft (27 ft VAP)	25 ft (25 ft VAP)
ESM Thickness	3 ft	5.5 ft (8.5 VAP)	3.5 ft (7.5 ft VAP)	3 ft (6 ft VAP)	3 ft (6 ft VAP)	3 ft (6 ft VAP)
ESM Volume	N/A	~260 CY	~200 CY	~165 CY	If semi-circle, ~265 CY	~210 CY
100-Year Flood Conveyance Area (<0.67 HW/D)	130 sqft	232 sqft (189 sqft VAP)	175 sqft (132 sqft VAP)	133 sqft (86 sqft VAP)	If semi-circle, 208 sqft (140 sqft VAP)	Depends on road elevation, but will be >200 sqft
Velocity @ Adult Fish Passage Flow	< 10 ft/sec (13 ft max wetted width @107 cfs)		ESM Specification			
Velocity @ Juv. Fish Passage Flow	< 3 ft/sec (23 ft max wetted width @21 cfs)		Greater than most bankfull widths but will be incorporated as an ESM specification if needed for the selected structure.			
Low-Flow Fish Passage Channel	1 ft wide		ESM Specification			

[1] This comparison was performed at the 65% design using a 22' diameter round culvert and other similarly sized structures. After selection of the preferred alternative, additional information and a desire to adhere to the Stream Simulation design methods discussed in Section 6.1 warranted an increase in the preferred structure size. A 26' round culvert was selected for the final design.

[2] A 22' x 16' pipe arch is not a readily available size. It was compared for theoretical reasons.

[3] The largest pipe arch readily available of 20.5' x 13.2' was included for comparison.

[4] A bridge price was not included but footers, very tall wingwalls, large volumes of cast-in-place concrete, similarly large volumes of excavation, tie backs, and material access restrictions make this alternative extremely costly and difficult to implement when compared to other alternatives.

8.1.1 Alternative 1 – Round Culvert

A 22-foot diameter round culvert would allow for channel realignment and be sufficiently large to allow for a bankfull width close to 19 feet when the bottom 5.5 feet is buried with substrate. A substrate depth of 5.5 feet sufficiently protects against the 3 ft maximum scour anticipated by the VAP analysis for all regions excepting the channel margins where the pipe's curve would force the streambed to be shallow. ESM will be installed for its entire length and will be sized for the hydraulic conditions of the preferred crossing. The largest rock sizes shall be used to create banks within the culvert. Leaving the uppermost 1/3 of the conveyance area free to transport floating debris and avoid pressurized flow, the conveyance area for a pipe this size, and embedded this much, would be approximately 232 square feet. In the unlikely event that the channel bed aggraded to 8.5 ft of depth, then the conveyance area (leaving 1/3 of the pipe free) would be 189 square feet and the bankfull width would increase to 21 ft.

As mentioned in the first note on the previous page, additional information after the initial structure selection and a desire to adhere to the Stream Simulation methods discussed in Section 6.1 required an increase in the design crossing size. The proposed round culvert currently shown in the plans has a 26' diameter. This preferred culvert is discussed in Section 8.2 and the achieved design metrics for the 26' culvert are discussed in Section 8.5.

8.1.2 Alternative 2 –Pipe Arch

A pipe arch with similar geometry to what already exists in Chamberlain Creek would need to be 22 ft wide and 16 ft tall to pass the 100-year flood with an HW/D ratio less than 0.67 and achieve minimum bankfull widths at every VAP eventuality. Since the bottom of this culvert is flatter than that of a round pipe, an ESM thickness of 3.5 ft (closer to that expected by the VAP analysis) could be used. Steel and ESM volumes used for this alternative would be significantly less than that of a round culvert, but the specialized pieces required for construction could make installation slightly unwieldy and similar in overall cost and effort to the round culvert. Pipe arches are generally good options for fish passage, but unless specially designed, they are typically limited to ~20 ft maximum width. This restricted bankfull width will not allow us to properly follow the Stream Simulation guidance outlined in Section 6.1 so a pipe arch is not a viable option for the Chamberlain Creek crossing.

8.1.3 Alternative 3 – Open Bottom Culvert with Footers

An open bottom culvert with footers will be able to meet the minimum design metrics laid out in Table 8, but the exact geometry will be dependent on material availability from the supplier. If a semi-circle is used, then the span will have to be 30 ft to successfully pass the 100-year flood with an HW/D ratio of 0.67. This geometry would require a large amount of ESM to ensure channel bed stability. If the shape is more rectangular, or even something similar to a pipe arch, then the materials needed for construction would decrease. The decreased low chord of this alternative compared to the enclosed culverts would allow for a lower road and even shorter crossing length. A shorter crossing length would further decrease material costs, but there is an additional cost from the footers with this alternative. Footers would be prefabricated, or sub-contracted out, and the overall excavation effort of this alternative is likely to be similar to that of the closed bottom culvert options. Geotechnical investigations discovered a poor load bearing material in line with the proposed crossing orientation. The exact extents of this material will be unknown until excavation, but it is reasonable to assume that over-excavation and backfilling with suitable materials is going to be needed to create viable foundations to place the footers on. Environmental concerns related to pouring concrete in the field are also associated with this alternative. It should be noted that an open bottom culvert eliminates the possibility of a perched inlet/outlet thereby securing fish passage indefinitely. This alternative also has advantages regarding ESM installation, which would occur after the placement of footings but before the arch tops are placed. This reduces the heavy equipment coordination that would be required for structures that must be assembled prior to or during ESM placement. Furthermore, ESM placement for this alternative would not warp or stress subgrade portions of the structure compared to an embedded pipe arch or round culvert where large ESM could affect structure geometry and therefore assembly.

8.1.4 Alternative 4 – Bridge

A bridge allows for the greatest floodplain and channel connectivity, the greatest flood resilience, the lowest stream crossing velocities, and the most flexibility when it comes to restoring the channel alignment. Implementing a bridge would require the installation of two vertical concrete wingwall abutments on either side of Chamberlin Creek. Within the confines of the 25-foot span, channel and streambed material would be designed to take a ‘stable and mobile’ approach where the bankfull width and local bathymetry would have the freedom to change over time. The 25-foot span was selected to allow Chamberlain Creek to flow under the structure at a more natural angle. The abutments would be set on footers well below the maximum expected scour, and the bridge low chord would be designed to handle the 100-year flood with at least 3 feet of freeboard. Since the cross-sectional area of this alternative is greater than any of the other culvert options, this alternative has the opportunity to lower the road elevation and shorten the requisite road fill length associated with the crossing. The actual length will be determined if this structure is selected, but an approximate overall length of 75 feet was used to compare this alternative to the others. Approach angles, bridge deck widths, and turn radii into and out of the structure will also be considered if this alternative is selected.

8.2 Preferred Alternative

The preferred alternative is a BridgeCor round culvert from Contech. ESM calculations were not completed prior to the 65% design analysis and the structural comparison presented above did not adequately account for smaller bankfull widths resulting from the use of appropriately sized bankline rock. An ESM gradation is presented in Table 9 and was calculated using results from the completed hydraulic model and equations recommended in the CDFW Restoration Manual (CDFG 2010). ESM sizing and gradation calculations can be found in Appendix G.

Table 9. ESM gradation for 100-yr flood

Classification	Size (in)
D100	62
D84	25
D50	10
D16	1
D8	0.1

Using D100 boulders to create banks within the culvert meant that the desired 19’ bankfull width became extremely difficult to achieve. Other limiting factors like depth to bedrock, minimum/maximum fill cover depths, channel slope, ESM thickness/volume, conveyance of the 100-year flood, fish passage, general constructability, and roadway restrictions were all balanced to create a design that is fits the design criteria. The design crossing is larger than the previously recommended structure and is now a 26’ diameter round culvert. Model results and an evaluation of the design criteria for this structure are presented in the following sections. Fully constructible details can be found in Appendix A.

8.3 Proposed Channel Realignment and Longitudinal Profile

The existing culvert is too short to accommodate the natural flow path of Chamberlain Creek, and as such, its current orientation unnaturally forces water to make sharp turns into and out of the pipe arch. The proposed creek alignment will connect to the same invert elevation at Station approximately 4+78 (station 5+05 for the existing stream alignment), but after rotating the crossing clockwise about 19 degrees, the outlet will connect very close to Station 3+78 (Figure 7). Realignment will shorten the stream length by approximately 50 feet and increase the channel slope through the crossing from 2.8% to 3.0%. However, the benefits to restoring the channel orientation outweigh the loss of stream length and minor increase in slope. In addition to allowing for an easier flow entry at the upstream side of the crossing, the proposed orientation will alleviate hydraulic forces on the left bank just past the outlet. Relieving these hydraulic forces will increase the scarp’s stability and reduce the likelihood of future sediment delivery to Chamberlain Creek.

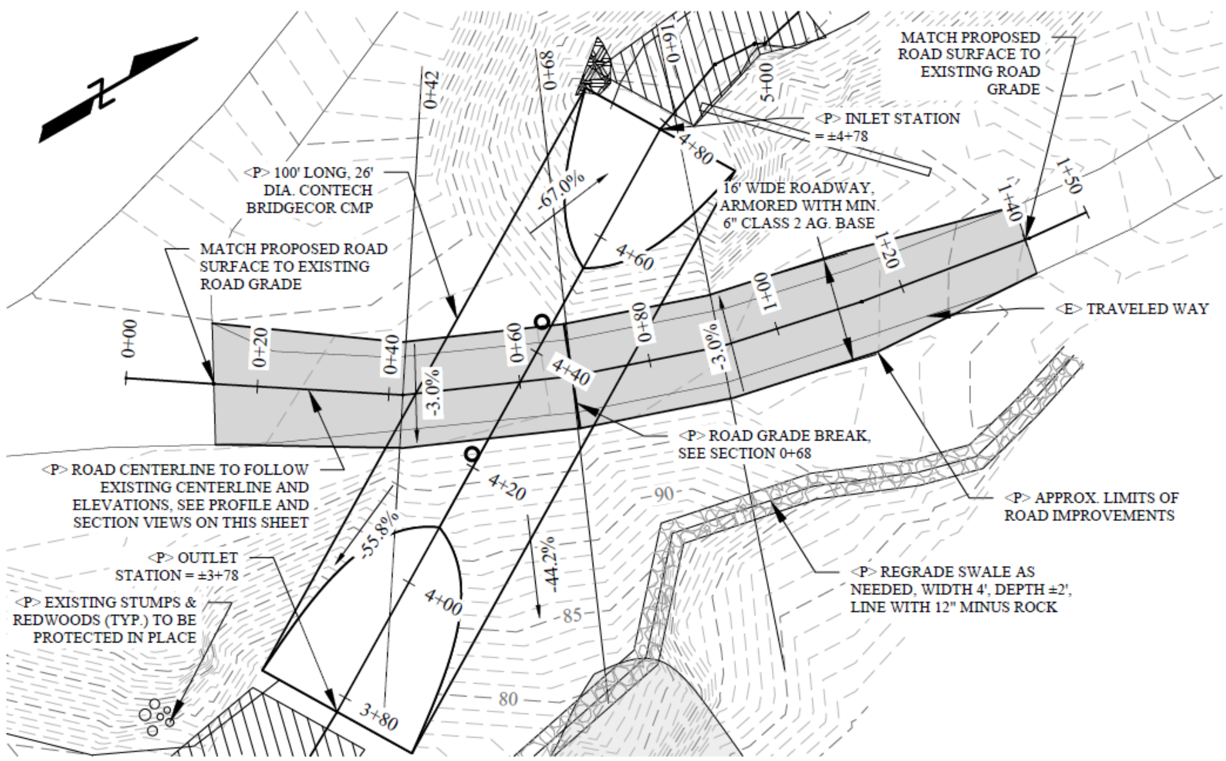

Figure 7. Plan view of proposed culvert and Chamberlain Road improvements (Appendix A, Sheet 6)

Realigning the channel will remediate lateral anthropogenic alterations to the channel, and restoring the channel's longitudinal profile will address vertical streambed issues related to the undersized crossing. Per Section 4.4, the reference reach represents a transitional zone that links the portion of Chamberlain Creek where there is some floodplain access to a boulder chute with pocket water habitat. As a result of shortening the stream length, a reconstructed channel profile with the ESM distribution shown in Table 9 will be embedded to depths informed by the VAP analysis. Due to the large size of the culvert, ESM will need to be an average of 8.7' thick to restore the channel grade to approximately 3.0% (Figure 8). Despite shortening the channel as a result of its realignment, the restored grade is only 15% steeper than the reference reach and is a mere 7% steeper than the 2.8% slope of the existing crossing. The proposed crossing meets the design criteria outlined in Section 6.3 and balances maximum slope allowances recommended by both Stream Simulation and Hydraulic Design approaches (NMFS 2023). With a typical channel slope around 2.8-3%, the culverted section of Chamberlain Creek was, and will continue to be, a transitional reach for salmonids. The primary goal remains ensuring aquatic organism access to the additional 1.6 miles of habitat above the crossing.

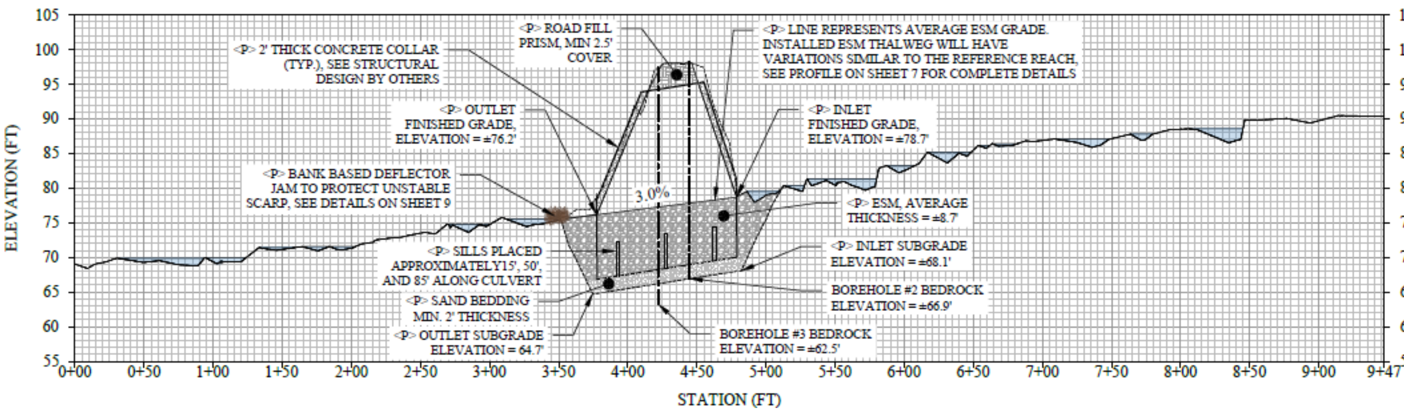

Figure 8. Proposed longitudinal profile, vertically exaggerated x5 (Appendix A, Sheet 5)

While the overall structure of the ESM in the crossing needs to remain in place and was sized for the 100-year flood, partial stability of the other bedload size classes is helpful for restoring the natural processes within the stream system. Allowing for scour, deposition, and interstitial flow through gravels will boost ecological productivity and create sustainable and passable habitat for salmonids and other organisms. To achieve this stable yet mobile approach, 5.5-foot-tall culvert straight spanning steel bed retention sills shall be welded to the culvert bottom and sides. These retention sills will provide structure for the largest boulders and will have the additional benefit of ensuring surface flows that allow for salmonid passage. These retention sills will not be subject to hydraulic forces from Chamberlain Creek since they will only be placed below the lower VAP line. Constructible details for the ESM and retention sills can be found in Appendix A on Sheet 7.

8.4 Proposed Hydraulic Model Results and Discussion

The results of the modeled proposed conditions show restored hydraulics when the realigned Chamberlain Creek is conveyed through the 26 ft diameter round culvert. Figure 9 shows the realigned profile through the proposed culvert and includes water surface elevations for a variety of flow regimes.

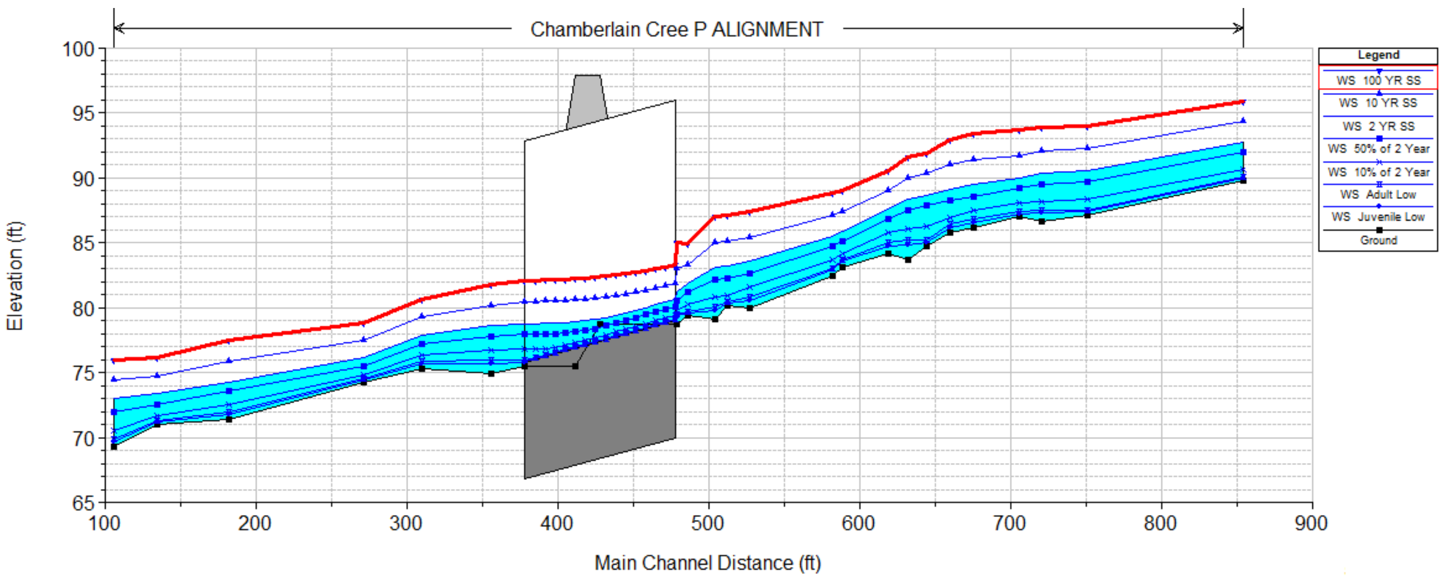

Figure 9. HEC-RAS profile of proposed conditions along Chamberlain Creek

For reference, the 2-year flood is filled in with light blue, the 100-year flood is the red line, and all of the other flows have different markers along the dark blue profile lines. While flow does initially decrease in elevation and accelerate as it is compressed laterally into the culvert, the water surface increases to a more natural level by the time it leaves the culvert. The values presented in Table 10 and Table 11 are best understood when compared to Table 6 and Table 7. The difference in upstream stationing is a result of the shortened thalweg in the model but all of the cross sections can be directly compared since they were taken at the exact same locations along Chamberlain Creek. The hydraulic parameters for the proposed crossing demonstrate great improvements to aquatic conditions for salmonids.

Table 10. Hydraulic results for upstream cross section and the proposed culvert inlet

		Upstream of Culvert (Station 5+88)			**Culvert Invert (Station 4+78)**	
	Flow (cfs)	Velocity (ft/s)	Depth (ft)	Shear Stress (lb/sq ft)	Velocity (ft/s)	Depth (ft)
100-year Flow	1040	9.03	5.88	13.45	9.01	6.33
50-year Flow	886	8.58	5.39	12.59	8.46	5.91
25-year Flow	742	8.11	4.91	11.66	7.89	5.5
10-year Flow	554	7.36	4.22	10.15	7.01	4.93
2-year Flow	214	5.22	2.69	6.00	4.51	3.71
Adult High Flow	107	4.14	1.96	4.27	3.88	2.77
Juvenile High Flow	21	2.62	1.01	2.37	1.78	1.87
Adult Low Flow	3	1.34	0.58	0.76	1.21	1.16
Juvenile Low Flow	1	0.97	0.42	0.44	1.12	0.51

Table 11. Hydraulic results for the proposed culvert outlet and downstream cross section

		Culvert Outlet (Station 3+78)		**Downstream of Culvert (station 3+10)**		
	Flow (cfs)	Velocity (ft/s)	Depth (ft)	Velocity (ft/s)	Depth (ft)	Shear Stress (lb/sq ft)
100-year Flow	1040	8.63	6.47	8.49	5.40	5.61
50-year Flow	886	8.09	6.04	8.00	4.99	5.14
25-year Flow	742	7.55	5.61	7.46	4.58	4.63
10-year Flow	554	6.79	4.97	6.67	3.99	3.92
2-year Flow	214	5.23	3.41	4.62	2.61	2.28
Adult High Flow	107	4.38	2.62	3.63	1.94	1.59
Juvenile High Flow	21	3.75	1.52	2.00	1.11	0.63
Adult Low Flow	3	4.15	0.62	1.12	0.55	0.24
Juvenile Low Flow	1	2.21	0.41	0.84	0.36	0.16

In contrast to model results from the existing culvert, the proposed design does not create extreme increases in flow velocities through the culvert. In fact, velocities primarily go down and depths primarily go up when Chamberlain Creek transitions from an unconfined stream into the upstream end of the culvert. Red values do not satisfy the recommendations from the California Salmonid Manual, and the main concern for the proposed design comes in the form of velocities for juveniles at the downstream outlet of the culvert. There is a direct trade-off between low-flow depths and low-flow velocities, and for this particular design, it was decided that achieving low-flow depths would benefit salmonids more than achieving low-flow velocity targets. Salmonids are adept at using channel margins or other velocity refugia like eddies to make their way up and down streams. To achieve that goal, a low-flow channel was created in the model to represent the desired physical characteristics in the ESM after construction.

In the model, peak flow conditions are simulated with a restricted culvert geometry that approximates the ESM as a flat surface but to accurately portray the low-flow channel, the lower flows were simulated as an open channel without a culvert. Ineffective-flow areas were created to emulate the walls of the culvert as is common practice when analyzing low-flow conditions for fish passage projects with natural bathymetry. A cross sectional comparison between the existing structure inlet (top image) and the proposed structure inlet at various flows is shown in Figure 10. For reference, the 2-year flood is filled in with light blue, the 100-year flood is the red line, and all of the other flows have different markers along the dark blue profile lines. The peak flood conditions in the proposed model are shown with a closed culvert (middle image), while the exceedance flows for the proposed conditions model are shown as an open channel (bottom image). The details of that low-flow channel, and other important information regarding ESM installation like bank-line rock and the aforementioned ribs, are specified in the Plans on Sheet 7 of Appendix A.

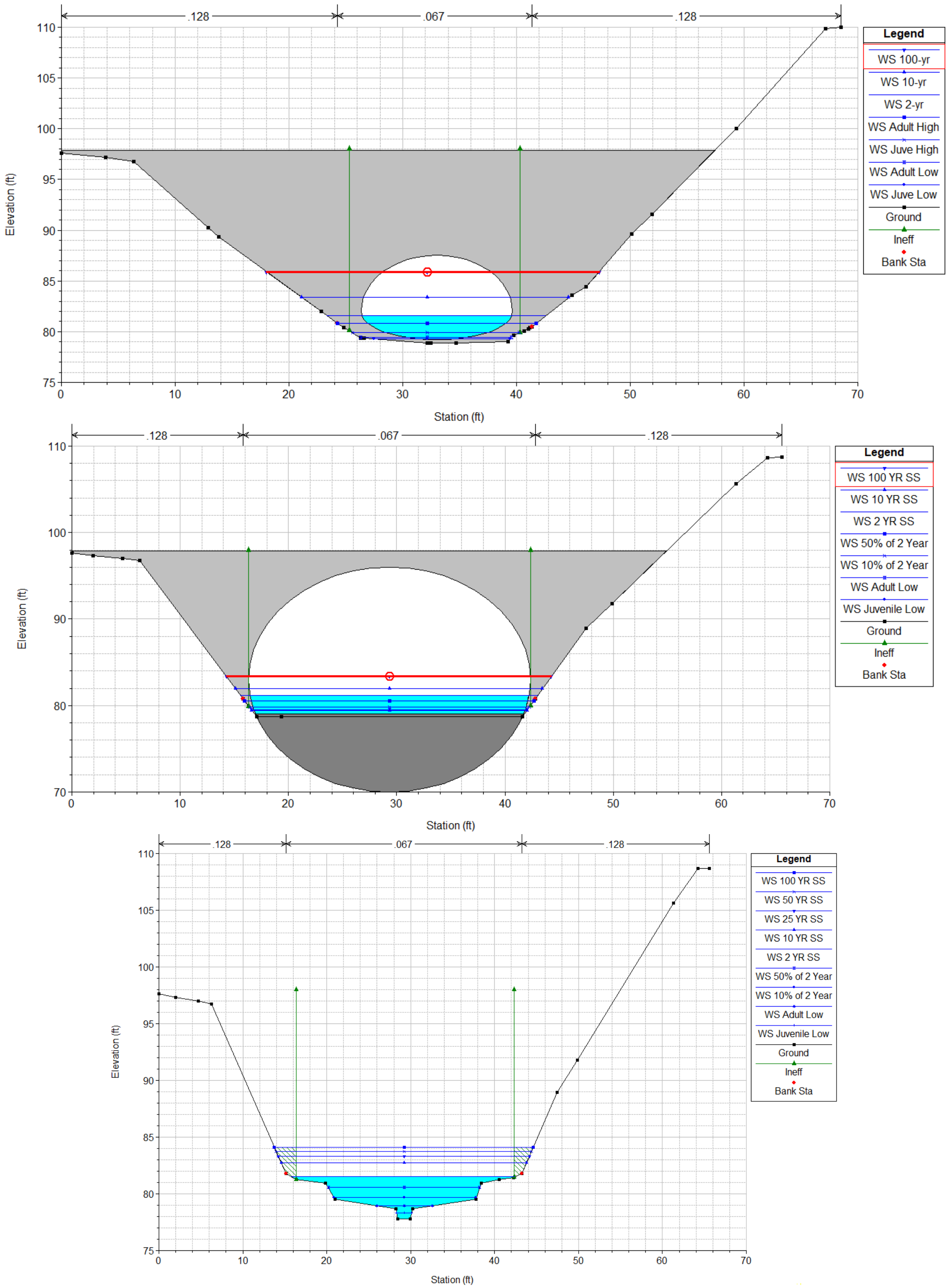

Figure 10. HEC-RAS inlet cross sections for existing (top) and proposed (middle/bottom) conditions

Despite highly accelerating the 100-year flood, and having no substrate in the culvert, the existing crossing has an HW/D ratio of 0.84 at its inlet. The proposed crossing has an HW/D ratio of 0.26. This is below the minimum design objective of 0.67 discussed in Section 6.3. The proposed culvert is hydraulically overdesigned, but from a Stream Simulation perspective, the bankfull width is slightly below what's desired. As discussed throughout this document, the overall design balanced many different, and occasionally conflicting, design criteria. The proposed crossing satisfies minimum design metrics for most categories and significantly overachieves in a few areas to ensure that fish passage is possible for all life stages of salmonids during all times of the year in Chamberlain Creek.

8.5 Proposed Deflector Jam

While the proposed channel realignment will direct a majority of flows away from the existing unstable scarp on channel left, a log deflector jam installed at the downstream toe of the scarp will further protect the unstable area from erosive forces and increase the area's stability and longevity. See Figure 11 for details of the proposed log deflector jam. The proposed deflector jam will be constructed using a minimum of six 40' long logs with rootwads. The structure will be anchored using a minimum of 3 two-ton boulders placed on the footer logs as ballast and logs shall be embedded at least 2/3 of the stick length into the left bank where possible. 3 bolts will connect the footer, runner, and top logs to each other. While interaction forces between logs do not show up in the PDF version of the Rafferty calculations, the additional ballast forces provided by 'Bot 3' was used to stabilize 'Runner,' and 'Runner' was used to stabilize 'Top 1' and 'Top 2' (Appendix G). Benefits of the proposed wood structure, which begin to address the concerns mentioned in Section 3.5, include the increase of large wood that provides habitat and refugia for migrating fish and the potential to increase sediment and flow variability.

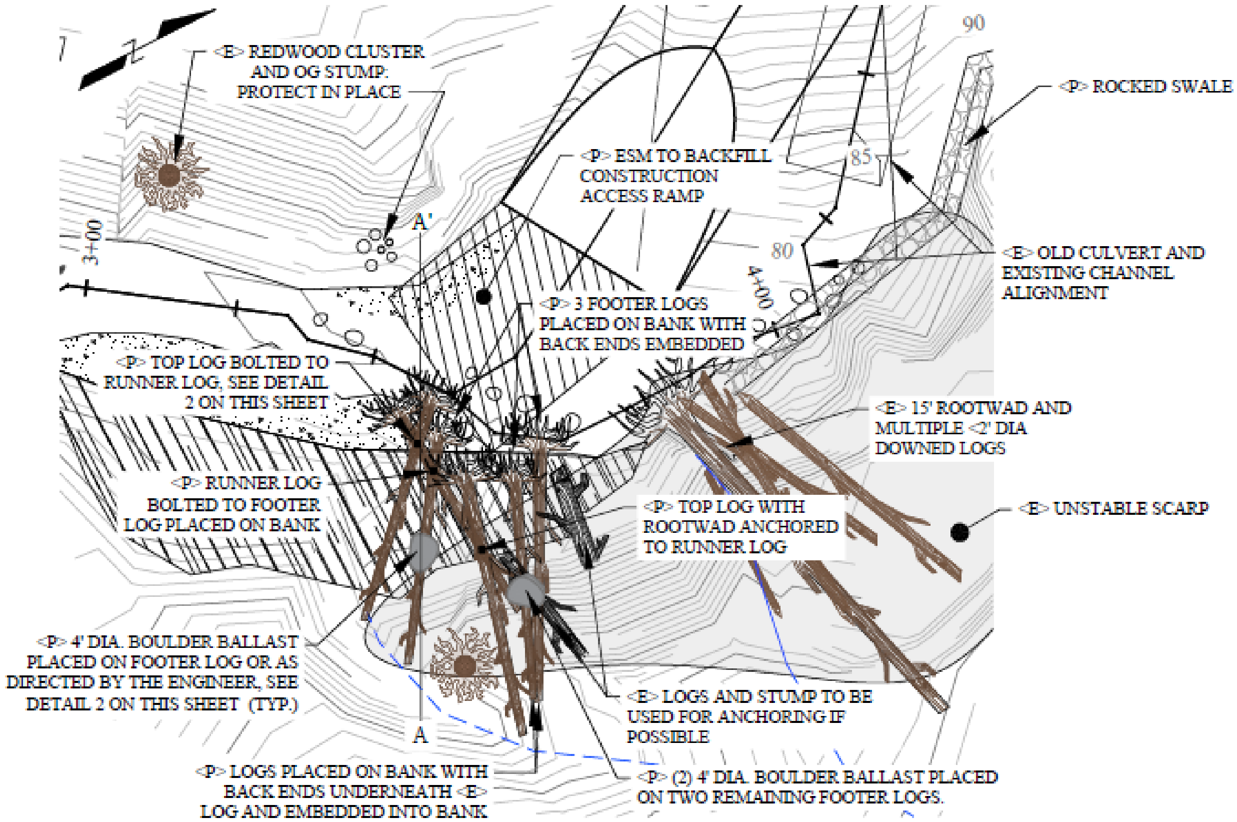

Figure 11. Proposed Deflector Jam at the toe of the existing scarp, plan view (Appendix A, Sheet 9)

8.6 Achieved Metrics and Design Criteria

To achieve design metrics and guidelines discussed in Section 6.1 and mitigate for any other potential risks discussed throughout this document, a 26-foot diameter round culvert was determined to be the best, and if needed, the most adaptable solution during construction. The proposed design:

- Maximizes flood resiliency of the crossing by passing the 100-year flood with a headwall to depth ratio of 0.26. This is far better than the HW/D design goal of 0.67 and allows for fish passage with flow regime changes caused by climate change. This additional conveyance area also allows for stochastic changes to the downstream thalweg elevation. The redirected flows are no longer projecting into the scarp, but if another landslide were to increase the bed elevation and that backfilled through the culvert, then there is plenty of conveyance area to accommodate significant vertical adjustments to the thalweg elevation.
- Minimizes the frequency and severity of water velocities that exceed the swimming capabilities of salmonids and maximizes hydraulic conditions suitable for fish passage. Modelled velocities in the culvert during the adult and juvenile fish passage design flows peak at 3.9 ft/s and 2.0 ft/s, respectively. These are well below the burst swimming design metrics of 10 ft/s and 3 ft/s.
- Maximizes floodplain connectivity and restores riparian processes within the project area. Bank and skeletal stability of ESM will be ensured up to the 100-yr flood, but the stable

yet mobile approach will allow for natural bedload distribution processes to function throughout the crossing reach. To avoid destabilizing the downstream bank below the culvert outlet, a bank-based deflector jam will disperse most of the projected flows and provide habitat for salmonids seeking cover or pools.

- Maximizes bathymetric variability using a wide mix of ESM sizes and ensures passage through the stable and mobile approach through the crossing. A low flow meander and bathymetric variability created during the ESM installation will ensure that there are no major jumps proposed in this design.
- Maximizes channel connectivity under low flow conditions using the wide variety of size classes represented in the ESM. Mimicking conditions in the reference reach and creating a low flow meander to concentrate low flows will ensure that migration after extreme conditions is still possible.
- Minimizes construction disturbances by having a relatively concentrated footprint. This crossing necessitates a rather large structure, but steps will be taken to ensure that shade trees and adjacent vegetation will be preserved where possible.
- Minimizes cost without significantly compromising design performance. The balancing act between material costs and installation effort were discussed throughout the life of this project's design. The preferred design achieves all the design metrics and the over-designed aspects allow for leniency if unpredictable events were to occur during excavation or come up later and change the creek system.

9 REFERENCES

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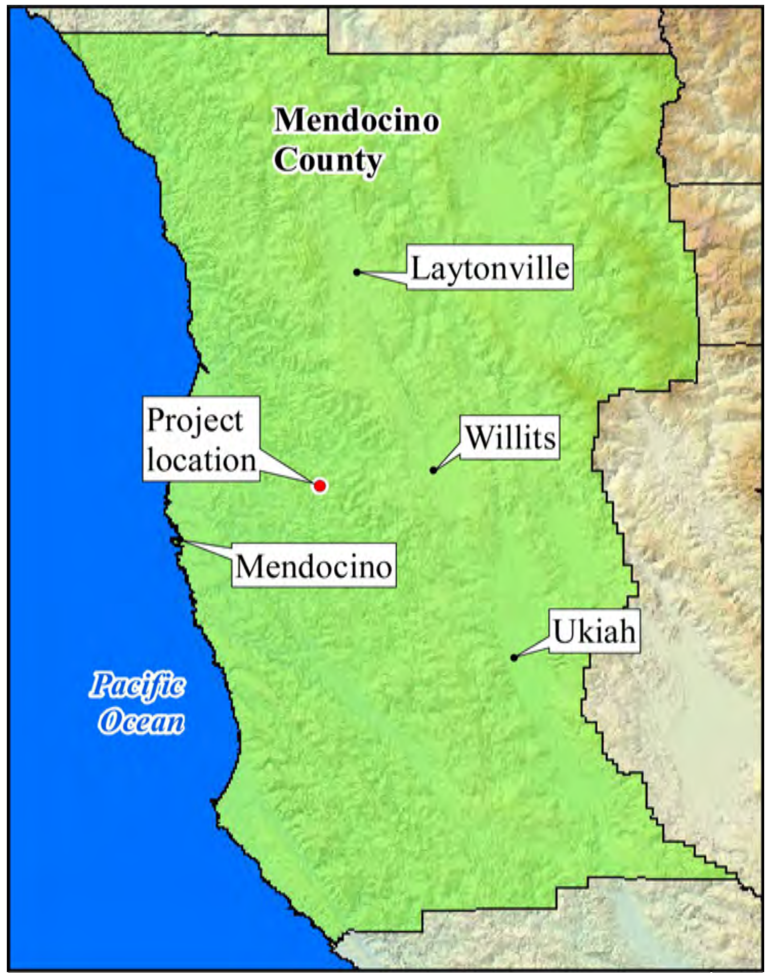
Appendix A.
100% Design Plans and
Opinion of Probable Construction Cost

CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT

PROJECT LOCATION: MENDOCINO COUNTY, CA

PREPARED FOR: MENDOCINO LAND TRUST & THE CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE

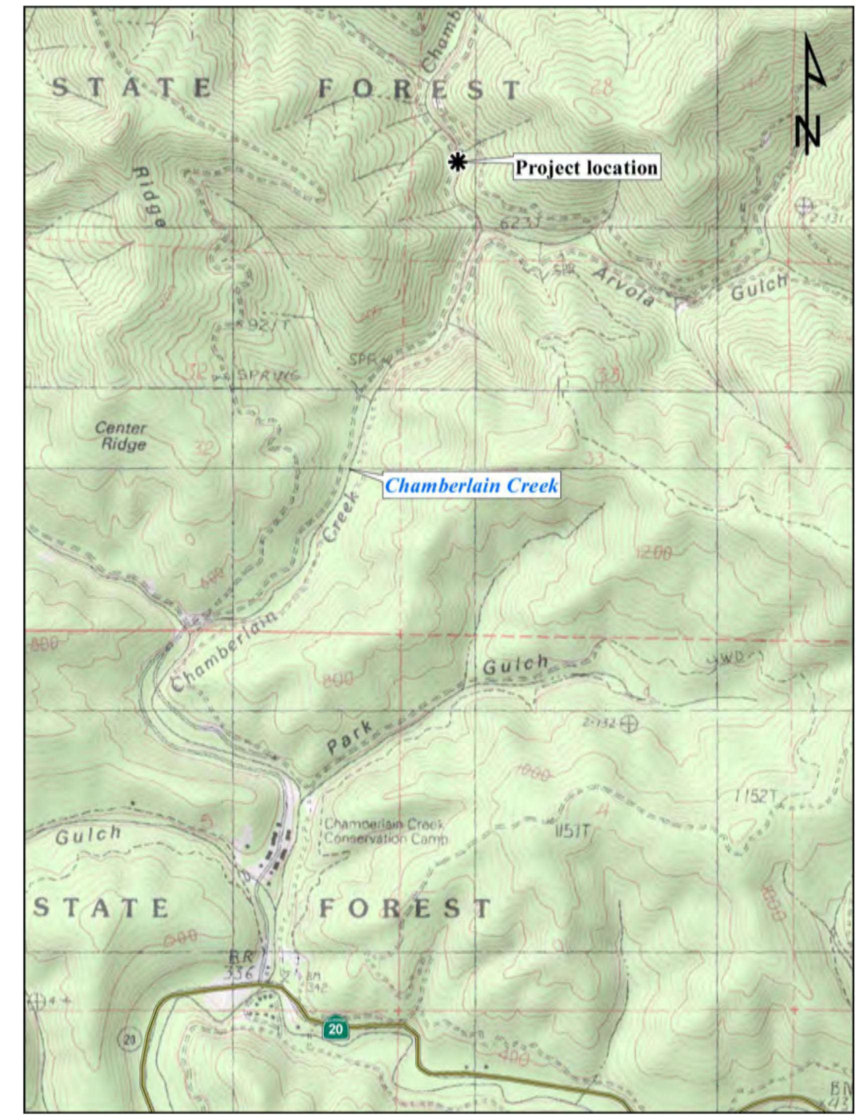
100% DESIGN PLANS



VICINITY MAP

Sheet List Table

Sheet Number	Sheet Title
1	COVER PAGE & SHEET INDEX
2	CONSTRUCTION NOTES & ABBREVIATIONS
3	EXISTING CONDITIONS - PLAN VIEW
4	PROPOSED CONDITIONS - PLAN VIEW
5	LONGITUDINAL PROFILES
6	ROAD CROSSING DETAILS
7	CULVERT DETAILS
9	DEFLECTOR JAM DETAILS
8	CULVERT & ESM SPECIFICATIONS
10	WATER CONTROL PLAN
11	EROSION CONTROL PLAN



LOCATION MAP

PROJECT DESCRIPTION

THE PROJECT WILL IMPROVE ACCESS TO HABITAT FOR COHO AND OTHER SALMONIDS IN THE CHAMBERLAIN CREEK WATERSHED BY REPLACING A FAILING MULTIPLATE CULVERT THAT CURRENTLY ACTS AS A COMPLETE PASSAGE BARRIER FOR JUVENILES AND A TEMPORAL PASSAGE BARRIER FOR ADULTS. FUTURE IMPLEMENTATION OF THE COMPLETED DESIGN WILL ENSURE ACCESS TO 1.6 MILES OF ADDITIONAL SALMONID HABITAT IN THE UPPER MAINSTEM OF CHAMBERLAIN CREEK. ADDITIONAL BENEFITS ASSOCIATED WITH THIS PROJECT WILL INCLUDE AN INCREASED DENSITY OF IN-STREAM HABITAT FEATURES, IMPROVED SEDIMENT METERING CAPABILITIES THROUGHOUT THE PROJECT REACH, REDUCED FLOOD IMPACTS TO THE ROAD CROSSING, AND RESTORED RIPARIAN HABITAT ALONG THE CHANNEL CORRIDOR.

REGISTERED PROFESSIONAL ENGINEER G. S. ORUM NO. C93662 EXP. 6/2024 CIVIL STATE OF CALIFORNIA

DATE 5/29/2023
NOTES PREPARED BY PWA
FIGURES CREATED BY BTK & JPS

PACIFIC WATERSHED ASSOCIATES
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ARCATA, CALIFORNIA 95518
PH: (707) 839-5130 FX: (707) 839-8168
www.pacificwatershed.com

SHEET DESCRIPTION: COVER PAGE & SHEET INDEX

PROJECT NAME AND LOCATION: CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT MENDOCINO COUNTY, CA

PWA JOB NO. 10382

GENERAL NOTES

1. THE CONTRACTOR SHALL HAVE SOLE AND COMPLETE RESPONSIBILITY FOR JOB SITE CONDITIONS DURING THE COURSE OF CONSTRUCTION OF THIS PROJECT, INCLUDING SAFETY OF ALL PERSONS AND PROPERTY. THIS REQUIREMENT SHALL APPLY CONTINUOUSLY AND SHALL NOT BE LIMITED TO NORMAL WORKING HOURS. THE CONTRACTOR SHALL DEFEND, INDEMNIFY, AND HOLD THE LANDOWNERS AND ITS REPRESENTATIVES HARMLESS FROM ANY LIABILITY, REAL, AND OR ALLEGED, IN CONJUNCTION WITH THE PERFORMANCE OF THIS PROJECT.
2. THE CONTRACTOR IS RESPONSIBLE FOR ASSURING THAT EXCAVATION, GRADING, AND FILL WORK IS CONSISTENT WITH ALL APPLICABLE PERMITS, MENDOCINO ROAD AND DEVELOPMENT STANDARDS, THE CALIFORNIA BUILDING CODE, CALIFORNIA FISH AND GAME CODE, CALIFORNIA WATER CODE, CALIFORNIA DEPARTMENT OF TRANSPORTATION STANDARD PLANS & SPECIFICATIONS, AND OTHER LOCAL CODES AND REQUIREMENTS.
3. A COPY OF THE SIGNED PLANS, SPECIFICATIONS, AND ALL PERMITS SHALL BE KEPT ON-SITE AT ALL TIMES WHEN EXCAVATION AND CONSTRUCTION WORK ARE ONGOING.
4. IF GROUND DISTURBANCE WILL OCCUR BETWEEN OCTOBER 15 AND MAY 15, THE MATERIALS CALLED OUT IN THE EROSION CONTROL PLAN SHALL BE PRESENT ON SITE BEFORE EXCAVATION COMMENCES. THE CONTRACTOR IS RESPONSIBLE FOR MONITORING WEATHER AND IMPLEMENTING THE BEST MANAGEMENT PRACTICES (BMPS) SPECIFIED IN THE EROSION CONTROL PLAN. BMPS SHALL BE IN PLACE AT LEAST 24 HOURS PRIOR TO A PREDICTED RUNOFF GENERATING STORM (>50% CHANCE OF >0.1 INCHES OF PRECIPITATION IN A 24 HOUR PERIOD). THE CONTRACTOR SHALL BE SOLELY LIABLE FOR VIOLATIONS OF ENVIRONMENTAL PERMITS AND CODES RESULTING FROM FAILURE TO IMPLEMENT BMPS IN A TIMELY MANNER.
5. THE CONTRACTOR SHALL IDENTIFY THE EXCAVATION BOUNDARIES AND DIRECTIONS TO THE EXCAVATION AREA USING WHITE PAINT IN ACCORDANCE WITH THE REQUIREMENTS OF USA NORTH 811. NOTIFICATION TO USA NORTH 811 SHALL BE MADE NOT LESS THAN 2 WORKING DAYS AND NOT MORE THAN 14 CALENDAR DAYS BEFORE DIGGING COMMENCES. USA NORTH 811 MEMBERS WILL IDENTIFY THE LOCATIONS OF UNDERGROUND UTILITIES ONCE THE CONTRACTOR RECEIVES A USA TICKET NUMBER BY CALLING 811 OR APPLYING ONLINE AT HTTP://USANORTH811.ORG/. IF THERE IS UNCERTAINTY REGARDING THE LOCATION OF UNDERGROUND UTILITIES WITHIN THE PERIMETER OF THE EXCAVATION AREA, THE CONTRACTOR SHALL HIRE A QUALIFIED PRIVATE UTILITY LOCATING SERVICE.
6. IF OVERHEAD UTILITIES ARE PRESENT, THE CONTRACTOR SHALL DETERMINE IF THE UTILITIES WILL INTERFERE WITH EQUIPMENT OPERATIONS. IF OVERHEAD UTILITIES COULD POTENTIALLY INTERFERE WITH EQUIPMENT OPERATIONS, THE CONTRACTOR SHALL PROVIDE A SPOTTER WHO SHALL BE CAPABLE OF COMMUNICATING CLEARANCE DISTANCES AND UNSAFE CONDITIONS TO THE EQUIPMENT OPERATOR.
7. THE CONTRACTOR IS SOLELY RESPONSIBLE FOR ALL DAMAGE TO OVERHEAD AND UNDERGROUND UTILITIES. IN THE EVENT OVERHEAD OR UNDERGROUND UTILITIES ARE DAMAGED THE CONTRACTOR SHALL CEASE EXCAVATION AND CALL 911 IMMEDIATELY.
8. IN THE EVENT THAT ARCHAEOLOGICAL RESOURCES ARE ENCOUNTERED DURING EXCAVATION, ALL EXCAVATION WORK SHALL CEASE UNTIL A QUALIFIED ARCHAEOLOGICAL AND/OR TRIBAL MONITOR IS CONSULTED. EXCAVATION WORK SHALL RESTART ONLY UPON THE APPROVAL OF THE QUALIFIED ARCHAEOLOGIST AND/OR TRIBAL MONITOR. IF HUMAN REMAINS OR EVIDENCE OF HUMAN BURIAL ARE ENCOUNTERED THE CONTRACTOR SHALL ALSO CONTACT THE COUNTY CORONER.
9. IF HAZARDOUS MATERIALS, DRUMS, OILY LIQUIDS, UNUSUAL ODORS, OR EVIDENCE OF NATURALLY OCCURRING ASBESTOS IS ENCOUNTERED DURING EXCAVATION, WORK SHALL CEASE AND THE CONTRACTOR SHALL CONTACT THE ENGINEER OR THEIR DESIGNATED REPRESENTATIVE AS SOON AS POSSIBLE. EXCAVATION SHALL RESUME ONLY UPON THE APPROVAL OF THE ENGINEER OR THEIR DESIGNATED REPRESENTATIVE.
10. MATERIAL STORAGE AND HANDLING PROCEDURES SHALL CONFORM WITH THE MANUFACTURER'S RECOMMENDATIONS AND/OR THE INDUSTRY'S GENERALLY ACCEPTED BEST MANAGEMENT PRACTICES.
11. DETAILS AND NOTES ON DRAWINGS SHALL TAKE PRECEDENCE OVER GENERAL NOTES OR DETAILS.
12. DRAWINGS SHALL NOT BE SCALED. DRAWINGS ARE GENERALLY TO SCALE AND NOT TO SCALE IS SHOWN ONLY WHERE DRAWING IS OBVIOUSLY OUT OF SCALE. WRITTEN DIMENSIONS ON THE DRAWINGS SHALL TAKE PRECEDENCE OVER GRAPHICAL SCALES SHOWN ON DRAWINGS.
13. THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS ON SITE BEFORE COMMENCING WORK. THE ENGINEER OR THEIR DESIGNATED REPRESENTATIVE SHALL BE NOTIFIED OF ANY DISCREPANCIES BEFORE WORK COMMENCES.
14. THE CONTRACTOR IS RESPONSIBLE FOR MAINTAINING A CLEAN, SAFE, AND ORDERLY JOB SITE.
15. THE CONTRACTOR SHALL THOROUGHLY INVESTIGATE THE SITE AFTER CLEARING AND GRUBBING IS COMPLETE AND BEFORE CONSTRUCTION COMMENCES. IF BURIED STRUCTURES SUCH AS CULVERTS, WOODY DEBRIS, FOUNDATIONS, CESSPOOLS, OR LARGE ROCKS ARE ENCOUNTERED, CONSTRUCTION SHALL CEASE AND THE ENGINEER OR THEIR DESIGNATED REPRESENTATIVE SHALL BE NOTIFIED IMMEDIATELY.
16. THE ENGINEER/GEOLOGIST OR THEIR DESIGNATED REPRESENTATIVE(S) SHALL NOT BE HELD LIABLE FOR CONSTRUCTION SITE SAFETY MATTERS, THE CONTRACTOR AND/OR THEIR SUBCONTRACTORS' ERRORS AND OMISSIONS, NOR FOR FAILURE OF THE CONTRACTOR'S AND THEIR SUBCONTRACTORS' FAILURE TO ADHERE TO THE CONSTRUCTION CONTRACT, SPECIFICATIONS, AND DRAWINGS.
17. ELEVATIONS SHOWN ON THE DRAWINGS ARE RELATIVE TO THE LOCAL GROUND CONDITIONS AND TEMPORARY BENCHMARKS PLACED FOR THE PURPOSE OF CONSTRUCTION.
18. THE CLIENT SHALL BE RESPONSIBLE FOR SECURING ALL REQUIRED PERMITS FOR CONSTRUCTION. PACIFIC WATERSHED ASSOCIATES SHALL NOT BE LIABLE FOR ANY FINES, FEES, OR VIOLATIONS DUE TO CONSTRUCTION COMPLETED WITHOUT THE REQUIRED PERMITS.
19. IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO MINIMIZE EROSION AND PREVENT THE DELIVERY OF SEDIMENT OR OTHER POLLUTANTS TO SURFACE WATERS OR OTHER SENSITIVE AREAS.
20. WORK WILL BE CONDUCTED DURING DRY WEATHER PERIODS WHEN ALL GRADING, EROSION CONTROL, AND SITE STABILIZATION MEASURES CAN BE IMPLEMENTED PRIOR TO RAINFALL.
21. THE CONTRACTOR SHALL KEEP PROJECT AREAS GENERATING DUST WATERED DURING THE TERM OF CONSTRUCTION. CONTRACTOR SHALL BE RESPONSIBLE FOR PROVIDING THEIR OWN WATER AND POWER FOR OPERATIONS, IRRIGATION, AND DUST CONTROL. WATER SHALL NOT BE PUMPED FROM THE CREEK FOR THESE USES.
22. SOLID WASTE SUCH AS TRASH, DEBRIS, AND SANITARY WASTE, SHALL BE PLACED IN CONTAINERS AND REMOVED FROM THE SITE PERIODICALLY OR DISPOSED OF AS DIRECTED BY THE OWNER OR THEIR DESIGNATED REPRESENTATIVE.
23. IF RAINFALL GREATER THAN 1 INCH IN A 24 HOUR PERIOD IS FORECAST PRIOR TO THE COMPLETION OF GRADING, OR IF ACCUMULATED PRECIPITATION HAS MADE FILL MATERIALS UNSUITABLE FOR COMPACTION AND STABLE CONSTRUCTION, THE SITE WILL BE STABILIZED AND PROTECTED FROM SURFACE EROSION. PLASTIC SHEETING WILL BE USED TO COVER ALL FILL STOCKPILES AND UNFINISHED SLOPES AND SECURED BY PLACEMENT OF MULTIPLE HEAVY OBJECTS.

INSPECTIONS:

1. EXCAVATION
2. SUBGRADE
3. STRUCTURE BEDDING
4. CROSSING STRUCTURE INSTALLATION
5. LARGE WOOD AND ESM INSTALLATION
6. STRUCTURAL BACKFILL
7. FINISHED GRADE
8. PLACEMENT OF SPOILS AND EROSION CONTROL MEASURES

REGISTERED PROFESSIONAL ENGINEER G. S. ORUM NO. C93662 EXP. 6/2024 CIVIL STATE OF CALIFORNIA

WATER POLLUTION CONTROL: THE CONTRACTOR SHALL DEVELOP THE DEWATERING/WATER CONTROL PLAN. AN EXAMPLE PLAN COVERING THE BASICS IS PROVIDED BUT THE EXACT INFRASTRUCTURE AND EXTENT OF THE WATER CONTROL PLAN SHALL BE DEFINED BY CONTRACTOR AND REVIEWED/APPROVED BY THE ENGINEER OR THEIR DESIGNATED REPRESENTATIVE PRIOR TO CONSTRUCTION.

LEGEND

1+00	ALIGNMENT STATIONING (FEET)
10	EXISTING CONTOUR WITH ELEVATION
10	PROPOSED CONTOUR WITH ELEVATION
x	FENCE LINE
	SILT FENCE
	LIMIT OF GRADING
	LIMIT OF DISTURBANCE
	SURVEY CONTROL POINT
	MONITORING WELL
S	STAFF PLATE / T-POST
	FLOW DIRECTION
	TREE
	SECTION LABEL (DETAIL #, SHEET #)
	LOG (HORIZONTAL INTO PAGE)
	LARGE WOODY MATERIAL
	WATER SURFACE
	TEMPORARY STAGING/STOCKPILE AREA

PROFILE/SECTION LABELS

2 — DETAIL IDENTIFIER
7 — SHEET IDENTIFIER

ABBREVIATIONS

APPROX,~	APPROXIMATELY
BDX	BEDROCK
CA	CALIFORNIA
CL	CENTERLINE
CMP	CORRUGATED METAL PIPE
CP	CONTROL POINT (SURVEY)
CY	CUBIC YARDS
DIA	DIAMETER
EL	ELEVATION
ESM	ENGINEERED STREAMBED MATERIAL
EOR	ENGINEER OF RECORD
<E>	EXISTING
FG	FINISHED GRADE
FT	FOOT/FEET
LOD	LIMIT OF DISTURBANCE
LWM	LARGE WOODY MATERIAL
MAX/MIN	MAXIMUM/MINIMUM
NTS	NOT TO SCALE
PT#	POINT NUMBER
<P>	PROPOSED
RD	ROAD
STA	STATION
SF	SQUARE FEET
SWM	SMALL WOODY MATERIAL
TYP	TYPICAL
(3:1)	SLOPE (HORIZONTAL:VERTICAL)

MATERIALS AND QUANTITIES

ITEM NO.	DESCRIPTION	UNIT	QUANTITY
1	MOBILIZATION	LS	1
2	CLEARING AND GRUBBING	AC	0.22
3	WATER MANAGEMENT	LS	1
4	EXISTING CULVERT REMOVAL AND DISPOSAL	LS	1
5	ROUND CULVERT, ASSEMBLY, AND INSTALLATION	LS	1
6	EARTHWORK	CY	9300
7	IMPORTED STRUCTURAL FILL	CY	450
8	ESTIMATED UNSUITABLE MATERIAL FOR END-HAUL	CY	1700
9	CLASS II AGGREGATE BASE	CY	40
10	CULVERT BEDDING - SAND	CY	275
11	CULVERT COLLAR - CONCRETE	CY	20
12	40' x 18" LOGS WITH ROOTWADS	EA	6
13	ANCHORING HARDWARE FOR WOOD STRUCTURE	EA	3
14	ENGINEERED STREAMBED MATERIAL (MIXED)	TONS	1100
15	12" MINUS RSP	TONS	60
16	EROSION CONTROL FABRIC	SY	500
17	EROSION CONTROL STRAW MULCH	BALE	30

*ESTIMATED QUANTITIES ARE FOR REFERENCE PURPOSES ONLY.

DATE 5/29/2023
NOTES PREPARED BY PWA
FIGURES CREATED BY BTK & JPS

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SHEET DESCRIPTION: CONSTRUCTION NOTES & ABBREVIATIONS

PROJECT NAME AND LOCATION: CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT MENDOCINO COUNTY, CA

PWA JOB NO. 10382

FILE PATH: P:\CAD\10382_Chamberlain_Creek\DWG\Construction Notes & Abbreviations.dwg SAVE DATE: 5/29/2023 10:20 AM SAVED BY:brycek

11"x17" SHEET. IF SHEET SIZE IS SMALLER, DRAWING HAS BEEN REDUCED.

GRAPHIC SCALE

0 20 40

(IN FEET)

1 inch = 40 ft.

LEGEND

EXPOSED BEDROCK

VEGETATED TERRACE

GRAVEL BAR

EXISTING MINOR CONTOURS

EXISTING MAJOR CONTOURS

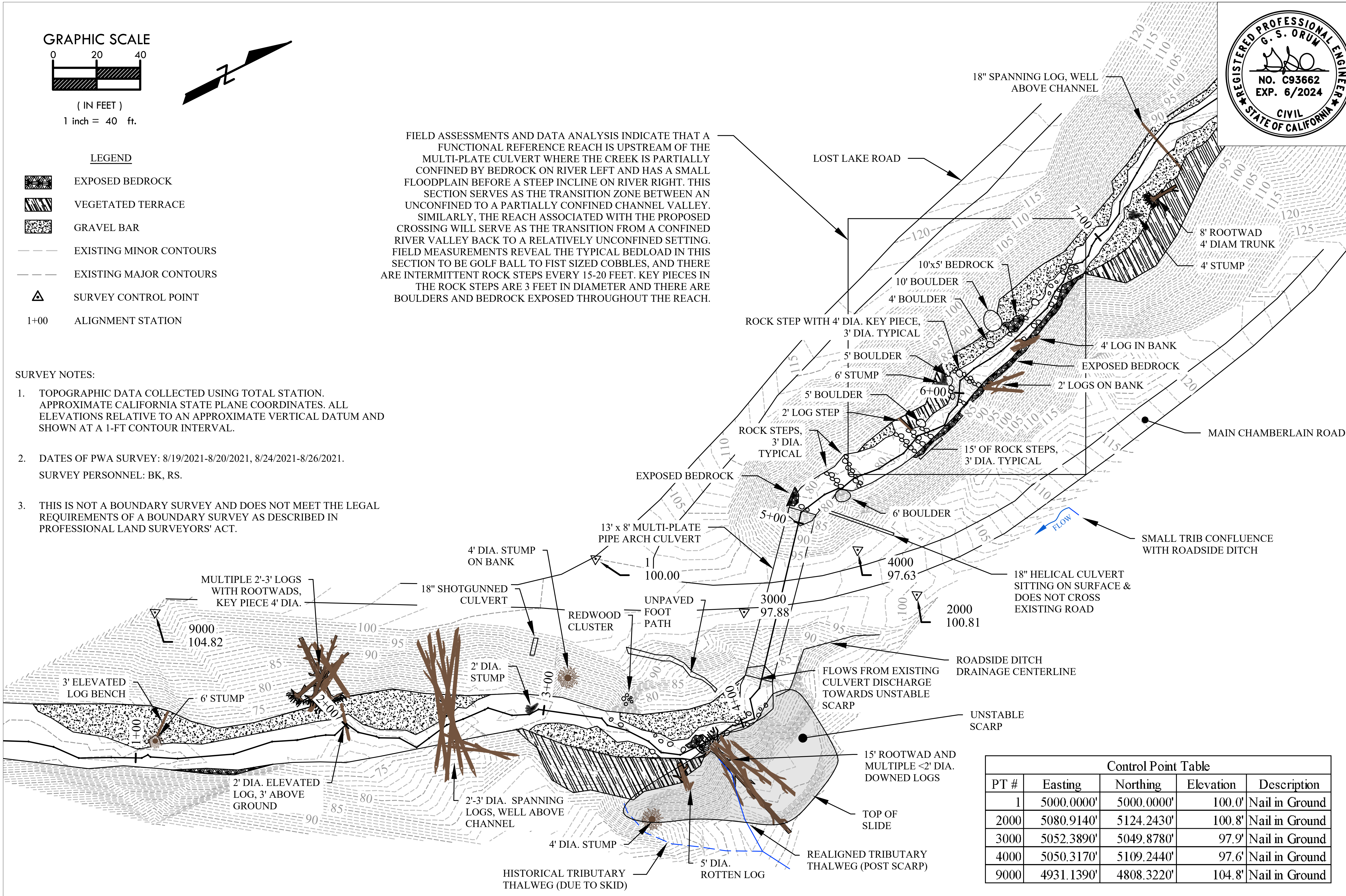
SURVEY CONTROL POINT

1+00 ALIGNMENT STATION

SURVEY NOTES:

1. TOPOGRAPHIC DATA COLLECTED USING TOTAL STATION. APPROXIMATE CALIFORNIA STATE PLANE COORDINATES. ALL ELEVATIONS RELATIVE TO AN APPROXIMATE VERTICAL DATUM AND SHOWN AT A 1-FT CONTOUR INTERVAL.
2. DATES OF PWA SURVEY: 8/19/2021-8/20/2021, 8/24/2021-8/26/2021.
   SURVEY PERSONNEL: BK, RS.
3. THIS IS NOT A BOUNDARY SURVEY AND DOES NOT MEET THE LEGAL REQUIREMENTS OF A BOUNDARY SURVEY AS DESCRIBED IN PROFESSIONAL LAND SURVEYORS' ACT.

FIELD ASSESSMENTS AND DATA ANALYSIS INDICATE THAT A FUNCTIONAL REFERENCE REACH IS UPSTREAM OF THE MULTI-PLATE CULVERT WHERE THE CREEK IS PARTIALLY CONFINED BY BEDROCK ON RIVER LEFT AND HAS A SMALL FLOODPLAIN BEFORE A STEEP INCLINE ON RIVER RIGHT. THIS SECTION SERVES AS THE TRANSITION ZONE BETWEEN AN UNCONFINED TO A PARTIALLY CONFINED CHANNEL VALLEY. SIMILARLY, THE REACH ASSOCIATED WITH THE PROPOSED CROSSING WILL SERVE AS THE TRANSITION FROM A CONFINED RIVER VALLEY BACK TO A RELATIVELY UNCONFINED SETTING. FIELD MEASUREMENTS REVEAL THE TYPICAL BEDLOAD IN THIS SECTION TO BE GOLF BALL TO FIST SIZED COBBLES, AND THERE ARE INTERMITTENT ROCK STEPS EVERY 15-20 FEET. KEY PIECES IN THE ROCK STEPS ARE 3 FEET IN DIAMETER AND THERE ARE BOULDERS AND BEDROCK EXPOSED THROUGHOUT THE REACH.



Control Point Table

PT #	Easting	Northing	Elevation	Description
1	5000.0000'	5000.0000'	100.0'	Nail in Ground
2000	5080.9140'	5124.2430'	100.8'	Nail in Ground
3000	5052.3890'	5049.8780'	97.9'	Nail in Ground
4000	5050.3170'	5109.2440'	97.6'	Nail in Ground
9000	4931.1390'	4808.3220'	104.8'	Nail in Ground

REGISTERED PROFESSIONAL ENGINEER G. S. ORUM NO. C93662 EXP. 6/2024 CIVIL STATE OF CALIFORNIA

DATE 5/29/2023
NOTES PREPARED BY PWA
FIGURES CREATED BY BTK & JPS

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SHEET DESCRIPTION:
EXISTING CONDITIONS - PLAN VIEW

PROJECT NAME AND LOCATION:
CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT
MENDOCINO COUNTY, CA

PWA JOB NO. 10382

GRAPHIC SCALE

0 20 40

(IN FEET)

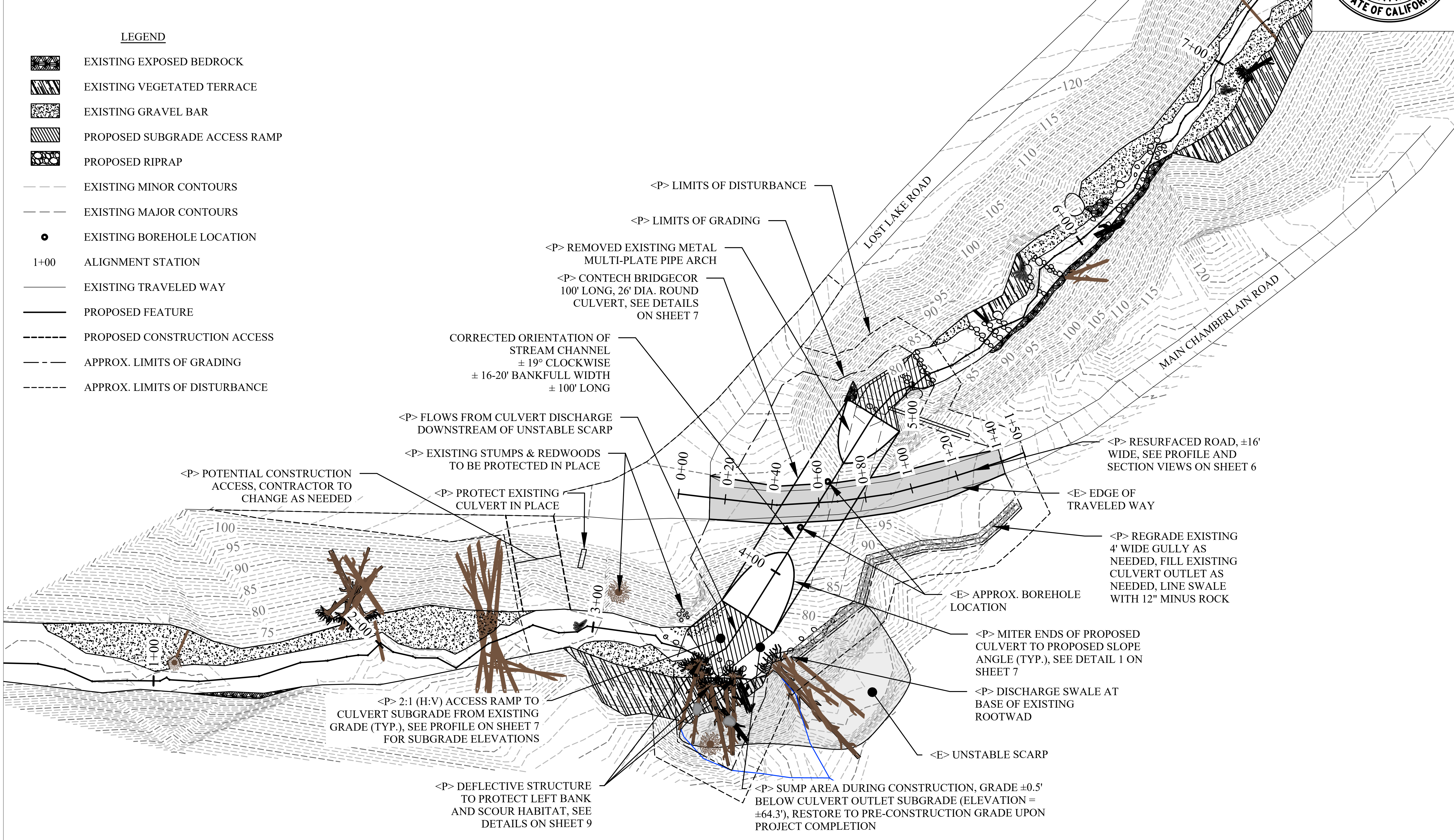
1 inch = 40 ft.

PROPOSED CULVERT INVERT COORDINATES			
	EASTING	NORTHING	ELEVATION
INLET INVERT	5025.1939'	5094.9256'	70.00'
OUTLET INVERT	5077.2884'	5008.1716'	66.80'

NOTE: ELEVATIONS SHOWN HERE ARE FOR THE CULVERT AND ARE BELOW ESM FINISHED GRADE.

LEGEND

- EXISTING EXPOSED BEDROCK
- EXISTING VEGETATED TERRACE
- EXISTING GRAVEL BAR
- PROPOSED SUBGRADE ACCESS RAMP
- PROPOSED RIPRAP
- EXISTING MINOR CONTOURS
- EXISTING MAJOR CONTOURS
- EXISTING BOREHOLE LOCATION
- 1+00 ALIGNMENT STATION
- EXISTING TRAVELED WAY
- PROPOSED FEATURE
- PROPOSED CONSTRUCTION ACCESS
- APPROX. LIMITS OF GRADING
- APPROX. LIMITS OF DISTURBANCE



REGISTERED PROFESSIONAL ENGINEER
G. S. ORUM
NO. C93662
EXP. 6/2024
CIVIL
STATE OF CALIFORNIA

DATE 5/31/2023
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SHEET DESCRIPTION:
PROPOSED CONDITIONS - PLAN VIEW

PROJECT NAME AND LOCATION:
CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT
MENDOCINO COUNTY, CA

PWA JOB NO. 10382

FILE PATH: P:\CAD\10382_Chamberlain_Creek\DWG\Proposed Features_JPS.dwg SAVE DATE: 5/31/2023 11:41 AM
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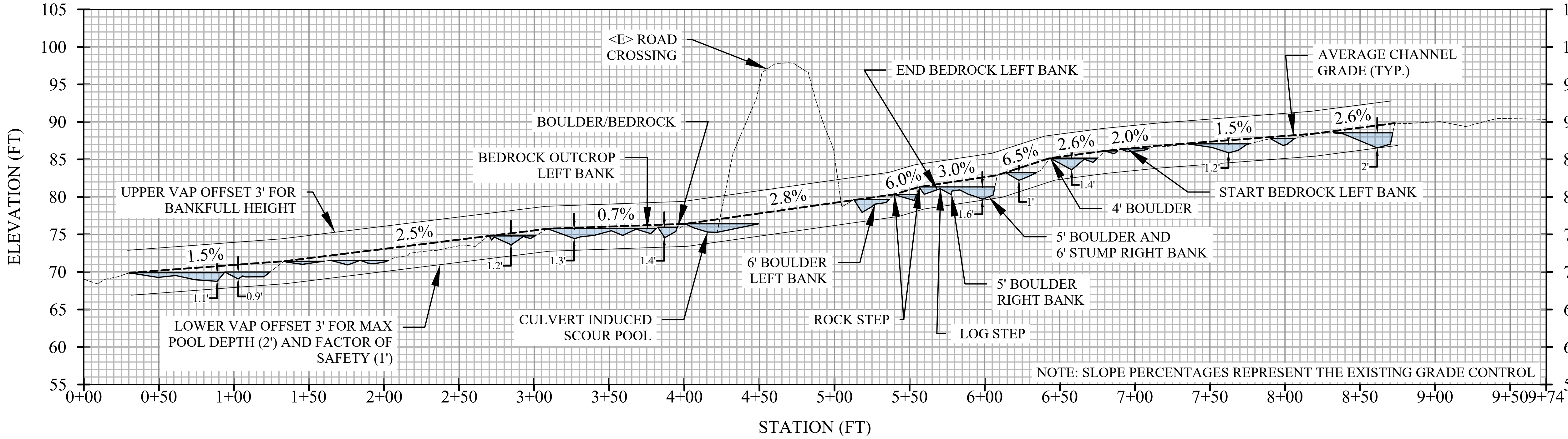
11"x17" SHEET. IF SHEET SIZE IS SMALLER, DRAWING HAS BEEN REDUCED.



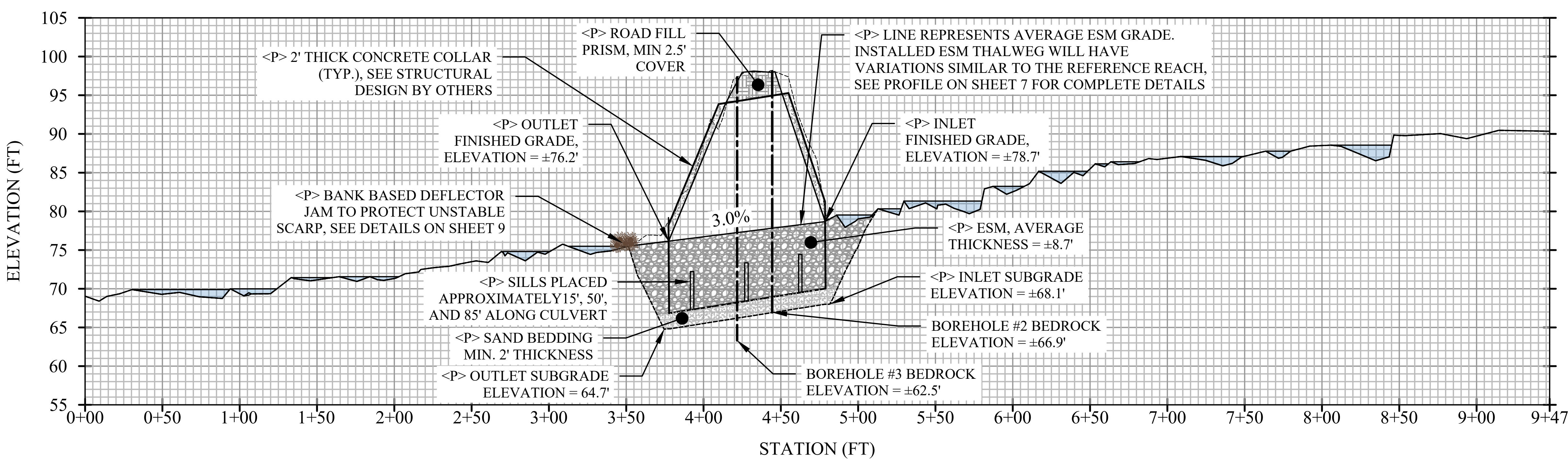
1/5 LONGITUDINAL PROFILE
EXISTING CHANNEL THALWEG
SCALE: 1" = 80'

EXISTING LONGITUDINAL PROFILE:

UPPER AND LOWER VERTICAL ADJUSTMENT PROFILES (VAP) WERE CREATED BY ESTIMATING THE MAXIMUM AGGRADATION LEVEL PRIOR TO OVERTOPPING AND EVALUATING THE MAXIMUM SCOUR DEPTH ALONG THE EXISTING THALWEG. USING STREAM SIMULATION METHODOLOGY TO DESIGN FOR FISH PASSAGE AT STREAM-ROAD CROSSINGS (USFS 2008), A FACTOR OF SAFETY OF 1 FOOT WAS ADDED TO THE LOWER VAP. THE UPPER AND LOWER VAPS REPRESENT THE ELEVATION RANGE THAT THE CHANNEL THALWEG COULD BECOME IF AGGREDATION OR EXTREME SCOUR EVENTS OCCURRED.

PROPOSED LONGITUDINAL PROFILE:

CHAMBERLAIN CREEK SHALL MOVE ALONG THE PROPOSED THALWEG ON TOP OF THE ESM VIA A LOW FLOW MEANDER. VARIATIONS IN CHANNEL PROFILE LIKE SMALL STEPS, CONCENTRATED FLOW SECTIONS, AND SPLIT FLOWS AROUND PROTRUDING BOULDERS IN THE ESM WILL MIMIC REFERENCE REACH CONDITIONS. ESM IS HYDRAULICALLY STABLE FOR THE 100 YEAR FLOOD, BUT SILLS HAVE BEEN INCORPORATED FOR ADDITIONAL ASSURANCE OF ESM STABILITY. SILLS ARE BELOW THE LOWER VAP, AND AS SUCH, ARE NOT ANTICIPATED TO INTERACT WITH CHAMBERLAIN CREEK HYDRAULICS. SILLS WILL HELP FORCE HYPORHEIC FLOWS CLOSE TO THE SURFACE AT SPECIFIED INTERVALS. ADDITIONAL DETAILS CAN BE FOUND ON SHEET 7.



2/5 LONGITUDINAL PROFILE
PROPOSED CHANNEL THALWEG
SCALE: 1" = 80'

LEGEND

- PROPOSED ROAD FILL
- PROPOSED ESM (TYP.)
- PROPOSED BEDDING
- MAX POOL DEPTH
- PROPOSED CONCRETE
- EXISTING GRADE
- PROPOSED SUBGRADE
- PROPOSED GRADE
- PROPOSED FEATURE
- AVERAGE CHANNEL GRADE
- UPPER AND LOWER VAPS
- EXISTING BOREHOLE

REGISTERED PROFESSIONAL ENGINEER
G. S. ORUM
NO. C93662
EXP. 6/2024
CIVIL
STATE OF CALIFORNIA

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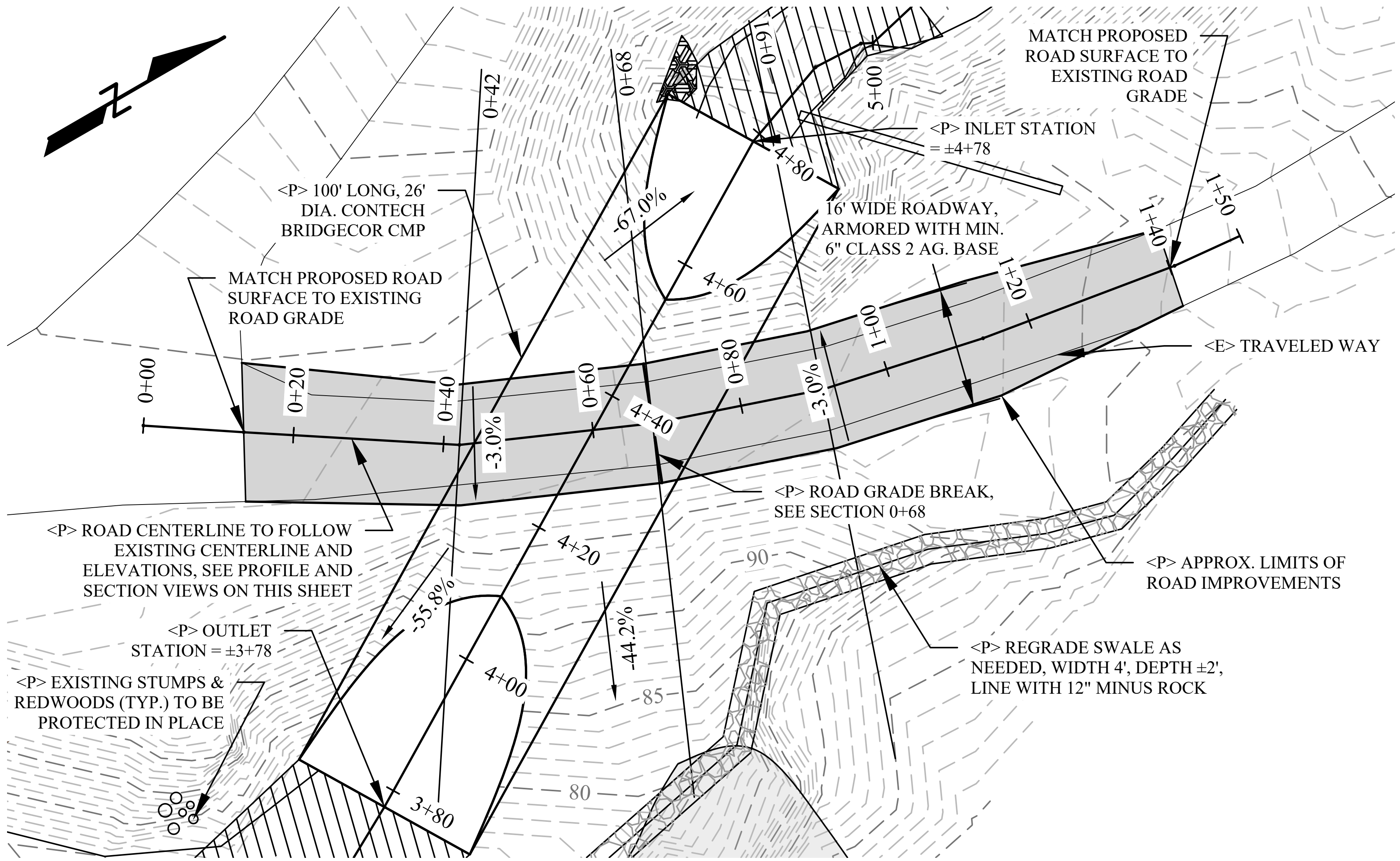
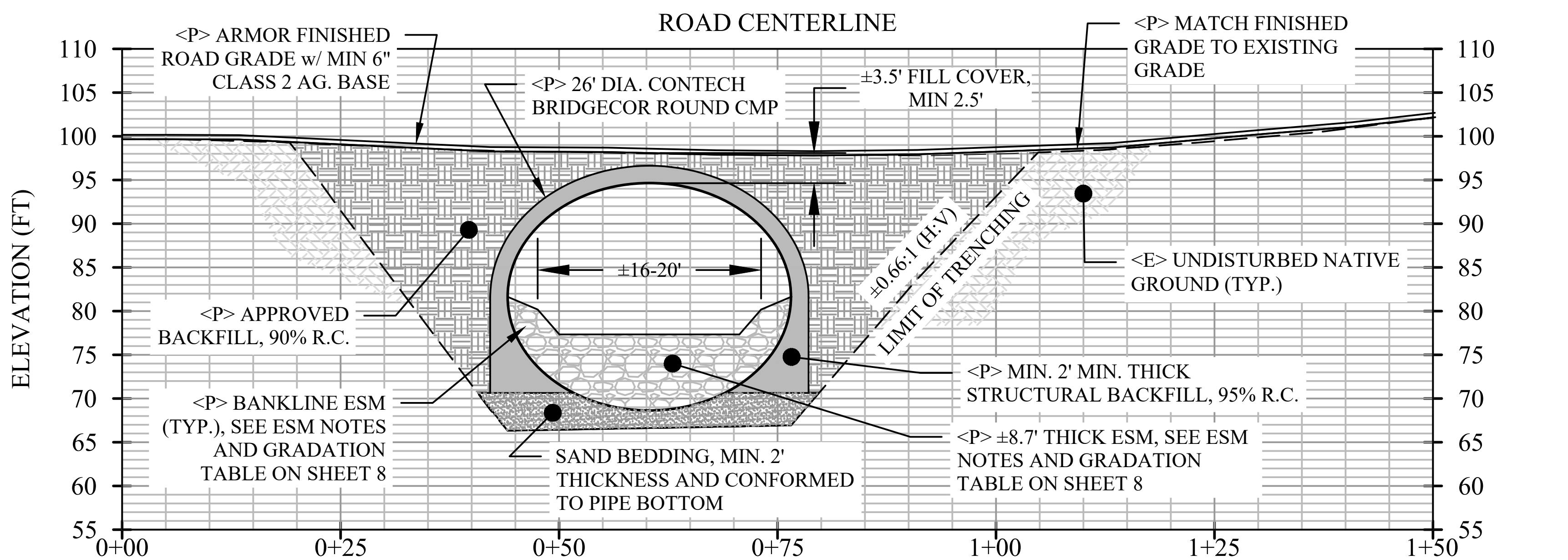
SHEET DESCRIPTION:
LONGITUDINAL PROFILES

PROJECT NAME AND LOCATION:
CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT
MENDOCINO COUNTY, CA
PWA JOB NO. 10382



1 / 6 PLAN VIEW
CHAMBERLAIN ROAD IMPROVEMENTS
SCALE: 1" = 20'



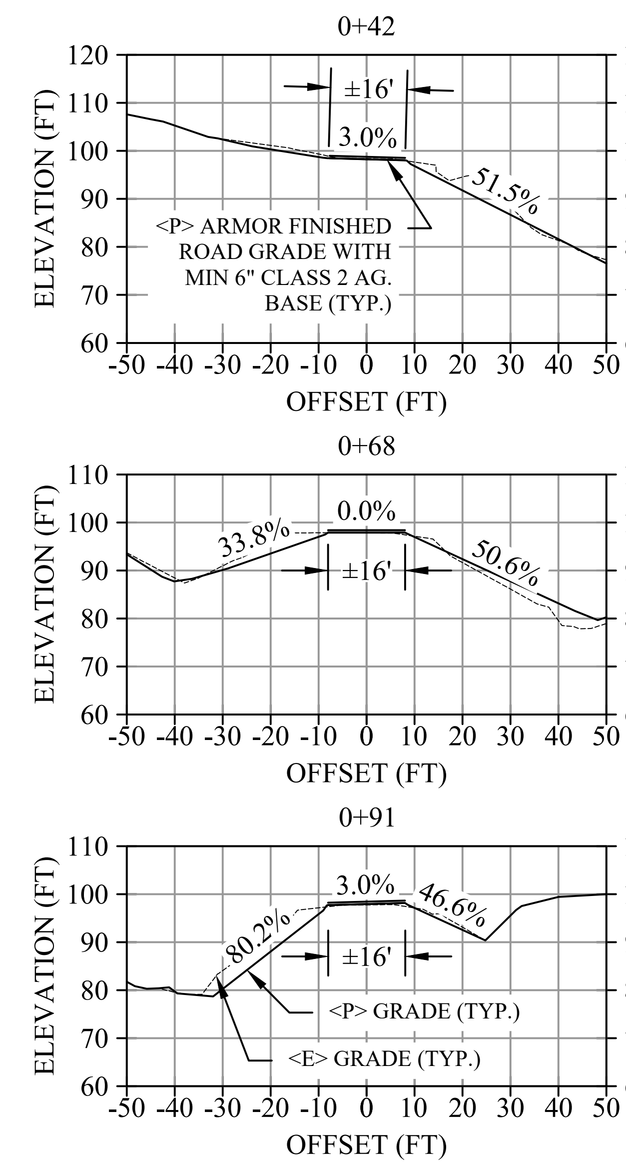
NOTE: PROFILE VIEW IS ALONG ROAD AND IS NOT PERPENDICULAR TO CULVERT. FOR CULVERT SECTION VIEW, SEE TYP. 3 ON SHEET 7.

2 / 6 PROFILE VIEW
CHAMBERLAIN ROAD IMPROVEMENTS
HORIZONTAL, VERTICAL SCALE: 1" = 20'

LEGEND

- PROPOSED BACKFILL
- EXISTING NATIVE GROUND
- PROPOSED ESM/RIPRAP
- PROPOSED BEDDING
- EXISTING MINOR CONTOUR
- EXISTING MAJOR CONTOUR
- EXISTING GRADE
- PROPOSED SUBGRADE
- PROPOSED GRADE
- PROPOSED FEATURE
- EXISTING TRAVELED WAY

NOTE:
1. ALL SECTION VIEWS LOOK NORTH ALONG ROAD CENTERLINE ALIGNMENT.
2. AGGREGATE BASE MATERIAL SHALL BE CLASS 2 BASE OR LOCALLY AVAILABLE CRUSHED ROCK, CONFORMING TO SECTION 26-1.02B & C OF CALTRANS STANDARD SPECIFICATIONS (2022).
3. ROAD GRADING SHALL COMPLY WITH CALTRANS STANDARD SPECIFICATIONS SECTION 19.



3 / 6 SECTION VIEWS
CHAMBERLAIN ROAD IMPROVEMENTS
HORIZONTAL, VERTICAL SCALE: 1" = 40'

REGISTERED PROFESSIONAL ENGINEER
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EXP. 6/2024
CIVIL
STATE OF CALIFORNIA

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SHEET DESCRIPTION: ROAD CROSSING DETAILS

PROJECT NAME AND LOCATION: CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT MENDOCINO COUNTY, CA

PWA JOB NO. 10382

6

FILE PATH: P:\CAD\10382_Chamberlain_Creek\DWG\Proposed Features_JPS.dwg SAVE DATE: 5/31/2023 11:41 AM
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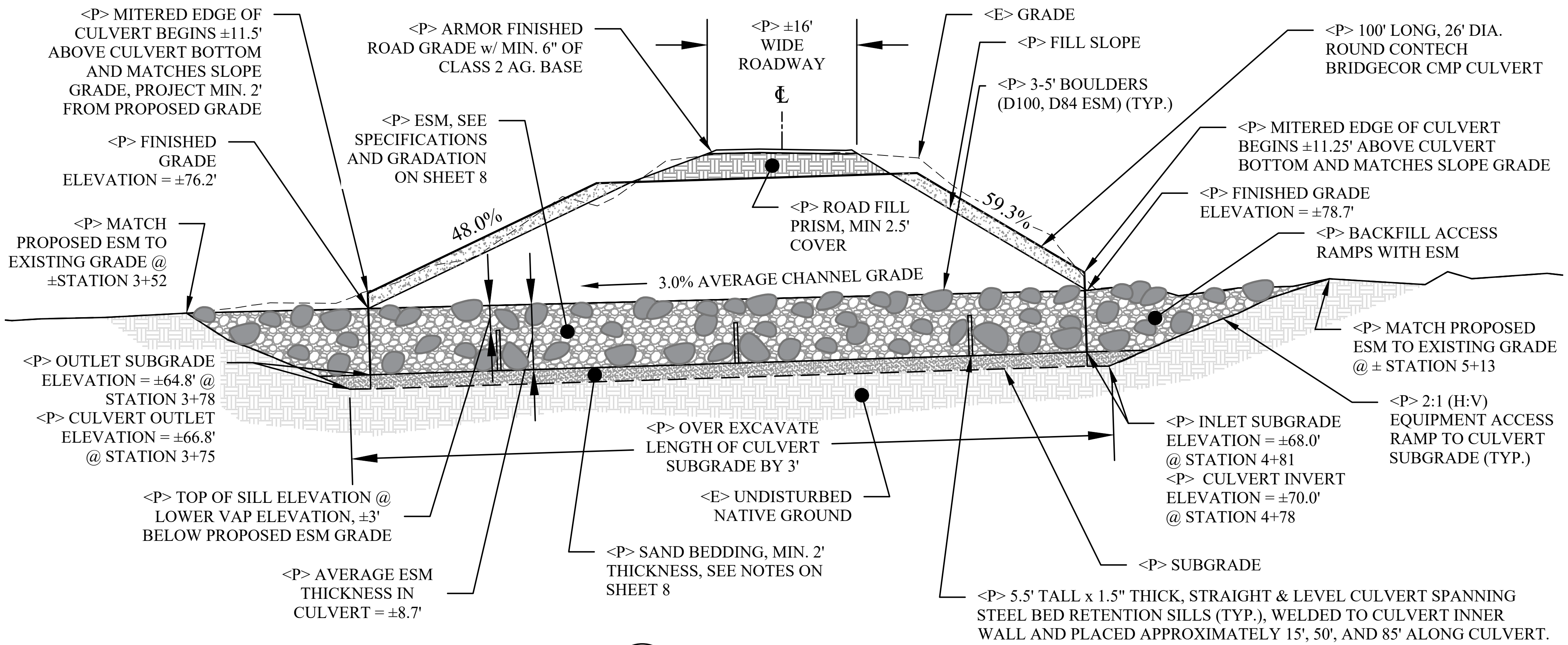
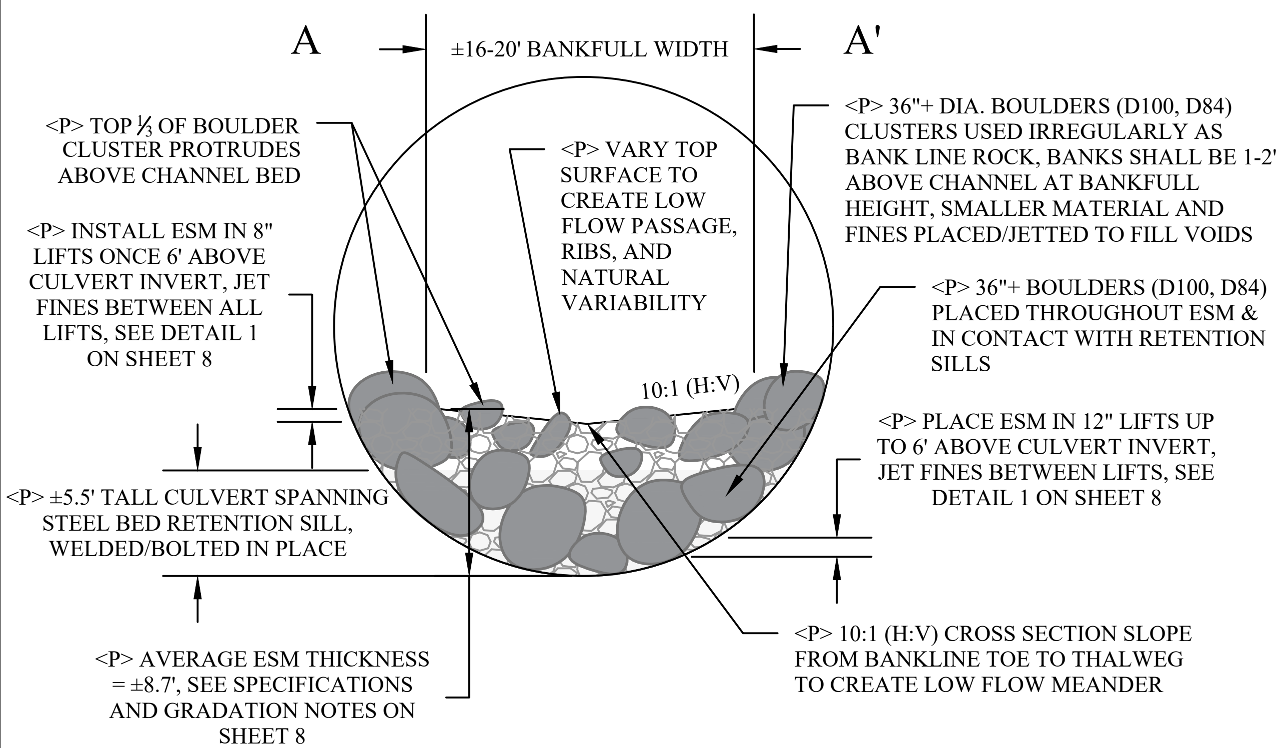
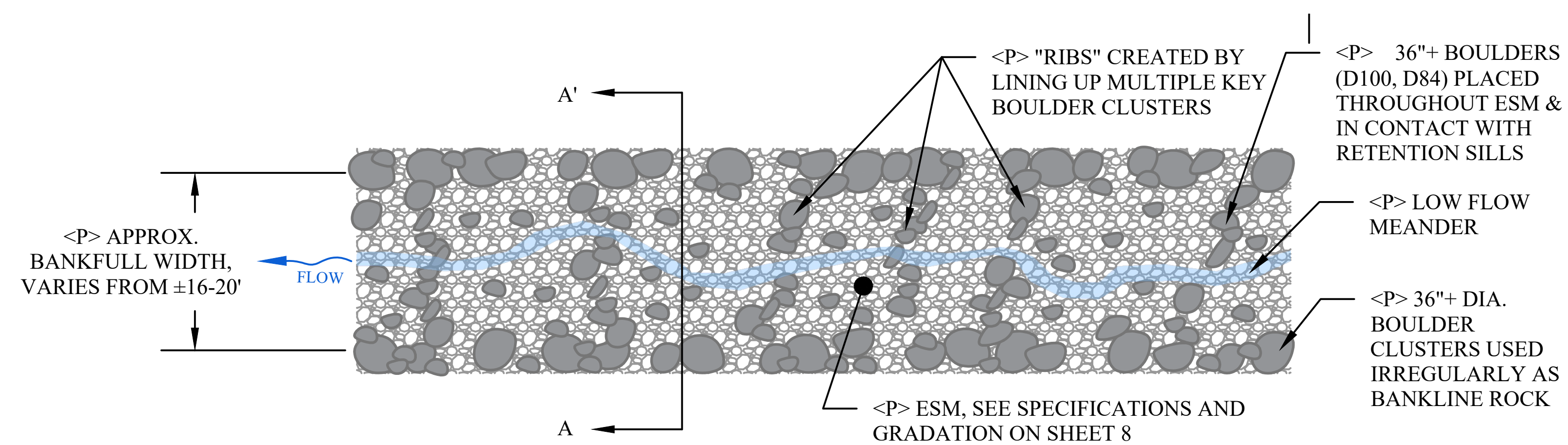


1/7 PROFILE VIEW
PROPOSED CULVERT
NOT TO SCALE



3/7 SECTION VIEW
PROPOSED CULVERT AND ESM
NOT TO SCALE



2/7 PLAN VIEW
PROPOSED CULVERT ESM
NOT TO SCALE

REGISTERED PROFESSIONAL ENGINEER G. S. ORUM NO. C93662 EXP. 6/2024 CIVIL STATE OF CALIFORNIA

DATE 5/31/2023
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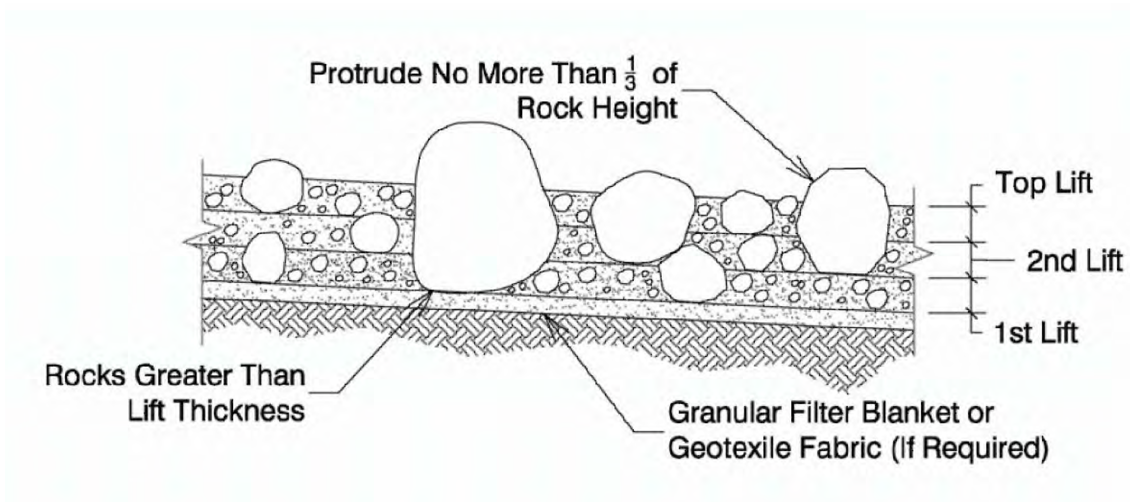
SHEET DESCRIPTION: CULVERT DETAILS

PROJECT NAME AND LOCATION:
CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT
MENDOCINO COUNTY, CA

PWA JOB NO. 10382



1/8 TYPICAL SECTION
ESM INSTALLATION
NOT TO SCALE

ENGINEERED STREAMBED MATERIAL SPECIFICATIONS

GENERAL

1. ENGINEERED STREAMBED MATERIAL (ESM) IS A SPECIFIC ROCK GRADATION TO BE PLACED IN CULVERT AND/OR ANYWHERE EXISTING STREAMBED HAS BEEN REMOVED/EXCAVATED.

PRODUCTS

1. FOR ESM WITH A DIAMETER GREATER THAN 8", ANGULAR IS PREFERRED.
2. ESM SHALL MATCH THE GRADATION SHOWN IN THE ESM GRADATION TABLE ON THIS SHEET.
3. NATIVE MATERIAL MAY BE REUSED, IF APPROVED BY EOR OR THEIR DESIGNATED REPRESENTATIVE.

EXECUTION

1. ESM MUST BE THOROUGHLY MIXED PRIOR TO INSTALLATION, IF ESM IS MIXED THEN TRANSPORTED TO THE PROJECT SITE, THE MATERIAL MUST BE REMIXED ON SITE AS IT WILL NATURALLY SORT IN TRANSPORT.
2. ESM SHALL BE INSTALLED PER DETAIL 1 ON THIS SHEET.
3. BEGIN EACH LIFT BY INDIVIDUALLY PLACING ROCKS LARGER THAN THE THICKNESS OF THE LIFT, FOLLOWING WITH PLACEMENT AND MIXING OF THE REMAINING PORTION OF THE ESM.
4. WORK FROM DOWNSTREAM TO UPSTREAM.
5. AT A MINIMUM, ESM SHALL BE PLACED TO THE EXTENTS SHOWN IN THESE PLANS.

ESM GRADATION	
PERCENT FINER THAN	SIZE (IN)
100	62
84	25
50	10
16	1
5	0.1

CULVERT SPECIFICATIONS

GENERAL

1. CULVERT CONSTRUCTION SHALL BE IN ACCORDANCE WITH THE MANUFACTURERS SPECIFICATIONS AND CALTRANS STANDARD SPECIFICATIONS (2022) SECTION 67.
2. EMBANKMENT CONSTRUCTION SHALL BE IN ACCORDANCE WITH CALTRANS STANDARD SPECIFICATIONS (2022) SECTION 19-6, UNLESS OTHERWISE SPECIFIED.

SUBMITTALS

1. PROVIDE DRAWINGS AND/OR PRODUCT SPECIFICATIONS AND MANUALS FOR PRODUCTS USED FOR THIS PROJECT. EOR TO APPROVE THE USE OF ANY PRODUCT PRIOR TO BEING INSTALLED.

PRODUCTS

1. PROPOSED CULVERT SHALL BE A 26' DIA. MULTI-PLATE ROUND CULVERT WITH A 100' LENGTH AS INDICATED IN THE DRAWINGS.
2. CULVERT MATERIALS SHALL CONFORM TO CALTRANS STANDARD SPECIFICATIONS (2022) SECTION 67.
3. SAND BEDDING SHALL CONFORM TO CALTRANS STANDARD SPECIFICATIONS (2022) SECTION 19-3.02F AND SECTION 19.303H
4. STRUCTURAL BACKFILL SHALL CONFORM TO CALTRANS STANDARD SPECIFICATIONS (2022) SECTION 19-3.02C.
5. NATIVE MATERIAL CAN BE SALVAGED AND USED AS EMBANKMENT BACKFILL IF APPROVED BY EOR OR THEIR REPRESENTATIVE.

EXECUTION

1. LARGE BOULDER AND/OR BEDROCK EXCAVATION METHOD TO BE DETERMINED BY CONTRACTOR AND APPROVED BY EOR OR THEIR DESIGNATED REPRESENTATIVE.
2. THE CULVERT SHALL BE ERECTED AND INSTALLED FOLLOWING MANUFACTURER INSTRUCTIONS AND CALTRANS STANDARD SPECIFICATIONS (2022) SECTION 67.
3. THE CULVERT SHALL BE INSTALLED AS SHOWN IN THESE DRAWINGS. ACCURACY OF ±O.1 FEET VERTICALLY AND ±0.5 FEET HORIZONTALLY IS REQUIRED UNLESS OTHERWISE STATED BY THE EOR OR THEIR DESIGNATED REPRESENTATIVE.
4. NATIVE EMBANKMENT BACKFILL SHALL BE PLACED IN 8-INCH LEFTS AND COMPACTED AS INDICATED IN THE DRAWINGS.

DATE 5/31/2023
NOTES PREPARED BY PWA
FIGURES CREATED BY BTK & JPS

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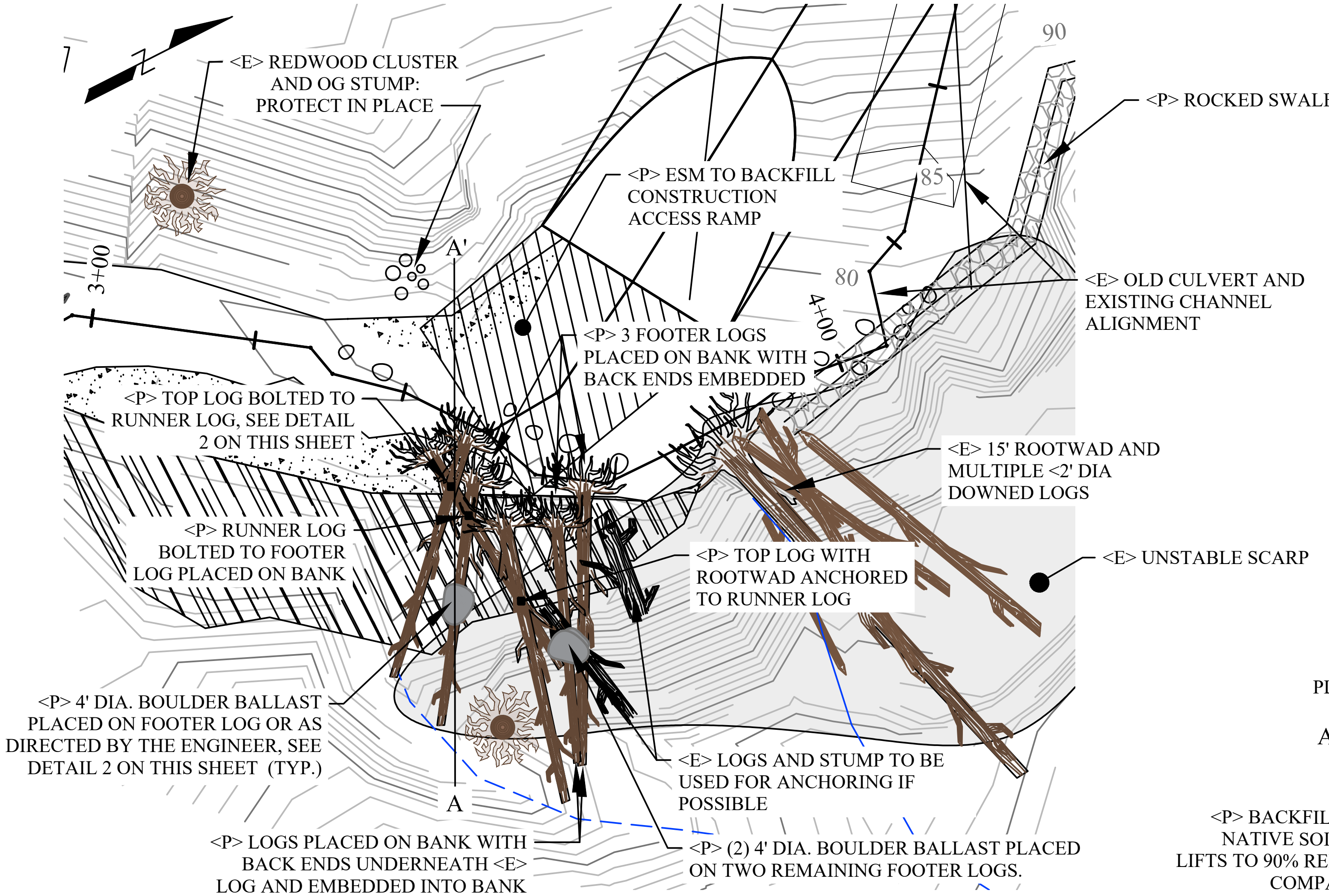
SHEET DESCRIPTION:
CULVERT & ESM SPECIFICATIONS

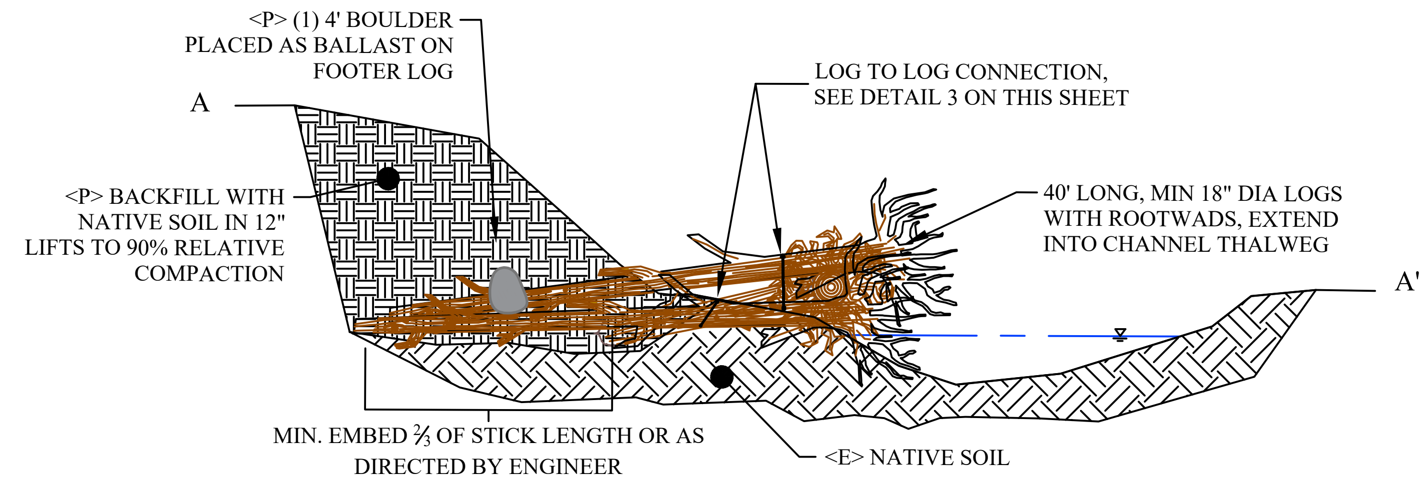
PROJECT NAME AND LOCATION:
CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT
MENDOCINO COUNTY, CA
PWA JOB NO. 10382

NOTE:
1. EXTENT OF STRUCTURE EXCAVATION SHALL FOLLOW PLANS OR BE AS DIRECTED BY THE ENGINEER.
2. PLACEMENT OF LOGS ON SUBGRADE SHALL FOLLOW PLANS OR BE FIT IN THE FIELD AS DIRECTED BY THE ENGINEER.
3. UNLESS OTHERWISE APPROVED BY ENGINEER, STRUCTURE SHALL BE ANCHORED USING THE MIN. (3) 4' DIAMETER BOULDERS AND WITH THE LOG TO LOG CONNECTIONS SHOWN IN THESE PLANS.

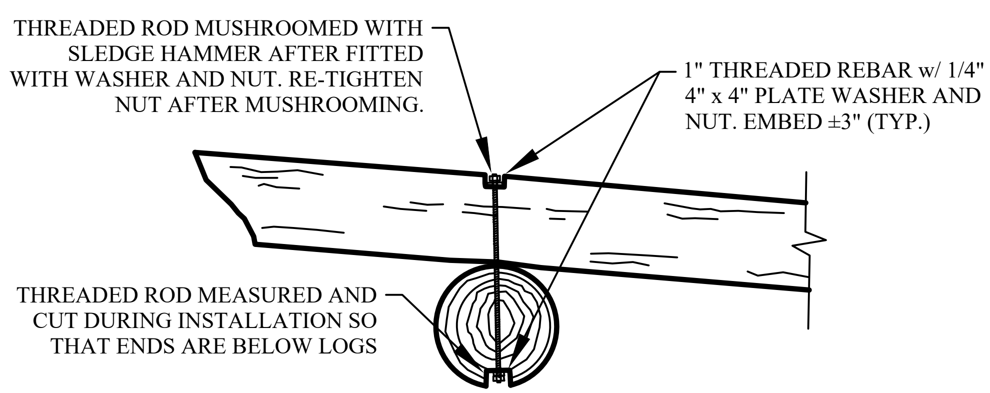
REGISTERED PROFESSIONAL ENGINEER
G. S. ORUM
NO. C93662
EXP. 6/2024
CIVIL
STATE OF CALIFORNIA



1/9 PLAN VIEW
DEFLECTOR JAM
SCALE: 1" = 20'



2/9 SECTION VIEW
DEFLECTOR JAM
NOT TO SCALE



3/9 TYPICAL DETAIL
LOG TO LOG CONNECTION
NOT TO SCALE

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11"x17" SHEET. IF SHEET SIZE IS SMALLER, DRAWING HAS BEEN REDUCED.

DATE 5/29/2023
NOTES PREPARED BY PWA
FIGURES CREATED BY BTK & JPS

PACIFIC WATERSHED ASSOCIATES
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P.O. BOX 4433
ARCATA, CALIFORNIA 95518
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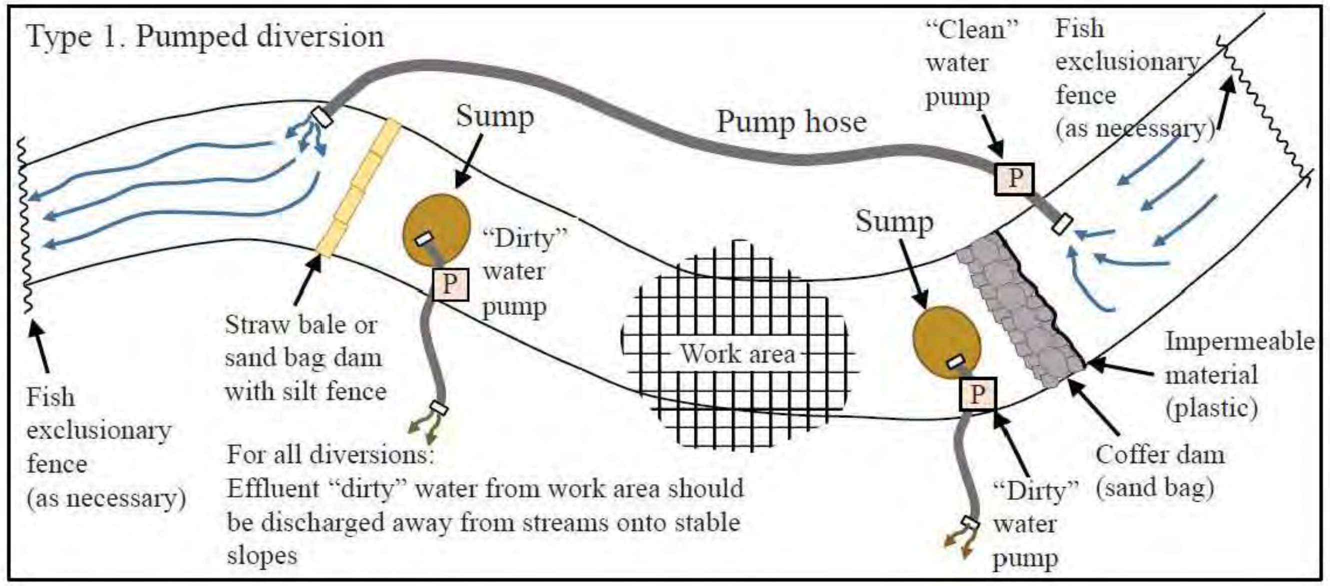
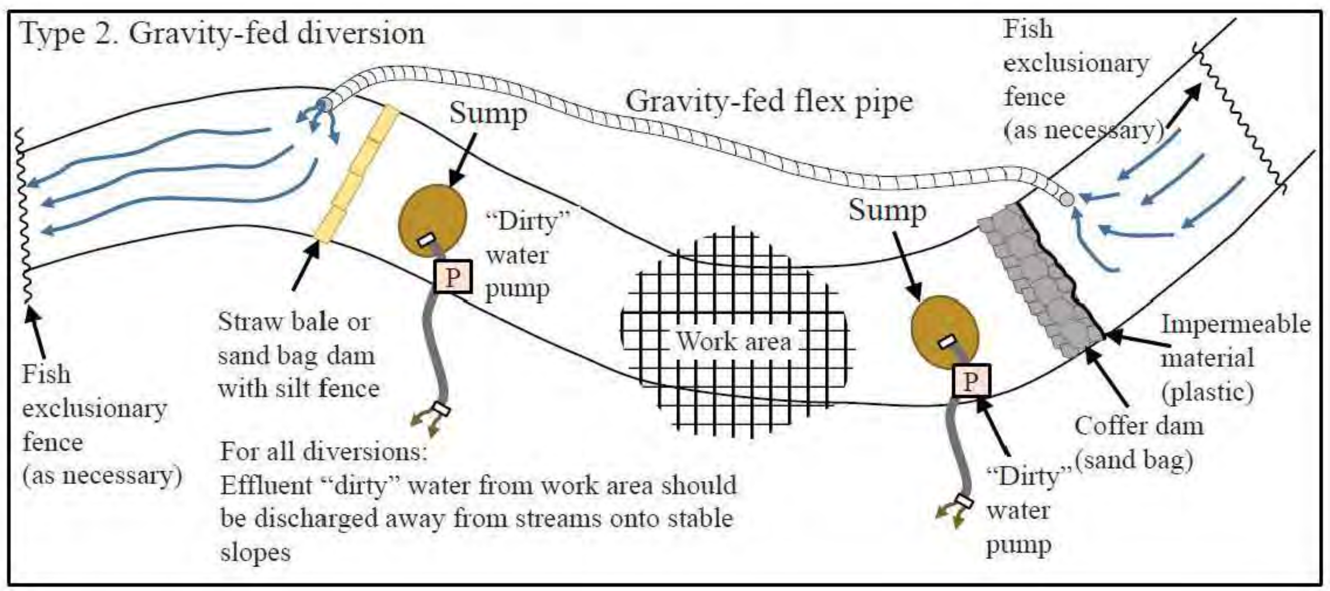
www.pacificwatershed.com

SHEET DESCRIPTION:
DEFLECTOR JAM DETAILS

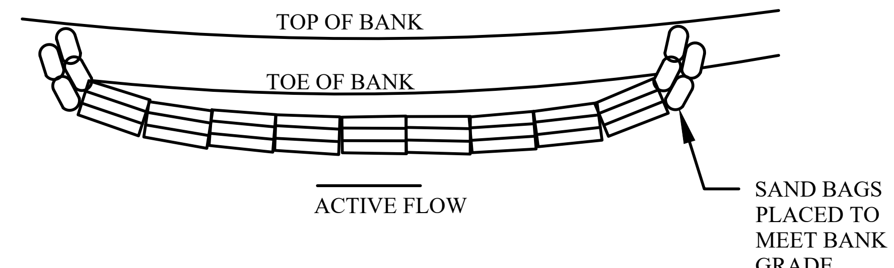
PROJECT NAME AND LOCATION:
CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT
MENDOCINO COUNTY, CA
PWA JOB NO. 10382

STREAM DEWATERING AND FISH EXCLUSION DETAILS:

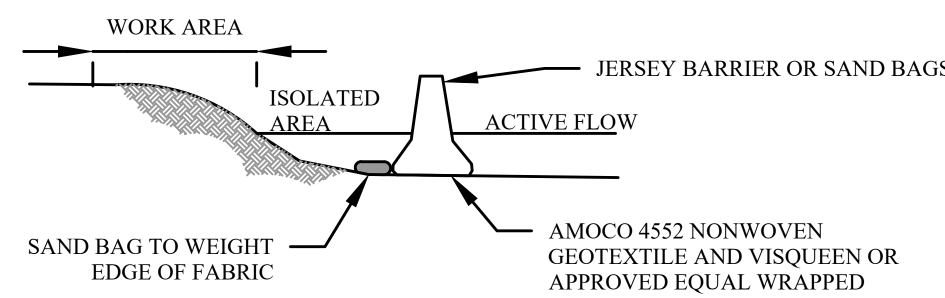




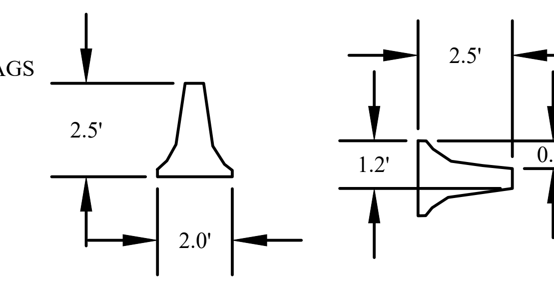
1 / 10 PLAN VIEW
PUMPED AND GRAVITY-FED WATER DIVERSIONS
SCALE: NTS



PLAN VIEW
NOT TO SCALE



SECTION A-A'
NOT TO SCALE



JERSEY BARRIER DIMENSIONS
NOT TO SCALE

2 / 10 SEDIMENT CONTROL BARRIER
NOT TO SCALE

STREAM DEWATERING NOTES:

PRIOR TO WORKING IN AND AROUND THE ACTIVE STREAM CHANNEL, PROPER STREAM DEWATERING AND AVOIDANCE OF INCREASING DOWNSTREAM TURBIDITY SHOULD BE EMPLOYED. STREAM FLOWS WILL BE KEPT FLOWING BELOW THE WORK AREA AND FLOWS WILL BE ISOLATED UPSTREAM OF THE WORK AREA USING COFFERDAMS AND CONVEYED DOWNSTREAM AROUND THE WORK SITE THROUGH EITHER A PUMPED DIVERSION (DETAIL 1- TYPE 1) AND/OR BY GRAVITY DIVERSION (DETAIL 1- TYPE 2). AN ADDITIONAL DAM WILL BE INSTALLED DOWNSTREAM OF THE WORK AREAS TO CAPTURE ANY SUBSURFACE FLOW THAT MIGHT TRAVEL THROUGH THE CONSTRUCTION AREA. ANY "DIRTY" WATER WILL BE COLLECTED AT THIS LOCATION AND PUMPED AWAY FROM THE SITE WHERE IT CAN INFILTRATE INTO THE GROUND WITHOUT THE POTENTIAL FOR CONNECTIVITY AND DELIVERY TO THE STREAM SYSTEM. WHERE THE WORK AREA CAN BE ISOLATED BY DEWATERING A PORTION OF THE CHANNEL (E.G. TO CONSTRUCT AN ALCOVE MOUTH), A SEDIMENT CONTROL BARRIER CAN BE USED TO DEWATER TO ISOLATED WORK ZONE (DETAIL 2).

GENERAL WATER POLLUTION CONTROL, FISH EXCLUSION AND SPOILS DISPOSAL NOTES:

1) THE CONTRACTOR IS RESPONSIBLE FOR IMPLEMENTING THE PROJECT IN A MANNER THAT DOES NOT DISCHARGE POLLUTANTS TO WATERS OF THE STATE OR SENSITIVE BIOLOGICAL AREAS. THE CONTRACTOR WILL BE RESPONSIBLE FOR ALL CLEAN-UP ASSOCIATED WITH WATER POLLUTION VIOLATIONS.
2) AT A MINIMUM, THE CONTRACTOR SHALL IMPLEMENT THE PROJECT SPECIFIC WATER POLLUTION CONTROL BMPS DESCRIBED.
3) IT SHALL BE THE CONTRACTOR'S RESPONSIBILITY TO IMPLEMENT ADDITIONAL BMPS AS NECESSARY TO PREVENT THE DISCHARGE OF POLLUTANTS TO WATERS OF THE STATE OR SENSITIVE BIOLOGICAL AREAS.
4) DEPENDING ON BASE STREAM FLOW CONDITIONS WITHIN THE CREEK, PROJECTS MAY LIKELY REQUIRE A CLEAR WATER DIVERSION AND FISH EXCLUSION FROM THE WORK SITE. THE CONTRACTOR WILL PROVIDE A QUALIFIED BIOLOGIST TO SET UP THE EXCLUSIONARY FENCING AND CONDUCT THE FISH EXCLUSION. NO EARTHWORK WILL BEGIN UNTIL FISH EXCLUSION ACTIVITIES HAVE BEEN COMPLETED. IN ADDITION, THE CONTRACTOR SHALL SUBMIT A NOTICE OF INTENT TO BEGIN CONSTRUCTION TO THE LANDOWNER 2 WEEKS PRIOR TO THE COMMENCEMENT OF CONSTRUCTION.
5) THE CONTRACTOR WILL BE RESPONSIBLE FOR PROVIDING AND MAINTAINING ALL SUPPLIES AND MECHANICAL DEVICES (PUMPS, ETC.) NECESSARY TO EFFECTIVELY DEWATER THE WORK SITE DURING CONSTRUCTION ACTIVITIES.
6) BMPS SHALL BE APPLIED WHERE SHOWN ON THESE PLANS AND AT OTHER APPLICABLE LOCATIONS AS NECESSARY. EXACT LOCATIONS ARE AT THE DISCRETION OF THE CONSTRUCTION MANAGER AND PROJECT ENGINEER/GEOLOGIST.
7) ALL UNSUITABLE SPOILS GENERATED BY THE PROJECT WILL EITHER BE HAULED OFF-SITE AND DISPOSED OF AT A LEGAL LOCATION OR WILL BE PLACED IN LIFTS ALONG FLOODPLAIN TERRACE SURFACES (<5% GRADE) WITH NO CHANCE FOR SEDIMENT DELIVERY AND WILL BE CONTOURED IN A MANNER TO DISPERSE RUNOFF. ALL SPOILS PLACED ON-SITE WILL BE MULCHED ACCORDING TO PROJECT SPECIFIC BMP REQUIREMENTS.

WATER QUALITY MONITORING REQUIREMENTS:

SURFACE WATER QUALITY MONITORING WILL BE PERFORMED WHEN:

A. PERFORMING ANY IN-WATER WORK;
B. PROJECT ACTIVITIES RESULT, OR MAY RESULT, IN DISCHARGE TO SURFACE WATERS; OR
C. PROJECT ACTIVITIES RESULT IN THE CREATION OF A VISIBLE TURBIDITY IN SURFACE WATERS.

SAMPLING AS DESCRIBED BELOW SHALL OCCUR UPSTREAM AND OUT OF THE INFLUENCE OF THE PROJECT AS WELL AS 300 FEET DOWNSTREAM OF THE WORK AREA.

1) TURBIDITY (NTU); IN SITU; EVERY 4 HOURS DURING IN-WATER WORK; DURING CONSTRUCTION/DEWATERING AND REMOVAL/REWATERING A MINIMUM OF 3 SAMPLES MUST BE TAKEN EACH DAY ACTIVITIES OCCUR.
2) VISIBLE CONSTRUCTION RELATED POLLUTANTS (OBSERVATIONS), VISUAL INSPECTIONS, CONTINUOUS THROUGHOUT THE CONSTRUCTION PERIOD.
3) pH (STANDARD UNITS); IN SITU, EVERY 4 HOURS, DURING CONSTRUCTION/DEWATERING AND REMOVAL/REWATERING A MINIMUM OF 3 SAMPLES MUST BE TAKEN EACH DAY ACTIVITIES OCCUR.
4) TEMPERATURE (°C); IN SITU; EVERY 4 HOURS; DURING CONSTRUCTION/DEWATERING AND REMOVAL/REWATERING A MINIMUM OF 3 SAMPLES MUST BE TAKEN EACH DAY ACTIVITIES OCCUR.
5) DISSOLVED OXYGEN (mg/L & % SATURATION), IN SITU, EVERY 4 HOURS; DURING CONSTRUCTION/DEWATERING AND REMOVAL/REWATERING, A MINIMUM OF 3 SAMPLES MUST BE TAKEN EACH DAY ACTIVITIES OCCUR.

REGISTERED PROFESSIONAL ENGINEER
G. S. ORUM
NO. C93662
EXP. 6/2024
CIVIL
STATE OF CALIFORNIA

DATE
5/29/2023
NOTES PREPARED BY
PWA
FIGURES CREATED BY
BTK & JPS

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SHEET DESCRIPTION:
WATER CONTROL PLAN

PROJECT NAME AND LOCATION:
CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT
MENDOCINO COUNTY, CA

PWA JOB NO. 10382

GRAPHIC SCALE

0 20 40

(IN FEET)

1 inch = 40 ft.

PROJECT SPECIFIC CASQA WATER POLLUTION AND EROSION CONTROL BMPS:

PROJECT SPECIFIC WATER POLLUTION CONTROL BMPS ARE DESCRIBED IN THE CALIFORNIA STORMWATER QUALITY ASSOCIATION (CASQA) BMP HANDBOOK FACT SHEETS. CASQA BMPS CHOSEN FOR THIS PROJECT INCLUDE AT A MINIMUM THE FOLLOWING:

EC-1, SCHEDULING WILL BE UTILIZED THROUGHOUT PROJECT PHASES TO ENSURE MAJOR EARTH DISTURBING ACTIVITIES OCCUR ONLY DURING NON-RAINY WEATHER.

EC-2, PRESERVATION OF EXISTING VEGETATION WILL BE IMPLEMENTED BY CLEARLY DELINEATING THE PROJECT BOUNDARIES.

EC-6, STRAW MULCH AND/OR **EC-8** WOOD MULCH MAY BE USED AS NECESSARY TO PROTECT BARE SOIL AREAS INCLUDING CUT/FILL AREAS, STOCKPILES AND DISTURBED GROUND AS A RESULT OF CONSTRUCTION.

EC-7, GEOTEXTILES AND MATS USED TO PROTECT BARE SOIL AREAS WITH SLOPES STEEPER THAN 3:1 (H:V).

EC-9, EARTH DIKES AND COFFER DAMS WILL BE USED AS NECESSARY TO DIVERT ACTIVE STREAMFLOW AROUND THE CONSTRUCTION AREA AT SPECIFIED LOCATIONS OR AS DIRECTED BY THE PROJECT ENGINEER.

EC-12, STREAMBANK STABILIZATION MEASURES MAY BE USED ALONG ALL STREAMBANK DISTURBANCE ZONES AT SPECIFIED LOCATIONS OR AS DIRECTED BY THE PROJECT ENGINEER OR GEOLOGIST. STREAMBANK STABILIZATION MAY INCLUDE MATS, RSP OR BIOTECHNICAL MEASURES AS NECESSARY TO PROTECT THE FRESHLY DISTURBED STREAMBANKS FROM EROSION.

NS-2, DEWATERING OPERATIONS AND **NS-5**, CLEAR WATER DIVERSIONS MAY BE IMPLEMENTED AT SPECIFIED LOCATIONS OR AS DIRECTED BY THE CONSTRUCTION MANAGER IN ORDER TO DEWATER THE CONSTRUCTION AREA WHILE EXCAVATION ACTIVITIES ARE TAKING PLACE.

NS-6, ILLICIT CONNECTION/ILLEGAL DISCHARGE DETECTION AND REPORTING WILL BE COMPLETED BY THE CONTRACTOR THROUGHOUT THE DURATION OF THE PROJECT.

NS-9, VEHICLE AND EQUIPMENT FUELING WILL BE CONDUCTED AT LEAST 100 FT FROM ANY STREAM, AND **NS-10**, VEHICLE AND EQUIPMENT MAINTENANCE WILL BE IMPLEMENTED IN A MANNER TO AVOID ANY RELEASE OF POTENTIAL POLLUTANTS.

WM-1, MATERIAL DELIVERY AND STORAGE, **WM-2**, MATERIAL USE AND **WM-6**, HAZARDOUS WASTE MANAGEMENT WILL BE IMPLEMENTED TO PREVENT DISCHARGES OF CONSTRUCTION MATERIALS AND WASTES DURING DELIVERY, STORAGE AND USE.

WM-3, STOCKPILE MANAGEMENT BMPS WILL BE IMPLEMENTED TO REDUCE OR ELIMINATE STORMWATER POLLUTION RUNOFF FROM STOCKPILES OF SOIL, MULCH, AGGREGATES OR OTHER MATERIALS. **SE-1** (SILT FENCE), **SE-5** (FIBER ROLLS) AND **SE-9** (STRAW BALE BARRIER) BMPS WILL BE APPLIED AS NECESSARY AT THE DISCRETION OF THE CONSTRUCTION MANAGER.

WM-4, SPILL PREVENTION AND CONTROL WILL BE IMPLEMENTED TO CONTAIN AND CLEAN UP SPILLS AND PREVENT MATERIAL DISCHARGES TO ANY STREAM OR WETLAND.

WM-5, SOLID WASTE MANAGEMENT BMPS REQUIRE THAT ANY SOLID WASTE BE CONTAINED IN A WATER TIGHT CONTAINER AND WILL BE LOADED DIRECTLY INTO TRUCKS FOR OFF-SITE DISPOSAL AT LEAST ON A WEEKLY BASIS.

WM-9, SANITARY/SEPTIC WASTE MANAGEMENT. IF SANITARY FACILITIES ARE NOT AVAILABLE ONSITE, PORTABLE TOILETS WILL BE BROUGHT IN AND WILL BE EMPTIED AT LEAST ON A WEEKLY BASIS.

LEGEND:

- EC-6, EC-8 EC-12, WM-2, WM-4, WM-6, SE-1, SE-5, SE-9
- NS-9, NS-10, WM-1, WM-2, WM-3, WM-4, WM-5,WM-6, WM-9
- EC-7, EC-12, WM-2, WM-4
- Ⓦ NS-2, NS-5, NS-6, EC-9, SE-5
- EXISTING MINOR CONTOURS
- EXISTING MAJOR CONTOURS
- LIMIT OF GRADING
- LIMIT OF DISTURBANCE
- POTENTIAL CONSTRUCTION ACCESS

REGISTERED PROFESSIONAL ENGINEER
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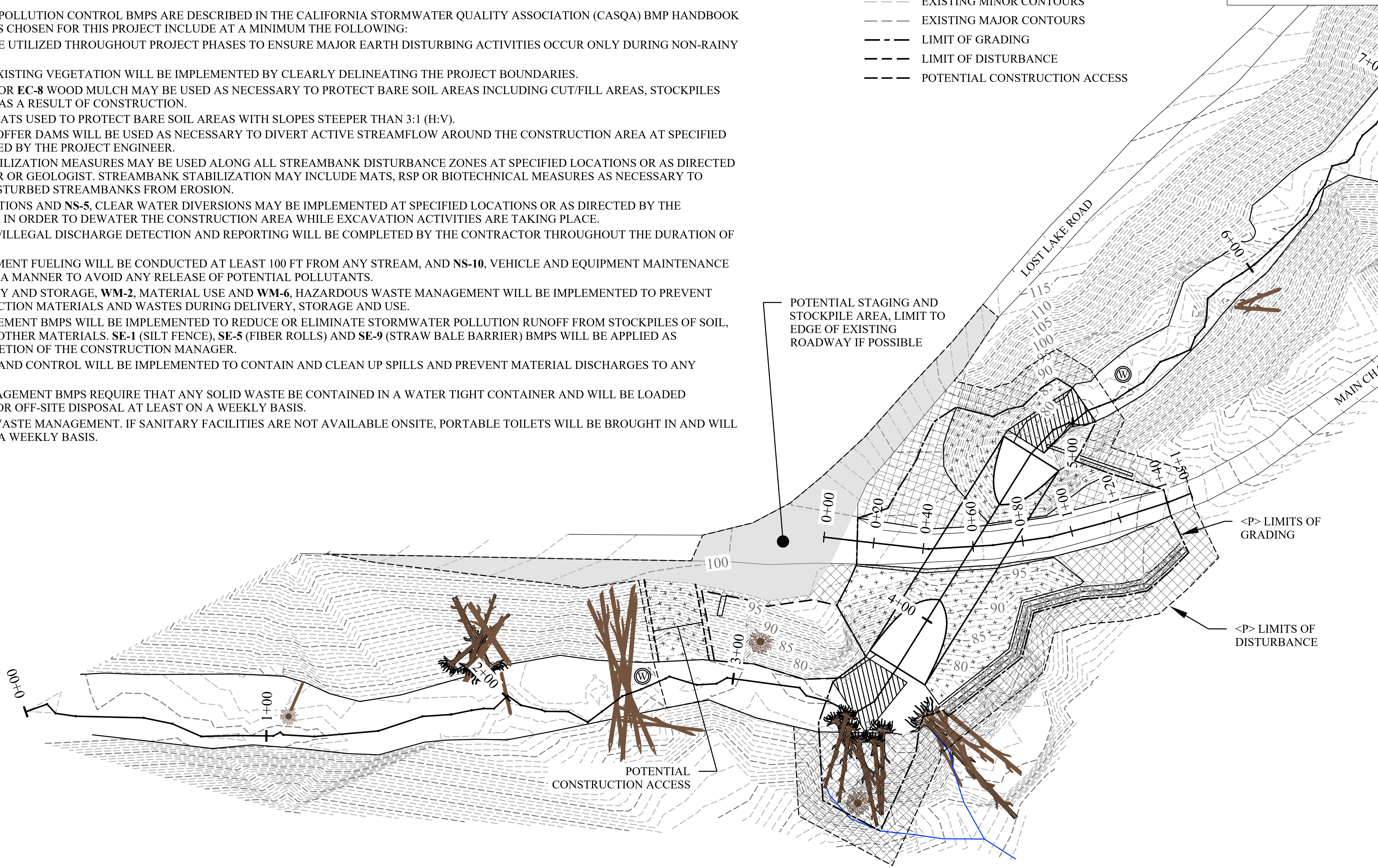

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11"x17" SHEET. IF SHEET SIZE IS SMALLER, DRAWING HAS BEEN REDUCED.

DATE 5/29/2023

NOTES PREPARED BY PWA

FIGURES CREATED BY BTK & JPS

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SHEET DESCRIPTION:

EROSION CONTROL PLAN

PROJECT NAME AND LOCATION:

CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT MENDOCINO COUNTY, CA

PWA JOB NO. 10382

Chamberlain Creek Coho Passage Design Project		
Opinion of Probable Construction Cost for 2025		
Item#	**Description**	**Cost**
1	**Mobilization/Demobilization**	**$93,000**
2	**Clearing and Grubbing**	**$16,000**
3	**Water Management**	**$170,000**
4	**Construction Staking**	**$17,000**
5	**Excavation and Material Off-Haul**	**$196,000**
6	**Existing Culvert Demolition and Removal**	**$28,000**
7	**New Culvert Subgrade Bedding and Installation**	**$38,000**
8	**New Culvert and Installation**	**$305,000**
9	**Backfill to Finished Grade**	**$186,000**
10	**New Culvert Concrete Collar**	**$30,000**
11	**ESM and Installation**	**$164,000**
12	**New Road Construction**	**$22,000**
13	**New Roadside Relief Swale**	**$10,000**
14	**Deflector Jam and Installation**	**$17,000**
15	**Erosion Control**	**$9,000**
	15% Contingency	**$196,000**
	Total	**$1,497,000**

*This cost estimate is meant to anticipate the potential costs of project implementation. Costs may vary depending on the methods, materials, and rates proposed by the contractor during the bidding process.

Appendix B.
NRCS Soil Resource Report

United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Mendocino County, Western Part, California

Chamberlain soil report

September 13, 2022

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

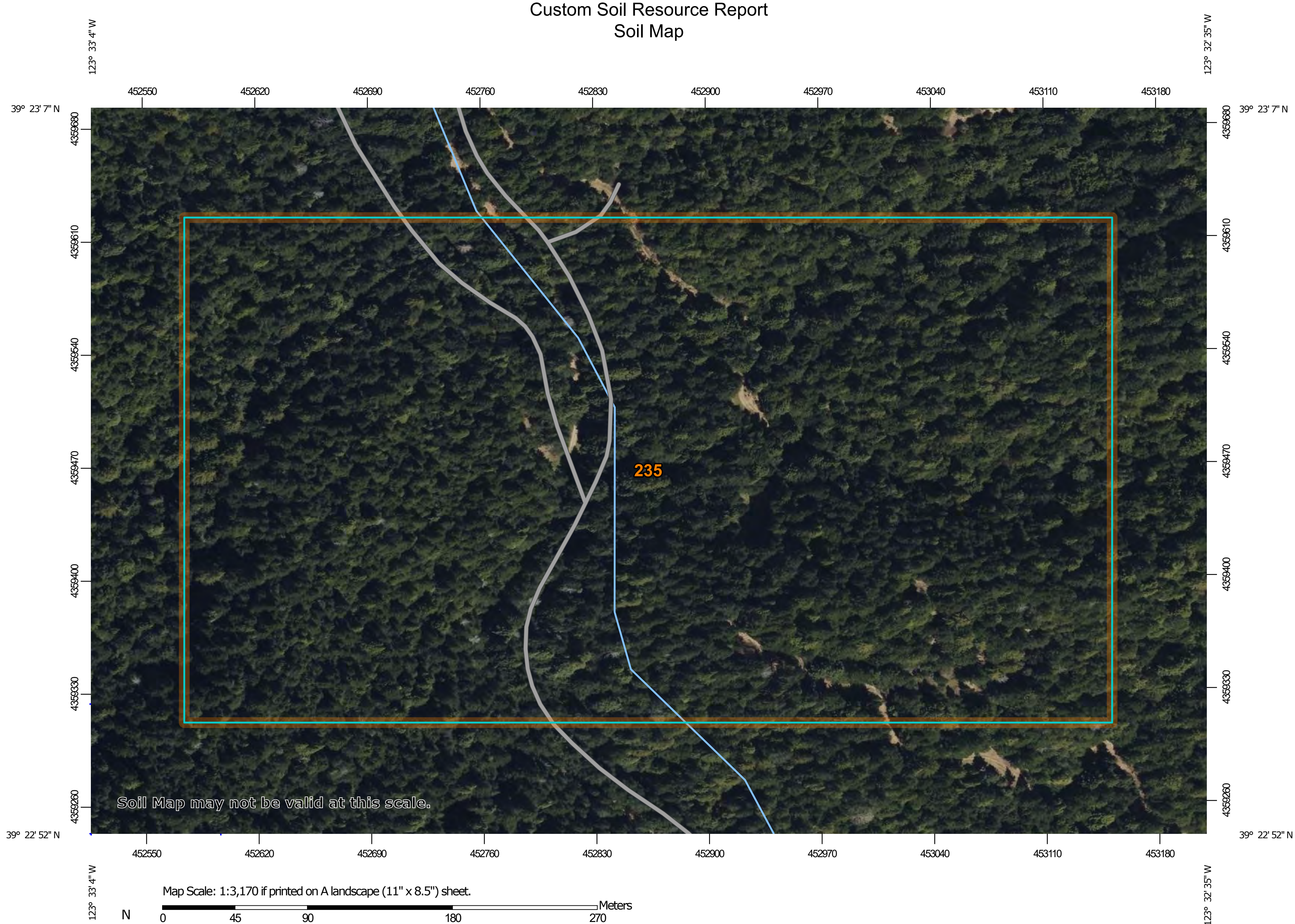
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map



Map Scale: 1:3,170 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 45, 90, 180, 270

Feet: 0, 150, 300, 600, 900

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Mendocino County, Western Part, California
Survey Area Data: Version 16, Sep 6, 2021

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Apr 7, 2022—May 31, 2022

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
235	Yellowhound-Kibesillah complex, 50 to 75 percent slopes, MLRA 4B	44.8	100.0%
Totals for Area of Interest		**44.8**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Mendocino County, Western Part, California

235—Yellowhound-Kibesillah complex, 50 to 75 percent slopes, MLRA 4B

Map Unit Setting

National map unit symbol: 2w91l
Elevation: 200 to 2,000 feet
Mean annual precipitation: 39 to 58 inches
Mean annual air temperature: 52 to 57 degrees F
Frost-free period: 220 to 320 days
Farmland classification: Not prime farmland

Map Unit Composition

Yellowhound and similar soils: 45 percent
Kibesillah and similar soils: 35 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Yellowhound

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Mountainflank, side slope
Down-slope shape: Concave, convex
Across-slope shape: Concave, convex
Parent material: Colluvium derived from conglomerate and/or colluvium derived from sandstone and/or residuum weathered from sandstone and/or residuum weathered from conglomerate

Typical profile

Oi - 0 to 1 inches: slightly decomposed plant material
A - 1 to 7 inches: gravelly loam
AB - 7 to 16 inches: gravelly loam
Bt1 - 16 to 29 inches: very gravelly loam
Bt2 - 29 to 46 inches: extremely gravelly loam
BCt - 46 to 54 inches: extremely gravelly loam
R - 54 to 64 inches:

Properties and qualities

Slope: 50 to 75 percent
Depth to restrictive feature: 39 to 59 inches to lithic bedrock
Drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 4.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: B
Ecological site: F004BK102CA - Fog-influenced, low elevation mountain slopes
Hydric soil rating: No

Description of Kibesillah

Setting

Landform: Hills, mountains
Down-slope shape: Convex, concave
Across-slope shape: Convex, concave
Parent material: Colluvium derived from sandstone and/or residuum weathered from sandstone

Typical profile

Oi - 0 to 0 inches: slightly decomposed plant material
A1 - 0 to 4 inches: very gravelly loam
A2 - 4 to 13 inches: very gravelly loam
Bt1 - 13 to 19 inches: very gravelly loam
Bt2 - 19 to 26 inches: extremely gravelly clay loam
R - 26 to 39 inches:

Properties and qualities

Slope: 50 to 75 percent
Depth to restrictive feature: 20 to 39 inches to lithic bedrock
Drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: Very low (about 2.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: C
Ecological site: F004BK103CA - Upper slopes and higher elevation mountains
Hydric soil rating: No

Minor Components

Zeni

Percent of map unit: 7 percent
Landform: Hills, mountains
Down-slope shape: Convex, concave
Across-slope shape: Convex, concave
Hydric soil rating: No

Ornbaun

Percent of map unit: 7 percent
Landform: Hills, mountains
Down-slope shape: Concave, convex
Across-slope shape: Concave, convex
Hydric soil rating: No

Rock outcrop

Percent of map unit: 6 percent
Hydric soil rating: No

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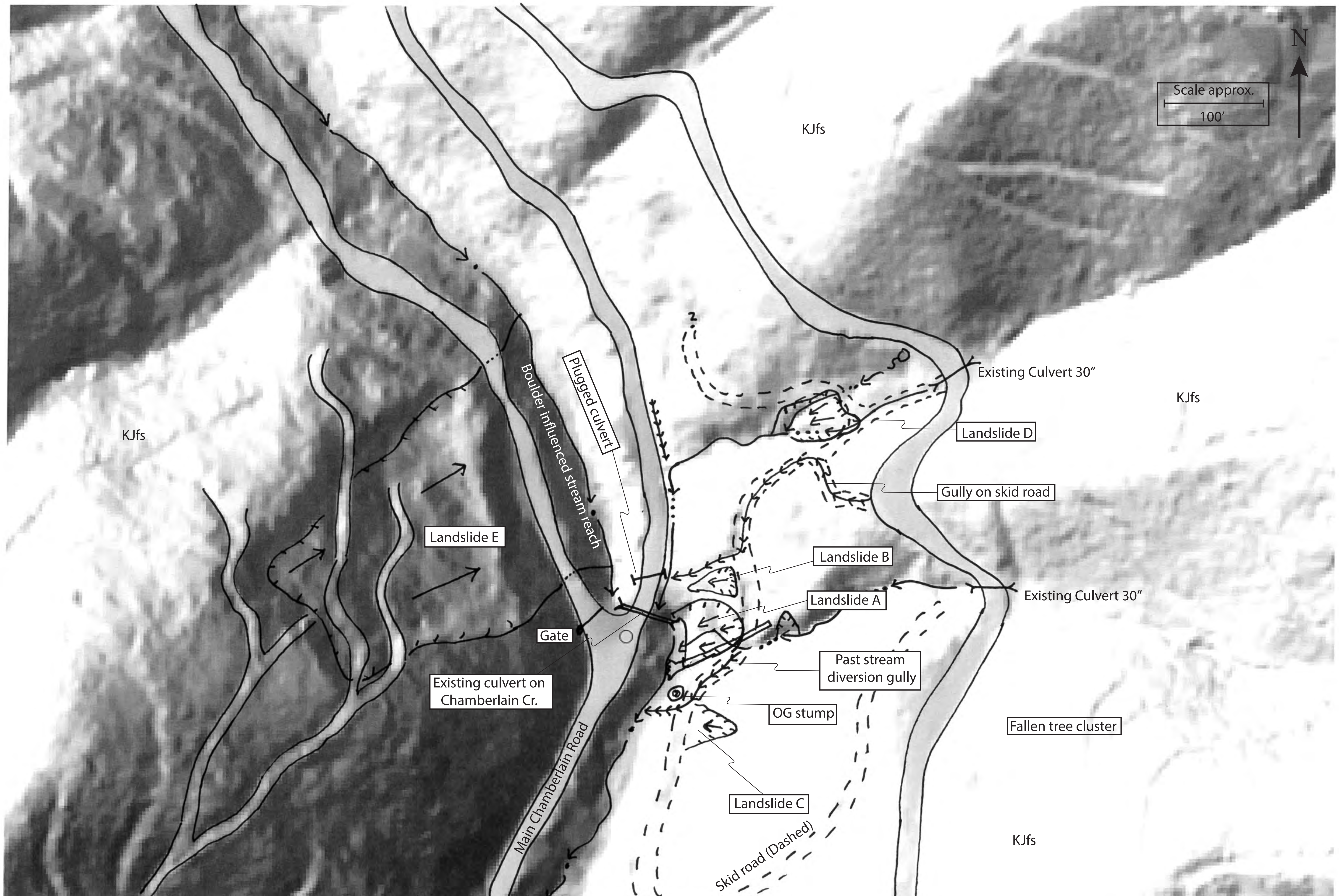
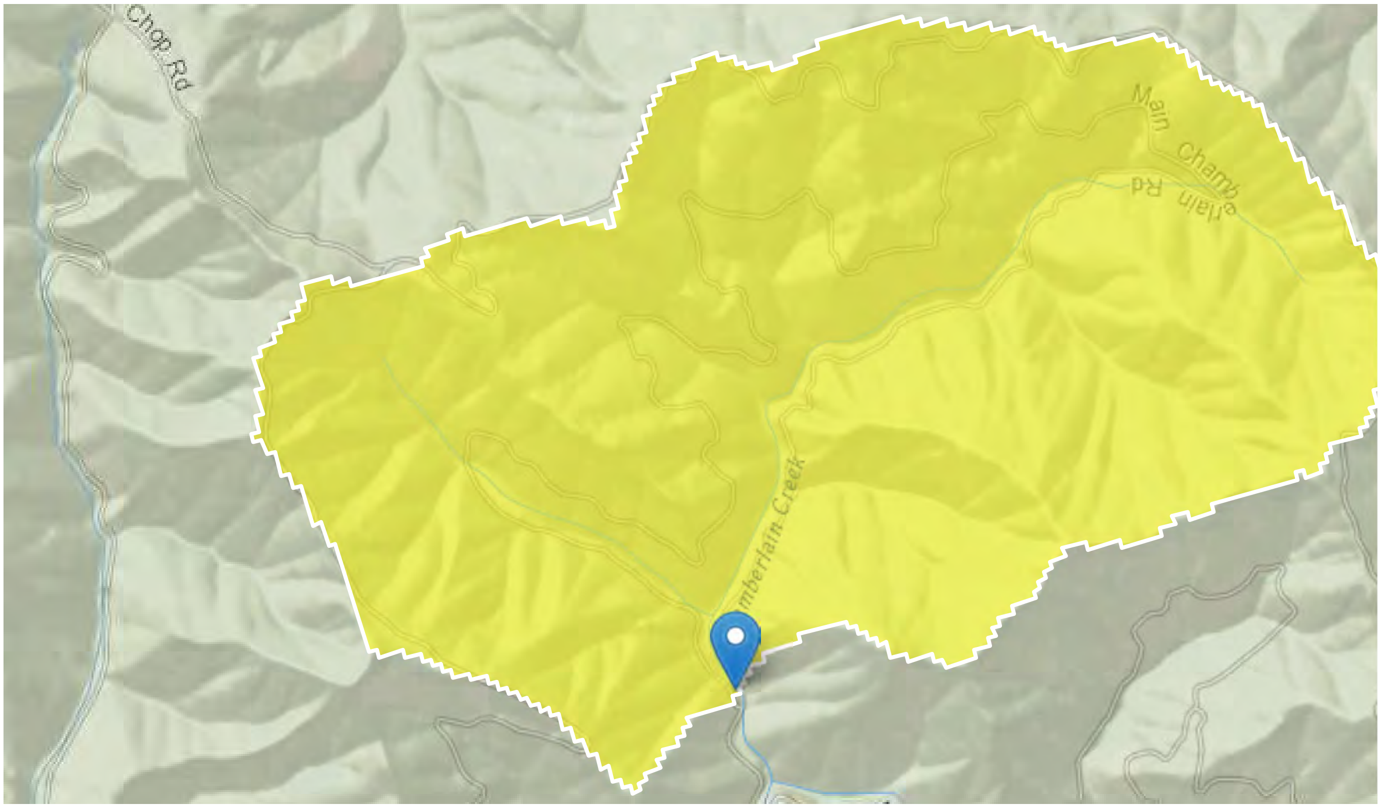
Appendix C.
PWA Landslide Characterization


N
Scale approx.
100′
KJfs
KJfs
KJfs
KJfs
Plugged culvert
Boulder influenced stream reach
Existing Culvert 30″
Landslide D
Gully on skid road
Landslide E
Landslide B
Existing Culvert 30″
Landslide A
Gate
Past stream diversion gully
Existing culvert on Chamberlain Cr.
OG stump
Fallen tree cluster
Main Chamberlain Road
Landslide C
Skid road (Dashed)

Appendix D.
USGS StreamStats Hydrological Report

Chamberlain Creek StreamStats Report

Region ID: CA
Workspace ID: CA20220826234811445000
Clicked Point (Latitude, Longitude): 39.38392, -123.54787
Time: 2022-08-26 16:48:33 -0700



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
BSLDEM30M	Mean basin slope computed from 30 m DEM	39.3	percent
DRNAREA	Area that drains to a point on a stream	2.8	square miles
ELEVMAX	Maximum basin elevation	1984	feet
FOREST	Percentage of area covered by forest	79.9	percent
MINBELEV	Minimum basin elevation	526	feet
PRECIP	Mean Annual Precipitation	49.6	inches

Peak-Flow Statistics

Peak-Flow Statistics Parameters [2012 5113 Region 1 North Coast]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	2.8	square miles	0.04	3200
PRECIP	Mean Annual Precipitation	49.6	inches	20	125

Peak-Flow Statistics Flow Report [2012 5113 Region 1 North Coast]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	ASEp
50-percent AEP flood	214	ft^3/s	87.5	523	58.6
20-percent AEP flood	412	ft^3/s	197	864	47.4
10-percent AEP flood	554	ft^3/s	274	1120	44.2
4-percent AEP flood	742	ft^3/s	379	1450	42.7
2-percent AEP flood	886	ft^3/s	451	1740	42.7
1-percent AEP flood	1040	ft^3/s	517	2090	44.3
0.5-percent AEP flood	1180	ft^3/s	585	2380	44.4
0.2-percent AEP flood	1370	ft^3/s	663	2830	46

Peak-Flow Statistics Citations

Gotvald, A.J., Barth, N.A., Veilleux, A.G., and Parrett, Charles,2012, Methods for determining magnitude and frequency of floods in California, based on data through water year 2006: U.S. Geological Survey Scientific Investigations Report 2012–5113, 38 p., 1 pl. (http://pubs.usgs.gov/sir/2012/5113/)

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Application Version: 4.10.1
StreamStats Services Version: 1.2.22
NSS Services Version: 2.2.1

Appendix E.
PWA Biological Survey

PACIFIC WATERSHED ASSOCIATES INC.

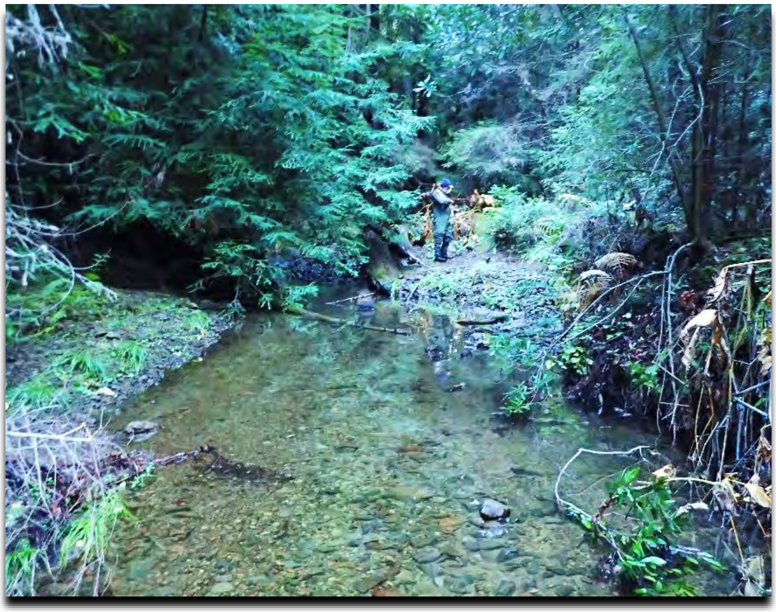
P.O. Box 4433 • Arcata, CA 95518-4433
Phone 707-839-5130 • Fax 707-839-8168
www.pacificwatershed.com

Chamberlain Creek Coho Passage Design Project
Biological Survey for Fish Habitat and Culverted Passage Barrier

The objectives of this project are to develop designs to improve passage for coho salmon and Pacific lamprey at a single crossing (PAD ID 736913). This crossing has been identified as a temporal barrier for coho adults and a complete low-flow barrier for juvenile coho in Chamberlain Creek, a tributary to the North Fork Big River. Chamberlain Creek supports endangered coho populations and this identified culvert is not only limiting access to an estimated 1.6 mile of upstream habitat but is also a high failure risk being in poor condition.

The existing fish habitat was evaluated under low-flow conditions. The purpose of this Level II Habitat Evaluation was to assess the existing fish habitat conditions throughout the identified project reach, beginning 300 feet downstream from the culverted crossing and ending 300 feet upstream from this crossing. The culvert was also evaluated for its current condition and fish passage potential for coho salmon at all life cycle stages.

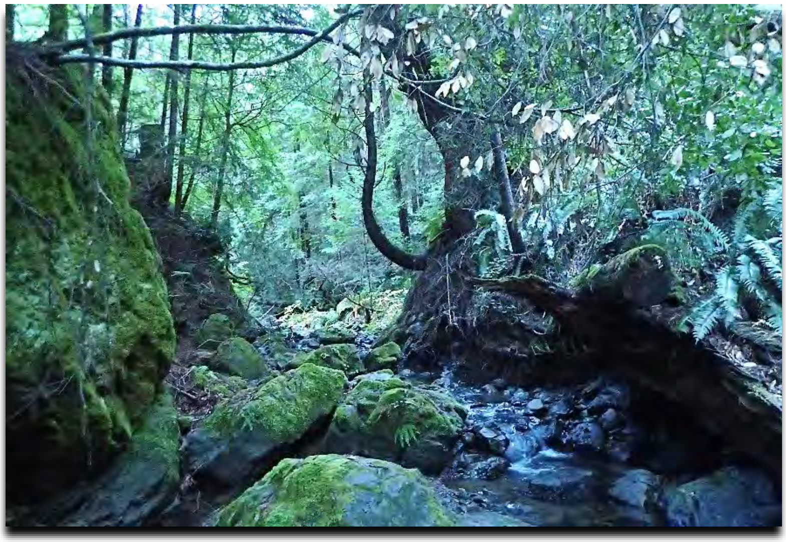
The complete survey length was 1,343 feet including the culvert. Excluding the culvert, 32 discrete fish habitat units were delineated into four general habitat classifications; pools, riffles, runs/step-runs, and glides. Pools comprised 27% of the habitat (by length) where 3 qualified as primary pools having maximum depths greater than 3 feet for 6% of habitat. For these primary pools, large wood provided the primary cover element and pool forming feature (Photographs 1 and 2). Half of all the pools contained suitable sand/silt substrates with detrital cover for lamprey ammocoete rearing.



Photograph 1. Looking upstream at Habitat Unit #1. A primary pool with a maximum depth of 3.1 feet and beginning of the survey for the project reach.

Photograph 2. Looking upstream at Habitat Unit #33. A primary pool with a maximum depth of 3.5 feet. Also the upstream survey end for the project reach.

Riffles and pool tails were dominated by gravel/cobble substrates with pool tail embeddedness averaging at 45% throughout for an embeddedness value of 2. Substrate embeddedness did decrease moving upstream where below the culvert embeddedness ranged from 40% to 60% and above the range was 30% to 40% with the lowest embeddedness percent measured in the furthest upstream pool (Photograph 2). Bedrock was present within the wetted channel and along the banks beginning about 100 feet downstream from the culvert and extending above the culvert by nearly 250 feet. The stream channel above also included boulders in conjunction with the bedrock (Photograph 3) and distinct step-run habitats not found below the culvert.



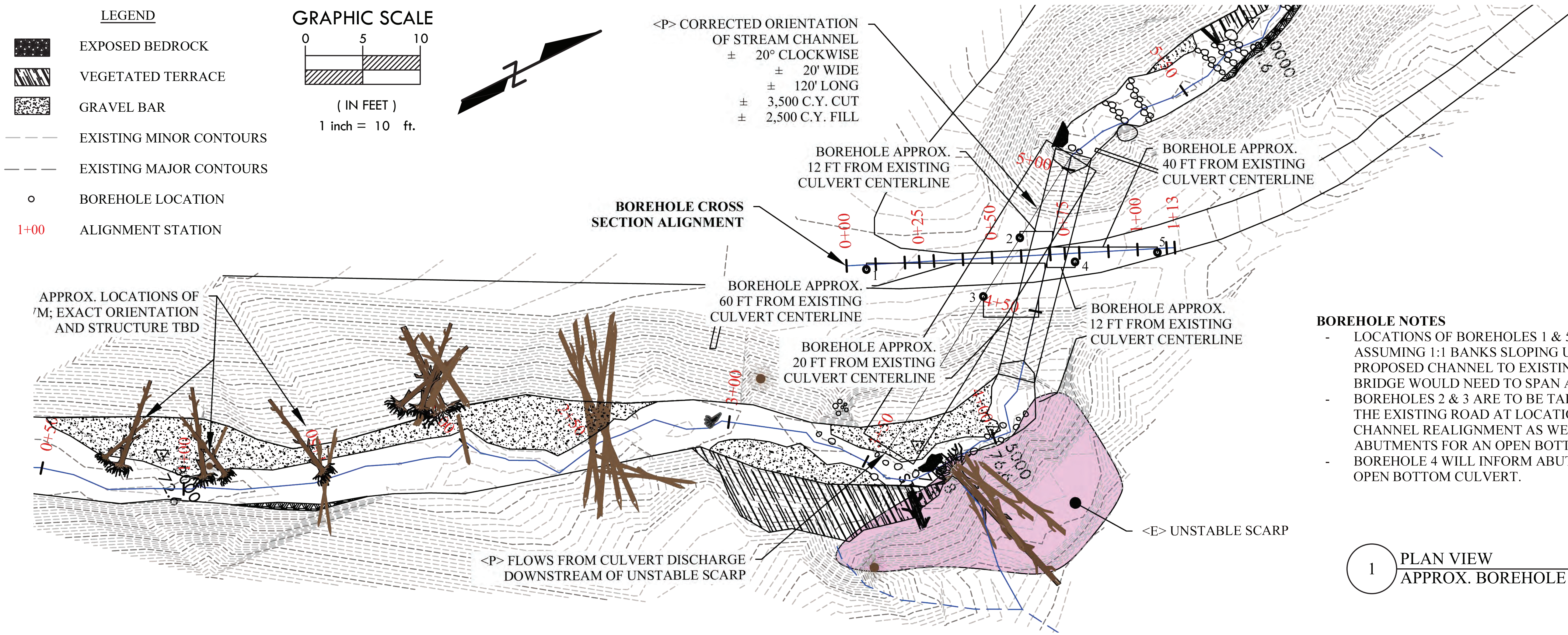
Photograph 3. Looking upstream at Habitat Unit #16. Showing boulders and bedrock within the channel forming, a step-run habitat type flowing into a secondary pool below.

Shallow pools bounded the culvert, both upstream and downstream (Photograph 4). These pools lacked any cover element or shelter value. Their formation appeared to be related more to bedrock than the culvert. The culvert is failing, and the bottom is nearly completely rusted through at about 1/3 up from the outlet (Photograph 4) with talus-like (angular) substrates aggraded within the pool head. This substrate accumulation is minimizing pool-jump depths and would limit access for adults to leap into the culvert and migrate to upstream habitats.

Photograph 4. Habitat Unit #13. Looking upstream at the culvert outlet and the upstream portion of the secondary pool at the outlet. This pool had a maximum depth of 1.75 feet.

Within the culverts downstream section flows are no longer being transported through the culvert rather, the creek is flowing through the rusted bottom and under the culvert. Under low flow conditions the culvert is a complete barrier to any salmonids seeking to move into the habitats upstream. Although the culvert was not assessed under winter base flows, the rusted holes in the bottom are large enough that stream would probably continue to flow under the culvert and remain a 100% upstream migration barrier for coho adults. The rust line indicates that water depths in the culvert used to remain relatively shallow during sustained winter flows at around 4 or 5 inches deep. These depths could support an adult swimming upstream but at burst speeds for the power to swim through the shallow water and traverse the culvert’s length. Deeper water levels within the culvert could also present as a barrier for adults, where the laminar flow velocities could exceed the burst speed needed for an adult to successfully reach the upstream side. Although inaccessible under the current condition, and most likely under winter base flows or higher flows driven by storm events, the habitat above the culvert is suitable for spawning and rearing coho and other salmonid populations, and for pacific lamprey populations, which all depend on this tributary watershed.

Appendix F.
Borehole Locations, Core Logs, and Subsurface Analysis

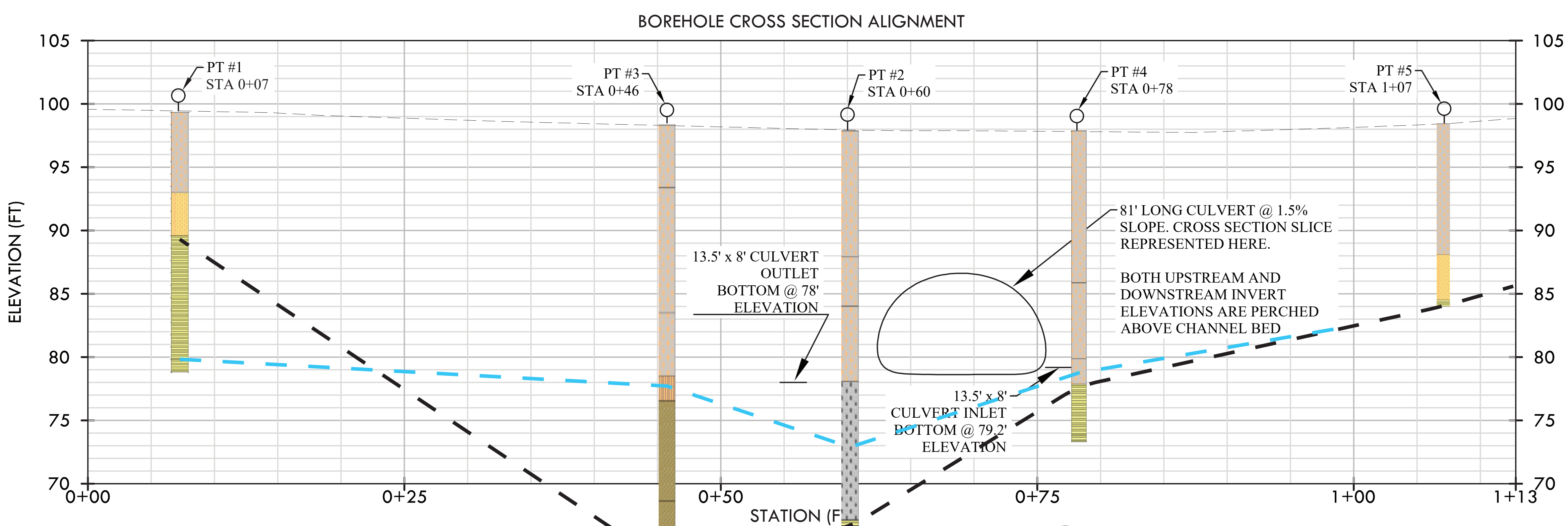


BOREHOLE NOTES

- LOCATIONS OF BOREHOLES 1 & 5 DETERMINED BY ASSUMING 1:1 BANKS SLOPING UP FROM EDGES OF PROPOSED CHANNEL TO EXISTING GRADE. REQUISITE BRIDGE WOULD NEED TO SPAN APPROX. 100 FEET.
- BOREHOLES 2 & 3 ARE TO BE TAKEN ON EITHER SIDE OF THE EXISTING ROAD AT LOCATIONS THAT WOULD INFORM CHANNEL REALIGNMENT AS WELL AS THE POTENTIAL ABUTMENTS FOR AN OPEN BOTTOM CULVERT.
- BOREHOLE 4 WILL INFORM ABUTMENT POTENTIAL FOR AN OPEN BOTTOM CULVERT.

1 PLAN VIEW
APPROX. BOREHOLE LOCATIONS

BOREHOLE CROSS SECTION ALIGNMENT



2 TYPICAL SECTION
APPROX. BOREHOLE LOCATIONS

REGISTERED PROFESSIONAL ENGINEER
G. S. ORUM
NO. C93662
EXP. 6/2024
CIVIL
STATE OF CALIFORNIA
DRAFT PLAN NOT FOR CONSTRUCTION

DATE 2/15/2023
NOTES PREPARED BY PWA
FIGURES CREATED BY BTK & JPS

PACIFIC WATERSHED ASSOCIATES, INC.
P.O. BOX 4433
ARCATA, CALIFORNIA 95518
PH: (707) 839-5130 FX: (707) 839-8168
www.pacificwatershed.com

SHEET DESCRIPTION:
APPROXIMATE BOREHOLE LOCATIONS & CROSS SECTION

PROJECT NAME AND LOCATION:
CHAMBERLAIN CREEK COHO PASSAGE DESIGN PROJECT
MENDOCINO COUNTY, CA

PWA JOB NO. 10382

N/A

FILE PATH: P:\CAD\10382_Chamberlain_Creek\XREFS\Chamberlain_Creek_CIVILBASE.dwg SAVE DATE: 2/15/2023 1:20 PM
SAVED BY:brycek

11"x17" SHEET. IF SHEET SIZE IS SMALLER, DRAWING HAS BEEN REDUCED.

PACIFIC WATERSHED ASSOCIATES			BORING LOG	
	Client:	**Mendocino Land Trust**		
	Project:	**Chamberlain Creek**	**Boring No.**	**CCB1**
	Address:	**2000 Main Chamberlain Road, Mendocino, CA**	**Page:**	**1 of 1**

Drilling Start Date:	**11/30/2022 8:30**	Boring Depth (ft):	**21**
Drilling End Date:	**11/30/2022 10:00**	Boring Diameter (in):	**6.00**
Drilling Company:	**Fisch Drilling**	Sampling Method(s):	**Shelby Tube, Split Spoon**
Drilling Method:	**Hollow Stem Auger**	DTW During Drilling (ft):	**20**
Drilling Equipment:	**Geoprobe 6600**	DTW After Drilling (ft):	**20**
Driller:	**Rick**	Ground Surface Elev. (ft):	**663.00**
Logged By:	**THL**	Location (Lat, Long):	**39.38322, -123.54768**

DEPTH (ft)	Sample Type	Time	Blow Counts	Recovery (ft)	N Value RQD%	SOIL/ROCK VISUAL DESCRIPTION	REMARKS	ELEVATION (ft)
0						(0') Silty GRAVEL with sand (GM); mostly fine-coarse grained gravel, some fine-coarse sand, few silt, trace clay, poorly graded, medium dense, dry, reddish-brown		
	SH	08:45		0.63			(2.5') ASTM D422 2.5-3.2 (') S-1 Soil	660
5	SS	08:50	4 6 11	1.13	17			
	SH	09:00		0.90		(6.5') Silty SAND with gravel (SM); some fine-coarse grained sand, some fine gravel, little silt, few clay, poorly graded, medium dense, dry, reddish-brown	(6.5') ASTM D422; ASTM 2937; DD = 80.3 pcf 6.5-7.5 (') S-2 Soil	655
10	SS	09:15	9 17 39	1.20	56	(10') SED ROCK (SANDSTONE); very fine sand, moderately bedded, slightly weathered, hard, moderately fractured, bluish-gray, dry, Franciscan Coastal Belt sandstone fractured bedrock (TKfs).		650
15	SS	09:25	4 10 30	0.75	40			
	SS	09:50	0 13 43	0.88	56			645
20						(20') SED ROCK (SANDSTONE); very fine sand, moderately bedded, fresh, very hard, very slightly fractured, bluish-gray, wet, Franciscan Coastal Belt sandstone bedrock (TKfs)		
						(21') Boring terminated		640
25								

NOTES: Hole precleared to 0.5' on 11/30/2022 8:15 using other.

Checked by: JF

PACIFIC WATERSHED ASSOCIATES	**Client:** Mendocino Land Trust **Project:** Chamberlain Creek **Address:** 2000 Main Chamberlain Road, Mendocino, CA	**BORING LOG** **Boring No.** CCB2 **Page:** 1 of 1

Drilling Start Date:	**11/29/2022 10:45**	Boring Depth (ft):	**31.5**
Drilling End Date:	**11/29/2022 12:45**	Boring Diameter (in):	**6.00**
Drilling Company:	**Fisch Drilling**	Sampling Method(s):	**Shelby Tube, Split Spoon**
Drilling Method:	**Hollow Stem Auger**	DTW During Drilling (ft):	**25.0**
Drilling Equipment:	**Geoprobe 6600**	DTW After Drilling (ft):	**25.0**
Driller:	**Rick**	Ground Surface Elev. (ft):	**656.00**
Logged By:	**THL**	Location (Lat, Long):	**39.38343, -123.54761**

DEPTH (ft)	Sample Type	Time	Blow Counts	Recovery (ft)	N Value RQD%	SOIL/ROCK VISUAL DESCRIPTION	REMARKS
0						(0') Silty GRAVEL with sand (GM); some fine-coarse grained gravel, some fine-medium sand, little silt, few clay, poorly graded, medium dense, dry, reddish-brown	
5	SS	11:00	4 6 6	0.75	12		
10	SS	11:15	5 4 4	1.13	8	(10') Silty GRAVEL with sand (GM); some fine-coarse grained gravel, some fine-coarse sand, few silt, few clay, poorly graded, medium dense, dry, dark reddish-brown	
	SH	11:30		1.35			(12.0') ASTM D422; ASTM D4318; LL = 29, PL = 21, PI = 8 12.0-13.0 (') S-1 Soil
14						(14') Silty GRAVEL with sand (GM); some fine-coarse grained gravel, some fine-coarse sand, few silt, few clay, poorly graded, medium dense, slightly moist, dark reddish-brown	
15	SS	11:45	3 5 6	0.75	11		
	SH	12:00		0.90			(18.0') ASTM D422 18.0-19.5 (') S-2 Soil
20	SS	12:15	5 5 4	1.13	9	(20') Poorly graded GRAVEL with sand (GP); fine-coarse grained, some fine-coarse sand, few silt, trace clay, medium dense, moist, dark brown	
25	SS	12:25	3 3 4	1.13	7		
30	SS	12:35	5 15 49	0.45	64		
31						(31') SED ROCK (SANDSTONE); moderately bedded, slightly weathered, hard, slightly fractured, bluish-gray, wet, Franciscan Coastal Belt sandstone bedrock. (31.5') Boring terminated	
35							

Water level symbol at 25 ft.

ELEVATION (ft): 655, 650, 645, 640, 635, 630, 625

NOTES: Hole precleared to 0.5' on 11/29/2022 10:30 using other.

Checked by: JF

PACIFIC WATERSHED ASSOCIATES	**Client:** Mendocino Land Trust **Project:** Chamberlain Creek **Address:** 2000 Main Chamberlain Road, Mendocino, CA	**BORING LOG** **Boring No.** CCB3 **Page:** 1 of 1

Drilling Start Date:	**11/30/2022 10:15**	Boring Depth (ft):	**35**
Drilling End Date:	**11/30/2022 12:45**	Boring Diameter (in):	**6.00**
Drilling Company:	**Fisch Drilling**	Sampling Method(s):	**Split Spoon**
Drilling Method:	**Hollow Stem Auger**	DTW During Drilling (ft):	**20**
Drilling Equipment:	**Geoprobe 6600**	DTW After Drilling (ft):	**20**
Driller:	**Rick**	Ground Surface Elev. (ft):	**656.00**
Logged By:	**THL**	Location (Lat, Long):	**39.38337, -123.54754**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	Time	Blow Counts	Recovery (ft)	N Value RQD%	SOIL/ROCK VISUAL DESCRIPTION	REMARKS	ELEVATION (ft)
0									(0') Silty GRAVEL (GM); fine-coarse grained, few fine sand, little silt, trace clay, poorly graded, loose, slightly moist, brown		655
5									(5') Silty GRAVEL (GM); fine-coarse grained, few fine sand, little silt, trace clay, poorly graded, loose, slightly moist, brown		650
10											645
15									(15') Silty GRAVEL (GM); mostly fine grained gravel, trace fine sand, some silt, trace clay, poorly graded, loose, moist, dark brown		640
20		▼		SS	11:35	0 0 1	1.35	1	(20') SILT with gravel (ML); little fine gravel, trace fine sand, mostly silt, trace clay, low plasticity, very soft, saturated, reddish		635
22									(22') Lean CLAY with sand (CL); few fine sand, few silt, some clay, low plasticity, very soft, saturated, bluish-gray		
25											630
30				SS	11:55	6 7 3		10	(30') Lean CLAY with sand (CL); few fine sand, few silt, some clay, low plasticity, medium stiff, moist, bluish-gray		625
34				SS	12:20	0 0 25	0.60	25	(34') SED ROCK (SANDSTONE); very fine sand, moderately bedded, slightly weathered, hard, very slightly fractured, bluish-gray, saturated, Franciscan Coastal Belt sandstone bedrock (TKfs).		
35									(35') Boring terminated		620
40											

NOTES: Hole precleared to 0.5' on 11/30/2022 10:00 using other.

Checked by: JF

	Client:	Mendocino Land Trust	BORING LOG
	Project:	Chamberlain Creek	Boring No. CCB4
	Address:	2000 Main Chamberlain Road, Mendocino, CA	Page: 1 of 1

Drilling Start Date:	**11/29/2022 13:15**	Boring Depth (ft):	**24.5**
Drilling End Date:	**11/29/2022 15:30**	Boring Diameter (in):	**6.00**
Drilling Company:	**Fisch Drilling**	Sampling Method(s):	**Shelby Tube, Split Spoon**
Drilling Method:	**Hollow Stem Auger**	DTW During Drilling (ft):	**18.5**
Drilling Equipment:	**Geoprobe 6600**	DTW After Drilling (ft):	**18.5**
Driller:	**Rick**	Ground Surface Elev. (ft):	**657.00**
Logged By:	**THL**	Location (Lat, Long):	**39.38345, -123.54752**

DEPTH (ft)	Sample Type	Time	Blow Counts	Recovery (ft)	N Value RQD%	SOIL/ROCK VISUAL DESCRIPTION	REMARKS
0						(0') Silty GRAVEL with sand (GM); some fine grained gravel, some fine-coarse sand, few silt, few clay, poorly graded, medium dense, dry, light reddish-brown	
5	SS	13:30	5 5 6	0.90	11		
10	SS	13:45	5 9 11	0.75	20		
12						(12') Silty GRAVEL with sand (GM); some fine grained gravel, some fine-coarse sand, few silt, few clay, poorly graded, medium dense, dry, brown	
15	SS	14:15	4 3	1.13	7		
16.5	SH	14:50	4	1.35			(16.5') ASTM D422; ASTM D4318; LL = 30, PL = 19, PI = 11 16.5-18.0 (') S-1; S-2 Soil
18						(18') Silty GRAVEL with sand (GM); some fine grained gravel, some fine-coarse sand, few silt, few clay, poorly graded, medium dense, moist, brown	
20	SS	15:10	7 12 13	0.60	25	(20') SED ROCK (SANDSTONE); very fine sand, moderately bedded, slightly weathered, moderately hard, moderately fractured, bluish-gray, wet	
24						(24') SED ROCK (SANDSTONE); very fine sand, moderately bedded, slightly weathered, hard, slightly fractured, bluish-gray, dry, Franciscan Coastal Belt sandstone bedrock.	
24.5						(24.5') Boring terminated	
30							

Elevation (ft): 655, 650, 645, 640, 635, 630

NOTES: Hole precleared to 0.5' on 11/29/2022 13:00 using other.

Checked by: JF

PACIFIC WATERSHED ASSOCIATES	**Client:** Mendocino Land Trust **Project:** Chamberlain Creek **Address:** 2000 Main Chamberlain Road, Mendocino, CA	**BORING LOG** **Boring No.** CCB5 **Page:** 1 of 1

Drilling Start Date:	**11/29/2022 8:15**	Boring Depth (ft):	**14**
Drilling End Date:	**11/29/2022 10:15**	Boring Diameter (in):	**6.00**
Drilling Company:	**Fisch Drilling**	Sampling Method(s):	**Shelby Tube, Split Spoon**
Drilling Method:	**Hollow Stem Auger**	DTW During Drilling (ft):	**N/A**
Drilling Equipment:	**Geoprobe 6600**	DTW After Drilling (ft):	**N/A**
Driller:	**Rick**	Ground Surface Elev. (ft):	**658.00**
Logged By:	**THL**	Location (Lat, Long):	**39.38355, -123.54749**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	Time	Blow Counts	Recovery (ft)	N Value RQD%	SOIL/ROCK VISUAL DESCRIPTION	REMARKS	ELEVATION (ft)
0									(0') Silty GRAVEL with sand (GM); some fine-coarse grained gravel, some fine-coarse sand, few silt, few clay, poorly graded, medium dense, dry, light reddish		
				SH	08:30		0.38			(2.5') ASTM D422; ASTM D2937; DD = 106.5 2.5-3.0 (') S-1 Soil	655
5				SH	08:45		0.45			(5.0') ASTM D422; ASTM D2937; DD = 102.0 5.0-5.5 (') S-2 Soil	
				SS	08:55	6 7 5	0.75	12			
				SS	09:05	3 8 6	1.13	14			650
10				SH	09:35		1.13		(10') Silty SAND (SM); fine-medium grained, trace fine gravel, some silt, little clay, poorly graded, medium dense, slightly moist, dark reddish-brown	(10.0') ASTM D422 10.0-11.5 (') S-3 Soil	
									(13.5') SED ROCK (SANDSTONE); moderately bedded, slightly weathered, hard, slightly fractured, bluish-gray, slightly moist, Franciscan Coastal Belt sandstone bedrock.		645
15									(14') Boring terminated		
											640
20											

NOTES: Hole precleared to 0.5' on 11/29/2022 8:00 using other.

Checked by: JF

BORING AND WELL LOG LEGEND

SURFACE
ASPHALT
CONCRETE
FILL
TOPSOIL
AIR
ICE

USCS
Well-graded GRAVEL (GW)
Poorly graded GRAVEL (GP)
Silty GRAVEL (GM)
Clayey GRAVEL (GC)
Silty, Clayey GRAVEL (GC-GM)
Well-graded GRAVEL with silt (GW-GM)
Poorly graded GRAVEL with silt (GP-GM)
Well-graded GRAVEL with clay (GW-GC)
Poorly graded GRAVEL with clay (GP-GC)
Well-graded SAND (SW)
Poorly graded SAND (SP)
Silty SAND (SM)
Clayey SAND (SC)
Silty, Clayey SAND (SC-SM)
Well-graded SAND with silt (SW-SM)
Poorly graded SAND with silt (SP-SM)
Well-graded SAND with clay (SW-SC)
Poorly graded SAND with clay (SP-SC)
SILT (ML)
Lean CLAY (CL)
Silty CLAY (CL-ML)
Organic SOIL (OL)
Elastic SILT (MH)
Fat CLAY (CH)
Organic SOIL (OH)
Organic SOIL (OL/OH)
PEAT (PT)
BEDROCK
IGNEOUS Rock
METAMORPHIC Rock
SEDIMENTARY Rock
WATER

Non-USCS
Gravel
Sand
Silt
Clayey Silt
Silt & Clay
Clay & Silt
Silty Clay
Clay
Boulders
Cobbles
Peastone
Glacial Till
Iron Ore
Wood
Peat
Saprolite
Ash
Waste

Volume Descriptors
Trace = <5%
Few = 5-10%
Little = 15-25%
Some = 30-45%
Mostly = >=50%

Water Levels
Water Level During Drilling
Water Level at End of Drilling/in Completed Well

Well/Boring Completion
Cap
Riser
Screen
End Plug
Annular Seal
Sanitary Seal (Bentonite Slurry/Chips/Pellets/Powder, Other)
Filter Pack (Sand, Gravel, Other)
Backfill

Sample Type
GR Grab
EN Encore
SS Split Spoon
SH Shelby Tube
CO Core Barrel
DP Direct Push
ID Lab Sample and ID

Appendix G.
Engineering Calculations

ESM Cal Salmon Stream Habitat Restoration Manual

Stream: Chamberlain Creek
Engineer: JPS ***Date:*** 4/11/2023
Design Q: 1040 ***100-year***

ACOE Method (from EM 1110-2-1601)

*For steep chutes with slopes of 2 - 20% (10%)**

Q = channel discharge	=	1040	cfs
W = bankfull width	=	19	ft
S = bed slope (ft/ft)	=	0.032	
b = bottom width	=	24.5	ft
q = discharge/unit width in cfs/ft	=	42.4	sf/s
g = 32.2 ft/s^2			

Equation 3-5:
$D_{30} = 1.95\ S^{0.555} 1.25 q^{0.67} / g^{0.33}$ D30 = 1.4 16.6 inches

California Restoration Manual XII-69

Gradation Based on ACOE D30

D30 =	16.6		
D100 = D84*2.5 =	62.1		← ESM
D84 = 1.5(D30) =	24.8		← ESM
D50 = D84*.4 =	9.9		← ESM
D16 = D84/8 =	2.07	0.8	← Fuller-Thompson n = 0.45
D5 =		0.06	← adjust n = 0.45 to 0.7 so that 5% of mix is sand and finer (D5<0.08")
	=	1.5 mm	

Max D100 73.5 No more than 1/4 of active channel

Summary:

D100 =	62 in	Large Rock Structure
D84 =	25 in	Large Rock Structure
D50 =	10 in	
D16 =	1 in	
D8 =	0.1 in	

Thickness: ESM (2/3*D100) = 42 in

Turbulence EDF = 62.4*V*S V (adult hi flows) = 107
= 213.7

<7ft*lb/s/ft^3 for adult salmon and steelhead (Bates et al. 2003)

Chamberlain Creek

Deflector Jam Stability Calcs

TABLE OF CONTENTS

Date of Last Revision: May 18, 2023

Designer:
Julian Sicaud, EIT

Reviewed by:
Greg Orum, PE

Large Wood Structure Stability Analysis Spreadsheet was developed by Michael Rafferty, P.E.
Version 1.1

Reference for Companion Paper:

Rafferty, M. 2016. *Computational Design Tool for Evaluating the Stability of Large Wood Structures.* Technical Note TN-103.1. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center. 27 p.

Chamberlain Creek
Factors of Safety and Design Constants

Spreadsheet developed by
Michael Rafferty, P.E.

Symbol	Description	Value
FS_V	Factor of Safety for Vertical Force Balance	**1.50**
FS_H	Factor of Safety for Horizontal Force Balance	**1.50**
FS_M	Factor of Safety for Moment Force Balance	**1.50**

Symbol	Description	Units	Value
C_{Lrock}	Coefficient of lift for submerged boulder (D'Aoust, 2000)	-	0.17
C_{Drock}	Coefficient of drag for submerged boulder (Schultz, 1954)	-	0.85
g	Gravitational acceleration constant	ft/s^2	32.174
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-	3.00
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-	1.50
SG_{rock}	Specific gravity of quartz particles	-	2.65
γ_{rock}	Dry unit weight of boulders	lb/ft^3	165.0
γ_w	Specific weight of water at 50ºF	lb/ft^3	62.40
η	Rootwad porosity from NRCS Tech Note 15 (2001)	-	0.20
ν	Kinematic viscosity of water at 50ºF	ft/s^2	1.41E-05

Chamberlain Creek
Hydrologic and Hydraulic Inputs

Spreadsheet developed by
Michael Rafferty, P.E.

Average Return Interval (ARI) of Design Discharge: 100 yr

Site ID	Proposed Station	Design Discharge, Q_{des} (cfs)	Maximum Depth, d_w (ft)	Average Velocity, u_{avg} (ft/s)	Bankfull Width, W_{BF} (ft)	Wetted Area, A_W (ft^2)	Radius of Curvature, R_c (ft)
Deflector Jam	3+50	1,040	6.87	6.97	22.0	171	50

Chamberlain Creek
Stream Bed Substrate Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Stream bed D_{50} (mm)	Stream Bed Substrate Grain Size Class	Bed Soil Class	Dry Unit Weight[1], γ_{bed} (lb/ft^3)	Buoyant Unit Weight, γ'_{bed} (lb/ft^3)	Friction Angle, ϕ_{bed} (deg)
Deflector Jam	3+50	**75.00**	Small Cobble	4	135.0	84.1	41
							45119
							45273

Source: Compiled from Julien (2010) and Shen and Julien (1993); soil classes from NRCS Table TS14E–2 Soil classification

[1] γ_{bed} (kg/m^3) = 1,600 + 300 log D_{50} (mm) (from Julien 2010)

1 kg/m^3 = 0.062 1 lb/ft^3

Chamberlain Creek
Bank Soil Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Bank Soils (from field observations)	Bank Soil Class	Dry Unit Weight, γ_{bank} (lb/ft^3)	Buoyant Unit Weight, γ'_{bank} (lb/ft^3)	Friction Angle, ϕ_{bank} (deg)
Deflector Jam	3+50	**Gravel/sand**	5	111.7	69.5	39

Chamberlain Creek
Large Wood Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Project Location: West Coast

Timber Unit Weights			Air-dried[1] γ_{Td} (lb/ft^3)	Green[2] γ_{Tgr} (lb/ft^3)
Selected Species	**Common Name**	**Scientific Name**		
Tree Type #1:	**Redwood, Coast (young)**	Sequoia sempervirens	24.5	50.0
Tree Type #2:				
Tree Type #3:				
Tree Type #4:				
Tree Type #5:				
Tree Type #6:				
Tree Type #7:				
Tree Type #8:				
Tree Type #9:				
Tree Type #10:				

[1] **Air-dried unit weight, γ_{Td}** = Average unit weight of wood after exposure to air on a 12% moisture content volume basis. Air-dried unit weight is used in the force balance calculations for the portion of wood that is above the proposed thalweg elevation (assuming unsaturated conditions).

[2] **Green unit weight, γ_{Tgr}** = Average unit weight of freshly sawn wood when the cell walls are completely saturated with water. Green unit weight is used in the force balance calculations as a conservative estimate of the unit weight for the portion of wood that is below the proposed thalweg elevation (assuming saturated conditions). For comparison, Thevenet, Citterio, & Piegay (1998) determined wood unit weight typically increases by more than 100% after less than 24 hours exposure to water.

Source for timber unit weights:

U.S. Department of Agriculture, U.S. Forest Service. (2009) Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America. Research Note NRS-38. Table 1A.

Chamberlain Creek

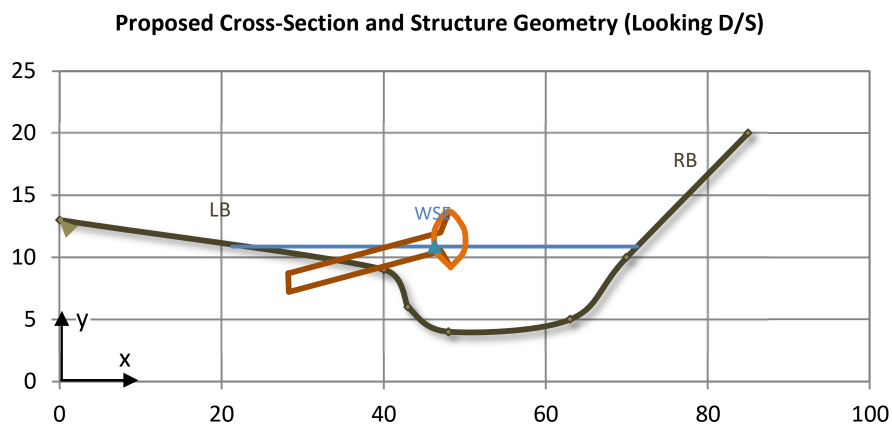
Spreadsheet developed by
Michael Rafferty, P.E.

Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Deflector Jam	Flow Deflection	Left bank	Outside	3+50	6.87	2.27	10.84

Multi-Log Structures	Layer	Log ID
	Stacked	Top 1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0	13
Top LB	40	9
Toe LB	43	6
Thalweg	48	4
Toe RB	63	5
Top RB	70	10
Fldpln RB	85	20

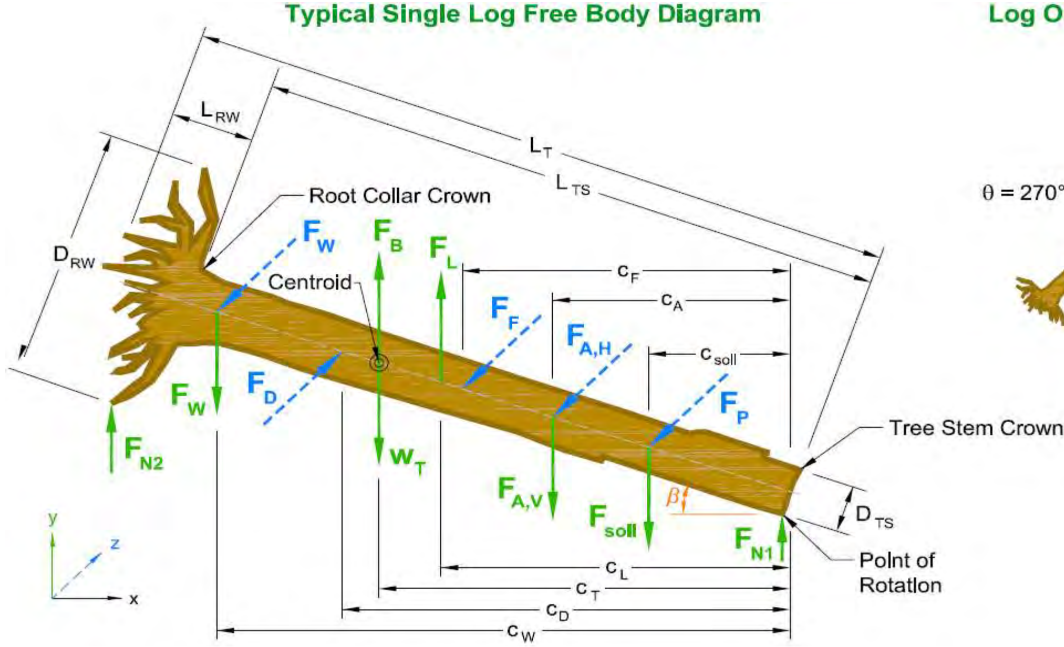


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Redwood, Coast (young)	Yes	40.0	1.50	2.25	4.50	24.5	50.0

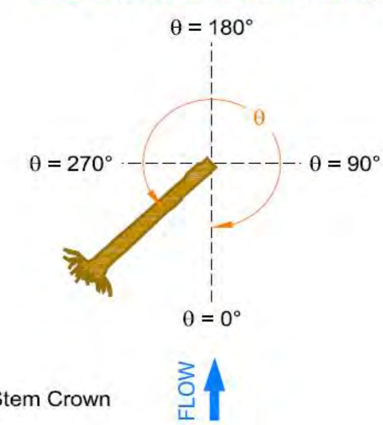
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	12-Jul	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	30.0	-5.0	Root collar: Crown	47.00	12.00	45,273.00	13.69	17.47

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Small Cobble	135.0	84.1	41.0	4	0.00	0.00	0.00
Bank	Gravel/sand	111.7	69.5	39.0	5	10.74	1.47	0.74

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	8.4	9.5	17.8	436	0
↓WS↑Thw	58.3	4.3	62.7	1,533	3,909
↓Thalweg	0.0	0.0	0.0	0	0
Total	66.7	13.8	80.5	1,969	3,909

Lift Force

C_{LT}	0.03
F_L (lbf)	57

Vertical Force Balance

F_B (lbf)	3,909	↑
F_L (lbf)	57	↑
W_T (lbf)	1,969	↓
F_{soil} (lbf)	823	↓
$F_{W,V}$ (lbf)	3,266	↓
$F_{A,V}$ (lbf)	0	
Σ F_V (lbf)	2,092	↓
FS_V	1.53	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	11.8	11.8	823
Total	0.0	11.8	11.8	823

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.10	1.56	1.21	0.02	1.52	3,031

Horizontal Force Balance

F_D (lbf)	3,031	→
F_P (lbf)	1,809	←
F_F (lbf)	1,704	←
$F_{W,H}$ (lbf)	23,761	←
$F_{A,H}$ (lbf)	0	
Σ F_H (lbf)	24,244	←
FS_H	9.00	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.81	0	2.00	0.87	153
Bank	4.40	1,809	21.70	0.81	1,551
Total	-	1,809	23.70	-	1,704

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
22.4	23.1	25.4	22.4	5.3	10.8	7.1

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	165,071
M_r (lbf)	990,280
FS_M	6.00 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Chamberlain Creek

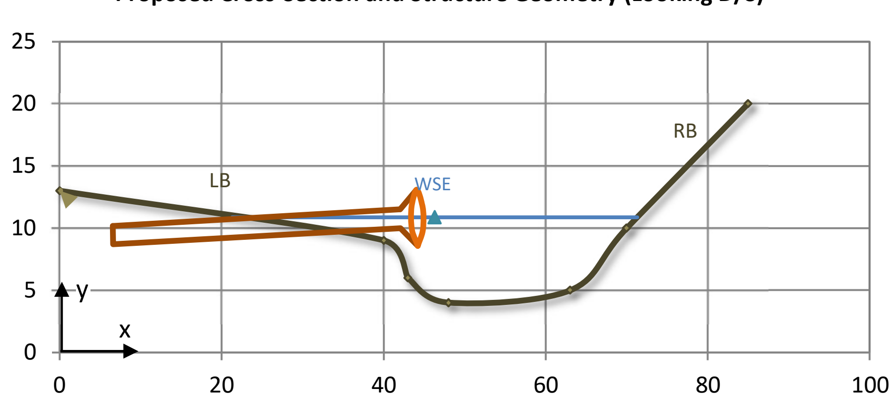
Spreadsheet developed by
Michael Rafferty, P.E.

Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Deflector Jam	Flow Deflection	Left bank	Outside	3+50	6.87	2.27	10.84

Multi-Log Structures	Layer	Log ID
	Stacked	Top 2

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0	13
Top LB	40	9
Toe LB	43	6
Thalweg	48	4
Toe RB	63	5
Top RB	70	10
Fldpln RB	85	20

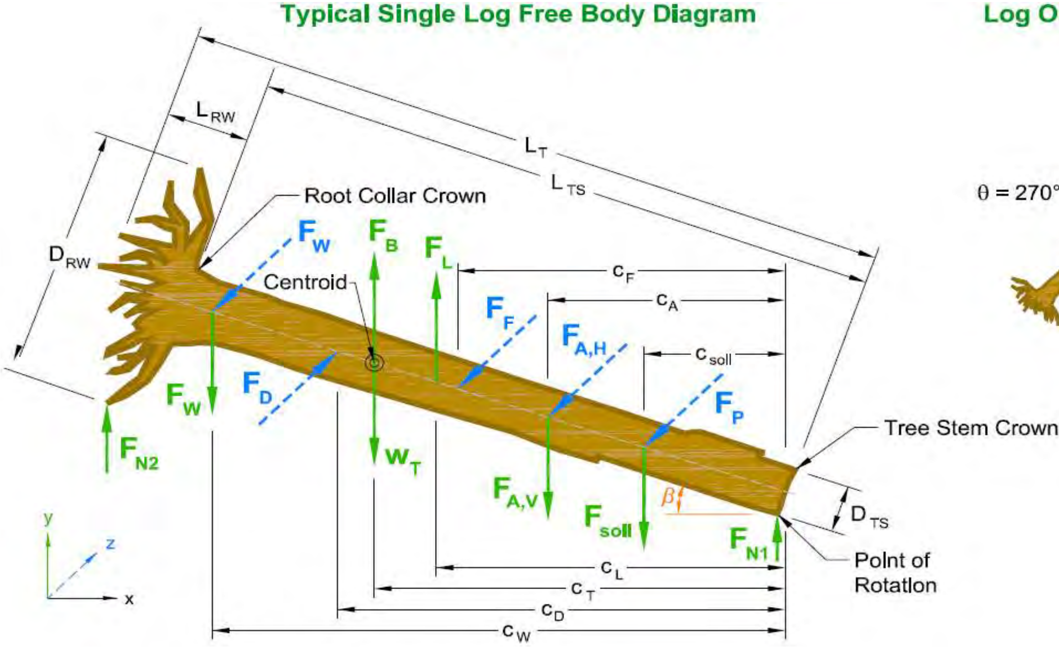


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Redwood, Coast (young)	Yes	40.0	1.50	2.25	4.50	24.5	50.0

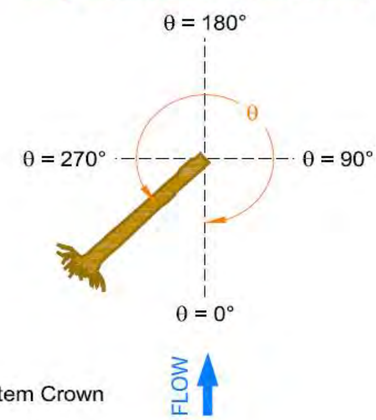
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	12-Jul	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	70.0	-2.0	Root collar: Crown	42.00	11.50	45,273.00	13.08	20.42

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Small Cobble	135.0	84.1	41.0	4	0.00	0.00	0.00
Bank	Gravel/sand	111.7	69.5	39.0	5	16.79	2.16	1.09

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	5.3	6.5	11.8	289	0
↓WS↑Thw	61.4	7.3	68.7	1,680	4,285
↓Thalweg	0.0	0.0	0.0	0	0
Total	66.7	13.8	80.5	1,969	4,285

Lift Force

C_{LT}	0.05
F_L (lbf)	127

Vertical Force Balance

F_B (lbf)	4,285	↑
F_L (lbf)	127	↑
W_T (lbf)	1,969	↓
F_{soil} (lbf)	2,625	↓
$F_{W,V}$ (lbf)	3,266	↓
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	3,449	↓
FS_V	1.78	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	17.4	9.9	27.2	2,625
Total	17.4	9.9	27.2	2,625

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.12	1.56	1.19	0.02	1.57	3,647

Horizontal Force Balance

F_D (lbf)	3,647	→
F_P (lbf)	5,770	←
F_F (lbf)	2,806	←
$F_{W,H}$ (lbf)	23,761	←
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	28,690	←
FS_H	8.87	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.81	0	2.00	0.87	197
Bank	4.40	5,770	28.50	0.81	2,610
Total	-	5,770	30.50	-	2,806

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
22.4	31.4	28.4	22.4	8.3	14.2	11.1

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	203,230
M_r (lbf)	893,615
FS_M	4.40 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Chamberlain Creek

Spreadsheet developed by
Michael Rafferty, P.E.

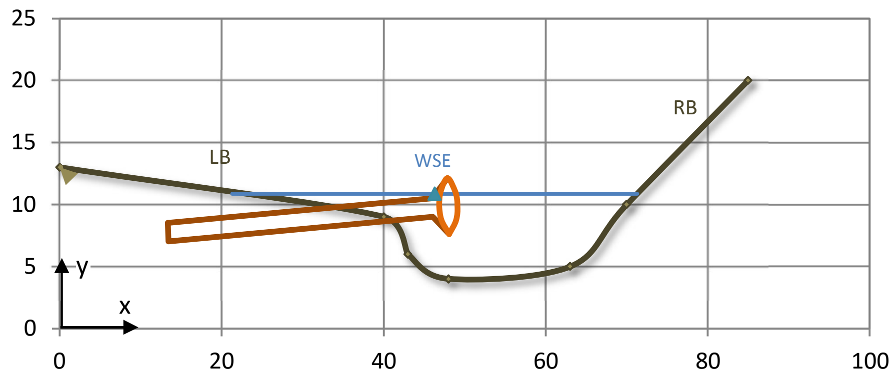
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Deflector Jam	Flow Deflection	Left bank	Outside	3+50	6.87	2.27	10.84

Multi-Log Structures	Layer	Log ID
	Stacked	Runner

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0	13
Top LB	40	9
Toe LB	43	6
Thalweg	48	4
Toe RB	63	5
Top RB	70	10
Fldpln RB	85	20

Proposed Cross-Section and Structure Geometry (Looking D/S)

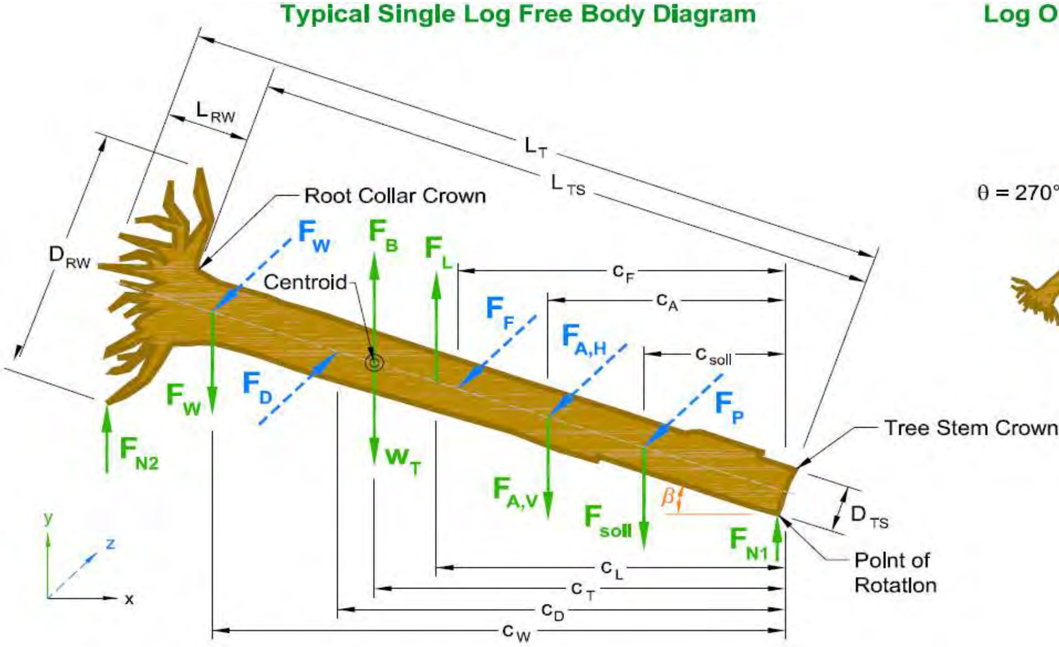


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Redwood, Coast (young)	Yes	40.0	1.50	2.25	4.50	24.5	50.0

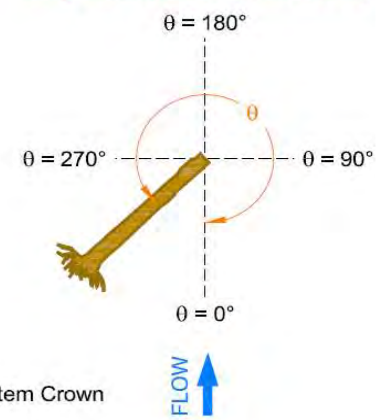
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	12-Jul	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	120.0	-3.0	Root collar: Crown	46.00	10.50	45,273.00	12.12	21.99

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Small Cobble	135.0	84.1	41.0	4	0.00	0.00	0.00
Bank	Gravel/sand	111.7	69.5	39.0	5	22.62	3.14	1.57

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	1.9	1.9	46	0
↓WS↑Thw	66.7	11.9	78.6	1,923	4,907
↓Thalweg	0.0	0.0	0.0	0	0
Total	66.7	13.8	80.5	1,969	4,907

Lift Force

C_{LT}	0.01
F_L (lbf)	21

Vertical Force Balance

F_B (lbf)	4,907	↑
F_L (lbf)	21	↑
W_T (lbf)	1,969	↓
F_{soil} (lbf)	3,935	↓
$F_{W,V}$ (lbf)	4,753	↓
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	5,730	↓
FS_V	2.16	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	5.5	47.8	53.3	3,935
Total	5.5	47.8	53.3	3,935

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.13	1.56	0.94	0.02	1.26	3,161

Horizontal Force Balance

F_D (lbf)	3,161	→
F_P (lbf)	8,648	←
F_F (lbf)	4,660	←
$F_{W,H}$ (lbf)	15,193	←
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	25,341	←
FS_H	9.02	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.81	0	2.00	0.87	299
Bank	4.40	8,648	31.30	0.81	4,361
Total	-	8,648	33.30	-	4,660

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
22.4	31.7	31.4	22.4	11.3	15.6	15.1

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	209,314
M_r (lbf)	977,914
FS_M	4.67 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Chamberlain Creek

Spreadsheet developed by
Michael Rafferty, P.E.

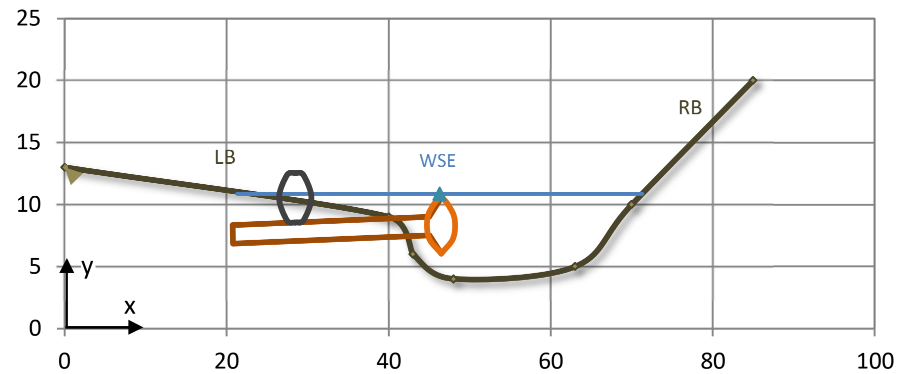
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Deflector Jam	Flow Deflection	Left bank	Outside	3+50	6.87	2.27	10.84

Multi-Log Structures	Layer	Log ID
	Footer	Bot 1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0	13
Top LB	40	9
Toe LB	43	6
Thalweg	48	4
Toe RB	63	5
Top RB	70	10
Fldpln RB	85	20

Proposed Cross-Section and Structure Geometry (Looking D/S)

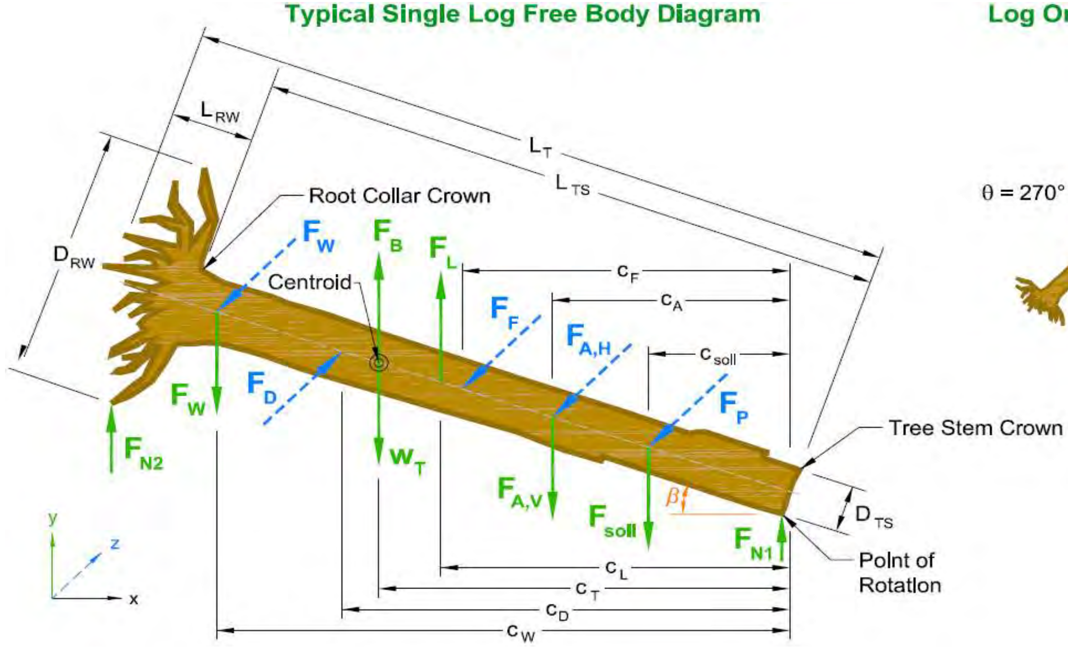


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Redwood, Coast (young)	Yes	40.0	1.50	2.25	4.50	24.5	50.0

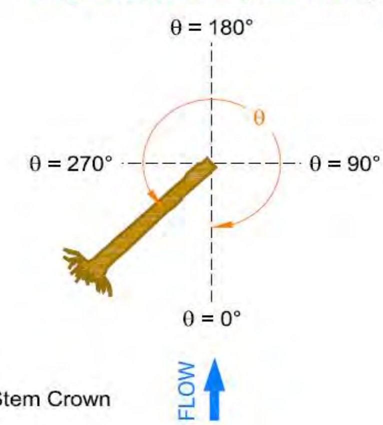
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	12-Jul	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	40.0	-1.0	Root collar: Crown	45.00	9.00	45,273.00	10.54	20.47

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Small Cobble	135.0	84.1	41.0	4	0.00	0.00	0.00
Bank	Gravel/sand	111.7	69.5	39.0	5	30.18	2.58	1.36

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	66.7	13.8	80.5	1,969	5,023
↓Thalweg	0.0	0.0	0.0	0	0
Total	66.7	13.8	80.5	1,969	5,023

Lift Force

C_{LT}	0.02
F_L (lbf)	54

Vertical Force Balance

F_B (lbf)	5,023	↑
F_L (lbf)	54	↑
W_T (lbf)	1,969	↓
F_{soil} (lbf)	4,254	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	4,180	↓
ΣF_V (lbf)	5,327	↓
FS_V	2.05	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	61.1	61.2	4,254
Total	0.0	61.1	61.2	4,254

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.12	1.56	1.15	0.01	1.51	3,514

Horizontal Force Balance

F_D (lbf)	3,514	→
F_P (lbf)	9,350	←
F_F (lbf)	4,332	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	10,169	←
FS_H	3.89	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.81	0	2.00	0.87	268
Bank	4.40	9,350	32.50	0.81	4,064
Total	-	9,350	34.50	-	4,332

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
22.4	33.0	35.1	22.4	15.0	16.2	20.0

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	237,383	↷
M_r (lbf)	501,412	↶
FS_M	2.11	✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
Above	4.00	12.0	12.8	20.7	4,235	55	276	4,180	0
								0	0
								0	0

Chamberlain Creek

Spreadsheet developed by
Michael Rafferty, P.E.

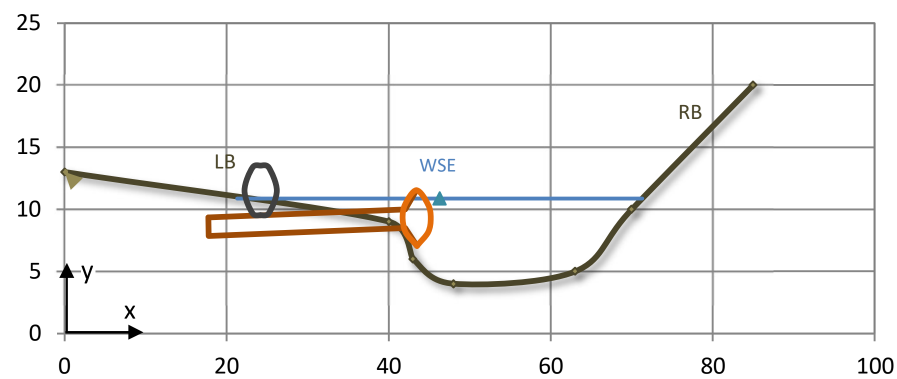
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Deflector Jam	Flow Deflection	Left bank	Outside	3+50	6.87	2.27	10.84

Multi-Log Structures	Layer	Log ID
	Footer	Bot 2

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0	13
Top LB	40	9
Toe LB	43	6
Thalweg	48	4
Toe RB	63	5
Top RB	70	10
Fldpln RB	85	20

Proposed Cross-Section and Structure Geometry (Looking D/S)

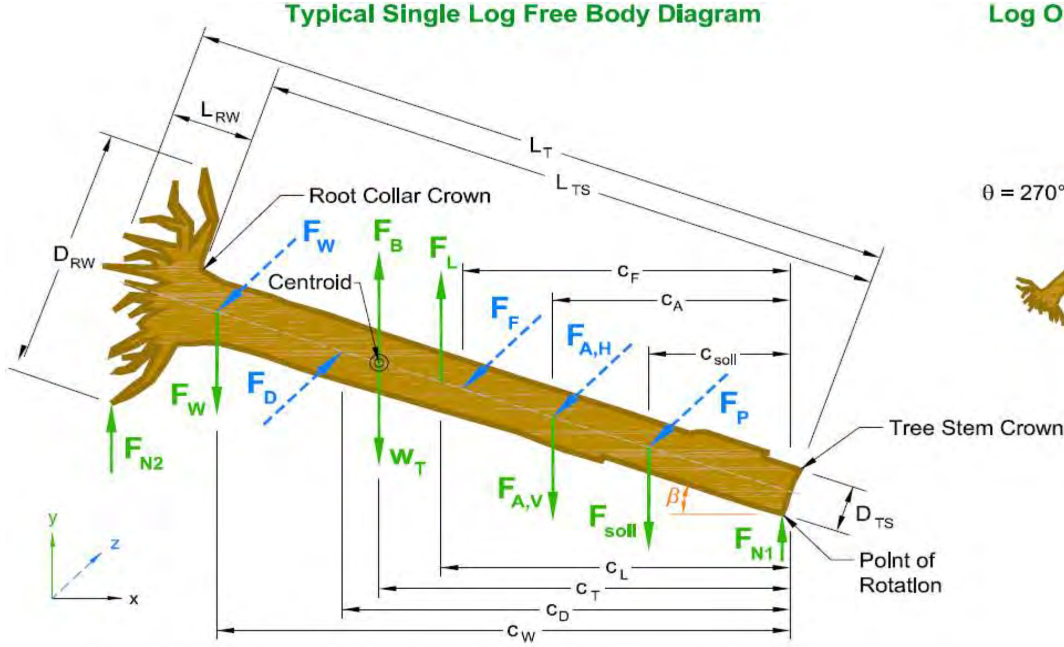


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Redwood, Coast (young)	Yes	40.0	1.50	2.25	4.50	24.5	50.0

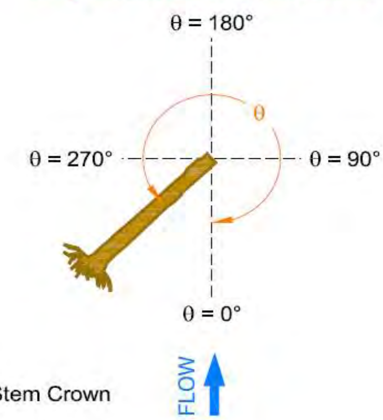
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	12-Jul	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	40.0	-1.0	Root collar: Crown	42.00	10.00	45,273.00	11.54	19.50

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Small Cobble	135.0	84.1	41.0	4	0.00	0.00	0.00
Bank	Gravel/sand	111.7	69.5	39.0	5	23.07	1.88	0.95

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.4	0.4	11	0
↓WS↑Thw	66.7	13.3	80.0	1,958	4,995
↓Thalweg	0.0	0.0	0.0	0	0
Total	66.7	13.8	80.5	1,969	4,995

Lift Force

C_{LT}	0.01
F_L (lbf)	32

Vertical Force Balance

F_B (lbf)	4,995	↑
F_L (lbf)	32	↑
W_T (lbf)	1,969	↓
F_{soil} (lbf)	2,329	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	4,952	↓
Σ F_V (lbf)	4,224	↓
FS_V	1.84	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	1.5	31.1	32.6	2,329
Total	1.5	31.1	32.6	2,329

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.11	1.56	1.15	0.02	1.49	3,309

Horizontal Force Balance

F_D (lbf)	3,309	→
F_P (lbf)	5,119	←
F_F (lbf)	3,434	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
Σ F_H (lbf)	5,244	←
FS_H	2.58	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.81	0	2.00	0.87	196
Bank	4.40	5,119	35.50	0.81	3,238
Total	-	5,119	37.50	-	3,434

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
22.4	36.1	31.6	22.4	11.5	17.7	15.3

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	217,369	↻
M_r (lbf)	334,308	↺
FS_M	1.54	✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
Above	4.00	10.0	24.6	8.9	4,972	20	102	4,952	0
								0	0
								0	0

Chamberlain Creek

Spreadsheet developed by
Michael Rafferty, P.E.

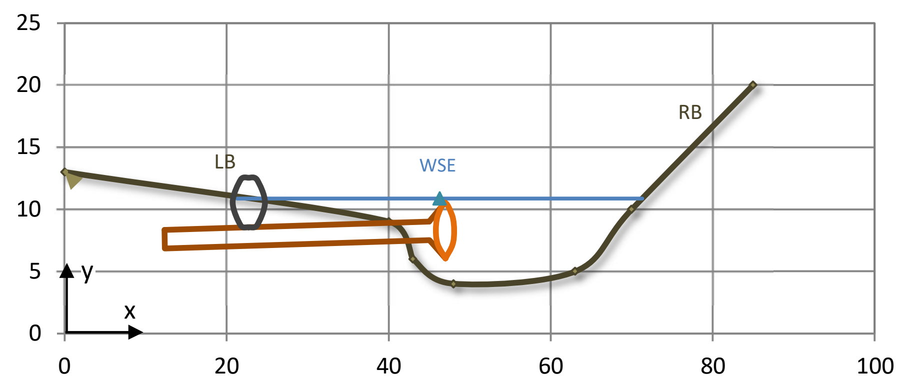
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Deflector Jam	Flow Deflection	Left bank	Outside	3+50	6.87	2.27	10.84

Multi-Log Structures	Layer	Log ID
	Footer	Bot 3

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0	13
Top LB	40	9
Toe LB	43	6
Thalweg	48	4
Toe RB	63	5
Top RB	70	10
Fldpln RB	85	20

Proposed Cross-Section and Structure Geometry (Looking D/S)

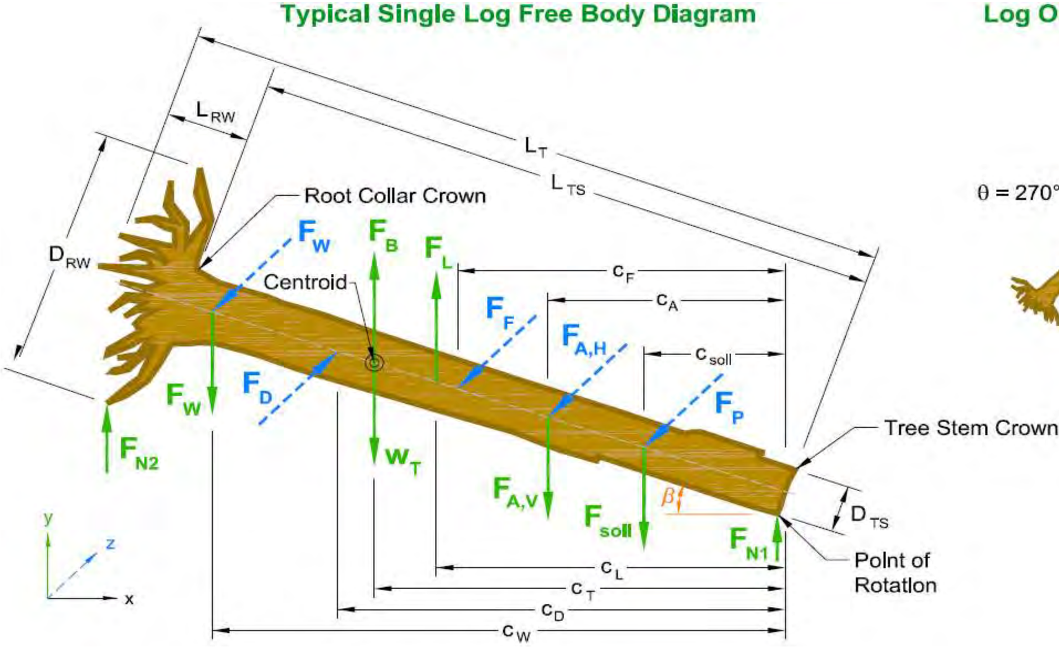


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Redwood, Coast (young)	Yes	40.0	1.50	2.25	4.50	24.5	50.0

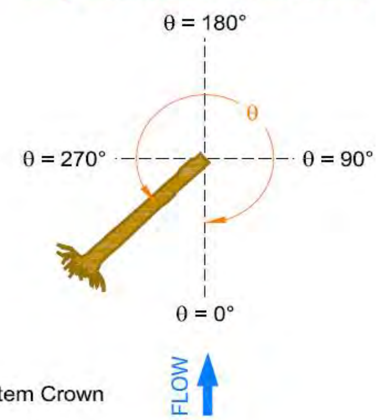
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	12-Jul	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	60.0	-1.0	Root collar: Crown	45.00	9.00	45,273.00	10.54	17.00

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Small Cobble	135.0	84.1	41.0	4	0.00	0.00	0.00
Bank	Gravel/sand	111.7	69.5	39.0	5	32.09	3.43	1.76

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	66.7	13.8	80.5	1,969	5,023
↓Thalweg	0.0	0.0	0.0	0	0
Total	66.7	13.8	80.5	1,969	5,023

Lift Force

C_{LT}	0.03
F_L (lbf)	56

Vertical Force Balance

F_B (lbf)	5,023
F_L (lbf)	56
W_T (lbf)	1,969
F_{soil} (lbf)	6,178
$F_{W,V}$ (lbf)	0
$F_{A,V}$ (lbf)	4,225
ΣF_V (lbf)	7,293
FS_V	2.44

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	7.0	77.6	84.6	6,178
Total	7.0	77.6	84.6	6,178

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.10	1.56	1.19	0.01	1.49	2,876

Horizontal Force Balance

F_D (lbf)	2,876
F_P (lbf)	13,578
F_F (lbf)	5,930
$F_{W,H}$ (lbf)	0
$F_{A,H}$ (lbf)	0
ΣF_H (lbf)	16,631
FS_H	6.78

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.81	0	2.00	0.87	355
Bank	4.40	13,578	33.70	0.81	5,575
Total	-	13,578	35.70	-	5,930

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
22.4	34.2	36.1	22.4	16.0	16.8	21.3

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	218,028
M_r (lbf)	705,254
FS_M	3.23

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
Above	4.00	12.0	12.8	20.7	4,235	11	54	4,225	0
								0	0
								0	0

Chamberlain Creek
Notation, Units, and List of Symbols

Notation

Symbol	Description	Unit
A_W	Wetted area of channel at design discharge	ft^2
A_{Tp}	Projected area of wood in plane perpendicular to flow	ft^2
c_D	Centroid of the drag force along log axis	ft
c_{Am}	Centroid of a mechanical anchor along log axis	ft
c_{Ar}	Centroid of a ballast boulder along log axis	ft
c_{Asoil}	Centroid of the added ballast soil along log axis	ft
$c_{F\&N}$	Centroid of friction and normal forces along log axis	ft
c_L	Centroid of the lift force along log axis	ft
c_P	Centroid of the passive soil force along log axis	ft
c_{soil}	Centroid of the vertical soil forces along log axis	ft
$c_{T,B}$	Centroid of the buoyancy force along log axis	ft
$c_{T,W}$	Centroid of the log volume along log axis	ft
c_{WI}	Centroid of a wood interaction force along log axis	ft
C_{Lrock}	Coefficient of lift for submerged boulder	-
C_{LT}	Effective coefficient of lift for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_D*	Effective coefficient of drag for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_W	Wave drag coefficient of submerged tree	-
$d_{b,avg}$	Average buried depth of log	ft
$d_{b,max}$	Maximum buried depth of log	ft
d_w	Maximum flow depth at design discharge in reach	ft
D_{50}	Median grain size in millimeters (SI units)	mm
D_r	Equivalent diameter of boulder	ft
D_{RW}	Assumed diameter of rootwad	ft
D_{TS}	Nominal diameter of tree stem (DBH)	ft
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-
e	Void ratio of soils	-
$F_{A,H}$	Total horizontal load capacity of anchor techniques	lbf
$F_{A,HP}$	Passive soil pressure applied to log from soil ballast	lbf
$F_{A,Hr}$	Horizontal resisting force on log from boulder	lbf
F_{Am}	Load capacity of mechanical anchor	lbf
$F_{A,V}$	Total vertical load capacity of anchor techniques	lbf
$F_{A,Vr}$	Vertical resisting force on log from boulder	lbf
$F_{A,Vsoil}$	Vertical soil loading on log from added ballast soil	lbf
F_B	Buoyant force applied to log	lbf
F_D	Drag forces applied to log	lbf
$F_{D,r}$	Drag forces applied to boulder	lbf
F_F	Friction force applied to log	lbf
F_H	Resultant horizontal force applied to log	lbf
F_L	Lift force applied to log	lbf
$F_{L,r}$	Lift force applied to boulder	lbf
F_P	Passive soil pressure force applied to log	lbf
F_{soil}	Vertical soil loading on log	lbf
$F_{W,H}$	Horizontal forces from interactions with other logs	lbf
$F_{W,V}$	Vertical forces from interactions with other logs	lbf

Notation (continued)

Symbol	Description	Unit
F_V	Resultant vertical force applied to log	lbf
Fr_L	Log Froude number	-
FS_V	Factor of Safety for Vertical Force Balance	-
FS_H	Factor of Safety for Horizontal Force Balance	-
FS_M	Factor of Safety for Moment Force Balance	-
g	Gravitational acceleration constant	ft/s^2
K_P	Coefficient of Passive Earth Pressure	-
$L_{T,em}$	Total embedded length of log	ft
L_{RW}	Assumed length of rootwad	ft
L_T	Total length of tree (including rootwad)	ft
L_{Tf}	Length of log in contact with bed or banks	ft
L_{TS}	Length of tree stem (not including rootwad)	ft
$L_{TS,ex}$	Exposed length of tree stem	ft
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-
M_d	Driving moment about embedded tip	lbf
M_r	Driving moment about embedded tip	lbf
N	Blow count of standard penetration test	-
p_o	Porosity of soil volume	-
Q_{des}	Design discharge	cfs
R	Radius	ft
R_c	Radius of curvature at channel centerline	ft
SG_r	Specific gravity of quartz particles	-
SG_T	Specific gravity of tree	-
u_{avg}	Average velocity of cross section in reach	ft/s
u_{des}	Design velocity	ft/s
u_m	Adjusted velocity at outer meander bend	ft/s
V_{dry}	Volume of soils above stage level of design flow	ft^3
V_{sat}	Volume of soils below stage level of design flow	ft^3
V_{soil}	Total volume of soils over log	ft^3
V_{RW}	Volume of rootwad	ft^3
V_S	Volume of solids in soil (void ratio calculation)	ft^3
V_T	Total volume of log	ft^3
V_{TS}	Total volume of tree	ft^3
V_V	Volume of voids in soil	ft^3
V_{Adry}	Volume of ballast above stage of design flow	ft^3
V_{Awet}	Volume of ballast below stage of design flow	ft^3
$V_{r,dry}$	Volume of boulder above stage of design flow	ft^3
$V_{r,wet}$	Volume of boulder below stage of design flow	ft^3
W_{BF}	Bankfull width at structure site	ft
W_r	Effective weight of boulder	lbf
W_T	Total log weight	lbf
x	Horizontal coordinate (distance)	ft
y	Vertical coordinate (elevation)	ft
$y_{T,max}$	Minimum elevation of log	ft
$y_{T,min}$	Maximum elevation of log	ft

Greek Symbols

Symbol	Description	Unit
β	Tilt angle from stem tip to vertical	deg
γ_{bank}	Dry specific weight of bank soils	lb/ft^3
$\gamma_{bank,sat}$	Saturated unit weight of bank soils	lb/ft^3
γ'_{bank}	Effective buoyant unit weight of bank soils	lb/ft^3
γ_{bed}	Dry specific weight of stream bed substrate	lb/ft^3
γ'_{bed}	Effective buoyant unit weight of stream bed substrate	lb/ft^3
γ_{rock}	Dry unit weight of boulders	lb/ft^3
γ_s	Dry specific weight of soil	lb/ft^3
γ'_s	Effective buoyant unit weight of soil	lb/ft^3
γ_{Td}	Air-dried unit weight of tree (12% MC basis)	lb/ft^3
γ_{Tgr}	Green unit weight of tree	lb/ft^3
γ_w	Specific weight of water at 50ºF	lb/ft^3
η	Rootwad porosity	-
θ	Rootwad (or large end of log) orientation to flow	deg
μ	Coefficient of friction	-
ν	Kinematic viscosity of water at 50ºF	ft/s^2
Σ	Sum of forces	-
ϕ_{bank}	Internal friction angle of bank soils	deg
ϕ_{bed}	Internal friction angle of stream bed substrate	deg

Units

Notation	Description
cfs	Cubic feet per second
ft	Feet
lb	Pound
lbf	Pounds force
kg	Kilograms
m	Meters
mm	Millimeters
s	Seconds
yr	Year

Abbreviations

Notation	Description
ARI	Average return interval
Avg	Average
DBH	Diameter at breast height
deg	Degrees
Dia	Diameter
Dist	Distance
D/S	Downstream
ELJ	Engineered log jam
Ex	Example
Fldpln	Floodplain
H&H	Hydrologic and hydraulic
ID	Identification
i.e.	That is
LB	Left bank
LW	Large wood
Max	Maximum
MC	Moisture content
Min	Minimum
ML	Multi-log
SL	Single log
N/A	Not applicable
no	Number
Pt	Point
rad	Radians
RB	Right bank
RW	Rootwad
SL	Single log
Thw	Thalweg (lowest elevation in channel bed)
Typ	Typical
U.S.	United States
WS	Water surface
WSE	Water surface elevation
↑	Above
↓	Below