Pacific Connector Gas Pipeline, LP

Fish Passage Plan for Pipeline Stream Crossings within the Coastal Zone Management Area (MPs 0.00 to 53.19) to Satisfy OAR 635-412-0005 - 0040

Pacific Connector Gas Pipeline Project

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1.0 INTRODUCTION – PLAN OVERVIEW

This Fish Passage Plan ("Plan") was prepared to comply with Oregon Administrative Rules ("OAR") 635-412-0005 - 0040 which regulate artificial obstructions that could create barriers to upstream or downstream migration by native fish species. The Plan describes Pacific Connector Gas Pipeline, LP's ("PCGP's") waterbody crossing procedures and Best Management Practices ("BMPs") that will be utilized during construction of the Pacific Connector Gas Pipeline Project (Pipeline or Pipeline project) to satisfy Oregon Department of Fish and Wildlife ("ODFW") Fish Passage requirements. The purpose of this Plan is to: 1) describe how PCGP's proposed waterbody crossing procedures ensure that the pipeline will not create a barrier to fish passage due to the pipeline depths, which have been designed to accommodate potential future streambed scour and channel migration; and 2) describe how the BMPs proposed to restore disturbed streambeds and banks and habitat features have been designed to ensure that they do not become a barrier to fish passage.. This Plan has been developed for the waterbodies crossed by the Pipeline within the Coastal Zone Management Area ("CZMA") between MPs 0.00 and 53.19.

Table 1 (see Appendix 1) lists the waterbodies that are crossed by the Pipeline within the CZMA by milepost location, stream name and unique ID. Fish presence information for each stream crossing is provided in Table 1 along with the waterbody stream type (intermittent, ephemeral, perennial) and ordinary high water mark ("OHWM") width, as well as the stream scour potential hazard rating and stream crossing risk ranking. The waterbody crossing method and rationale for each stream crossing is specified, along with the ODFW-recommended in-water work window. Temporary bridge installation information for each crossing is also noted in Table 1 and if one pass will be required to install the bridge within the ODFW-recommended in-water work window. Table 2 in Appendix 1 provides the location information for each waterbody crossing (Section, Township and Range, and Longitude and Latitude) within the CZMA.

Within the CZMA, the Map Volume includes: 1) 1:24,000 scale topographic quad maps showing the waterbody crossing locations; 2) detailed aerial photo maps of each waterbody and wetland crossing – the extent of the detailed aerial photo maps are shown on the quad maps (Note: these maps were developed for Oregon Department of State Lands and include wetland and ditch features that are within the 400-foot wide project study area but are not affected by the Pipeline project and are not included on Table 1); and 3) aerial photo environmental alignment sheets of the Pipeline. The environmental alignment sheets detail various resource information, such as all work areas (construction right-of-way, temporary extra work areas ["TEWAs"], and uncleared storage areas ["UCSAs"]), contours, erosion control measures/BMPs, etc. The environmental alignment sheets are also provided digitally if needed for larger, on-screen review.

PCGP's proposed waterbody crossing methods and their individual limitations are generally described in Section 2.0 below. Detailed descriptions of the dry open cut crossing methods, flume and dam and pump, which will be used on the majority of the waterbody crossings, are provided in Appendix 2, and detailed horizontal directional drill ("HDD") design plans are provided in Appendix 3. Site-specific crossing plans for larger waterbodies are provided in Appendix 4.

PCGP proposes to cross all waterbodies within the ODFW-recommended in-water work windows[1] (OAR 635-412-0035 10 (a) and understands that fisheries construction windows only apply to those waterbodies flowing at the time of construction and that the windows do not apply to trenchless crossing methods (HDD, Direct Pipe, or conventional bore). Although the

[1] https://www.dfw.state.or.us/lands/inwater/Oregon_Guidelines_for_Timing_of_%20InWater_Work2008.pdf.

trenchless crossing methods allow fish passage during the construction process, the dry open cut crossing methods (flume and dam and pump) temporarily restrict fish passage. Section 2.0 describes the duration in which fish passage would be temporarily restricted for these crossing methods.

Section 3.0 describes the temporary bridges that will be installed at a majority of the waterbody crossings to enable construction traffic along the construction right-of-way. The construction right-of-way provides the primary transportation corridor for equipment and materials; therefore, installation of temporary bridges across waterbodies is critical to facilitate construction and avoid significant new road construction. A typical temporary bridge design is included in Appendix 4.

PCGP has developed a Fish Salvage Plan (see Appendix 5), which would be implemented during dry open cut crossings to minimize adverse effects to Endangered Species Act ("ESA") listed salmonids (Southern Oregon/Northern California Coast coho salmon and Oregon Coast coho salmon), non-listed salmonids (Chinook, steelhead, cutthroat trout), and ESA-listed catostomids (Lost River sucker and shortnose sucker) as well as to comply with OAR 635-412-0035 (10)(B)(e) and OAR 635-043. The plan has been developed to:

1. Exclude fish from in-stream construction sites;
2. Minimize risk of injury or death while capturing fish that might remain after exclusion efforts;
3. Minimize risk of injury or death due to handling captured fish; and
4. Release of fish to non-impacted environments.

The plan specifies procedures to 1) isolate the work area; 2) remove fish and dewater the work area; 3) handle, hold, and release fish; and 4) document fish that have been captured, handled, held, and released and notify the National Marine Fisheries Service ("NMFS") and U.S. Fish and Wildlife Service ("FWS").

A stream crossing risk analysis was completed by PCGP (see Section 8.0 and Appendix 6) according to the protocol identified by Oregon Department of Environmental Quality ("ODEQ"). The analysis approach was confirmed through progress meetings with ODEQ, U.S. Army Corps of Engineers ("USACE"), and FWS representatives. Table 1 in Appendix 1 includes the risk analysis management category (Green, Blue, Yellow, or Orange) for each stream crossing ranked in the risk analysis. Pipeline construction and/or restoration measures were developed based on the results of the risk assessment; the measures range from site-specific design to typical construction methods (see Appendix 6). The risk analysis also provides the long-term monitoring plan (10 years) for the stream crossings, which was developed following consultation with a representative from FWS and NMFS.

As described in Section 9.0, fluvial erosion is a potential hazard where channel migration, avulsion, widening, and/or streambed scour are capable of exposing the pipe. Stream crossings were evaluated with respect to potential future risk to the pipeline that could result from channel bed scour and/or lateral migration. The Channel Migration and Scour Analysis, prepared by GeoEngineers (2018), is provided in Appendix 7 and includes all stream crossings (inside and outside the CZMA). Table 1 in Appendix 1 lists the results of the scour analysis for the stream crossings within the CZMA and notes the potential 100-year scour depth calculated in alluvium (assuming absence of bedrock). Figure 1 in Appendix 7 depicts the proposed pipeline burial depth for streams with low and high scour potential. On low scour hazard streams, the pipeline burial depth will be 1-3 feet below bedrock, if encountered at depths shallower than 5 feet, or buried a minimum of 5 feet from the top of the pipe below the thalweg elevation where alluvium is encountered to depth. On high scour hazard streams, the pipeline burial depth will be 1-3 feet below the bedrock if encountered at depths shallower than the calculated scour depth, or buried a minimum of 1-3 feet below the calculated scour depth where alluvium is encountered to depth. On both low and high scour stream crossings, the pipeline burial depth will extend across the Channel Migration Zone ("CMZ").

2.0 WATERBODY CROSSING METHODS

This section describes PCGP's proposed waterbody crossing methods. The construction method proposed for each waterbody within the CZMA is listed in Table 1 in Appendix 1.

2.1 Non-Flowing Intermittent and Ephemeral Streams and Ditches

PCGP proposes to use different waterbody crossing methods, depending on site-specific conditions. Many of the waterbodies crossed by the Pipeline are minor intermittent or ephemeral streams or ditches that are expected to be dry or non-flowing at the time of construction. For all intermittent or ephemeral waterbodies without flow at the time of construction, PCGP will utilize standard upland, cross-country construction methods. At these crossings, the depth of cover will be 5 feet (from the top of pipe to the bottom of streambed). If any waterbody is flowing at the time of construction, a dry crossing technique will be used (i.e., flume or dam and pump).

2.2 Waterbodies and Flowing Streams

For perennial and other waterbodies that are flowing at the time of construction, PCGP has listed the crossing methods (and rationales) in Table 1 in Appendix 1. Descriptions of the proposed crossing methods are provided below. These construction methods follow the Federal Energy Regulatory Commission's ("FERC's") Wetland and Waterbody Procedures (available upon request) and are designed to maintain water flow, minimize changes in waterbody flow characteristics, and minimize the potential for turbidity and suspended sediment generated during the crossings. The dry open cut crossing methods isolate in-stream construction from the flowing stream. The trenchless crossing method (i.e., HDD) allow fish passage throughout the construction process. Both dry open cut crossing methods (flume and dam and pump) temporarily restrict fish passage during the construction process; however, the flume crossing method allows downstream fish passage if the temporary block nets are removed (once the flume has been successfully installed). The crossing method descriptions in Section 2.2.1 include the expected duration of temporary fish passage restrictions.

PCGP will utilize dry crossing methods for most (45 of the 58) of the waterbodies within the CZMA. Of the 45 dry open cut waterbodies, 21 are perennial and 24 are intermittent. Four waterbodies will be crossed by HDD (Coos Bay Estuary/West and East, Coos River, and an intermittent Trib. to Middle Creek). Nine waterbodies are within or adjacent to the construction right-of-way but would not be crossed by the pipeline (1 estuary, 3 perennial, 5 intermittent). Turbidity and sedimentation impacts associated with dry open cut crossing methods are minor, lasting typically for only a few hours, and are associated with 1) installation and removal of the upstream and downstream dams used to isolate the construction area for flume or dam and pump crossing methods; 2) movement of in-stream rocks and boulders to allow proper alignment and installation of the flume and dams; and 3) the time when streamflow is returned to the construction work area after the crossing is completed and the dams and flume are removed.

2.2.1 Dry Open Cut Crossing Methods

As indicated in Table 1 in Appendix 1, the "Dry Open Cut" crossing method is listed for numerous waterbody crossings within the CZMA, without specifying either flume or dam and pump. Both flume and dam and pump methods use temporary structures to divert water around or through the construction work area, so that installation of the pipeline across the waterbody occurs in an area isolated from stream flow, allowing a "dry" open cut crossing to minimize effects to water quality and to aquatic species. All dry open cut crossings would be completed within the ODFW-recommended in-water work periods to further minimize potential effects to aquatic species. PCGP would allow the contractor to select either crossing method, unless ODFW stipulates the crossing method for a specific waterbody.

2.2.1.1 Flume

The flume method typically is used to cross small to intermediate-sized flowing waterbodies that are either fish-bearing or non-fish-bearing to divert/isolate stream flow from the construction area so that the pipeline crossing can be constructed in the "dry." The flume technique involves diversion of stream flow into a carefully positioned steel pipe(s) of suitable diameter to convey the maximum flow of the stream across the work area that is expected to occur while the flume is in place; therefore, stream flow rate is not interrupted. All flumed crossings in the CZMA would occur within the ODFW-recommended, in-water work window, which is between July 1 and September 15[2] (see Table 1 in Appendix 1).

Prior to installing the flume pipe and initiating in-stream construction activities, temporary block nets will be installed, in the short-term, upstream and downstream of the pipeline crossing to comply with ODFW Fish Passage Criteria OAR 635-412-0035 10 (B) (d), which requires construction sites to be isolated from stream flow and fish. Once the block nets have been securely installed, fish and aquatic life will be safely collected, removed from the construction site between the upstream and downstream block nets, and placed in the flowing stream by an authorized person with a collection permit issued by ODFW, consistent with ODFW Fish Passage Criteria OAR 635-412-0035 10(B)(e). PCGP's Fish Salvage Plan is provided in Appendix 5.

PCGP's Environmental Inspectors ("EIs") will inspect the flume pipes before they are hauled to the construction right-of-way to ensure they are free of dirt, grease, oil, or other pollutants. Excessive dirt will be removed from the flume pipe and it will be steam-cleaned, if necessary, prior to transporting it to the construction right-of-way to remove oil or grease.

In-stream activities associated with flume installation are generally limited to:

- placement of sandbag diversion dams and flume pipe(s) to divert the flow into the flume pipe;
- placement of baffle structures to dissipate flow energy at the flume pipe outlet; and
- some in-stream movement of rocks and boulders for proper alignment of the flumes and dams.

Typically, three rows of sandbags are laid on the streambed to support the upstream and downstream ends of the flume pipe. Short-term, elevated levels of turbidity are expected to occur. Measures which minimize these increases, include: 1) all in-stream work will be carried out on foot and no equipment will operate in the streambed; 2) sandbags will be filled with a non-leachable material such as clean, pre-washed sand; 3) sandbags will be tied securely before they are installed; and 4) sheets of plastic will be interwoven between the layers of sandbags to ensure an effective seal.

The flume pipe will not be pushed or pulled over the banks and into the water. After the flume is laid on the sandbags, construction on the upstream dam will immediately begin, followed by installation of the downstream dam. During installation, the outfall of the flume would be set to ensure safe downstream migration of fish into the stream channel. Depending on the site, the distance between the dams is expected to be about 50-75 feet. The reason for damming the downstream end of the flume is to prevent downstream water from backflowing into the

[2] http://www.dfw.state.or.us/lands/inwater/Oregon_Guidelines_for_Timing_of_%20InWater_work2008.pdf.

streambed and flooding the crossing work area. A detailed description of fluming procedures is provided in Appendix 2.

After fish and aquatic life are salvaged between the block nets and the flume has been installed, the water between the flume dams will be pumped out, as will any seepage of water into the area between the dams as a result of sub-surface flow and/or some leakage around and under the dams. Water that is pumped out of the work area will be released to upland areas through a filtration structure such as a straw bale structure or sediment filter bag or to allow infiltration. The block nets will be removed once the flume has been successfully installed to allow downstream migration of fish during construction of the waterbody crossing, if recommended by ODFW; otherwise as indicated in Section 3.1 of the Fish Salvage Plan (see Appendix 5), the block nets will remain in place until the crossing has been completed and the flume pipe or dam-and-pump diversion is removed. PCGP anticipates that the block nets would generally be in place for approximately 3 to 4 days, but could potentially be in place for a week, at most, to allow fish salvage and installation of the flume. This duration estimate considers the multiple waterbodies that need to be crossed by the Pipeline within the ODFW-recommended in-water work window within the CZMA. The contractor will have a waterbody crossing crew(s) completing the waterbody crossings separate from mainline construction, which will require specialized/authorized personnel that are responsible for installing the block nets and salvaging fish at the crossings prior to the construction crew initiating construction. To efficiently maintain the construction schedule, the specialized fish salvage personnel will be simultaneously working at multiple sites along the alignment to ensure the construction contractor is not waiting for fish salvaging efforts to be completed when arriving to complete a crossing.

Following pipe installation and backfilling, which includes replacing appropriately sized washed spawning gravels in the streambed, the streambanks will be re-established to approximate pre-construction contours and stabilized. During construction, trench plugs/breakers will be installed on either side of the waterbody to prevent potential loss of surface water as the construction site is re-watered. Installation of trench plugs will be overseen by PCGP's inspector or authorized representative. The flume pipe will be removed immediately after the streambed and streambanks are reestablished and stabilized based on the Stream Crossing Risk Analysis (see Appendix 6), by slowly removing the downstream dam and then the upstream dam to re-water the work area in a manner to minimize turbidity. Erosion and sediment control measures will be installed across the construction right-of-way to reduce streambank and upland erosion and sediment transport into the waterbody, as indicated in the Erosion Control and Revegetation Plan (available upon request).

All erosion and sediment control measures in active construction areas will be inspected daily by PCGP's EIs. FERC will have designated third-party monitors to observe the installation and condition of erosion and sediment control measures and all BMPs during pipeline construction and work area reclamation to ensure compliance with FERC's Upland Plan and Wetland and Waterbody Procedures. BLM/Forest Service/Reclamation personnel and/or representatives will be allowed to visit and monitor any location of the PCGP Project on the public lands they respectively manage and to consult with PCGP's EIs. Personnel that handle and/or remove fish on federally-managed lands will be approved by the Forest Service or the BLM or Reclamation or be done directly by agency personnel if approved by ODFW.

The flume method has proven to be an effective technique for constructing a pipeline through a waterbody. Because the streamflow is carried across the construction work area through flume pipe(s), the sediments generated from trench excavation and backfilling operations are isolated within the construction work area between the upstream and downstream dams, and only limited amounts of suspended sediment or turbidity leave the work area. Typically, larger volumes of water can be carried through flume pipes than moved by pumps used in dam and pump crossings. For this reason, larger streams are generally crossed using the flume method. In addition, the flume method allows for continued fish passage downstream (and potentially upstream) through the construction work area during pipe installation.

Limitations of the Flume Crossing Method. The flume remains in place for the duration of installation so if the construction equipment excavating the trench or installing the pipe hits the flume pipe(s), a leak may occur between the flumes or in the dam, allowing additional water to bypass the dams. As a result, water leaking past the upstream dam can enter the disturbed construction work area and possibly transport sediment downstream of the crossing if the downstream dam cannot be adequately sealed or if dewater pumps are not sufficiently sized to pump out the water entering the work area. Furthermore, construction equipment (e.g., trackhoes) must reach under the flume(s) to excavate the trench to the appropriate depth. Use of numerous flume pipes on larger waterbodies required to carry higher flow volumes may prevent the equipment from fully excavating the trench. This limitation can restrict the size of stream which can be flumed. Additionally, depending on the Stream Crossing Risk Analysis management category of a crossing (see Table 1 in Appendix 1 and Appendix 6) and the restoration BMP that may need to be installed, the flume method could hinder installation of the restoration measures. Within the CZMA, in-stream blasting is not anticipated because of the soft, rippable substrates expected to be encountered (see Section 6.0). However, if hard bedrock is exposed or encountered in the streambed and blasting is required to achieve the design depth at the crossing, the flume may restrict blasting activities (dry open cut is the preferred crossing method where blasting is required).

Activities associated with the flume method that may produce sedimentation and turbidity include:

- installation and removal of the upstream and downstream dams;
- movement of in-stream rocks and boulders to allow proper alignment and installation of the flume and dams;
- water leaking through the upstream dam, flowing across the work area (picking up sediments), and leaking past the downstream dam; and/or
- a short pulse of sedimentation and turbidity when streamflow is returned to the construction work area after the crossing is complete and the dams and flume are removed.

Compared to the wet open cut crossing method (not proposed for the Pipeline project), the flume method requires additional time for installation of the flume and dams, construction of the crossing, and removal of in-stream fluming structures. Construction of a flume crossing typically requires 48 hours, but can take up to 7 days (4 days to install and remove the structures and 3 days to install the pipeline). This extended construction period increases the potential for higher stream flows to compromise the crossing, for the dams to develop significant leaks, or for the trench to collapse, requiring additional excavation.

2.2.1.2 Dam and Pump

The dam and pump method is an alternative to fluming and includes similar objectives. With the dam and pump method, stream flow is diverted by pumping water through hoses over or around the construction work area. The goal of this technique is to create a relatively “dry” work area to avoid or minimize the transportation of heavy sediment loads and turbidity downstream of the crossing. This crossing method may be used on all waterbodies where stream flow can feasibly be diverted by pumping around the work area. PCGP proposes to cross streams using this method within the ODFW-recommended in-water construction windows (July 1 to September 15 within the CZMA) to minimize potential impacts to aquatic species. Fish passage will be temporarily obstructed while the dams are in place.

The dam and pump method is the preferred where, according to the Stream Crossing Risk Analysis (see Appendix 6), BMPs are necessary for bed or bank restoration and the flume crossing method could hinder the installation of the BMPs because of the in-place flume pipe(s).

The dam and pump method involves installation of two in-stream dams with the intent of stopping the volume of water flowing through the crossing. In some instances, the terrain of the stream channel does not provide a positive seal and some water may seep into the area. One dam is placed upstream of the construction work area, while the other dam is installed downstream of the construction work area. Dams can be constructed of sandbags with a plastic liner, sheet piling, steel plates, jersey barriers with sandbags, aquadams, portadams, and a variety of other materials. Some in-stream movement of rocks and boulders may be necessary to enhance the seal at the dam. While the dams are being installed, appropriately sized pumps and hoses begin transporting upstream water around the construction area. Pump intakes are appropriately screened to prevent entrainment of aquatic species according to ODFW/NMFS criteria[3]. An energy-dissipation device is used to prevent scouring of the streambed at the discharge location.

As with the flume crossing method, prior to installing the dam and pump crossing and initiating in-stream construction activities, temporary block nets will be installed in the short-term upstream and downstream of the pipeline crossing to comply with ODFW Fish Passage Criteria ORS 635-412-0035 10(d), which requires construction sites to be isolated from stream flow and fish. Once the temporary block nets have been securely installed, fish and aquatic life will be safely collected, removed from the construction site between the upstream and downstream block nets, and released upstream of the upstream block net by an authorized person with a collection permit issued by ODFW, consistent with ODFW Fish Passage Criteria ORS 635-412-0035 10(e). Appendix 5 provides PCGP's Fish Salvage Plan.

The block nets will be removed immediately after the crossing is competed and the dams have been removed. PCGP anticipates that the block nets would be in place for approximately one week (at most) to allow for fish salvage, installation of the dam and pump crossing, construction across the waterbody streambed, and bank restoration. This estimate may be slightly extended if mechanical excavation is required to complete the crossing or restoration measures as outlined in the Stream Crossing Risk Analysis (see Appendix 6) are necessary. This duration estimate considers the multiple waterbodies within the CZMA that need to be crossed within the ODFW-recommended in-water work window. As described in the fluming section above, the contractor will have a waterbody crossing crew(s) completing the waterbody crossings separate from mainline construction, which will require specialized/authorized personnel that are responsible for installing the block nets and salvaging fish at the crossings prior to the construction crew initiating construction. To efficiently maintain the construction schedule, the specialized fish salvage personnel will be simultaneously working at multiple sites along the alignment to ensure the construction contractor is not waiting for fish salvaging efforts to be completed when arriving to complete a crossing.

After the dam and pump operation is set up to effectively bypass streamflow around the construction area, the area between the dams (work area) is dewatered to the extent possible. The trench is then excavated through the stream using trackhoes or draglines operating from the banks, from within the streambed, or on equipment bridges. Spoil removed from the trench

[3] National Marine Fisheries Service (NMFS). 2008. Anadromous Salmonid Passage Facility Design. NMF, Northwest Region, Portland, Oregon.

is generally placed in, or relayed to, an upland area adjacent to the stream crossing. In some cases, trench spoil is stored in the stream channel between the two dams.

Trench plugs are maintained between the upland trench and the waterbody crossing until the pipe is ready for installation. Once the trench is fully excavated, the pipeline is carried into place and the trench is backfilled. Restoration of the streambed to original contours and initial restoration and stabilization of streambanks is then completed. Once construction reaches this stage, the downstream dam is removed (by hand or with equipment), in a careful manner to re-water the work area to minimize turbidity, followed by removal of the upstream dam. After the dams have been removed, the pumping operation is halted, and the pumps are removed. A detailed description of dam and pump crossing procedures is provided in Appendix 2.

Limitations of the Dam and Pump Method. The dam and pump method is an effective method for reducing potential sediment and turbidity impacts associated with construction activities. Although it is not always possible to completely seal the upstream and downstream dams, substantially all streamflow is routed around the construction work area, effectively isolating sediments generated from construction to the area within the dams and significantly reducing the amount of sedimentation and turbidity leaving the construction work area.

Certain limitations are associated with dam and pump operations. These include limits on the volume of water that can be transported around the work area by the pumps; potential difficulties with isolating the streamflow; and potential difficulties with obtaining an effective seal on the upstream and downstream dams to reduce water moving across the work area.

Turbidity and sedimentation impacts associated with the dam and pump method are generally minor. Activities associated with the dam and pump method that may produce sedimentation and turbidity include:

- installation and removal of the upstream and downstream dams;
- if needed, excavation of a sump or basin to withdraw water upstream of the pipeline crossing;
- water leaking through the upstream dam, flowing across the work area (picking up sediments), and leaking past the downstream dam; and/or
- a short pulse of sedimentation and turbidity that occurs when streamflow is returned to the construction work area after the crossing is complete.

The dam and pump method limits movement of fish upstream and downstream through the construction work area during the crossing period.

2.2.2 Horizontal Directional Drilling

The HDD method involves drilling under a feature and pulling the pipeline into place through the drillhole that has been reamed to accommodate the diameter of the pipeline. This procedure involves three main phases, pilot hole drilling, subsequent reaming passes, and pipe pullback. HDD typically is used for the crossing of major waterbodies (greater than 100 feet wide). Within the CZMA, PCGP is proposing to use the HDD method for the crossings of the Coos Bay Estuary (Coos Bay West/MPs 0.28 to 1.00 and Coos Bay East/MPs 1.46 to 3.02), and the Coos River (MP 11.13R). A Trib. to Middle Creek (MP 25.18) will also be crossed by an HDD (the purpose of this HDD is topographical rather than specific to the waterbody – see Appendix 3).

The HDD crossing method requires no in-water work and fish passage is maintained throughout the HDD process. The ODFW in-stream construction window for the Coos Bay Estuary and Coos River mainstem is from October 1 to February 15. Because PCGP's Coos Bay West HDD footprint overlaps with the LNG Terminal facilities, the HDD needs to be completed prior to construction of the LNG Terminal to prevent construction conflicts and delays. Therefore, PCGP may complete the HDD outside the ODFW-recommended in-water work window. Due to the extensive wetland located on the east side of Coos Bay within Kentuck Slough, PCGP plans to schedule the Coos Bay East HDD outside the in-water work window to minimize surface impacts within the saturated floodplain wetland. Similarly, because of the extensive wetland location on the south side of the Coos River, PCGP has scheduled the HDD during the dry season, outside the in-water work window between August 1 and September 30, to minimize surface impacts within the saturated floodplain wetland. The HDD of the Coos River is expected to last up to 4 months.

Pilot Hole. The pilot hole establishes the ultimate position of the installed pipeline. For this operation, an initial hole is drilled from the entry point to the exit point on the opposite side of the crossing. The head of the pilot drill string contains a pivot joint to provide directional control of the drill string. By altering or steering the drill head, the operator can control the direction as the drill progresses. Thus, the pilot hole can be directed downward at an angle until the proper depth is achieved, then turned and directed horizontally for the required distance, and finally angled upward to the surface. Tracking and steering of the HDD drill head is generally guided using a two-wire system. The system consists of two insulated wires (approximately 0.25-inch in diameter) that are laid on the ground and are charged with an electrical current. A magnetometer accelerometer probe located behind the drill bit detects the electric current to triangulate the drill bit for steering.

As the pilot drill string is advanced, additional sections of drill pipe are added at the drill rig located at the entry point. High-pressure jetting of drilling fluid at the drill head and, in harder soil formations, rotation of the drill bit, facilitates advancement of the drill string. The drilling fluid (mud) is typically a non-toxic bentonite clay mixed with freshwater to make a slurry. Once the pilot hole exits in an acceptable location, the reaming operation is initiated.

Reaming. During the reaming phase, a reaming head is attached to the drill pipe and pulled back through the pilot hole to enlarge it. Several reaming passes may be made with incrementally larger reaming heads to enlarge the hole to approximately 1.5 times the diameter of the pipeline. Various reaming heads can be utilized, depending on the substrate encountered. High-pressure drilling fluid is jetted through the reaming head to float out drill cuttings and debris, to cool the drilling head, and to provide a cake wall to stabilize the hole. Once the drill hole is enlarged to the proper diameter, the pipe is pulled back through the reamed hole.

Pullback. The last step to complete a successful installation is the pullback of the pre-fabricated product pipe into the enlarged hole. The pullback process is the most critical step of the HDD process. A reinforced pullhead is welded to the leading end of the product pipe and to a swivel connected to the end of the drill pipe. The swivel is placed between the drill rig and the product pipe to reduce torsion and prevent rotation from being passed to the product pipe.

During pullback, the pre-tested carrier pipe pull section is supported with a combination of roller stands and/or product pipe handling equipment to direct the product pipe into the hole at the correct angle, reduce tension during pullback, and prevent the product pipe from being damaged. After the product pipe is in place, the installed crossing is pigged (optional), tie-in welds on each side of the crossing are completed, and the crossing is hydrostatically tested. The detailed Coos Bay West, Coos Bay East, and Coos River HDD Crossing Plans are provided in Appendix 3.

Limitations of the HDD Method. The HDD pipeline-design must consider hoop stresses, bending stresses, and tension stresses. The combination of these three stresses cannot exceed the yield strength of the pipe. The bending stresses approach their limit at approximately 1 inch of deflection for every 100 feet in length of pipe. The relative rigidity of the pipe requires long swooping angles to navigate large elevation changes. Therefore, the minimum length of an HDD is driven by the physical site conditions available at the specific crossing.

The HDD method is not always appropriate for installation of a large-diameter pipeline. The success of an HDD crossing can be limited by a combination of technical factors, including but not limited to: diameter of the pipe, length of the crossing, surrounding topography, aboveground structures, and geologic substrate at the drill location. Substrates lacking cohesion (i.e., lacking fines) or having significant quantities or venialities of coarse fragments (e.g., gravel, cobble, or boulders) may contribute to failure of the HDD effort. Gravel/cobble substrate often limits the potential for a successful drilling operation. Failure of the HDD method can result from the inability to keep the hole open or the inability to direct/steer the HDD (common in cobbly/gravelly substrates), or from the collapse of the hole around the pipeline during pullback. In such cases, the HDD method may be re-attempted along a different drill path or abandoned in favor of an alternate crossing method. The duration of a large diameter HDD generally takes several weeks or months to complete.

The HDD method has the potential for inadvertent releases of drilling mud into the waterbody. Drilling mud typically is comprised of bentonite clay and water, and can include additional additives specific to each drilling operation. PCGP will approve any additive compounds prior to use by the drilling contractor to ensure compliance with all applicable environmental and safety regulations. Toxic additives will not be used in the bentonite drilling mud. If a fault or crack in the overburden is encountered, the drilling mud can escape to the surface in an upland and/or waterbody/wetland area. This is referred to as an inadvertent release. Inadvertent releases range from minor releases, which are easily controlled and cleaned up, to major releases (hundreds of thousands of gallons). Major releases may be difficult to clean up and may significantly affect water quality in waterbodies and wetland or upland areas. However, the impacts associated with an inadvertent release of drilling mud would be limited because the probability of an inadvertent release is greatest when the drill bit is working near the surface (i.e., near the entry and exit points). At the proposed HDD sites where this could occur, PCGP has designed the HDDs so that areas at greatest risk to a potential inadvertent release are in upland areas away from the water's edge. Locating the HDD entry and exit points as far as practical away from the banks of the waterbody minimizes the potential for an inadvertent release into a waterbody.

HDDs associated with large diameter pipe have a minimum required length and radius angle which is based on several factors including design geometry, diameter of product pipe, minimum radius calculations, installation stresses, and operating stresses. Locating TEWAs large enough to accommodate the drilling activities may also increase the drill length. HDDs do not follow a straight line and there are no bore pits like a conventional bore. The pilot hole bit is capable of making gradual vertical turns as needed to traverse the crossing. The drill generally enters the ground at a 10 degree angle ($\pm$ 2 degrees) to the horizontal plane. After reaching the required depth, the drill makes an arc to approximately the horizontal plane and then generally follows that tangent through the crossing area. After passing through the crossing area, the drill then makes another arc upwards to the ground surface and exits, generally at a 10 degree angle ($\pm$ 2 degrees). An HDD drill path may have two vertical arcs, one on each side of the crossing, or, if the crossing is short, a single vertical arc at the center of the crossing. The arc (or curve) of the drill path cannot be too sharp because the carrier pipe section is limited by its ability to flex to follow the drill path when it is pulled into the reamed hole.

To insure that unacceptable geometrical deformation or mechanical stress on the pipe does not occur, engineering standards limit the amount of "deflection" to which the pipe can be subjected. Therefore, there is a minimum allowable "arc radius" for the drill path. The "minimum arc radius" is determined by the diameter of the pipe to be installed. The greater the pipe diameter, the greater the arc radius. Based on the design geometry and the diameter of the proposed 36" diameter product pipe, the minimum allowable three joint radius over any consecutive three joint sections should not be less than 2,600 feet. The design radius for the entry and exit curves would be 3,600 feet.

Topography plays a large role in the location of the entry and exit hole sites. A relatively flat area that is large enough for the rig and equipment is needed. TEWAs would be utilized to weld and test the pipe section for the crossing and should be straight and aligned with the drill path and slightly longer than the drill path. It is optimal for the entry and exit holes to be as close to the same elevation as possible. This allows better circulation and return of the drill mud and cuttings and mitigates the risk of drill failure. The rig and all the support equipment require a good access road with large turnouts. Water trucks and mud trucks run 24 hours per day during active drilling operations.

If an inadvertent return occurs, the HDD operation would be stopped temporarily to determine an appropriate response plan. PCGP would attempt to determine the cause of the hydraulic fracture and inadvertent return and would implement procedures, which may reduce the chance of recurrence. One possible corrective measure would be increasing the drilling fluid viscosity in an attempt at sealing the release point. Drilling mud primarily consists of water mixed with bentonite, which is a naturally occurring clay material. The only other possible additives would be nontoxic solid materials (e.g., sawdust, nut shells, bentonite pellets, or other commercially available nontoxic products) that could be needed to plug an inadvertent release. The drilling operation may be suspended for a short period (i.e., overnight) to allow the fractured zone to become sealed with the higher viscosity drilling fluid.

GeoEngineers Inc. has evaluated the feasibility of the HDD crossings of the Coos Bay Estuary (West and East) and the Coos River (see Appendix 3). Although GeoEngineers, Inc. (see Appendix 3) indicates that the HDDs of the Coos Bay Estuary (West and East) and the Coos River can be successfully implemented at the proposed crossing locations, in the event of an unsuccessful HDD, the HDD would be reattempted at the same location, or slightly offset. If a reattempted or offset HDD were not successful, PCGP would evaluate implementing a Direct Pipe ("DP") crossing at the same location. An overview of DP Technology is available upon request.

The proposed schedule for HDD crossings allows adequate time to apply for the required permits, if necessary, within the overall construction schedule in the event that an HDD crossing is unsuccessful.

2.3 Site-Specific Construction Plan

In addition to the general construction methods described above, FERC requires site-specific drawings for crossings of waterbodies that are greater than 100 feet in width. Based on FERC's guidelines and agency requests during interagency working group meetings conducted between 2007-2009, site-specific drawings and plans were developed for the East Fork and North Fork Coquille river crossings within the CZMA (see Appendix 4).

3.0 TEMPORARY CONSTRUCTION BRIDGES

If water is present in streambeds at the time of construction, PCGP will utilize temporary construction bridges during all phases of construction to cross the waterbodies to prevent sedimentation caused by construction traffic. In general, equipment/temporary bridges will not be installed on intermittent waterbodies which are dry at the time of construction; however, if a storm occurs which results in water in the streambed of the otherwise intermittent waterbody, no equipment will cross the waterbody until the streambed is dry or until a bridge is installed. PCGP will consult with the applicable land management agency (i.e., BLM, Forest Service, or Reclamation) on the type of temporary crossings. Although FERC's Wetland and Waterbody Procedures allow clearing equipment and equipment necessary for installation of the temporary bridges to cross waterbodies prior to bridge installation, PCGP will not allow clearing equipment to cross waterbodies prior to bridge placement. Furthermore, where feasible, PCGP's contractors will attempt to lift, span, and set the bridges from the streambanks. Where it is not feasible to install or safely set the temporary bridges from the streambanks, only the equipment necessary to install the bridge will cross the waterbody. Any equipment required to enter a waterbody to set a bridge will be inspected to ensure it is clean and free of dirt or hydrocarbons. Table 1 in Appendix 1 indicates the waterbodies where temporary bridge crossings within the construction right-of-way are proposed and if one pass of equipment is expected to be necessary to install the bridge.

Although the pipeline crossings are proposed to be constructed within ODFW-recommended, in-water construction windows, the temporary bridges will need to be installed outside the in-water construction windows to allow clearing and construction traffic to travel up and down the construction right-of-way. The temporary bridges will be designed according to FERC's Wetland and Waterbody Procedures as well as according to the USACE, Oregon Department of State Lands ("ODSL"), ODEQ, Forest Service, BLM, and ODFW approvals. If temporary bridges were not allowed to be installed outside of the ODFW-recommended, in-water construction windows, in many locations PCGP would be required to construct new roads to access the construction right-of-way on either side of stream crossings. Construction of roads for stream crossing access would result in significantly more disturbance than installing temporary bridges outside the in-water work window(s). The temporary bridges will be removed when construction and restoration are completed.

The temporary equipment bridges will be constructed to maintain unrestricted flow and to prevent soil from entering the waterbody. Soil will not be used to stabilize equipment bridges. Bridges will be designed and will be maintained to withstand and pass the highest flow expected to occur while the bridge is in place. The highest flow expected will be determined during the season of construction and will take into account an evaluation of regional climate and physical conditions as well as existing historic stream flow data and peak discharge statistics from nearby USGS gauging stations.

Where feasible, bridges will be designed to span the entire OHWM of the waterbody. ODFW recommends 3 feet of freeboard from the OHWM/Active channel to the bottom of the bridge. The majority of the proposed bridge crossings in Table 1 (see Appendix 1) are narrow crossings where the OHWM is expected to be easily spanned using temporary equipment mats which are typically 30 to 40 feet in length, or a railroad flat car that can be up to 89[4] feet in length. If the contractor determines it is not possible to safely span the OHWM with a bridge and determines a temporary mid-stream culvert or pier is required to support a bridge, these culverts/piers would be installed to minimize flow restrictions; to prevent streambank erosion or scour from deflected stream flow; and to maintain fish passage. If a mid-stream support is necessary, the contractor would design, permit, and receive ODFW fish passage approval prior to installing any mid-stream support culverts/piers. Drawing B8300.01-13A-00003, included in Appendix 4, provides typical design details for temporary bridges.

Temporary bridges will be set during clearing operations and during construction. The temporary bridges will not be left in place across a waterbody over the winter. Additionally, if there will be more than 1 month between final cleanup and the beginning of permanent seeding

[4] https://www.up.com/customers/all/equipment/descriptions/flatcars/index.htm.

and reasonable alternate access to the right-of-way is available, equipment bridges will be removed as soon as possible after final cleanup, as required by FERC's Wetland and Waterbody Procedures. Equipment bridges will be maintained throughout construction and cleaned as necessary to minimize potential sedimentation.

4.0 STREAMBANK PROTECTION

To minimize construction impacts associated with waterbody crossings, equipment bridges and mats will be used, as necessary, to provide stable work planes. TEWAs for spoil storage and pipe staging will be set back from the banks, as discussed below, and temporary sediment barriers will be installed around disturbed areas, where necessary, in accordance with FERC's Wetland and Waterbody Procedures. The Stream Crossing Risk Assessment (see Appendix 6) provides the proposed measures that will be used to stabilize and restore streambanks.

5.0 SEDIMENTATION CONTROL

PCGP will install temporary equipment bridges across perennial or intermittent waterbodies flowing at the time of construction to prevent sedimentation caused by construction and vehicular traffic (see Section 3.0).

Trench spoil excavated from within the waterbody will be placed at least 10 feet from the water's edge or in a TEWA. In some streams, native washed streambed boulders, cobbles, and gravels removed from the surface of the trench may be stored within the construction right-of-way in the streambed in areas isolated from stream flow (i.e., within the dammed area for flumes or dam and pump crossing). Storing this material in the streambed will minimize handling and help to ensure the material will be available for backfill and streambed restoration. Staging areas and additional spoil storage areas will be located at least 50 feet away from waterbody boundaries, where topographic conditions and other site-specific conditions allow. Where topographic conditions do not allow a 50-foot setback, spoil storage areas will be located at least 10 feet from the water's edge. Sediment control devices, such as silt fences and straw bales, will be placed around the spoil piles to prevent spoil flow back into the waterbody.

All erosion and sediment control measures will be inspected daily by PCGP's EIs in active construction areas. FERC will have designated third-party monitors observing the installation and condition of erosion and sediment control measures and all BMPs during pipeline construction and work area reclamation to ensure compliance with FERC's Upland Plan and Wetland and Waterbody Procedures. BLM/Forest Service/Reclamation personnel and/or representatives will be allowed to visit and monitor any location of the Pipeline project on the public lands they respectively manage and consult with PCGP's EIs.

6.0 BLASTING

Section 5.2 of the Geologic Hazards and Mineral Resources Report (available upon request) describes the locations where blasting may be required for construction in areas where hard, non-rippable bedrock occurs within the trench profile as well as proposed mitigation measures to minimize impacts. Within the CZMA, blasting is not anticipated because the bedrock that may be encountered within the design depth at the various waterbody crossings would be sedimentary strata that are expected to be soft, rippable material that can be excavated by mechanical or through hydraulic techniques such as hammering.

7.0 STREAM CROSSING RISK ANALYSIS

A Stream Crossing Risk Analysis and Addendum were completed (see Appendix 6) according to the protocol identified by ODEQ. PCGP confirmed the approach through progress meetings with ODEQ, USACE, and FWS representatives. Table 1 in Appendix 1 includes the risk analysis management category (Blue, Yellow, Orange) for each stream crossing ranked within the CZMA. Pipeline construction and/or restoration measures commensurate with the results of the risk assessment have been developed and are described in the report and addendum and include approaches that range from typical construction methods to site-specific design. The risk analysis provides information on stream channel characteristics to assist PCGP in identifying stream crossings that require atypical approaches to waterbody crossing and site restoration. Appendix B to the risk assessment addendum provides BMP recommendations for Yellow management category streams and includes typical design drawing BMPs for bed restoration and bank restoration. All BMPs are designed to meet ODFW Fish Passage requirements. Appendix C to the risk analysis addendum includes site-specific restoration plans for 4 crossings within the CZMA (i.e., Middle Creek/MP 27.04; Elk Creek/MP 32.40; Trib to Big Creek/MP 37.35; and Upper Rock Creek/MP 44.21). The risk analysis addendum also provides the long-term monitoring plan (10 years) for the stream crossings, which was developed following consultation with representatives from FWS and NMFS. The long-term monitoring will ensure success of the restoration, maintenance of fish passage, and identify channel erosion, scour or migration that could destabilize the site or expose the pipeline.

8.0 CHANNEL MIGRATION AND SCOUR

The principal hazard resulting from channel migration and streambed scour is exposure of the pipeline within the channel from streambed and bank erosion or within the floodplain from channel migration and/or avulsion. To address this potential hazard, PCGP completed a channel migration and scour analysis (see Appendix 7), which evaluated stream crossings with respect to channel bed scour and/or lateral migration. The evaluation was conducted in two phases: Phase I involved a desk top evaluation and small field investigation in which all stream crossings were ranked for potential risk; and Phase II involved detailed field investigations and analyses of those stream crossings that were concluded to pose risk to the pipeline based on the Phase I study. Table 1 in Appendix 1 includes the scour rating for each waterbody within the CZMA.

To minimize the effects of migration and scour hazards to the pipeline, at a minimum, PCGP will design all waterbody crossings to meet DOT CFR 49 Part 192 standards. PCGP may also implement one or more of the following measures provided in GeoEngineer's (2018) Channel Migration and Scour Analysis (see Appendix 7):

1. At each channel crossing, bury the pipe below the estimated 100-year depth of streambed scour. Where bedrock is encountered at shallower depths than the estimated 100-year scour depth, the elevation of competent bedrock represents the limit of scour.
2. Where feasible, place the pipe into bedrock.
3. Within floodplains adjacent to migrating channels, bury the pipe below the projected 100-year scour depth of the channel thalweg within the 50-year channel migration zone ("CMZ").

PCGP will design all pipeline crossings within the 50-year CMZ based on the results of the Channel Migration and Scour Analysis (see Appendix 7). As noted in the analysis, the potential CMZ over a 100-year time span was not considered because: (1) predicting channel migration behavior over 100 years is considered unreliable; and (2) the design life of the Pipeline project is 50 years. Figure 1 in Appendix 7 depicts the proposed pipeline burial depth for low and high scour potential streams within the CMZ.

Appendix 1
Tables

Table 1 Fish Utilization Table - CZMA
Table 2 Landowner – Location Table – CZMA

Table 1
Fish Utilization, EFH in, and Crossing Techniques and In-Water Work Windows for Waterbodies Crossed by the Proposed Route (revised April 2018 and February 2019)

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Coast Range Ecoregion, Coos Sub-basin (HUC 17100304), Coos Bay-Frontal Pacific Ocean (HUC 1710030403) Fifth field Watershed [8], Coos County, Oregon												
Estuary Drain (Alt Wet NH (West))	17100304006491 State	0.00	Estuarine Major Pullback TEWA Adjacent to Pipeline	Risk Mgmt.: N/A Scour Rating: Level N/A	The Estuary Drain is not crossed by the centerline. TEWA 0.10, which crosses the drain, is required for the HDD of Coos Bay to fabricate the HDD pipe string and to facilitate the HDD pullback operations. The Estuary Drain will be bridged to minimize disturbance	• Southern DPS Green Sturgeon, T, CH • Oregon Coast ESU Coho, migration, rearing habitat T, CH	Fall Chinook, Coho, Winter Steelhead, Pacific Lamprey	Various Marine Fish and Shellfish	4 Coastal Pelagic spp., 21 Groundfish spp, 2 Salmonid spp. Pelagic, Groundfish, and Salmonids (see Table 3B- 6)	Coastal Pelagic spp., Groundfish spp, Salmonid spp. Fall Chinook/ Coho Rearing, Migration	Oct 1 to Feb 15 [10a]	Y
Coos Bay (NE-26) WB-T02-001	17100304006491 State	0.28 to 1.00	Estuarine Major HDD	Risk Mgmt.: N/A Scour Rating: Level N/A	HDD feasibility based on geometry, topography, and expected geotechnical conditions along proposed alignment. Primary HDD activities are significantly set back from crossing. The HDD crossing method will not encumber the Federal Navigation crossed along the HDD alignment. The HDD avoids in-water open cut crossing methods. Other trenchless crossing methods (conventional bore and Direct Pipe®) are not feasible based on crossing length.	• Southern DPS Green Sturgeon, T, CH • Oregon Coast ESU Coho, migration, rearing habitat T, CH	Fall Chinook, Coho, Winter Steelhead, Pacific Lamprey	Various Marine Fish and Shellfish	4 Coastal Pelagic spp., 21 Groundfish spp, 2 Salmonid spp. Pelagic, Groundfish, and Salmonids (see Table 3B- 6)	Coastal Pelagic spp., Groundfish spp, Salmonid spp. Fall Chinook/ Coho Rearing, Migration	Oct 1 to Feb 15 [10a]	N

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Coos Bay (NE-26) WB-T02-002 W-T02-001D	171003040064961 State	1.46 to 3.02	Estuarine Major HDD	Risk Mgmt.: N/A Scour Rating: Level N/A	HDD feasibility based on geometry, topography, and expected geotechnical conditions along proposed alignment. Primary HDD activities are significantly set back from crossing. The HDD crossing method will not encumber the Federal Navigation crossed along the HDD alignment. The HDD avoids in-water open cut crossing methods. Other trenchless crossing methods (conventional bore and Direct Pipe®) are not feasible based on crossing length.	• Southern DPS Green Sturgeon, T, CH • Oregon Coast ESU Coho, migration, rearing habitat T, CH	Fall Chinook, Coho, Winter Steelhead, Pacific Lamprey	Various Marine Fish and Shellfish	4 Coastal Pelagic spp., 21 Groundfish spp, 2 Salmonid spp. Pelagic, Groundfish, and Salmonids (see Table 3B- 6)	Coastal Pelagic spp., Groundfish spp, Salmonid spp. Fall Chinook/ Coho Rearing, Migration	Oct 1 to Feb 15 [10b]	N
Trib to Coos Bay (S1-01/EE-6)	17100304000767 Private	6.39R	Perennial Minor Dry Open-Cut	Risk Mgmt.: Blue Scour Rating: Level 0	Dry open-cut method feasible/practical on small channelized tributary within golf coarse lacking effect riparian vegetation.	• Oregon Coast ESU Coho, assumed habitat T	Coho Assumed, Winter Steelhead	Assumed	Coho Assumed	Unknown	Jul 1 to Sep 15	Y*
Willanch Slough (EE-7) S1-04 (EE-7 MOD))	17100304001393 Private	8.27R	Perennial Intermediate Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut method feasible/practical on small tributary within pasture/hayfield lacking effect riparian vegetation.	• Oregon Coast ESU Coho, migration, rearing habitat T, CH	Coho, Winter Steelhead	Assumed	Coho	Coho Rearing, Migration	Jul 1 to Sep 15	Y*
Johnston Creek Willanch Creek S1-05 (GDX-29 / EE-8 (MOD))	17100304000413 17100304000409 Private	8.35R	Perennial Adjacent riparian zone	Risk Mgmt.: N/A Scour Rating: Level N/A	Adjacent riparian zone overlaps construction right-of-way	• Oregon Coast ESU Coho, spawning habitat T, CH	Coho, Winter Steelhead	Assumed	Coho	Coho Rearing, Migration	Jul 1 to Sep 15	
Trib. to Willanch Slough S-T0-1-003(GDX030)	Private	8.46R	Intermittent Intermediate Dry Open-Cut	Risk Mgmt.: Blue Scour Rating: Level 0	Dry open-cut method feasible/practical on small intermittent channelized tributary on edge of pasture.	None	Unknown	Unknown	None	None	Jul 1 to Sep 15	Y*
Trib. to Cooston Channel (Echo Creek) S-T01-003 (SS-100-002)	17100304005045 Private	10.21R	Intermittent Intermediate Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut method feasible/practical on small headwater tributary, if flowing at the time of construction.	• Oregon Coast ESU Coho, spawning habitat T	Winter Steelhead Coho	Assumed	Coho	Coho Spawning, Rearing	Jul 1 to Sep 15	Y*

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	**Equipment Bridges** Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Coos River (BSP-119)	17100304005030 Private	11.13R	Estuarine Major HDD [10]	Risk Mgmt.: N/A Scour Rating: Level 1 [11]	HDD feasible based on geometry, topography, and geotechnical conditions along proposed alignment. Primary HDD activities are significantly set back from crossing. Conventional bore not feasible/practical because of crossing length and high groundwater areas on either side of river. Dry open-cut or diverted open-cut methods not practical/feasible based on flow volumes and tidal influence.	• Southern DPS Green Sturgeon, T, CH • Oregon Coast ESU Coho, migration, rearing habitat T, CH	Fall Chinook, Coho, Winter Steelhead, Green Sturgeon, Pacific Lamprey	Various Marine Fish and Shellfish	Chinook, Coho Pelagic, Groundfish, (see Table 3B- 5)	Fall Chinook/ Coho (Rearing, Migration)	Oct 1 to Feb 15 [10c]	N
Vogel Creek (SS-100-005)	17100304005031 Private	11.55BR	Perennial Minor Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut methods feasible/practical during low flow period within fish window. A conventional bore crossing is problematic because of expected high groundwater levels within the Coos River floodplain that would be encountered within the bore pit at design depths.	• Oregon Coast ESU Coho, spawning habitat T, CH	Coho, Winter Steelhead	Assumed	Coho	Coho Rearing, Migration	Jul 1 to Sep 15	Y*
Ditch Trib. to Vogel Creek (BR-S-04)	17100304000790 Private	11.88BR	Intermittent Intermediate Dry Open-Cut	Risk Mgmt.: N/A Scour Rating: Level N/A	Dry open-cut methods feasible/practical on small intermittent ditched tributary if flowing at the time of construction.	None	None	None	None	None	Jul 1 to Sep 15	Y*
Ditch Trib. to Vogel Creek (BR-S-06)	17100304000798 Private	12.11BR	Intermittent Minor Dry Open-Cut	Risk Mgmt.: N/A Scour Rating: Level N/A	Dry open-cut methods feasible/practical on small 2' wide intermittent ditched tributary if flowing at the time of construction.	None	None	Assumed	None	None	Jul 1 to Sep 15	Y*

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. to Stock Slough (BR-S-31)	17100304002068 Private	14.72BR	Intermittent Minor Dry Open-Cut	Risk Mgmt.: N/A Scour Rating: Level N/A	Dry open-cut methods feasible/practical on small non-fish intermittent ditched tributary if flowing at the time of construction.	None	None	None	None	None	Jul 1 to Sep 15	Y*
Trib. to Stock Slough (Laxstrom Gulch) (BR-S-30)	17100304000493 Private	14.82BR	Intermittent Adjacent riparian zone	Risk Mgmt.: N/A Scour Rating: Level N/A	Adjacent riparian zone overlaps construction right-of-way	• Oregon Coast ESU Coho, spawning habitat T, CH	Coho, Winter Steelhead,	Assumed	Coho	Coho Spawning, Rearing	Jul 1 to Sep 15	
Stock Slough (BR-S-36)	17100304000507 Private	15.11BR	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut methods feasible/practical on creek during low flow period within fish window. A conventional bore crossing is problematic because of expected high groundwater levels within the Stock Slough floodplain and Laxstrom Gluch that would be encountered within the bore pit at design depths.	• Oregon Coast ESU Coho, spawning habitat T, CH	Coho, Winter Steelhead,	Assumed	Coho	Coho Spawning, Rearing	Jul 1 to Sep 15	Y*
Trib. To Stock Slough (Laxstrom Gulch)	17100304000493 Private	15.16BR	Intermittent Minor Adjacent to centerline; crossed by PAR 15.07	Risk Mgmt.: N/A Scour Rating: Level N/A	PAR 15.07 uses an existing road with a culverted crossing that does not need to be improved for project use - no impacts	• Oregon Coast ESU Coho, spawning habitat T	Coho, Winter Steelhead	Assumed	Coho	Coho Spawning, Rearing	Jul 1 to Sep 15	N
Stock Slough (EE-SS-9068)	17100304000507 Private	15.32BR	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut methods feasible/practical on small waterbody during low flow period within fish window and if flowing at the time of construction. A conventional bore crossing is problematic because of expected high groundwater levels within the Stock Slough floodplain that would be encountered within the bore pit at design depths. A bore crossing is not feasible because of topographic constraints on west side of creek because of grading/excavation requirements for a bore pit.	• Oregon Coast ESU Coho, spawning habitat T, CH	Coho, Winter Steelhead,	Assumed	Coho	Coho Spawning, Rearing	Jul 1 to Sep 15	Y*

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Coast Range Ecoregion, Coquille Sub-basin (HUC 17100305), North Fork Coquille River (HUC 1710030504) Fifth field Watershed [8] Coos County, Oregon												
Steinnon Creek (SS-500-003; BR-S-63)	17100305000361 BLM	20.20BR	Perennial Minor Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut methods feasible/practical on small non-fish tributary. Steep topographic conditions prevent a conventional bore because of bore pit grading/excavation requirements on both sides of the crossing.	None	Unknown	Assumed	None	None	Jul 1 to Sep 15	Y
Steinnon Creek (BR-S-63)	171003050000361 BLM	24.32BR	Perennial Intermediate Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut methods feasible/practical during low flows periods within ODFW in- water work window. Right-of- way has been necked down to 75 feet and TEWAs located in cleared areas to minimize riparian disturbance. A conventional bore (geotechnical conditions unknown) would require additional riparian impacts because TEWAs to accommodate the bore pits would be required closer to the waterbody in forested riparian areas.	• Oregon Coast ESU Coho, spawning, rearing habitat T, CH	Fall Chinook, Coho, Winter Steelhead, Pacific Lamprey	Assumed	Chinook, Coho	Fall Chinook, Coho Rearing, Migration	Jul 1 to Sep 15	Y-1i
Ditch (DA-10X)	17100305012102 Private	22.72	Intermittent Minor Dry Open-Cut	Risk Mgmt.: N/A Scour Rating: Level 0	Dry-open cut methods feasible/practical on small field drainage ditch if flowing during construction.	None	Unknown	Assumed	None	None	Jul 1 to Sep 15	Y*
North Fork Coquille River (BSP-207)	17100305000339 Private	23.06	Perennial Intermediate Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 1 [11]	Dry open-cut method feasible/practical on 20' wide river during low flow period within fish window. Impacts to riparian vegetation minimized by placement/setbacks of TEWAs on west side of river in field and eastside setback 100 feet from waterbody. Right-of-way also necked down to 75 feet. Topographic conditions on east side of the crossing prevent HDD crossing methods because of elevation differences between entry/exit and necessary workspace grading requirements.	• Oregon Coast ESU Coho, spawning, rearing, migration habitat T, CH	Spring Chinook, Fall Chinook, Coho, Winter Steelhead, Pacific Lamprey	Cutthroat Trout, Assumed	Chinook, Coho	Spring and Fall Chinook, Coho Rearing, Migration	Jul 1 to Sep 15	Y-1i

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	**Equipment Bridges** Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. to Middle Creek S-T02-001 (EE-SS-9073)	17100305012832 Private	25.18	Intermittent Minor HDD	Risk Mgmt.: N/A Scour Rating: Level 0	An HDD was incorporated to avoid the steep narrow powerline in this area; therefore the small intermittent headwater, non- fish-bearing tributary will be crossed using the HDD method.	None	None	None	None	None	Jul 1 to Sep 15	Y*
Trib. to Middle Creek (BSI-137)	BLM- Coos Bay District	27.01	Intermittent Intermediate Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0	Intermittent tributary to be crossed at the same time as the crossing of Middle Creek at MP 27.04 using dry open-cut. Tributary expected to be dry at the time of construction.	None	Unknown	Unknown	None	None	Jul 1 to Sep 15	Y*
Trib. to Middle Creek (BSI-135)	BLM- Coos Bay District	27.03	Intermittent Minor Adjacent to centerline	Risk Mgmt.: N/A Scour Rating: Level N/A	Intermittent tributary not crossed by centerline.	None	Unknown	Unknown	None	None	Jul 1 to Sep 15	N
Middle Creek (BSP-133)	17100305000323 BLM- Coos Bay District	27.04	Perennial Intermediate Dry Open-Cut	Risk Mgmt.: Orange Scour Rating: Level 2 [11] (10.5 ft.)	Dry open-cut methods feasible/practical on creek during low flow period within fish window. A conventional bore crossing is not feasible because of topographic constraints on west side of creek because of grading/excavation requirements for bore pit. An HDD is not feasible because of topographic/geometry conditions.	• Oregon Coast ESU Coho, rearing, migration habitat T, CH	Fall Chinook, Coho, Winter Steelhead, Pacific Lamprey	Cutthroat Trout	Chinook, Coho	Fall Chinook, Coho Rearing, Migration	Jul 1 to Sep 15	Y-1i

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	**Equipment Bridges** Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Coast Range Ecoregion, Coquille Sub-basin (HUC 17100305), East Fork Coquille River (HUC 1710030503) Fifth field Watershed [8], Coos County, Oregon												
Trib. To E. Fork Coquille (BSP-77)	7100305002504 Private	28.86	Perennial Intermediate Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 1 (Streambed-bedrock) [12]	Dry open-cut methods feasible/practical on small incised headwater trib. Dam and pump crossing method most logical dry open-cut method based on topographic conditions to eliminate difficulties of threading pipe string under flume with associated safety risks including upsetting flume during process. Steep topographic conditions prevent a conventional bore because of bore pit grading/excavation requirements on both sides of the crossing.	• Oregon Coast ESU Coho, assumed habitat T	Assumed	Cutthroat Trout	Coho Assumed	Unknown	Jul 1 to Sep 15	Y
Trib. To E. Fork Coquille (BSP-74)	17100305002598 Private	29.30	Intermittent Intermediate Dry Open-Cut	Risk Mgmt. Yellow: Scour Rating: Level 0	Dry open-cut methods feasible/practical on small tributary. Steep topographic conditions prevent a conventional bore because of bore pit grading/excavation requirements on west side of the crossing.	• Oregon Coast ESU Coho, assumed habitat T	Assumed	Present	Coho Assumed	Unknown	Jul 1 to Sep 15	Y*
Trib. To E. Fork Coquille (BSI-76)	17100305002647 Private	29.47	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0 (Streambed-bedrock) [12]	Dry open-cut methods feasible/practical on small 3-4' intermittent tributary if flowing at the time of construction.	• Oregon Coast ESU Coho, assumed habitat T	Assumed	Unknown	Coho Assumed	Unknown	Jul 1 to Sep 15	Y*

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
East Fork Coquille River (BSP-71)	17100305000286 Private	29.85	Perennial Intermediate Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 1 [11]	Project alignment was selected based on landowner negotiations and requirement to avoid landowner's air strip. Dry open-cut methods feasible/practical during low flow crossing period during ODFW in-water work window. Conventional bore is not practical because of significant grading/excavation requirements for bore pits. The river is deeply incised below stream banks requiring extensive pits for installation below streambed. Continued bore pit dewatering would be required to keep bore pits dry. A temporary bridge is also necessary to prevent entire spread move around. A crossing bridge will require bank grading for crossing access. An HDD is probable at the approximate crossing location based on the topography, geometry and expected geotechnical conditions. Significant HDD costs, HDD time requirements and the need for a crossing bridge were the determinants for the proposed dry-open cut crossing method.	• Oregon Coast ESU Coho, spawning, rearing, migration habitat T, CH	Spring Chinook, Fall Chinook, Coho, Winter Steelhead, Pacific Lamprey	Cutthroat Trout	Chinook, Coho	Spring Chinook Rearing, Migration Fall Chinook Spawning, Rearing, Coho Rearing, Migration	Jul 1 to Sep 15	Y-1i
Trib. to E. Fork Coquille (SS-003-007A)	17100305002813 Private	30.22	Perennial Minor Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut methods feasible/practical on small intermittent tributary if flowing at the time of construction	None	Unknown	Unknown	None	None	Jul 1 to Sep 15	Y*
Trib. to E. Fork Coquille (SS-003-007B)	17100305002813 Private	30.29	Perennial Minor Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut methods feasible/practical on small intermittent tributary if flowing at the time of construction.	• Oregon Coast ESU Coho, assumed habitat T	Assumed	Assumed	Coho Assumed	Unknown	Jul 1 to Sep 15	Y*

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. To E. Fork Coquille (BSI-70)	17100305018097 BLM- Coos Bay District	31.64	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0	Small 1-wide intermittent headwater tributary, dry open- cut methods feasible/practical, if flowing at time of construction.	None	Unknown	Unknown	None	None	Jul 1 to Sep 15	Y*
Elk Creek (BSP-57)	1240218431116 Private	32.40	Perennial Minor Dry Open-Cut	Risk Mgmt.: Orange Scour Rating: Level 1 [11]	Dry open-cut methods feasible/practical on small 8' wide tributary. Steep topographic conditions on north side of stream prevent a conventional bore because of grading/excavation requirements for bore pit. StreamNet data indicates anadromy below crossing (~ 1 mile). Waterbody is within the ¼ mile buffer of MAMU-occupied stand (C3098). Conflicts with ODFW recommended in-water work periods are not expected based on proposed two-year construction schedule. However, proposed Year Two daily timing restrictions during construction to minimize impacts to MAMU should be waived during the stream crossing installation to minimize the duration of instream work and installation of flumes or dams/pumps.	• Oregon Coast ESU Coho, assumed habitat T	Assumed	Cutthroat Trout, Assumed	Coho Assumed	Unknown	Jul 1 to Sep 15	Y

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	**Equipment Bridges** Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. To Elk Creek S-T01-008 (BSP-55)	1239513431370 Private	32.44	Perennial Minor Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0 (Streambed-bedrock) [12]	Dry open-cut methods feasible/practical on small 3-4' wide tributary. Waterbody is within the ¼ mile buffer of MAMU-occupied stand (C3098). Conflicts with ODFW-recommended in-water work periods are not expected based on proposed two-year construction schedule. However, proposed Year Two daily timing restrictions during construction to minimize impacts to MAMU should be waived during the stream crossing installation to minimize the duration of instream work and installation of flumes or dams/pumps.	• Oregon Coast ESU Coho, assumed habitat T	Assumed	Assumed	Coho Assumed	Unknown	Jul 1 to Sep 15	Y
Trib. To Elk Creek S-T01-004 (SS-100-030)	7100305021871 Private	32.56	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0	Dry open-cut methods feasible/practical on small/non-fish-bearing intermittent headwater tributary if flowing at time of construction. Topographic conditions on both sides of stream limit a conventional bore because of grading/excavation requirements for bore pits.	None	Nonen	None	None	None	Jul 1 to Sep 15	Y*
Trib. To Elk Creek (BSP-49)	17100305003372 Private	33.00	Perennial Minor Dry Open-Cut	Risk Mgmt.: Yellow* Scour Rating: Level 0	Dry open-cut methods feasible/practical on small 10' wide tributary. Topographic conditions on both sides of stream limit a conventional bore because of grading/excavation requirements for bore pits.	None	None	None	None	None	Jul 1 to Sep 15	Y

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. To Elk Creek (BSP-50)	17100305003372 Private	33.02	Perennial Minor Adjacent to centerline	Risk Mgmt.: Blue* Scour Rating: Level 0 (Streambed-bedrock) [12]	Not crossed by pipeline centerline. Small 2' wide headwater tributary expected to be dry during construction. Trib. would be crossed at the same time as BSP049 at MP 32.99.	None	None	None	None	None	Jul 1 to Sep 15	Y*
South Fork Elk Creek (CSP-5)	17100305000591 Private	34.46	Perennial Intermediate Dry Open-Cut	Risk Mgmt.: Blue Scour Rating: Level 2[11] (Streambed-bedrock) [12] (6.0 ft.)	Dry open-cut methods feasible/practical on stream. Steep topographic conditions on both sides of stream prevent conventional bore crossing methods because of grading/excavation requirements for bore pits.	• Oregon Coast ESU Coho, spawning, rearing habitat T, CH	Coho, Winter Steelhead	Cutthroat Trout	Coho	Coho Spawning, Rearing	Jul 1 to Sep 15	Y
Trib. To S. Fork Elk Creek (BSI-251)	17100305021783 BLM-Coos Bay District	35.51	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0	Dry open-cut methods feasible/practical on small 4' wide intermittent headwater tributary, if flowing at time of construction. Crossing will occur adjacent to road where existing culvert is in place. This waterbody is located within an occupied MAMU- stand (C3093). Conflicts with ODFW-recommended in-water work periods are not expected based on the proposed two- year construction schedule. However, the proposed Year Two daily timing restrictions during construction to minimize impacts to MAMU should be waived during the stream crossing installation to minimize the duration of instream work and the installation of flumes or dams/pumps.	None	None	None	None	None	Jul 1 to Sep 15	N (In existing road)
Coast Range Ecoregion, Coquille Sub-basin (HUC 17100305), Middle Fork Coquille River (HUC 1710030501) Fifth field Watershed [8], Coos County, Oregon												

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	<u>Equipment Bridges</u> Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. to Big Creek (BLM 35.87 (CSP-2))	17100305025781 BLM-Coos Bay District	35.87	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0	Dry open-cut methods feasible/practical on small intermittent headwater tributary, if flowing at time of construction. Crossing occurs within Elk Creek Road (BLM 28-11-29-0) and flows through a 12" culvert which will be replaced. Waterbody is within the ¼ mile buffer of MAMU-occupied stand (C3093). Conflicts with ODFW-recommended in-water work periods are not expected based on proposed two year construction schedule. However, proposed Year Two daily timing restrictions during construction to minimize impacts to MAMU should be waived during the stream crossing installation to minimize the duration of instream work and to allow the removal of road culvert, installation of flumes or dams/pumps, and replacement of the road culvert	None	None	Unknown	None	None	Jul 1 to Sep 15	Y*
Trib. To Big Creek (BLM 36.48)	17100305026477 BLM-Coos Bay District	36.48	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0	Dry open-cut methods feasible/practical on small intermittent headwater tributary, if flowing at time of construction. This waterbody is located adjacent to an occupied MAMU-stand (C3073). Conflicts with ODFW-recommended in-water work periods are not expected based on the proposed two-year construction schedule. However, the proposed Year Two daily timing restrictions during construction to minimize impacts to MAMU should be waived during the stream crossing to facilitate the crossing and allow the installation/removal of flumes or dams/pumps and to minimize the duration of instream work.	None	None	Unknown	None	None	Jul 1 to Sep 15	Y*

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. To Big Creek (GSI-25/BSI-253)	17100305004068 BLM-Coos Bay District	36.54	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0	Dry open-cut methods feasible/practical on small 4' wide intermittent headwater tributary, if flowing at time of construction. No additional workspace required. ODFW fish passage barrier data reports a downstream boulder canyon with a 10-foot falls at upper end (RecordID 52488). StreamNet data indicates anadromy below crossing (~ 0.5 mile) at ODFW barrier 52488. This waterbody is located within an occupied MAMU- stand (C3073). Conflicts with ODFW-recommended in-water work periods are not expected based on the proposed two- year construction schedule. However, the proposed Year Two daily timing restrictions during construction to minimize impacts to MAMU should be waived during the stream crossing installation to minimize the duration of instream work and the installation of flumes or dams/pumps.	None	None	Unknown	None	None	Jul 1 to Sep 15	Y*

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. To Big Creek (BLM 36.85)	17100305025748 BLM-Coos Bay District	36.85	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0	Dry open-cut methods feasible/practical on small intermittent headwater tributary, if flowing at time of construction. Crossing occurs within Elk Creek Road (BLM 28-11-29-0) and flows through a 12-18" culvert which will be replaced. This waterbody is located within an occupied MAMU- stand (C3073). Conflicts with ODFW-recommended in-water work periods are not expected based on the proposed two- year construction schedule. However, the proposed Year Two daily timing restrictions during construction to minimize impacts to MAMU should be waived during the stream crossing to facilitate the crossing and allow the installation/removal of flumes or dams/pumps and to minimize the duration of instream work.	None	None	Unknown	None	None	Jul 1 to Sep 15	Y*

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. To Big Creek (BSI-252)	17100305004061 BLM-Coos Bay District	36.92	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0	Dry open-cut methods feasible/practical on small 3' wide intermittent headwater tributary, if flowing at time of construction. No additional workspace required. Alignment and trib. crossing along existing road. ODFW fish passage barrier data reports a downstream boulder canyon with a 10 foot falls at upper end (RecordID 52488). StreamNet data indicates anadromy below crossing (~ 1 mile) at ODFW barrier 52488. This waterbody is located within an occupied MAMU- stand (C3073). Conflicts with ODFW-recommended in-water work periods are not expected based on the proposed two- year construction schedule. However, the proposed Year Two daily timing restrictions during construction to minimize impacts to MAMU should be waived during the stream crossing installation to minimize the duration of instream work and the installation of flumes or dams/pumps.	None	None	Unknown	None	None	Jul 1 to Sep 15	N (In existing road)

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. To Big Creek (ESI-19)	17100305026126 BLM-Coos Bay District	37.32	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut methods feasible/practical on small 3' wide intermittent headwater tributary, if flowing at time of construction. No additional workspace required. ODFW fish passage barrier data reports a downstream boulder canyon with a 10 foot falls at upper end (RecordID 52488). StreamNet data indicates anadromy below crossing (~ 1 mile) at ODFW barrier 52488. StreamNet data indicates anadromy below crossing (~ 1 mile) at ODFW barrier 52488. This waterbody is located within an occupied MAMU- stand (C3090). Conflicts with ODFW-recommended in-water work periods are not expected based on the proposed two- year construction schedule. However, the proposed Year Two daily timing restrictions during construction to minimize impacts to MAMU should be waived during the stream crossing installation to minimize the duration of instream work and the installation of flumes or dams/pumps.	None	None	Unknown	None	None	Jul 1 to Sep 15	Y*

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. To Big Creek (ESP-20)	17100305000606 BLM-Coos Bay District	37.35	Perennial Intermediate Dry Open-Cut	Risk Mgmt.: Orange Scour Rating: Level 1 [11]	Dry open-cut methods feasible/practical on stream. Dam and pump crossing method most logical dry open- cut method based on topographic conditions to eliminate difficulties of threading pipe string under flume with associated safety risks including upsetting flume during process. Steep topography on both sides of stream prevents conventional bore crossing methods because of grading/excavation requirements for bore pits. No additional workspace proposed. ODFW fish passage barrier data reports a downstream boulder canyon with a 10 foot falls at upper end (RecordID 52488). StreamNet data indicates anadromy below crossing (~ 1 mile) at ODFW barrier 52488. This waterbody is located within an occupied MAMU- stand (C3090). Conflicts with ODFW-recommended in-water work periods are not expected based on the proposed two- year construction schedule. However, the proposed Year Two daily timing restrictions during construction to minimize impacts to MAMU should be waived during the stream crossing installation to minimize the duration of instream work and the installation of flumes or dams/pumps.	None	None	Unknown	None	None	Jul 1 to Sep 15	Y

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Upper Rock Creek (BSP-41)	17100305000252 Private	44.21	Perennial Intermediate Dry Open-Cut	Risk Mgmt.: Orange Scour Rating: Level 1	Dry open-cut methods feasible/practical on stream. Dam and pump crossing method most logical dry open- cut method based on topographic conditions to eliminate difficulties of threading pipe string under flume with associated safety risks including upsetting flume during process. Steep topography on both sides of stream prevents conventional bore crossing methods because of grading/excavation requirements for bore pits. ODFW fish passage barrier data indicated two potential downstream falls may limit passage one report as 6-8 feet (RecordID 52484). StreamNet data indicates anadromy below crossing (~ 6 miles) at ODFW barrier RecordID 52484.	None	None	Cutthroat Trout Assumed	None	None	Jul 1 to Sep 15	Y
Klamath Mountains Ecoregion, Coquille Sub-basin (HUC 17100305), Middle Fork Coquille River (HUC 1710030501) Fifth field Watershed [8], Douglas County, Oregon												
Tributary Trib. to Upper Rock Creek (S3-07 /BW-38)	17100305005585 Private	46.56	Perennial Minor Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut methods feasible/practical on small non-fish-bearing headwater tributary.	None	None	None	None	None	Jul 1 to Sep 15	Y
Ditch (S3-06)	Private	48.21	Intermittent Minor Dry Open- Cut	Risk Mgmt.: N/A Scour Rating: Level 0	Dry open-cut methods feasible/practical on small intermittent road ditch if flowing at time of construction.	None	None	None	None	None	N/A	Y*
Deep Creek (BSP-257)	17100305005863 BLM-Roseburg District	48.27	Perennial Intermediate Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 1	Dry open-cut methods feasible/practical on broad stream and associated wetlands. ODFW fish passage barrier data (Recordid 56033) reports downstream falls on the Middle Fork Coquille River restrict anadromy at crossing.	None	None	Cutthroat Trout	None	None	Jul 1 to Sep 15	Y-1i

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	**Equipment Bridges** Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Ditch (BDX-32)	Private	49.94	Intermittent Minor Adjacent to right-of-	Risk Mgmt.: N/A Scour Rating: Level N/A	Right-of-way was necked-down to avoid the ditch.	None	None	None	None	None	Jul 1 to Sep 15	~~N~~
Ditch (BDX-31)	Private	50.02	Intermittent Minor Dry Open-Cut	Risk Mgmt.: N/A Scour Rating: Level N/A	Dry open-cut methods feasible/practical on small intermittent field ditch if flowing at time of construction.	None	None	None	None	None	N/A	Y*
Middle Fork Coquille River (BSP-30)	17100305000232 Private	50.28	Perennial Intermediate Dry Open-Cut	Risk Mgmt.: Orange Scour Rating: Level 1 [11] (Streambed-bedrock) [12]	Dry open-cut methods feasible/practical on broad stream during low flows within ODFW in-water work windows. Right-of-way has been necked down to 75 feet and TEWAs located in existing cleared areas to minimize riparian impacts. ODFW fish passage barrier data (Recordid 56033) reports downstream falls on the Middle Fork Coquille River restrict anadromy at crossing. StreamNet data also indicates duplicates this anadromy restriction at this barrier.	None	None	Cutthroat Trout	None	None	Jul 1 to Sep 15	Y-1i
Trib. to Middle Fork Coquille (GDX-36/BSI-66/67)	17100305005874 Private	50.45	Intermittent Minor Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0	Dry open-cut methods feasible/practical on small 1-4' wide intermittent ditched tributary in ag field if flowing at time of construction.	None	None	None	None	None	Jul 1 to Sep 15	Y*
Belieu Creek (BSP-61/GSI-37)	17100305000706 Private	50.71	Perennial Minor Dry Open-Cut	Risk Mgmt.: Yellow Scour Rating: Level 0	Dry open-cut methods feasible/practical on small 3' wide headwater tributary. Steep topography on west side of crossing prevents conventional bore because of grading/excavation requirements for a bore pit. ODFW fish passage barrier data (RecordID 56033) reports downstream falls on the Middle Fork Coquille River restrict anadromy at the crossing.	None	None	Cutthroat Trout	None	None	Jul 1 to Sep 15	Y

Waterbodies Crossed and Waterbody ID	NHD Waterbody Reach Code and Jurisdiction	Approximate Pipeline Milepost (MP)	Waterbody Type Size [1] Proposed Crossing[3]	Risk Assessment/ Management Category [13] Scour Level[2]	Waterbody Crossing Rationale	ESA Species Present/Habitat [4, 5]	Anadromous Species Present [6]	Resident Coldwater Species Present	EFH Species Present [6]	EFH Component Present [6]	Fishery Construction Window [7]	Equipment Bridges Y=Yes, Y* = Yes if flowing at time of construction, 1o = 1 pass required outside fish window 1i = 1 pass required inside fish window, i = set inside fish window, N=None
Trib. to Middle Fork Coquille (S1-07/GSI-38)	17100305022784 Private	51.02	Intermittent Intermediate Dry Open-Cut	Risk Mgmt.: Blue* Scour Rating: Level 0	Dry open-cut methods feasible/practical on small 1-4' wide intermittent headwater tributary if flowing at time of construction. No additional workspace required.	None	None	None	None	None	Jul 1 to Sep 15	Y
Trib to Jim Belieu Creek (SS-222-006)	Private	51.71	Intermittent Minor Adjacent to centerline	Risk Mgmt.: Blue* Scour Rating: Level 0	Dry open-cut methods feasible/practical on small intermittent field ditch if flowing at time of construction.	None	None	None	None	None	Jul 1 to Sep 15	Y*

[1] FERC waterbody definitions:
Minor = less than or equal to 10 feet wide
Intermediate = greater than 10 feet wide but less than or equal to 100 feet wide Major = greater than 100 feet wide

[2] Level 1 and 2 waterbodies have been identified; all others are Level 0. According to GeoEngineers 2018 Channel Migration and Scour Analysis for the PCGP Project, channel migration is defined as the lateral movement, over time, of an entire channel segment perpendicular to the direction of stream flow; channel avulsion is the sudden abandonment of an active channel for a newly created or previously abandoned channel located on the floodplain; channel widening is defined as erosion and subsequent recession of one or both stream banks that widens the channel without changing the channel location; streambed scour is erosion of the streambed resulting in the development of deep pools and/or the systematic lowering of the channel floor elevation.
Level 0 = streams not likely subject to migration, avulsion and/or scour
Level 1 = streams with a moderate potential for migration, avulsion and/or scour Level 2 = streams with a high potential for migration, avulsion and/or scour
(Estimated 100-year scour depth assumes absence of bedrock)

[3] Dry open-cut crossing methods include Flume or Dam and Pump procedures. Dam and Pump methods would be utilized where streambed blasting is anticipated to eliminate blasting around the flume. The Dam and Pump crossing method is the preferred crossing procedure in steep incised drainage valleys where worker safety may be compromised when placing ("threading") the pipe string under the flume pipe and where there is a risk of upsetting the flume during this operation. The Dam and Pump crossing method is also the preferred crossing method on small streams under low flow conditions during the ODFW recommended in-water work period. PCGP requests permission for temporary/short-term fish passage restriction when completing Dam and Pump crossings within the ODFW recommended in-water work period.

[4] FWS, NMFS, and StreamNet. T = Threatened, E = Endangered, CH = Critical Habitat

[5] ODFW, 2012 (Oregon Department of Fish and Wildlife. 2012. Fish Distribution Data, 1:24,000 Scale. Oregon Department of Fish and Wildlife Natural Resources Information Management Program. Online: https://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=fishdistdata).

[6] PFMC, 1999; ODFW, 2012.

[7] PCGP understands that fisheries' construction windows only apply to those waterbodies flowing at the time of construction and that the windows do not apply to HDD crossings.

[8] USGS Hydrologic Unit Codes.

[9] Key Watershed.

[10a] ODFW's recommended in-water work window is from October 1 through February 15. Because PCGP's Coos Bay HDD footprint overlaps with the LNG Terminal facilities, the HDD needs to be completed prior to construction of the LNG terminal to prevent construction conflicts and delays; therefore PCGP may complete the HDD outside the ODFW recommended in-water work window.

[10b] ODFW's recommended in-water work window is from October 1 through February 15. Because of the extensive wetland located on the east side of Coos Bay within Kentuck Slough, PCGP plans to schedule the HDD outside the in-water work window to minimize surface impacts within the saturated floodplain wetland.

[10c] ODFW's recommended in-water work window is from October 1 through February 15. Because of the extensive wetland location on the south side of the Coos River, PCGP has scheduled the HDD during the dry season outside the in-water work window between August 1 and September 30 to minimize surface impacts within the saturated floodplain wetland.

[11] These sites were field reviewed and analyzed for potential migration, avulsion and/or scour (see GeoEngineers 2018 Channel Migration and Scour Analysis).

[12] Streambed bedrock based on PCGP's Wetland and Waterbody delineation surveys. Streambed bedrock may require special construction techniques to ensure pipeline design depth. Special construction techniques may include rock hammering, drilling and hammering, or blasting. PCGP does not expect blasting to be required in streambeds within the CZMA as potential substrate bedrock is expected to be soft sedimentary rock that can be excavated using mechanical methods. The need for blasting would be determined by the contractor and would only be initiated after ODFW blasting permits are obtained.

[13] Steam Crossing Risk Assessment Management Category (Blue, Yellow and Orange) as described in GeoEngineers, Inc., 2017 Stream Crossing Risk Analysis and GeoEngineers, Inc., 2018 Stream Crossing Risk Analysis Addendum.

* The various Risk Management Rankings noted with an * indicate that access permission has not been acquired to confirm previous Risk Management Rankings. Confirmation surveys will be completed prior to construction once access permission has been acquired. Rankings are based on the Stream Crossing Risk Analysis (GeoEngineers, 2018).

Table 2
Landowners Associated with Waterbodies Affected by the Pipeline Project within the CZMA

Milepost	Wetland ID	NHD Reach Code and Jurisdiction	County	PLS	Longitude	Latitude
0.00	AI_Wetl_N M Haynes Inlet	State	Coos	Section 4, T25S, R13W	-124.244	43.43358
0.28 to 1.00 1.46-3.02	NE-26 Coos Bay	17100304000262 State	Coos	Coos Bay	-124.229724	43.446285
3.28 – 6.39R	EE-SS-9004 (EE-6) Kentuck Slough	17100304000262 Private	Coos	Section 1 &12 T25S, R13W	-124.184	43.42203
6.39R	S1-01 (EE-6) Trib to Coos Bay	17100304000767 Private	Coos	Section 6, T25S, R12W	-124.177	43.42695
8.27R	S1-04 (EE-7 (MOD)) Willanch Slough	17100304001393 Private	Coos	Section 18, T25S, R12W	-124.16	43.40633
8.46R	S-T01-002 GDX-30 Trib to Willanch Slough	Private	Coos	Section 17, T25S, R12W	-124.159	43.40463
10.21R	S-T01-003 (SS-100-002) Trib to Cooston Channel (Echo Creek)	17100304005045 Private	Coos	Section 20, T25S, R12W	-124.15	43.38282
11.13R	BSP-119 Coos River	17100304000093 State	Coos	Section 29, T25S, R12W	-124.146	43.37058
11.55BR	SS-100-005 (BR-S-02) Vogel Creek	17100304005031 Private	Coos	Section 28, T25S, R12W	-124.135	43.36628
11.88BR	BR-S-04 Trib to Vogel Creek	17100304000790 Private	Coos	Section 33, T25S, R12W	-124.135	43.36495
12.11BR	BR-S-06 Trib to Vogel Creek	17100304000798 Private	Coos	Section 33, T25S, R12W	-124.131	43.3639
14.72BR	BR-S-31 Trib to Stock Slough	17100304002068 Private	Coos	Section 4, T26S, R12W	-124.136	43.33846
15.11BR	BR-S-36 Stock Slough	17100304000507 Private	Coos	Section 9, T26S, R12W	-124.136	43.33272
15.16BR	BR-S-30 Trib to Stock Slough (Laxstrom Gulch)	17100304000493 Private	Coos	Section 9, T26S, R12W	-124.135	43.33829
15.32BR	EE-SS-9068 Stock Slough	17100304000507 Private	Coos	Section 9, T26S, R12W	-124.135	43.33143
20.20BR	SS-500-003 (BR-S-63) Steinnon Creek	17100305000361 BLM	Coos	Section 26, T26S, R12W	-124.093	43.28288
24.32BR	BR-S-63 Steinnon Creek	17100305000361 Private	Coos	Section 26, T26S, R12W	-124.094	43.23157
22.72	DA-10X Trib to North Coquille	17100305012102 Private	Coos	Section 24, T27S, R12W	-124.079	43.21028
23.06	BSP-207 North Fork Coquille River	17100305000339 Private	Coos	Section 25, T27S, R12W	-124.075	43.2069
24.32	BR-S-63 Steinnon Creek	17100305000361 BLM-Coos Bay District	Coos	Section 14, T27S, R12W	-124.093	43.231486
25.18	S-T02-001 (EE-SS-9073) Trib to Middle Creek	17100305012832 Private	Coos	Section 30, T27S, R11W	-124.045	43.20047
27.01	BSI-137 Trib to Middle Creek	BLM- Coos Bay District	Coos	Section 5, T28S, R11W	-124.031	43.17786
27.03	BSI-135 Trib to Middle Creek	BLM- Coos Bay District	Coos	Section 5, T28S, R11W	-124.03	43.17773
27.04	BSP-133 Middle Creek	17100305000323 BLM	Coos	Section 5, T28S, R11W	-124.03	43.17767
28.86	BSP-77 Trib to East Fork Coquille	17100305002530 Private	Coos	Section 10, T28S, R11W	-124.005	43.16262
29.30	BSP-74 Trib to East Fork Coquille	17100305002598 Private	Coos	Section 10, T28S, R11W	-124	43.15786
29.47	BSI-76 Trib to East Fork Coquille	17100305002647 Private	Coos	Section 10, T28S, R11W	-123.997	43.15673
29.85	BSP-71 East Fork Coquille	17100305000286 Private	Coos	Section 10, T28S, R11W	-123.989	43.15392
30.22	SS-003-007A Trib to East Fork Coquille	Private	Coos	Section 14, T28S, R11W	-123.984	43.15071
30.29	SS-003-007B Trib to East Fork Coquille	17100305002813 Private	Coos	Section 14, T28S, R11W	-123.982	43.15036

Milepost	Wetland ID	NHD Reach Code and Jurisdiction	County	PLS	Longitude	Latitude
31.64	BSI-70 Trib to East Fork Coquille	17100305018097 BLM- Coos Bay District	Coos	Section 13, T28S, R11W	-123.964	43.1414
32.40	BSP-57 Elk Creek	17100305000284 Private	Coos	Section 24, T28S, R11W	-123.951	43.13717
32.50	S-T01-008 (BSP-55) Trib to Elk Creek	17100305021880 Private	Coos	Section 24, T28S, R11W	-123.951	43.13658
32.56	S-T01-004 (SS-100-030) Trib to Elk Creek	17100305021871 Private	Coos	Section 24, T28S, R11W	-123.95	43.13485
33.00	BSP-49 Trib to Elk Creek	17100305003372 Private	Coos	Section 24, T28S, R11W	-123.949	43.12918
33.02	BSP-50 Trib to Elk Creek	17100305003372 Private	Coos	Section 24, T28S, R11W	-123.949	43.12891
34.46	CSP-5 South Fork Elk Creek	17100305000591 Private	Coos	Section 19, T28S, R10W	-123.933	43.11326
35.51	BSI-251 Trib to South Fork Elk Creek	17100305021783 BLM-Coos Bay District	Coos	Section 29, T28S, R10W	-123.914	43.10942
35.87	BLM-35.87 (CSP-2) Trib to Big Creek	17100305025781 BLM-Coos Bay District	Coos	Section 29, T28S, R10W	-123.911	43.10618
36.48	BLM-36.48 Trib To Big Creek	17100305026477 BLM – Coos Bay District	Coos	Section 29, T28S, R10W	-123.902	43.10411
36.54	GSI-25 (BSI-253) Trib To Big Creek	17100305004068 BLM-Coos Bay District	Coos	Section 28, T28S, R10W	-123.9	43.10535
36.85	BLM-36.85 Trib to Big Creek	17100305025748 BLM-Coos Bay District	Coos	Section 28, T28S, R10W	-123.895	43.10494
36.92	BSI-252 Trib to Big Creek	17100305004061 BLM-Coos Bay District	Coos	Section 28, T28S, R10W	-123.893	43.10627
37.32	ESI-19 Trib to Big Creek	17100305026126 BLM-Coos Bay District	Coos	Section 28, T28S, R10W	-123.887	43.10566
37.35	ESP-20 Trib to Big Creek	17100305000606 BLM-Coos Bay District	Coos	Section 28, T28S, R10W	-123.886	43.10535
44.21	BSP-41 Upper Rock Creek	17100305000252 Private	Coos	Section 8, T29S, R9W	-123.788	43.06394
46.56	S3-07 (BW-38) Trib to Upper Rock Creek	17100305005585 BLM – Roseburg District	Douglas	Section 10, T29S, R9W	-123.749	43.05843
48.21	S3-06 Trib to Deep Creek	17100305022853 Private	Douglas	Section 14, T29S, R9W	-123.723	43.05115
48.27	BSP-257 (MOD) Deep Creek	17100305005863 BLM – Roseburg District	Douglas	Section 13, T29S, R9W	-123.72	43.05035
49.94	BDX-32 Ditch	Private	Douglas	Section 7, T29S, R8W	-123.688	43.05519
50.02	BDX-31 Ditch	Private	Douglas	Section 7, T29S, R8W	-123.686	43.05513
50.28	BSP-30 Middle Fork Coquille River	17100305000232 Private	Douglas	Section 7, T29S, R8W	-123.681	43.05539
50.45	GDX-36 (BSI-66/67) Trib to Middle Coquille River	17100305005874 Private	Douglas	Section 8, T29S, R8W	-123.674	43.0569
50.71	GSI-37 (BSP-61) Belieu Creek	17100305000706 Private	Douglas	Section 8, T29S, R8W	-123.668	43.05561
51.02	S1-07 (GSI-38) Trib to Middle Fork Coquille	17100305022784 BLM-Roseburg District	Douglas	Section 17, T29S, R8W	-123.666	43.05399
51.71	SS-222-006 Trib to Belieu Creek	Private	Douglas	Section 16, T29S, R8W	-123.657	43.04988

Appendix 2
Dry Open Cut Waterbody Crossing Methods

Flume Procedures
Dam and Pump Procedures

Pacific Connector GAS PIPELINE

Pacific Connector Gas Pipeline, LP

Stream Fluming Procedures

Pacific Connector Gas Pipeline Project

September 2017

STREAM FLUMING PROCEDURES

During construction various local, state and federal permits will require that flowing streams with coldwater fisheries be crossed utilizing a "dry crossing" technique. Fluming is one of the methods which may be utilized to achieve a dry crossing of a flowing stream. The purpose of this appendix is to outline the techniques that will be utilized to flume stream crossings during construction of the project. These guidelines are subject to change based on permits issued by regulatory agencies.

1.0 Purpose of Flumed Stream Crossings

The primary purpose of fluming a stream is to assure that in-stream construction activities comply with water quality standards for turbidity that have been established by the state to protect aquatic life and other beneficial uses. Overall, a properly installed and maintained flume can be very effective in reducing turbidity during in-stream construction. In most cases, detectable increases in turbidity are limited to short durations when the flume is installed and when the flume is removed from the streambed.

However, installation of a flume does not guarantee that compliance with water quality standards will occur. Flumes require monitoring and occasional repair during the crossing period to ensure the integrity of the structure(s). Adequate pumps play an integral role in a successful flumed crossing.

2.0 Where Flumes Will Be Installed

Any minor or intermediate waterbody with water flowing in the streambed at the time of construction, which has a coldwater fishery as defined by the Oregon Department of Fish and Wildlife (ODFW), may be flumed. A list of streams where dry open cut crossing methods (fluming, dam and pump or diverted open cut) may be utilized is provided as part of Resource Report 2.

3.0 General Layout of a Typical Flumed Stream Crossing

Figure 1 shows a plan view of a typical flumed stream crossing. The primary components of a flumed crossing include:

- flume pipe or multiple flume pipes;
- sandbag/plastic dams;
- spoil storage and staging areas;
- pumps and pump containment structure (s);
- dewater structure(s);
- erosion control structures; and
- spill containment and cleanup materials.

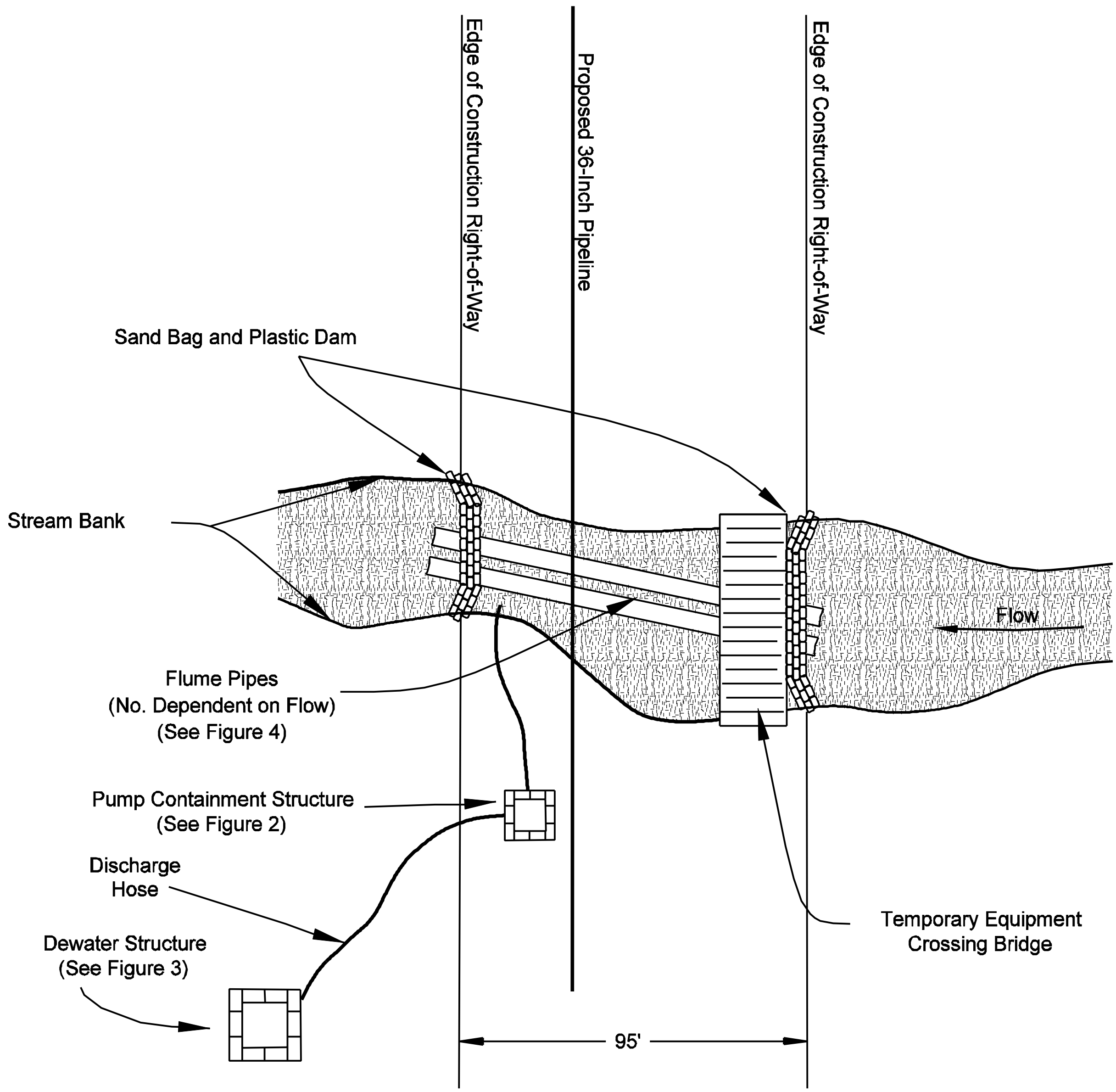


FIGURE 1
PLAN VIEW OF TYPICAL FLUMED STREAM CROSSING

A single or multiple flume pipe(s) are used to temporarily convey the stream flow over the construction area, thereby reducing the introduction of sediments into the water column during ditching and backfilling. The sandbag/plastic dams are used to support and seal the ends of the flume pipe(s) and to direct stream flow into the flume pipe and over the construction area. These structures are also utilized to prevent downstream water from flowing upstream into the construction area. They also serve to contain water that infiltrates into the construction area before it can be removed by the pumps and discharged to an upland area. Finally, the downstream structure serves to contain turbid water, which rises quickly in the construction area during backfilling of the trench.

All waterbodies with water in the streambed at the time of construction must have an equipment crossing bridge.

The temporary spoil storage area is where spoil trenched from the streambed will be stored until backfilling is completed. These temporary extra work areas are identified on the Environmental Alignment Sheets. FERC's Wetland and Waterbody Procedures prohibit the location of staging areas or additional right-of-way within 50 feet of the stream banks or edge of adjacent wetlands unless site-specific conditions such as topography prevent the setback and a variance is approved. Trench spoil must be placed at least 10 feet away from stream banks at all flowing stream crossings. In addition, these areas must be enclosed with silt fence and/or straw bales to prevent runoff of the spoil into the stream.

Adequate pumps are essential for the successful completion of flumed stream crossings. During several phases of the crossing process, it will be necessary to quickly remove large quantities of water from the construction area to prevent overflow or leakage of the sandbag/plastic dams or the temporary equipment crossing bridge. The most effective means of quickly removing water from the construction area is by utilizing well-maintained pumps with adequate pumping rates. In addition, backup pumps will be located on-site, hooked up and maintained as fully operational during the entire crossing process. Backup pumps will be tested prior to the start of construction. Pumps will be located in a spill containment structure that is designed to fully contain any spills of fuel or oil (see Figure 2).

Dewater structures (see Figure 3) will be utilized to reduce the velocity of pump discharge water and subsequent erosion of upland areas. These structures are essential in preventing erosion and the flow of turbid water overland and back into the stream - such overflow effectively defeats the purpose of the flumed crossing by introducing turbid water into the stream.

Runoff control structures are utilized to prevent runoff from the spoil piles or from drainage of water from the trackhoe bucket from flowing around the sandbag/plastic dams or temporary equipment crossing bridges and adding sediment to the stream. Containment and control materials are necessary to respond to any spills of fuel or lubricating oils from operating equipment. A Spill Prevention, Containment, and Countermeasures (SPCC) Plan will be implemented by the contractor in accordance with the provisions of that plan. Erosion control structures address the prevention of runoff from the right-of-way into the stream during and after construction is complete.

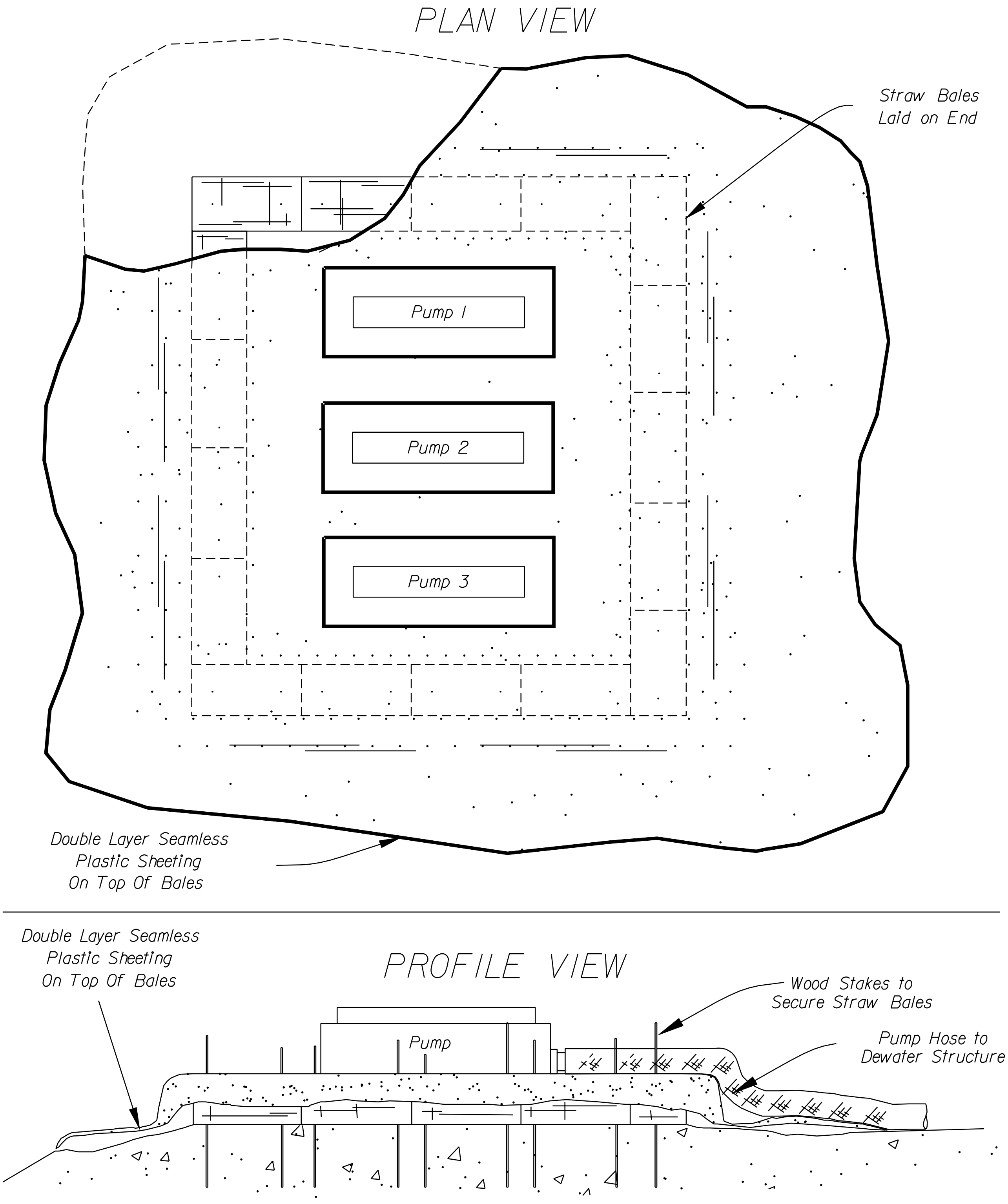


Figure 2
Typical Pump Containment Structure

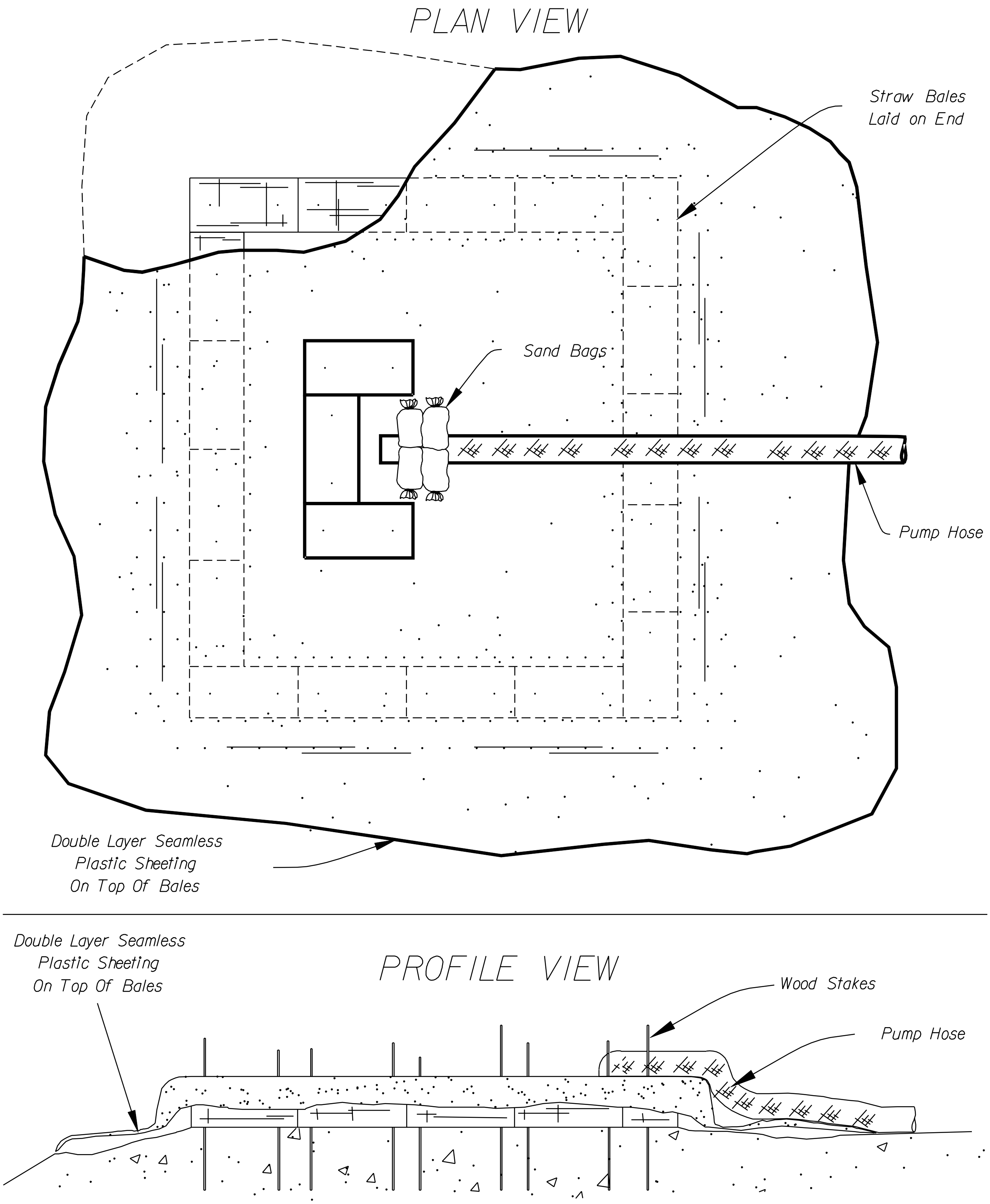


Figure 3
Typical Dewater Structure

4.0 Materials Required to Install and Maintain a Flumed Stream Crossing

The materials discussed below will accommodate most stream crossings. However, certain situations will arise where additional materials are required. Those streams that require additional materials will be addressed on a case-by-case basis.

Typically, scrap steel pipe will be utilized to construct the flume. Before the flume pipe is installed in the stream, it will be inspected to assure that it is free of grease, oil or other pollutants. In addition, excessive dirt will be removed from the flume pipe. If oil or grease is present on the flume pipe, it will be steam-cleaned before the flume pipe is placed in the stream.

Both the inlet and outlet of the flume pipe will be sandbagged and lined with plastic to create a proper seal (see Figure 4). The reason for sandbagging the downstream end of the flume is to create a contained area where turbid water is trapped and to prevent downstream water from flowing up the streambed and flooding the trench.

Sandbags will be filled with a non-leachable material such as clean, pre-washed sand. Sandbags are most effective if they are only filled to approximately 2/3 their capacity. Bags filled to capacity conform poorly to the adjacent bags and make creation of a seal more difficult. The bags must be tied securely before they are installed. If the bags are left un-tied, they tend to spill upon removal from the streambed and are nearly impossible to remove with a trackhoe. It is preferable to utilize burlap sandbags to construct the upstream and downstream dams. Plastic bags tend to rip when removed from the stream and are often too porous to adequately contain small grain sand.

Sandbags alone are often not sufficient to completely seal the upstream and downstream ends of the flume pipes. The dams are typically more effective when sheets of thick plastic are interwoven within the sandbags (see Figure 5). The plastic, when applied as shown on Figure 5, will effectively seal the dams and will greatly reduce the amount of water leaking into the construction area from behind the upstream and downstream sandbag dam.

5.0 Flume Pipe Design

A number of flume pipe designs have been used with varying degrees of success. To improve success, flume pipes with wings welded to the front end of the pipe provide for better conveyance of stream flow into the mouth of the flume (see Figure 6). The most effective wings extend to each stream bank and are angled slightly upstream. Where the bottom of the stream is other than rock, the wings extend approximately 12 inches below the bottom of the flume pipe and are pushed into the stream substrate utilizing a trackhoe during installation. The upstream and downstream portions of the wings are then sandbagged and overlain with plastic as needed to prevent leaks as shown in Figure 7.

The flume pipe(s) installed at the crossing will be of sufficient length so that the integrity of the upstream and downstream sandbag dams are not jeopardized by excessive top of ditch widths within the stream or adjacent stream banks. It is tempting to restrict the flumed width to an area smaller than the actual construction right-of-way. However, experience has shown that the contractor often needs to utilize the majority of the construction right-of-way to complete the crossing. Therefore, the flume pipes must be long enough to span the entire construction right-of-way through the stream (see Figure 4).

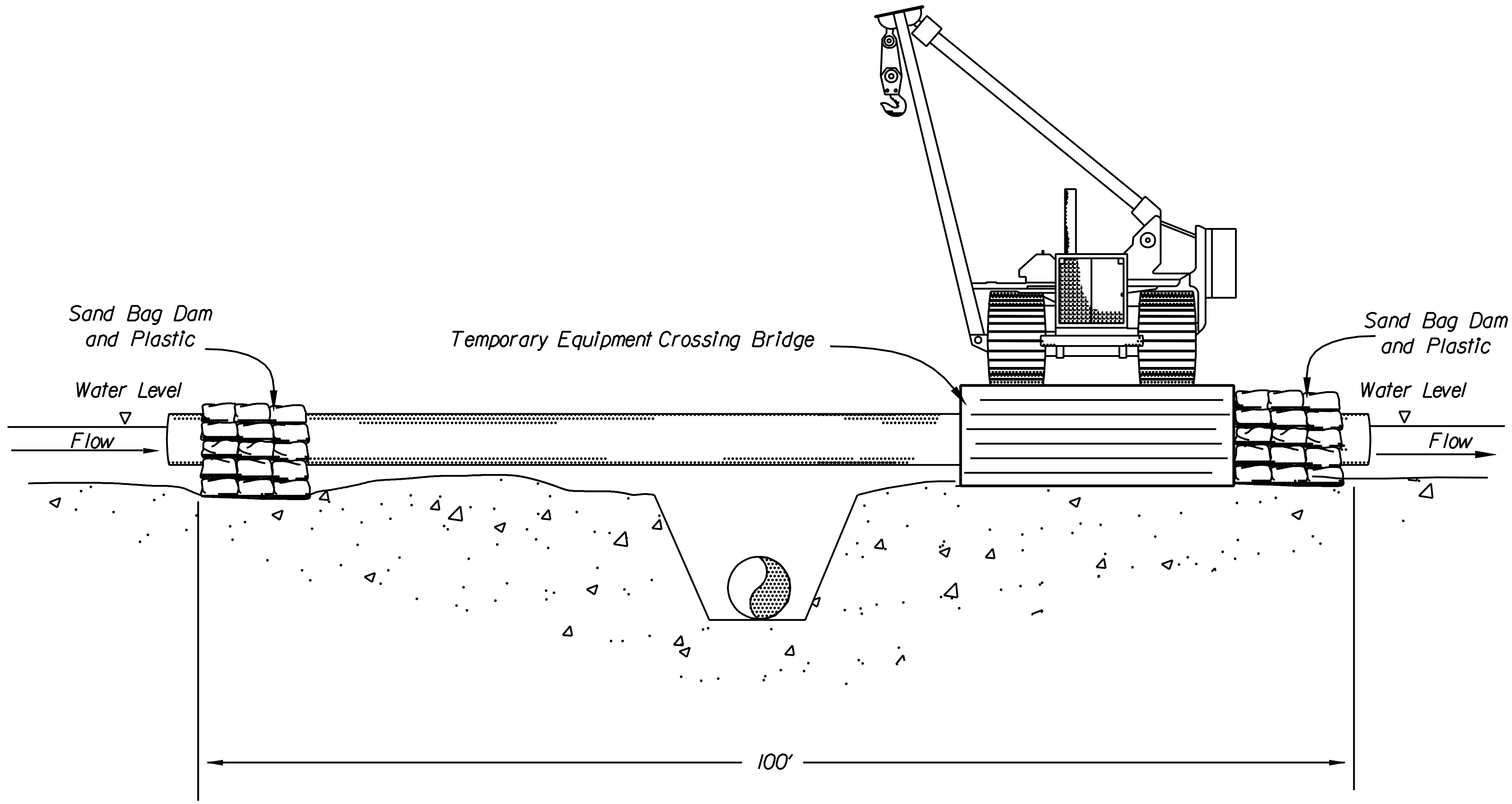


FIGURE 4
FLUME PIPE PLACEMENT ACROSS RIGHT-OF-WAY

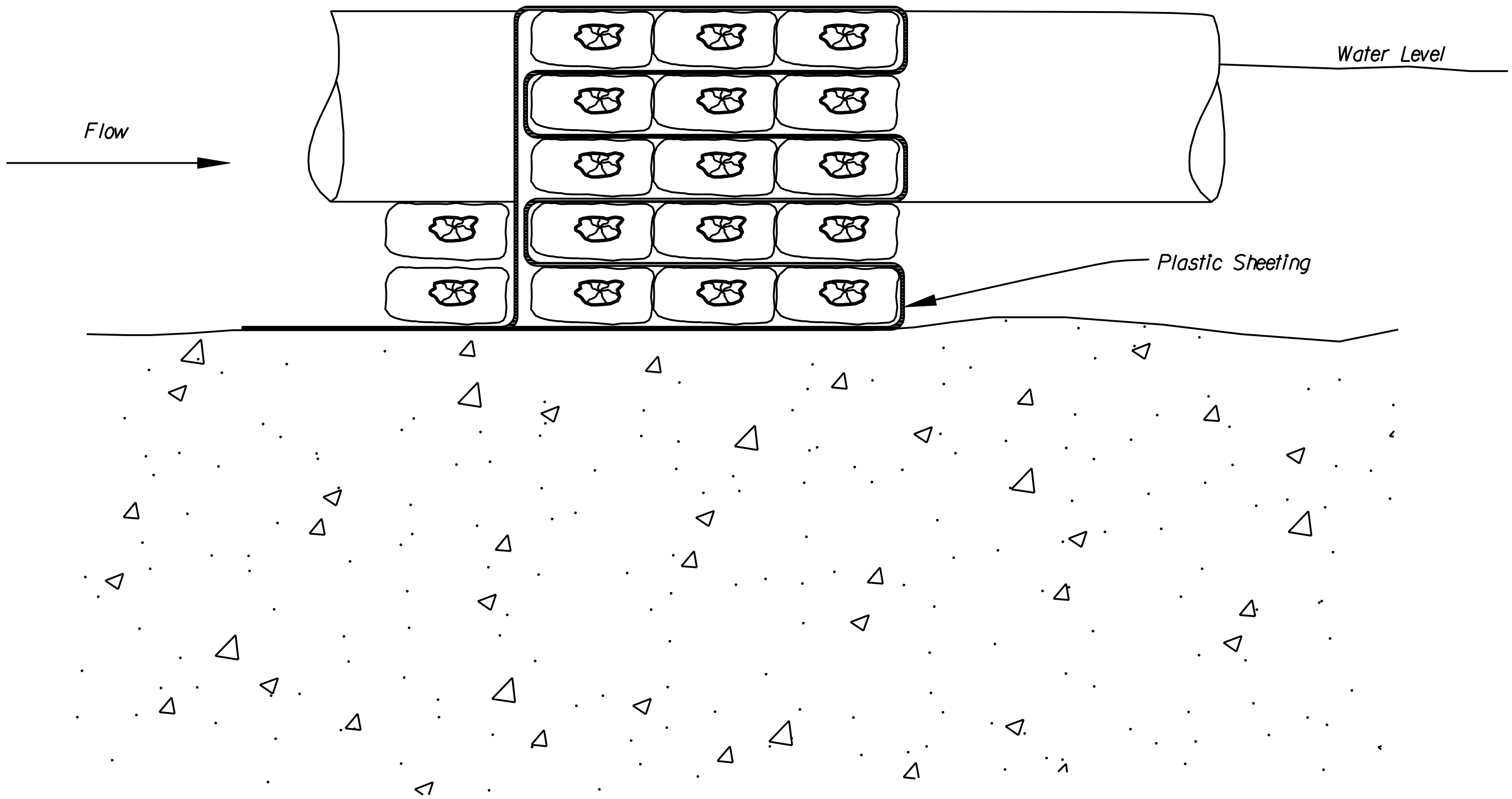


FIGURE 5
PLASTIC SHEETING INTERWOVEN INTO A SAND BAG DAM

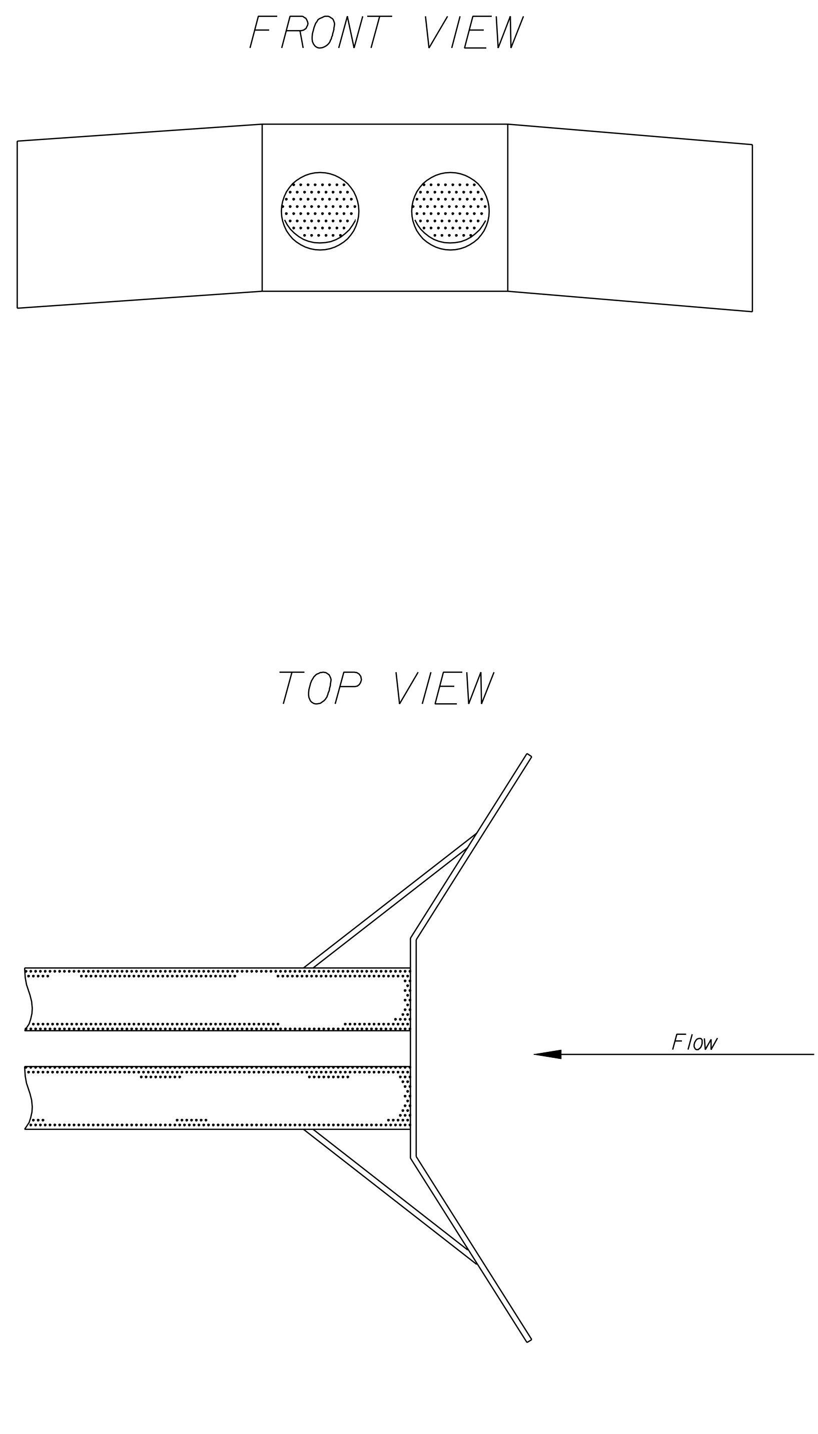


Figure 6
Upstream Flume Wings

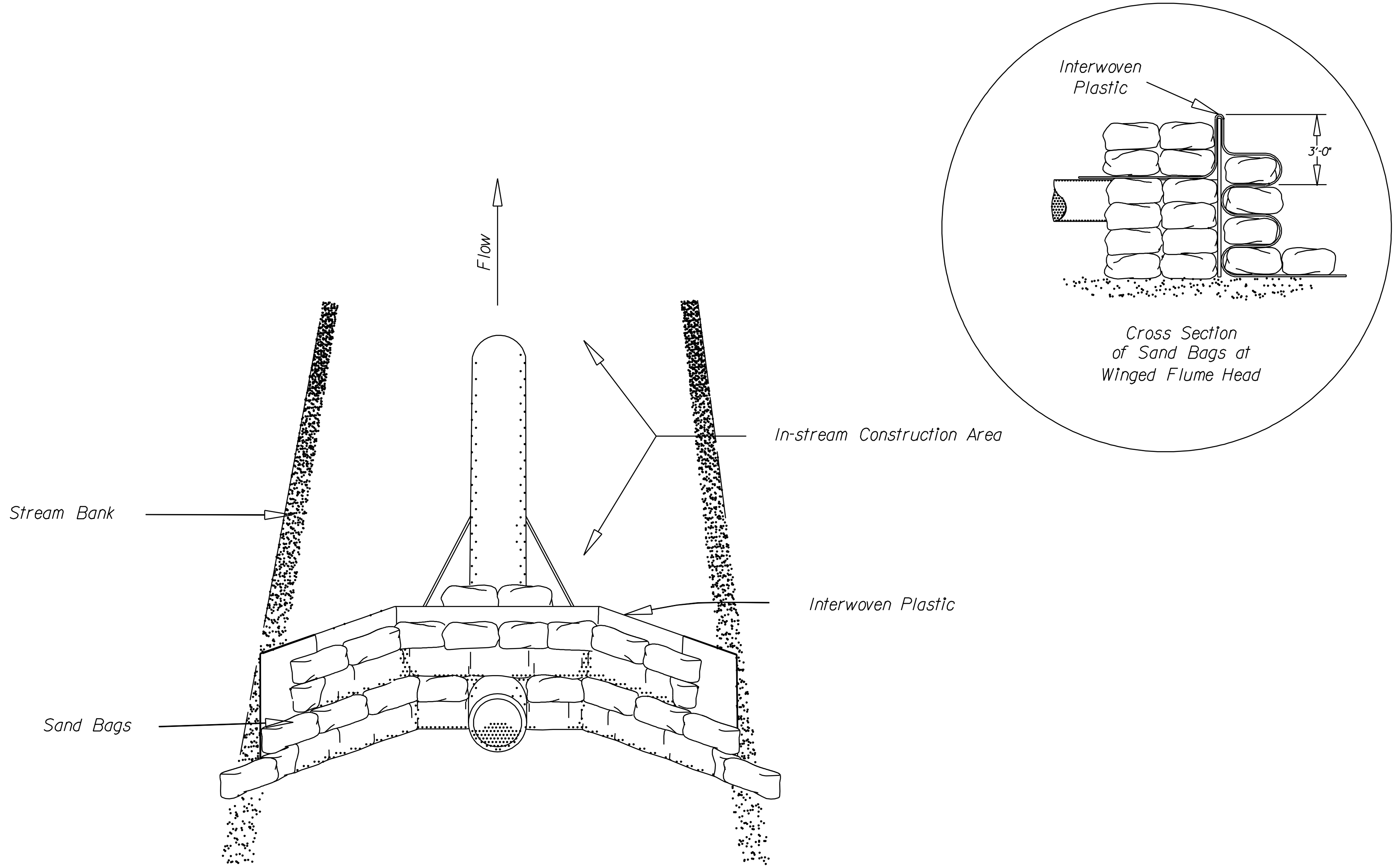


Figure 7
Sand Bag and Plastic Dam

As a general rule, a flume pipe of at least 80 feet in length will be utilized for crossings. The diameter of the flume pipe (s) will depend on the stream discharge at the time of the crossing. However, in all cases the flume pipe diameter will be oversized to accommodate any storm events that might occur during the crossing period.

6.0 Installation of the Flume Pipe

Short-term elevated levels of turbidity are expected to occur during installation of the flume pipe. However, several measures can be taken to minimize the increased turbidity. Before the contractor attempts to install the flume pipe, all materials necessary to complete the installation process will be located on-site. Installation of the flume cannot begin until all of the precautions outlined in the SPCC Plan have been undertaken. Turbidity sampling will be conducted during all flumed crossings in accordance with the Stormwater Pollution Prevention Plan.

Installing the Flume Utilizing Only Sandbag/Plastic Dams

The first step in installing the flume pipe is to clear away any large rocks and boulders from the sandbag/plastic dam area and under the flume pipe that will prohibit placement of the flume pipe or affect the integrity of the sandbag/plastic dam. It may be necessary to utilize a trackhoe to assist in removing these rocks. However, under no circumstances will the bucket be allowed to dig into the streambed to remove rocks. Rather, the edge of the bucket should be utilized to roll the rocks to the side or a thumb on the bucket will be used to pick up and move rock obstacles.

Before the flume pipe is installed, the contractor will lay at least three rows of sandbags on the streambed (at least two sandbag layers tall) to support the upstream and downstream portions of the flume pipe (see Figure 5). The sandbags may be laid on top of the plastic sheeting that will be used to help seal the sandbag dam. The plastic will be laid such that when it is wrapped around the sandbag dam, the plastic sheeting lays on the upstream face of the dam so that water pressure holds the plastic firmly against the sandbag dam face. The sandbags will be properly seated over the plastic and onto the stream bottom and packed as tightly together as possible.

Once the first rows of sandbags are in place, the flume pipe can be lowered into position. The flume pipe will be lifted over the stream and carefully aligned before it is lowered onto the sandbags over the streambed. The contractor will not push or pull the flume pipe over the stream banks and into the water. Rather, the flume pipe will be suspended over the crossing and lowered into place.

After the flume pipe is laid on the sandbags, the contractor will begin to construct the upstream sandbag/plastic dam. First, the winged upstream portion of the flume pipe will be pushed into the streambed substrate, where possible. Sandbags will be installed upstream and downstream of the wings and interwoven with plastic sheeting to form a tight seal. Typically, the sandbag/plastic dam will extend at least three feet above the water level of the stream to accommodate increased stream discharge during the crossing period (see Figure 7).

After the upstream sandbag/plastic dam is complete, the contractor will immediately begin installation of the downstream dam. The downstream sandbag/plastic dam will be constructed to a height at least three feet above the downstream water level.

7.0 Maintenance of the Flume During Construction

Flumed crossings require constant monitoring and occasional repair during the crossing process. The longer the flume remains in the water, the greater the probability that the dams will begin to leak and that water will invade the construction area in significant quantities. Therefore, it is imperative that once trenching within the stream begins that the construction process is carried to completion non-stop. Typically, this involves installing the flume on the day immediately proceeding construction of the crossing. Ditching of the stream channel should begin early the following morning and the pipe pulled under the flume pipe immediately following completion of the trench. Backfilling should commence immediately following the stringing of the drag section. For most streams it typically, requires 3 to 7 days to install the flume, dig the trench, install the pipe drag section under the flume, backfill the trench and restore and stabilize the stream banks. Smaller streams (less than 10 feet in width) generally require less time to cross using fluming procedures.

While the flume is in place, the contractor will provide a sufficient crew that will be responsible for maintaining the flumed crossing. The crew will apply additional plastic to the dams and add additional sandbags as necessary. In addition, the crew will be responsible for operating the pumps and maintaining the discharge structures. When the crossing is complete, the crew will immediately install the erosion control structures pursuant to FERC's Wetland and Waterbody Procedures.

To be adequately prepared to repair the flume, the contractor must have on-site rolls of thick plastic sheeting and extra filled and tied sandbags. These materials need to be stored directly adjacent to the stream crossing so that they are readily accessible should the need to repair the flume arise.

8.0 Length of the Drag Section

One of the biggest problems encountered during construction of flumed stream crossings is the installation of extremely long drag sections across the stream in a single drag section. The extra length requires that the flume be in place longer than necessary which increases the probability of serious problems with the integrity of the sandbag/plastic dams. In addition, the extra time required to dig additional ditch to accommodate long drag sections can result in integrity problems with the flume dams.

Segments must be kept short and extend only the distance necessary to allow for later tie-in to the upland portions of the pipeline. On most streams the drag section to be pulled under the flume should only be long enough to incorporate the sag bends. In other locations, it may be necessary to install additional pipe to complete the crossing.

The entire drag section must be made up prior to the start of in-stream trenching. Once the drag section is complete (welds x-rayed and joints coated), the drag section can be installed immediately following trenching.

9.0 Trenching Under the Flume Pipes

At some point prior to initiating trenching, chains should be hung from the flume pipe over the ditch line. These chains will be utilized to hang the pump heads or intake pipe into the ditch.

Digging the ditch under the flume requires careful preparation and execution. Two trackhoes will begin trenching from each stream bank at the same time. The trackhoes will begin by trenching under the flume pipe(s) and dig back to the stream banks. Finally, the trackhoes will dig the upland portion of the ditch necessary to install the drag section.

Generally, pumping water from the construction area is not necessary during trenching as the amount of spoil removed from the streambed generally exceeds the volume of water that infiltrates the construction area. However, at times the water flow into the construction area becomes excessive, pumping is necessary to avoid overflow or leakage from the downstream dam.

10.0 Spoil Storage During Trenching

Spoil must be stored in a manner such that runoff from the spoil does not flow into the stream or off the right-of-way. For streams in flat topography, runoff from the spoil storage pile is not typically a problem. However, on steep sloping stream banks water can run back down the right-of-way and enter the stream upstream or downstream of the dams creating a water quality problem. The problem can be compounded as the trackhoes working on the stream banks lift water saturated spoil from the stream and lay it on the right-of-way adjacent to the stream bank before it can be conveyed uphill by additional equipment. To accomplish runoff control during trenching, diversion structures or trenches will be dug within the right-of-way to direct the runoff back into the construction area as shown on Figure 8.

11.0 Spoil Transfer During Construction

Some of the stream crossings may occur adjacent to steep upland areas. In these cases, it will be necessary to utilize additional equipment (trackhoes, dozers, loaders) to transfer spoil dug by the trackhoes at each stream bank to the temporary spoil storage area.

In most cases, the contractor will utilize dozers to push the spoil to the temporary storage area. In other areas, trackhoes will be required to transfer spoil dug by the trackhoe working on the stream bank uphill to a flatter area where it can be moved by dozers. When two trackhoes are utilized to transfer spoil uphill, the trackhoe working on the stream bank places the spoil into a pit (see Figure 9). The spoil from the pit is then picked up by the second trackhoe and lifted further uphill. The pit will significantly reduce the amount of water from the spoil that runs downhill. The pit can be maintained and dug by the trackhoe working uphill from the crossing.

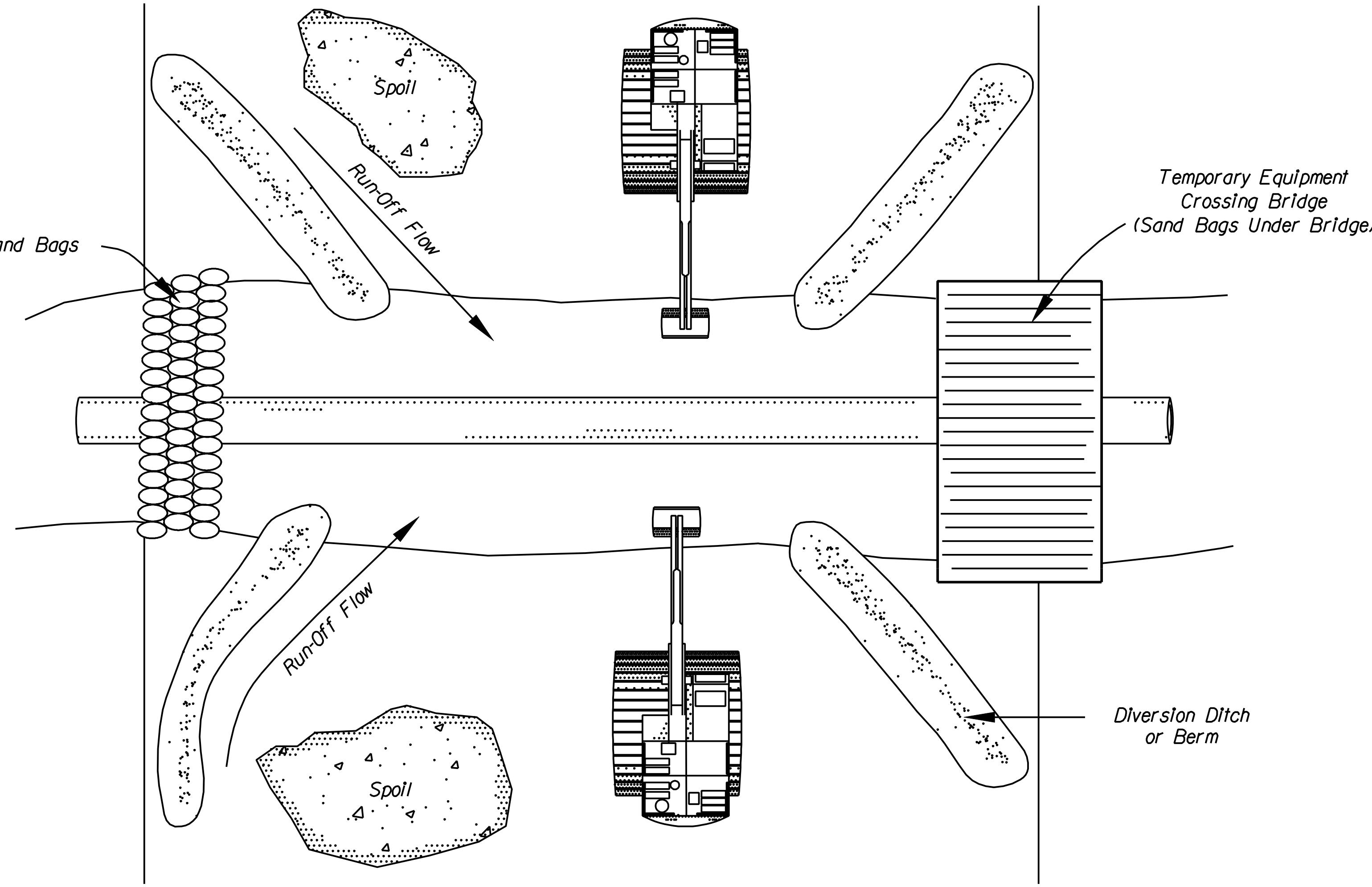


FIGURE 8
DIVERSION DITCH OR BERMS

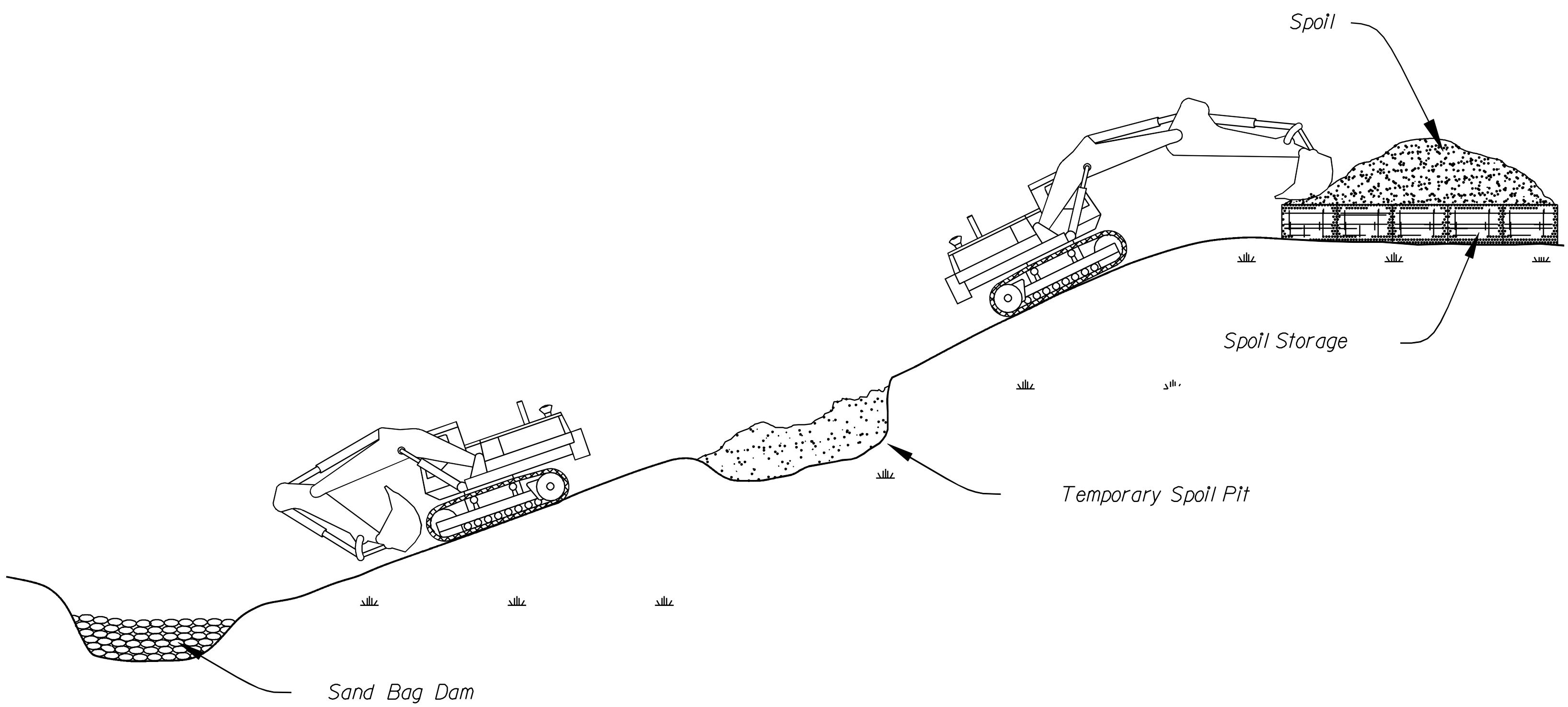


Figure 9
Uphill Slope Transfer

12.0 Installing the Pipe

While trenching is being conducted, the contractor will hook up the drag section to the sideboom tractors so that the pipe may be installed as soon as trenching is completed. It will be necessary at many crossings to float the pipe across the trench (i.e., it may not be feasible to completely dewater the ditch). While the drag section is being slid under the flume pipe, it is essential that pumps be operated to assure that turbid water does not leak through or flow over the dams. The contractor will operate the pumps at a rate so that water displaced by the pipe is immediately removed and discharged to the dewater site.

13.0 Dewatering the Construction Area

Proper operation of pumps is essential to the successful completion of a flumed stream crossing. Pumps will be utilized by the contractor as necessary to control the level of water in the construction area. The purpose of the pumps is not to completely dewater the trench.

If the water level in the construction area exceeds the upstream or downstream level of the dams, the environmental inspectors will notice small amounts of turbid water escaping into the stream either upstream or downstream of the dams. This is known as "bleeding" and the problem can be quickly resolved by increasing the pumping rate and reducing the water level within the construction area. Although bleeding will not typically result in a violation of water quality standards downstream, if left unchecked it can quickly result in erosion of the dams and serious downstream water quality problems.

The contractor will utilize pumps at each crossing to control the water level in the construction area. The contractor will also install backup pumps that will be tested and fully functional prior to the start of the crossing process. Pumps will be installed and tested and the dewater sites constructed the day prior to any in-stream construction. For most crossings, the contractor will setup three pumps. Additional pumps may be required at a few of the stream crossings. Two of the pumps will serve to remove water from the construction area and the third pump will serve as a backup should one of the primary pumps fail.

The pumps will be set in a containment area as shown on Figure 2. The primary purpose of the containment area is to fully contain any fuel or lubricating oil spills. If hydraulic pumps are used, the hose couplings on the side of the pump body will be oriented in the containment area such that they point perpendicularly away from the stream banks. The purpose of orienting the couplings away from the stream is to protect the stream should one of these couples fail and hydraulic fluid escape.

The contractor will carefully inspect each pump prior to its delivery to the crossing site. In particular, any frayed hoses or apparent leaks will be repaired before the pumps are delivered to the crossing site. Pump heads and the hoses will be cleaned of any free hydraulic oil prior to placing the pump heads into the stream.

All pumps will be installed with individual intake hoses or hydraulic heads, trash filters and discharge hoses. All three hydraulic heads will remain in the water during the entire construction process including backfill. In this manner, the backup pump can be immediately employed should one of the primary pumps fail.

Each of the pumps (including the backup pump) will be equipped with a minimum of 300 feet of discharge hose. It is important to stretch the hose on the backup pump and install a dewater structure for that pump at the same time the primary pumps are installed. Hoses should be free of leaks and in good operating condition.

In many cases, it is difficult to locate dewater sites where water will flow away from wetlands or streams. In these cases, careful attention will be paid to the dewater sites and alternative sites (which require additional discharge hose) selected prior to the start of in-stream construction. Often it is necessary to move the location of the dewater site several times during construction of the stream crossing to avoid dewater from reaching sensitive areas.

Dewater structures will be constructed of straw bales and plastic and wooden stakes as shown on Figure 3. The intent of the design provided on Figure 3 is to allow the water to fill the dewater structure and flow evenly over the tops of the bales. Straw bales will be securely staked to the ground utilizing wooden stakes. Alternative structures are also provided in the Erosion Control and Revegetation Plan.

14.0 Backfilling the Ditch

The highest potential for water quality problems during a flumed crossing is during backfilling of the ditch. Quick backfilling into the ditch by the contractor can cause the water level in the construction area to overflow or leak through the downstream dam. Pumps must be carefully managed during backfilling to control the water level in the construction area. The contractor must carefully monitor the effectiveness of the pumps and control the rate of backfill to preclude bleeding through the downstream dam. If backfilling occurs too quickly, the pumps will not be capable of removing the water from the construction area quick enough to prevent the escape of turbid water.

To prevent turbidity, backfilling of the ditch will be conducted in a slow, well-planned manner. Backfilling will begin in the center of the stream directly under the flume pipes and proceed toward each bank simultaneously. In this manner, much of the water in the ditch will be pushed to the ditch outside of the stream channel. If upland portions of the trench are backfilled first, the water in the ditch is pushed into the stream channel and will inevitably leak through or overflow the downstream dam.

Once backfilling of the entire stream channel is complete, the contractor will compact the streambed and construct solid plugs on both banks. Water will remain trapped in the ditch outside of the stream channel. This water will be pumped from the ditch at a later time in the manner described for dewatering the construction area (see Section 13).

15.0 Flume Removal

After the ditch is backfilled, clean gravel fill is placed on the top one foot of the ditch (where necessary). Plugs will be installed at each stream bank and the stream banks stabilized and the flume will be removed from the crossing. To prevent excessive increases in turbidity during flume removal, the contractor will remove all of the sandbags from the downstream dam. A trackhoe can be utilized to remove the top layers of the sandbags as long as the operator takes great care not to dig into the streambed or to increase turbidity.

After the downstream sandbags are completely removed from the streambed (except those few left directly under the flume), the contractor will begin removing the sandbags from the upstream dam. The top rows of sandbags should be removed by hand until the water begins to overflow the top of the dam and flows slowly over the construction area. For the first 10 to 30 minutes, turbidity downstream of the crossing area could increase considerably. However, the streambed portion of the construction area will be flushed clean of sediments left over from construction and the water will flow clear over the disturbed stream bed area. After the turbidity level has decreased to acceptable levels or that of upstream levels, the contractor can proceed with removing the remainder of the upstream dam sandbags.

Once the majority of the sandbags are removed, the flume pipe will be removed. The flume pipe will be raised directly from the streambed in a single movement. Under no circumstances will the contractor drag the flume pipe from the streambed. Rather, it will be lifted and then carried from the crossing area. After the flume is removed, the remaining few sandbags, which were laid directly under the flume pipe, can be removed by hand.

Pacific Connector Gas Pipeline, LP

Dam & Pump Procedures

Pacific Connector Gas Pipeline Project

September 2017

DAM & PUMP PROCEDURES

During construction various local, state and federal permits will require that flowing streams with coldwater fisheries be crossed utilizing a "dry crossing" technique. Dam & pump is one of the methods which may be utilized to achieve a dry crossing of a flowing stream. The purpose of this appendix is to outline the techniques that will be utilized to temporarily dam stream crossings and pump the flowing water around the site during construction of the project. These guidelines are subject to change based on permits issued by regulatory agencies.

1.0 Purpose of Dam & Pump Stream Crossings

The primary purpose of damming a stream is to assure that in-stream construction activities comply with water quality standards for turbidity that have been established by the state to protect aquatic life and other beneficial uses. Overall, properly installed and maintained dams can be very effective in reducing turbidity during in-stream construction. In most cases, detectable increases in turbidity are limited to only the short duration when the dams are installed or removed from the streambed.

However, simply installing the dams is no guarantee that compliance with water quality standards will occur. Dams require monitoring and occasional repair during the crossing period to ensure the integrity of the structure(s). Adequate pumps play an integral role in a successful dam & pump crossing.

2.0 Where Dams & Pumps Will Be Installed

Any minor or intermediate waterbody with water flowing in the streambed at the time of construction, which has a coldwater fishery as defined by the Oregon Department of Fish and Wildlife (ODFW), may be dammed & pumped. A list of streams where dry open cut crossing methods (fluming, dam and pump or diverted open cut) may be utilized is provided in Resource Report 2.

3.0 General Layout of a Typical Dam & Pump Stream Crossing

Figure 1 shows a plan view of a typical dam & pump stream crossing. The primary components of a dam & pump crossing include:

- sandbag/plastic dams or other functional designs (e.g., metal plates, water bladders, etc.);
- spoil storage and staging areas;
- pumps and pump containment structure (s);
- dewater structure(s);
- erosion control structures; and
- spill containment and cleanup materials.

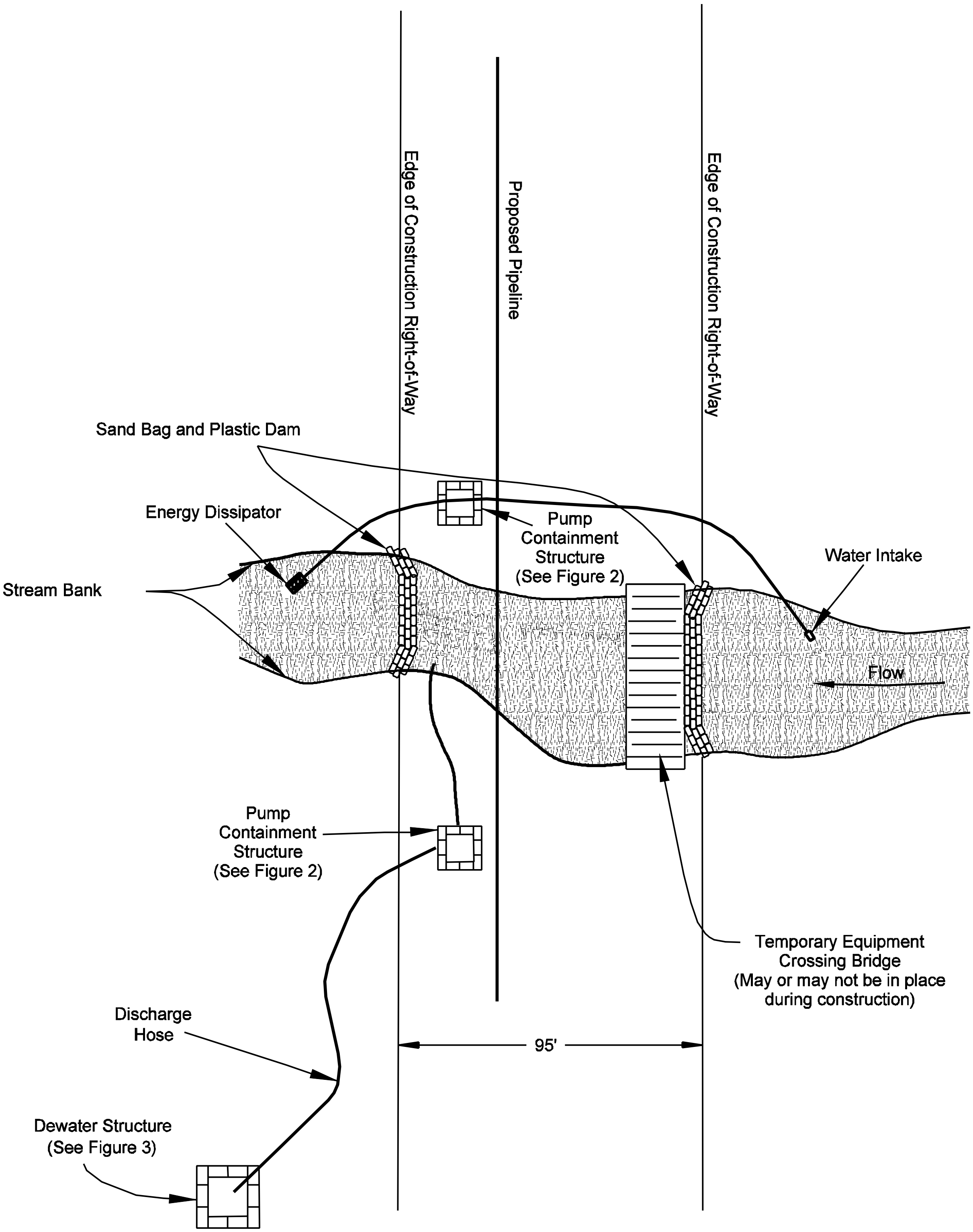


FIGURE 1
PLAN VIEW OF TYPICAL DAM & PUMP STREAM CROSSING

The sandbag/plastic dams (or other functional designs such as metal plates or water bladders) are used to isolate the stream flow from the area of construction. A single pump or multiple pumps are used to temporarily convey the stream flow around the construction area, thereby reducing the introduction of sediments into the water column during ditching and backfilling. These structures are also utilized to prevent downstream water from flowing upstream into the construction area. They also serve to contain water that infiltrates into the construction area before it can be removed by pumps and discharged to an upland area. Finally, the downstream structure serves to contain turbid water, which rises quickly in the construction area during backfilling of the trench.

All waterbodies with water in the streambed at the time of construction must have an equipment crossing bridge.

The temporary spoil storage area is where spoil trenched from the streambed will be stored until backfilling is completed. These temporary extra work areas are identified on the Environmental Alignment Sheets. FERC's Wetland and Waterbody Procedures prohibit the location of staging areas or additional right-of-way within 50 feet of the stream banks or edge of adjacent wetlands unless site-specific conditions such as topography prevent the setback and a variance is approved. Trench spoil must be placed at least 10 feet away from stream banks at all flowing stream crossings. In addition, these areas must be enclosed with silt fence and/or straw bales to prevent runoff of the spoil into the stream.

Adequate pumps are essential for the successful completion of dam & pump stream crossings. During several phases of the crossing process, it will be necessary to quickly remove large quantities of water from the construction area to prevent overflow or leakage of the sandbag/plastic dams. In order to quickly and effectively remove water from the construction area, well-maintained pumps with adequate pumping rates must be utilized. In addition, backup pumps will be located on-site, hooked up and maintained as fully operational during the entire crossing process. Backup pumps will be tested prior to the start of construction. Pumps will be located in a spill containment structure that is designed to fully contain any spills of fuel or oil (see Figure 2).

Dewater structures (see Figure 3) will be utilized to reduce the velocity of pump discharge water and subsequent erosion of upland areas. These structures are essential in preventing erosion and the flow of turbid water overland and back into the stream - such overflow defeats the purpose of the dam & pump crossing by introducing turbid water into the stream.

Runoff control structures are utilized to prevent runoff from the spoil piles or from drainage of water from the trackhoe bucket from flowing around the sandbag/plastic dams or temporary equipment crossing bridges and adding sediment to the stream. Containment and control materials are necessary to respond to any spills of fuel or lubricating oils from operating equipment. A Spill Prevention, Containment, and Countermeasures (SPCC) Plan will be implemented by the contractor in accordance with the provisions of that plan. Erosion control structures address the prevention of runoff from the right-of-way into the stream during and after construction is complete.

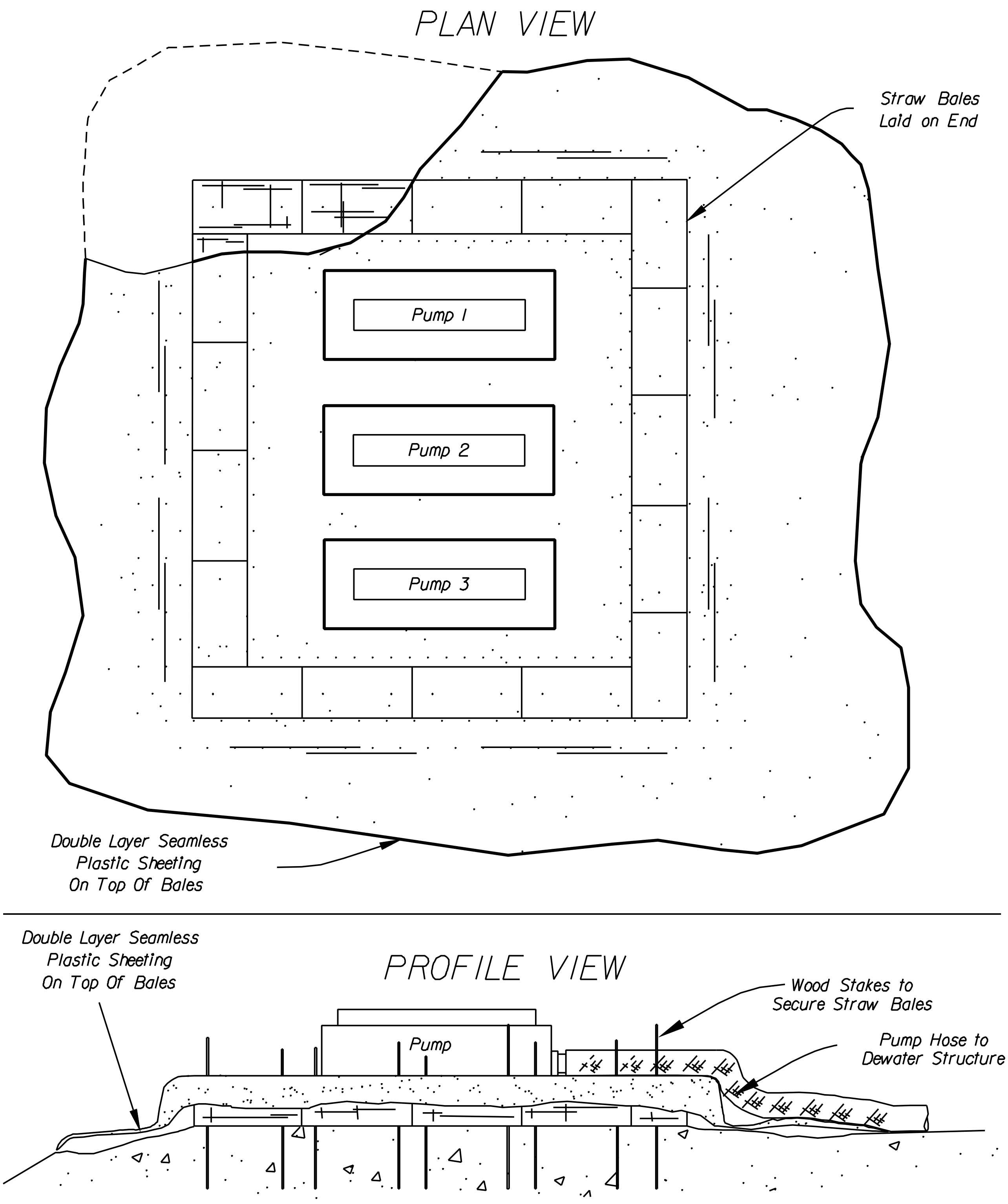


FIGURE 2
TYPICAL PUMP CONTAINMENT STRUCTURE

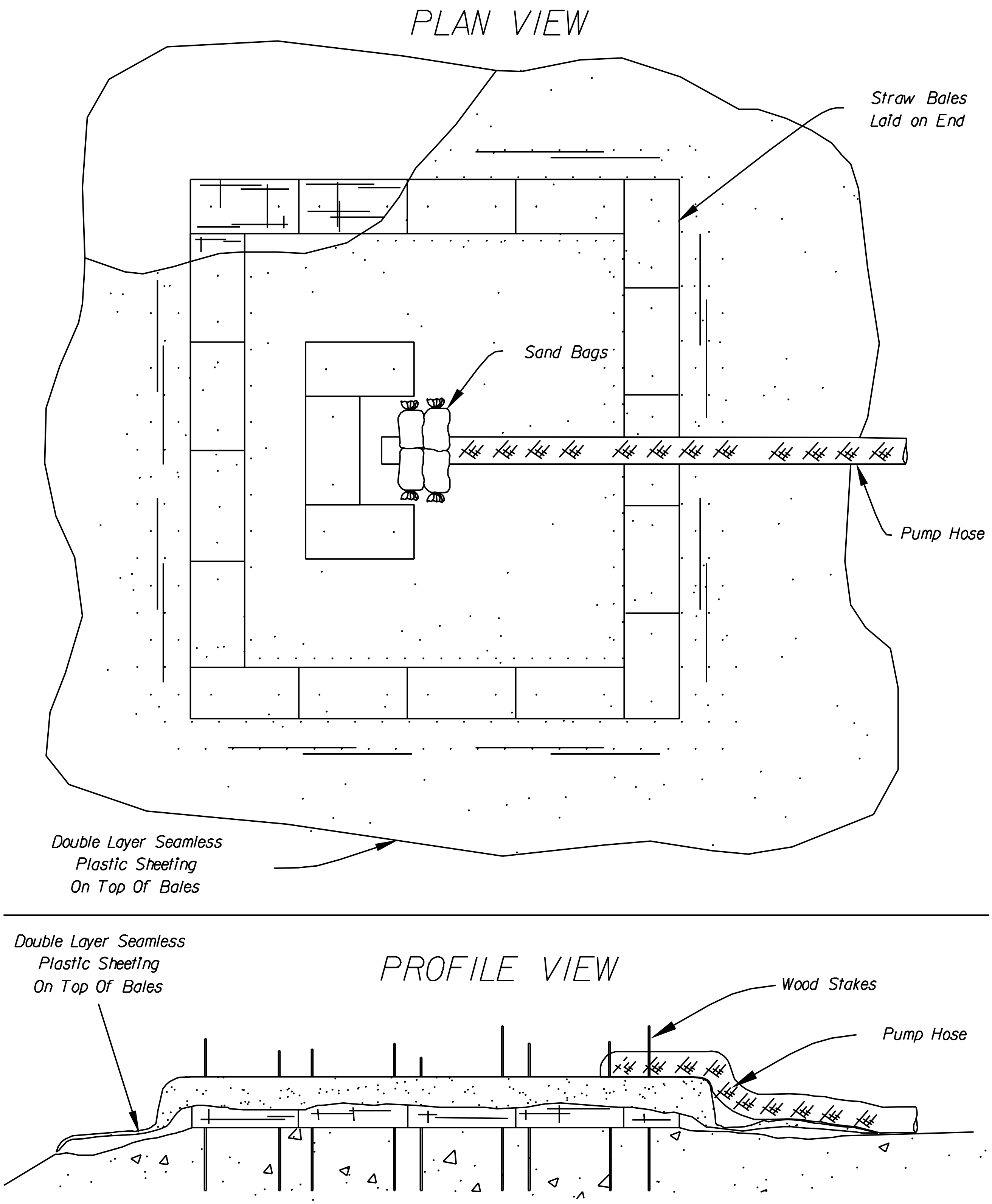


FIGURE 3
TYPICAL DEWATER STRUCTURE

4.0 Materials Required to Install and Maintain a Dam & Pump Stream Crossing

The materials discussed below will accommodate most stream crossings. However, certain situations will arise where additional materials are required. Those streams that require additional materials are site specific and will be addressed on a case-by-case basis.

Sandbags will be filled with a non-leachable material such as clean, pre-washed sand. Sandbags are most effective if they are only filled to approximately 2/3 their capacity. Bags filled to capacity conform poorly to the adjacent bags and make creation of a seal more difficult. The bags must be tied securely before they are installed. If the bags are left un-tied, they tend to spill upon removal from the streambed and are nearly impossible to remove with a trackhoe. It is preferable to utilize burlap sandbags to construct the upstream and downstream dams. Plastic bags tend to rip when removed from the stream and are often too porous to adequately contain small grain sand.

Sandbags alone may not completely seal the upstream and downstream ends of the construction area. The dams are typically more effective when sheets of thick plastic are interwoven within the sandbags (see Figures 4 and 5). The plastic, when applied as shown on Figure 4, will effectively seal the dams and will greatly reduce the amount of water leaking into the construction area from behind the upstream and downstream sandbag dams.

5.0 Installation of the Dams

Short-term elevated levels of turbidity are expected to occur during installation of the dams. However, several measures can be taken to minimize the increased turbidity. Before the contractor attempts to install the dams, all materials necessary to complete the installation process will be located on-site. Installation of the dams cannot begin until all of the precautions outlined in the SPCC Plan have been undertaken. Turbidity sampling will be conducted during all dam & pump crossings in accordance with the Stormwater Pollution Prevention Plan.

Installing the Sandbag/Plastic Dams

The first step in installing the dams is to clear away any large rocks and boulders from the sandbag/plastic dam area that may affect the integrity of the sandbag/plastic dams. It may be necessary to utilize a trackhoe to assist in removing these rocks. However, the bucket will not dig into the streambed to remove rocks. Rather, the edge of the bucket will be utilized to roll the rocks to the side or a thumb on the bucket will be used to pick up and move rock obstacles.

The sandbags may be laid on top of the plastic sheeting that will be used to help seal the sandbag dam. The plastic will be laid such that when it is wrapped around the sandbag dam, the plastic sheeting lays on the upstream face of the dam so that water pressure holds the plastic firmly against the sandbag dam face. The sandbags will be properly seated over the plastic and onto the stream bottom and packed as tightly together as possible.

Sandbags will be installed upstream and downstream and interwoven with plastic sheeting to form a tight seal. Typically, the sandbag/plastic dams will extend at least three feet above the water level of the stream to accommodate increased stream discharge during the crossing period (see Figures 4 and 5).

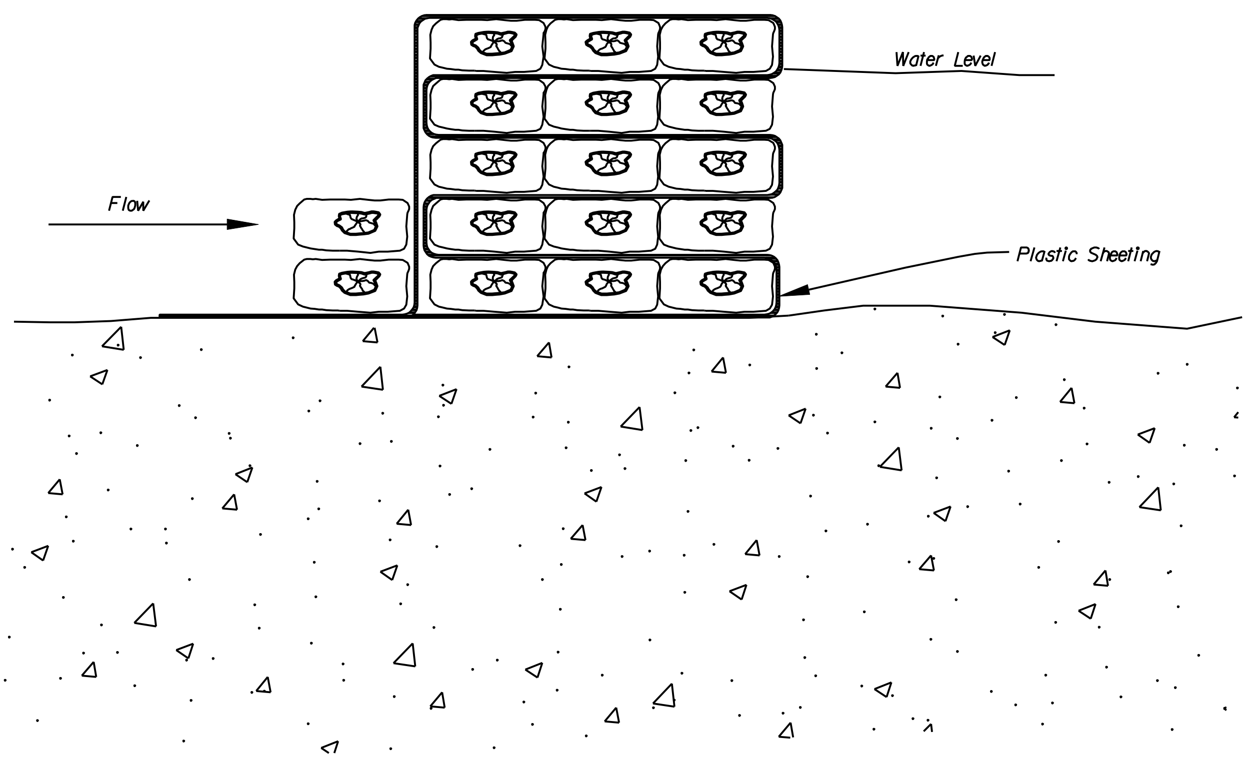


FIGURE 4
PLASTIC SHEETING INTERWOVEN INTO A SAND BAG DAM

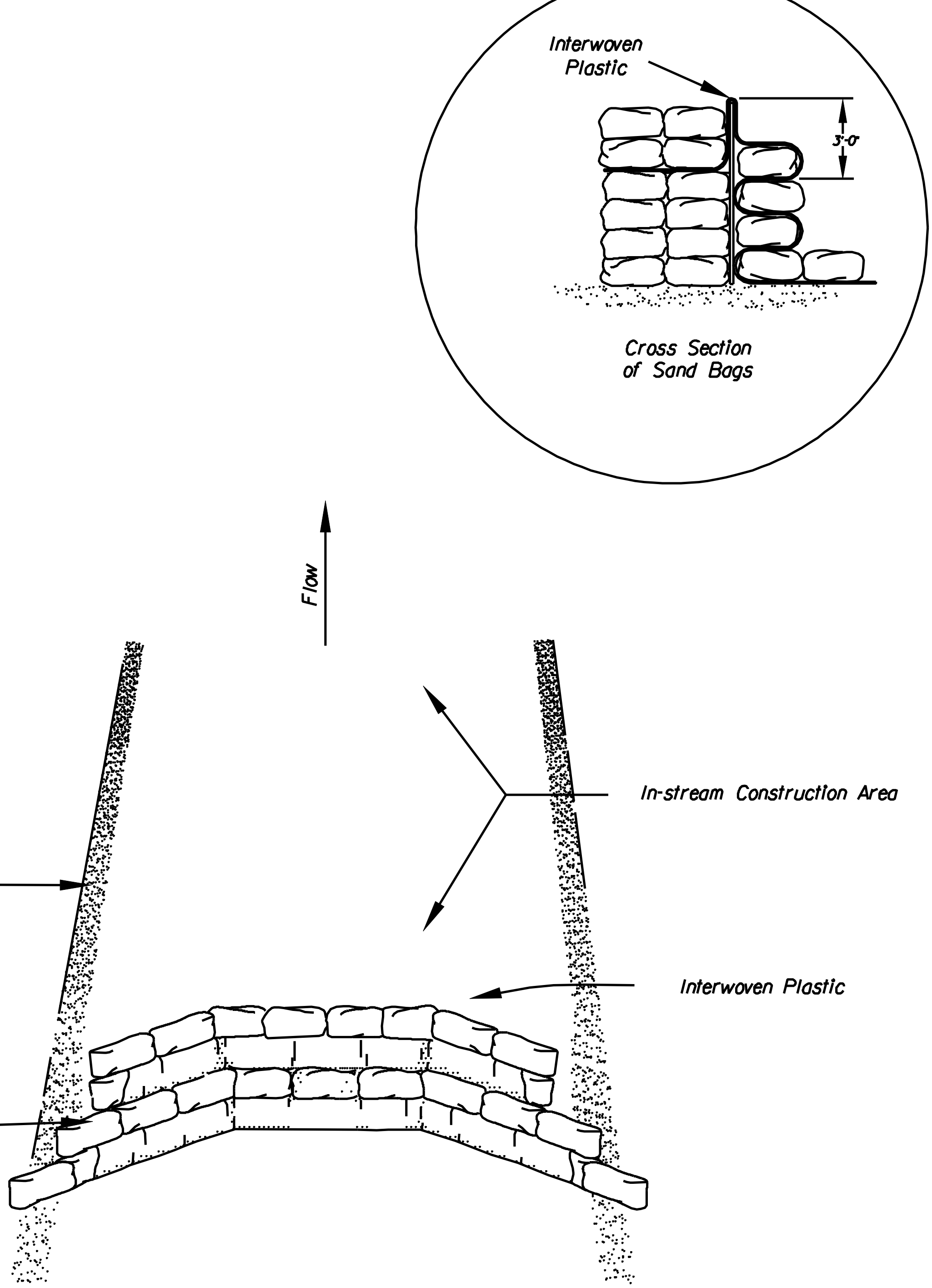


FIGURE 5
SAND BAG AND PLASTIC DAM

While the upstream dam is being installed a properly sized pump(s) will be operating to move stream flow around the dam to prevent stream erosion or bank scour. After the upstream sandbag/plastic dam is complete, the contractor will immediately begin installation of the downstream dam. The pump(s) will continue operating to divert stream flow around the dams throughout installation of the dams and completion of the crossing. The downstream sandbag/plastic dam will be constructed to a height at least three feet above the downstream water level.

6.0 Maintenance of the Dams and Pumps During Construction

Dam & pump crossings may require constant monitoring and occasional repair during the crossing process. The longer the dams remain in the water, the greater the probability they will begin to leak and that water will invade the construction area in potentially significant quantities. Therefore, it is imperative that once trenching within the stream begins that the construction process is carried to completion non-stop. Typically, this involves installing the dams on the day immediately preceding construction of the crossing. Ditching of the stream channel should begin early the following morning and the pipe pulled immediately following completion of the trench. Backfilling should commence immediately following the stringing of the drag section. Most stream crossings typically require approximately 7 - 14 days to install the dams, dig the trench, install the pipe drag section, backfill the trench and restore and stabilize the stream banks depending on site conditions. Smaller streams (less than 10 feet in width) generally require less time to cross using dam & pump procedures.

While the dams are in place, the contractor will provide a sufficient crew that will be responsible for maintaining the dam & pump crossing. That crew will apply additional plastic to the dams and add additional sandbags as necessary. In addition, this crew will be responsible for operating, maintaining and fueling the pumps and maintaining the discharge structures. When the crossing is complete, this crew will immediately install the erosion control structures pursuant to FERC's Wetland and Waterbody Procedures.

To be adequately prepared to repair the dams, the contractor will have on-site rolls of thick plastic sheeting and extra filled and tied sandbags. These materials will be stored directly adjacent to the stream crossing so that they are readily accessible should the need to repair the dams arise.

7.0 Length of the Drag Section

One of the biggest problems encountered during construction of dam & pump stream crossings is the installation of extremely long drag sections across the stream in a single drag section. The extra length requires that the dams be in place longer than necessary which increases the probability of serious problems with the integrity of the sandbag/plastic dams. In addition, the extra time required to dig additional ditch to accommodate long drag sections can result in integrity problems with the sandbag/plastic dams.

Segments must be kept short and extend only the distance necessary to allow for later tie-in to the upland portions of the pipeline. On most streams the drag section should only be long enough to incorporate the sag bends. In other locations, it may be necessary to install additional pipe to complete the crossing.

The entire drag section must be made up prior to the start of in-stream trenching. Once the drag section is complete (welds x-rayed and joints coated), the drag section can be installed immediately following trenching.

8.0 Spoil Storage During Trenching

Spoil must be stored in a manner such that runoff from the spoil does not flow into the stream or off the right-of-way. For streams in flat topography, runoff from the spoil storage pile is not typically a problem. However, on steep sloping stream banks water can run back down the right-of-way and enter the stream upstream or downstream of the dams creating a serious water quality problem. The problem can be compounded as the trackhoes working on the stream banks lift water saturated spoil from the stream and lay it on the right-of-way adjacent to the stream bank before it can be conveyed uphill by additional equipment. To accomplish runoff control during trenching, diversion structures or trenches will be dug within the right-of-way to direct the runoff back into the construction area as shown on Figure 6.

9.0 Spoil Transfer During Construction

Some of the stream crossings may occur adjacent to steep upland areas. In these cases, it will be necessary to utilize additional equipment (trackhoes, dozers, loaders) to transfer spoil by the trackhoes at each stream bank to the temporary spoil storage area.

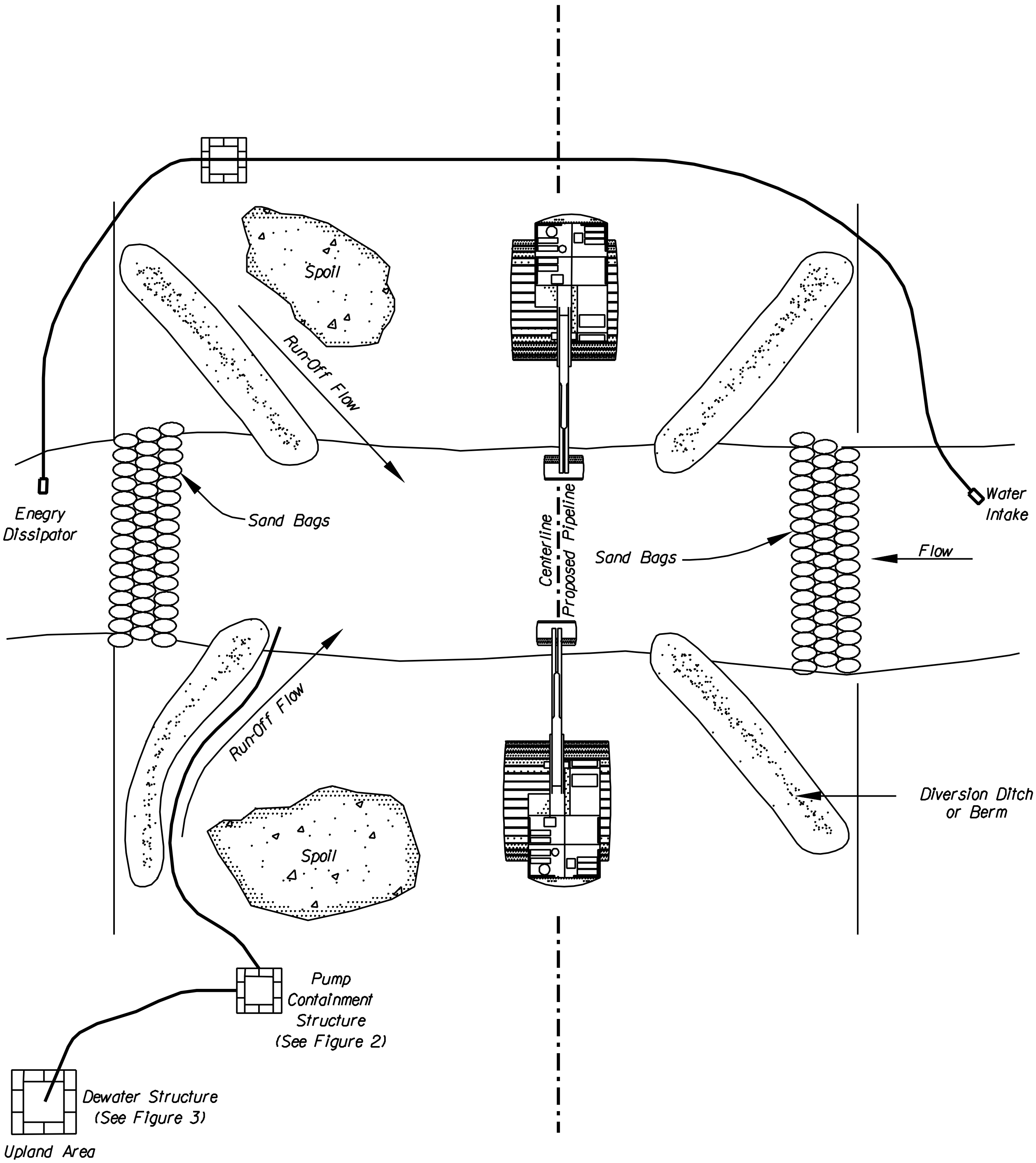
In most cases, the contractor will utilize dozers to push the spoil to the temporary storage area. In other areas, trackhoes will be required to transfer spoil dug by the trackhoe working on the stream bank uphill to a flatter area where it can be moved by dozers. Where two trackhoes are utilized to transfer spoil uphill, it is often desirable to have the trackhoe working on the stream bank place the spoil into a pit (see Figure 7). The spoil from the pit is then picked up by the second trackhoe and lifted further uphill. The pit will significantly reduce the amount of water from the spoil that runs downhill. The pit can be maintained and dug by the trackhoe working uphill from the crossing.

10.0 Installing the Pipe

While trenching is being conducted, the contractor will hook up the drag section to the sideboom tractors so that the pipe may be installed as soon as trenching is completed. It will be necessary at many crossings to float the pipe across the trench (i.e., it may not be feasible to completely dewater the ditch). While the drag section is being lowered into the trench, it is essential that pumps be operated to assure that turbid water does not leak through or flow over the dams. The contractor will operate the pumps at a rate so that water displaced by the pipe is immediately removed and discharged to the dewater site.

11.0 Dewatering the Construction Area

Proper operation of pumps to dewater the construction area is essential to the successful completion of a dam & pump stream crossing. Pumps will be utilized by the contractor as necessary to control the level of water in the construction area. The purpose of the pumps is not to completely dewater the trench.



NOTE:

Temporary Bridge may or may not be in place during trenching operations.

FIGURE 6
DIVERSION DITCH OR BERMS

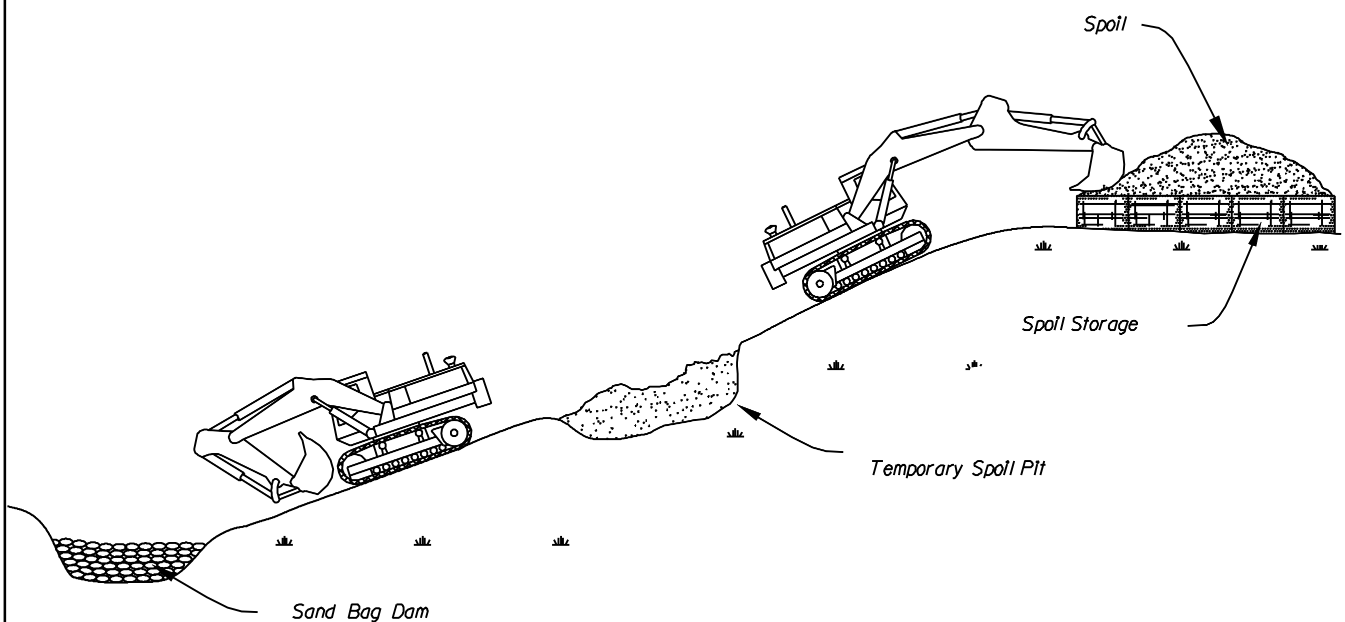


FIGURE 7
UPHILL SPOIL TRANSFER

If the water level in the construction area exceeds the upstream or downstream level of the dams, environmental inspectors will notice small amounts of turbid water escaping into the stream either upstream or downstream of the dams. This is known as "bleeding" and the problem can be quickly resolved by increasing the pumping rate and reducing the water level within the construction area. Although bleeding will not typically result in a violation of water quality standards downstream, if left unchecked it can quickly result in erosion of the dams and serious downstream water quality problems.

The contractor will utilize pumps at each crossing to control the water level in the construction area. The contractor will also install backup pumps that will be tested and fully functional prior to the start of the crossing process. Pumps will be installed and tested and the dewater sites constructed the day prior to any in-stream construction. For most crossings, the contractor will setup three pumps. Additional pumps may be required at a few of the stream crossings. Two of the pumps will serve to remove water from the construction area and the third pump will serve as a backup should one of the primary pumps fail.

The pumps will be set in a containment area as shown on Figure 2. The primary purpose of the containment area is to fully contain any fuel or lubricating oil spills. If hydraulic pumps are used, the hose couplings on the side of the pump body will be oriented in the containment area such that they point perpendicularly away from the stream banks. The purpose of orienting the couplings away from the stream is to protect the stream should one of these couples fail and hydraulic fluid escape.

The contractor will carefully inspect each pump prior to its delivery to the crossing site. In particular, any frayed hoses or apparent leaks will be repaired before the pumps are delivered to the crossing site. Pump heads and the hoses will be cleaned of any free hydraulic oil prior to placing the pump heads into the stream.

All pumps will be installed with individual intake hoses or hydraulic heads, trash filters and discharge hoses. All hydraulic heads will remain in the water during the entire construction process including backfill. In this manner, the backup pump can be immediately employed should one of the primary pumps fail.

Each of the pumps (including the backup pump) will be equipped with a minimum of 300 feet of discharge hose. It is important to stretch the hose on the backup pump and install a dewater structure for that pump at the same time the primary pumps are installed. Hoses should be free of leaks and in good operating condition.

In many cases, it is difficult to locate dewater sites where water will flow away from wetlands or streams. In these cases, careful attention will be paid to the dewater sites and alternative sites (which require additional discharge hose) selected prior to the start of in-stream construction. Often it is necessary to move the location of the dewater site several times during construction of the stream crossing to avoid dewater from reaching sensitive areas.

Dewater structures will be constructed of straw bales and plastic and wooden stakes as shown on Figure 3. The intent of the design provided on Figure 3 is to allow the water to fill the dewater structure and flow evenly over the tops of the bales. Straw bales will be securely staked to the ground utilizing wooden stakes. Alternative structures are also provided in the Erosion Control and Revegetation Plan.

12.0 Backfilling the Ditch

The highest potential for water quality problems during a dam & pump crossing is during backfilling of the ditch. Quick backfilling into the ditch by the contractor can cause the water level in the construction area to overflow or leak through the downstream dam. Pumps must be carefully managed during backfilling to control the water level in the construction area. The contractor must carefully monitor the effectiveness of the pumps and control the rate of backfill to preclude bleeding through the downstream dam. If backfilling occurs too quickly, the pumps will not be capable of removing the water from the construction area quick enough to prevent the escape of turbid water.

To prevent turbidity, backfilling of the ditch will be conducted in a slow, well-planned manner. Backfilling will begin in the center of the stream and proceed toward each bank simultaneously. In this manner, much of the water in the ditch will be pushed to the ditch outside of the stream channel. If upland portions of the trench are backfilled first, the water in the ditch is pushed into the stream channel and will inevitably leak through or overflow the downstream dam.

Once backfilling of the entire stream channel is complete, the contractor will compact the streambed and construct solid plugs on both banks. Water will remain trapped in the ditch outside of the stream channel. This water will be pumped from the ditch at a later time in the manner described for dewatering the construction area (see Section 11).

13.0 Removal of Dams

After the ditch is backfilled, clean gravel fill will be placed on the top one foot of the ditch (where necessary). Plugs will be installed at each stream bank and the stream banks stabilized and the dams will be removed from the crossing. To prevent excessive increases in turbidity during dam removal, the contractor will remove all of the sandbags from the downstream dam. A trackhoe can be utilized to remove the top layers of the sandbags as long as the operator takes great care not to dig into the streambed or to increase turbidity.

After the downstream sandbags are completely removed from the streambed, the contractor will begin removing the sandbags from the upstream dam. The top rows of sandbags should be removed by hand until the water begins to overflow the top of the dam and flows slowly over the construction area. For the first 10 to 30 minutes, turbidity downstream of the crossing area could increase considerably. However, the streambed portion of the construction area will be flushed clean of sediments left over from construction and the water will flow clear over the disturbed stream bed area. After the turbidity level has decreased to acceptable levels or that of upstream levels, the contractor can proceed with removing the remainder of the upstream dam sandbags.

Appendix 3
HDD Plans – CZMA

Coos Bay West HDD Feasibility Evaluation
Coos Bay East HDD Feasibility Evaluation
Coos River HDD Design
MP 25 HDD Design

GeoEngineers
1200 NW Naito Pkwy., Ste. 180
Portland, Oregon 97209
503.624.9274

September 14, 2017

Pacific Connector Gas Pipeline, LP
5615 Kirby Drive, Suite 500
Houston, Texas 77004

Attention: John Walls

Subject: HDD Feasibility Evaluation
Coos Bay West Crossing
Pacific Connector Gas Pipeline Project
Coos County, Oregon
File No. 22708-001-01

INTRODUCTION AND PROJECT UNDERSTANDING

GeoEngineers, Inc. (GeoEngineers) is pleased to present this horizontal directional drilling (HDD) feasibility evaluation for the proposed 36-inch-diameter pipeline installation beneath Coos Bay in Coos Bay, Oregon. The proposed Coos Bay West HDD crossing will be a part of the 229-mile-long Pacific Connector Gas Pipeline (PCGP), beginning at the proposed Jordan Cove Liquefied Natural Gas (LNG) Terminal near Coos Bay, Oregon and terminating near Malin, Oregon. The site is shown with respect to the surrounding area in the Vicinity Map, Figure 1.

Our feasibility evaluation of the proposed Coos Bay West HDD is based on limited subsurface data. Our conclusions should be considered preliminary pending completion of a subsurface exploration program. Table 1 below provides our understanding of the design basis for the proposed HDD.

TABLE 1. BASIS OF DESIGN FOR THE COOS BAY HDD

Product Pipe Data	Design Parameter
Product Pipe Specifications	36 inches x 0.823 inches w.t.[a] API-5L X-70 Steel Pipe
Approximate Horizontal Crossing Length	5,192 feet
Maximum Allowable Operating Pressure	1,600 psig[b]
Maximum Operating Temperature	100 degrees F

Product Pipe Data	Design Parameter
Tie-In Temperature	70 degrees F
Design Factor[c]	0.5

Notes:

[a] w.t. – wall thickness

[b] psig – pounds per square inch gauge

[c] as defined in 49 CFR Parts 195.106 and 192.111

PURPOSE AND SCOPE OF SERVICES

The purpose of our services was to utilize existing subsurface and site survey information in order to evaluate the feasibility of the proposed HDD installation. Our specific scope of services included the following:

1. Reviewed geologic maps and boring logs of previously completed borings in the project area to evaluate geologic conditions along the HDD alignment.
2. Evaluated the feasibility of the proposed HDD from the workspace considerations, subsurface considerations and geometric feasibility standpoints.
3. Prepared a conceptual HDD plan and profile drawing.
4. Prepared this HDD feasibility report summarizing HDD feasibility and construction considerations.

SURFACE CONDITIONS

The Coos Bay West HDD extends from the North Spit at Milepost 0.0 of the proposed pipeline and extends a distance of approximately 5,192 feet to the southeast, crossing the Coos Bay navigation channel and terminating at North Point in North Bend, Oregon as shown in the Site Plan and Profile, Figure 2A. Surface conditions at both ends of the Coos Bay West HDD consist of a relatively flat ground surface vegetated with sparse grass. The conceptual HDD alignment crosses a railroad trestle bridge within Coos Bay.

SUBSURFACE SOIL AND GROUNDWATER CONDITIONS

Site Geology

Published geologic mapping shows that the shallow subsurface conditions along the HDD alignment is dominated by young alluvium. Alluvium is described as "…variable amounts of clay, silt, sand, and gravel."

Sedimentary bedrock of the Eocene-age Coaledo Formation is mapped by Baldwin et al. (1973) as underlying the uplands surrounding Coos Bay. Baldwin et al. (1973) notes that "(t)he Coaledo Formation occupies a north-plunging basin surrounding Coos Bay," implying that the Coaledo forms the bedrock within Coos Bay and is likely underlying the surficial alluvium.

The most detailed structural geology of the Coaledo Formation in north Coos Bay (Duncan 1953) includes an east-west cross section through Coos Bay, 1 mile north of the HDD alignment. It shows the upper contact of the Coaledo Formation beneath Coos Bay as an irregular basin deepening to the west to as much as

- 300 feet mean sea level (MSL). The top of the sedimentary rock is shown rising to approximately -150 feet MSL in the eastern half of Coos Bay.

SUBSURFACE EXPLORATIONS

GeoEngineers has completed a number of exploratory borings in Coos Bay to investigate various PCGP pipeline alignments. Two exploratory borings have been completed in the vicinity of the Coos Bay West HDD. Boring HIB-2 was completed at the south end of North Spit, approximately 265 feet southwest of the proposed exit point. Boring WCB-1 was completed within Coos Bay, approximately 1,037 feet northeast of the alignment. The boring locations are shown relative to the HDD alignment in Figure 2A. The boring logs of HIB-2 and WCB-3 are presented in Figures 3 and 4, respectively.

Boring HIB-2 encountered loose sand to a depth of 30 feet, where the sand grades to dense to a depth of 35 feet. Below 35 feet, very dense sand was observed to a depth of 90 feet, the maximum depth explored. Boring WCB-1 encountered very loose to loose fine sand with silt to a depth of 25 feet, where loose fine sand (no silt) was observed to 35 feet. At a depth of 35 feet, the sand grades to medium dense consistency and becomes very dense at a depth of 40 feet to 51.5 feet, the maximum depth explored.

HDD PLAN AND PROFILE

We developed a conceptual HDD Plan and Profile of the Coos Bay West HDD as shown in Figure 2A. The conceptual Coos Bay West HDD has a horizontal design length of approximately 5,192 feet. It is likely that the HDD will be completed using pilot hole intersect methods, but for discussion purposes we are referring to the southeast end of the Coos Bay West HDD as the entry point because the proposed pipe stringing and fabrication area is at the northwest end of the HDD. The conceptual entry point is located about 600 feet west of Highway 101, within a relatively flat area covered with sparse grass.

The conceptual exit point is located within a relatively flat area vegetated with sparse grass at the southern end of North Spit. We chose relatively steep entry and exit angles at 12 degrees, and 10 degrees respectively, in order to reach the dense sand layer as quickly as possible. The bottom tangent was placed at an elevation of -180 feet, with the assumption that the bottom tangent and horizontal curve will be within bedrock at that depth. Based on this HDD geometry, the conceptual HDD profile passes approximately 158 feet below the railroad trestle bridge and approximately 138 feet below the deepest part of the navigation channel. The depth and the locations of the railroad trestle foundations are unknown at this time. Although, we anticipate that the foundations are unlikely to conflict with the conceptual HDD alignment at its depth of 138 feet at the crossing location, this will need to be confirmed prior to final design.

HDD FEASIBILITY CONCLUSIONS

Based on our evaluation, it is our opinion that the proposed Coos Bay West HDD is technically feasible, pending the results of the subsurface exploration program and provided the considerations in this report are addressed in the design, preconstruction and construction phases of the project. The following section provides a discussion of considerations for design and construction based on the existing limited subsurface data. The existing boring logs extend to a maximum depth of 91.5 feet below ground surface.

Additional borings are planned to be completed within Coos Bay to 20 feet below the planned bottom tangent elevation, or an approximate depth of 200 feet below the mudline.

Hole Stability

The subsurface conditions anticipated along the conceptual HDD path includes loose sand to depths of about 30 feet along the entry and exit tangents, and dense sand to sandstone bedrock along the remaining portions of the HDD path. The HDD contractor may encounter hole instability and/or steering difficulty through the portions of the entry and exit tangents within the loose sand. Installation of casing at entry can serve to maintain drill hole stability and provide a reaction mass for allowing a greater transfer of axial loads through the drill pipe string to the drill bit during pilot hole drilling. In addition, the installation of casing will reduce the risk of drilling fluid surface release to the ground surface near the entry point. If casing is utilized, upon completion of the pilot hole or prior to reaming the cased section of the hole, the casing is typically removed, but could remain in place through product pipe pullback to maintain drill hole stability within the entry tangent. The specific casing diameter and installation would be determined by the HDD installation contractor.

Hydraulic Fracture and Inadvertent Returns

Drilling fluid loss can occur as a result of either formational fluid loss or hydraulic fracture. The loss of drilling fluid downhole is accompanied by either partial or full loss of drilling fluid returns to the entry and/or exit pits.

Formational drilling fluid losses typically occur when the drilling fluid flows through the pore spaces in the surrounding formation. Thus, a formation with a higher porosity can potentially absorb a larger volume of drilling fluid than a formation with a lower porosity. Coarse sands and gravel units with low percentages of silt and clay and fractured rock formations have a moderate to high susceptibility for drilling fluid loss. The fine to medium sand anticipated along the HDD path will have a low to moderate potential for formational fluid loss.

Hydraulic fracture is a term typically used to describe the condition in which the downhole drilling fluid pressure exceeds the overburden pressure and shear strength of the formation surrounding a drill path. The risk of hydraulically fracturing subsurface formations during the HDD process generally depends on the type and shear strength of the formation and the downhole drilling fluid pressures. Drilling fluid pressures used for HDD construction are not typically high enough to cause hydraulic fracture of intact bedrock because the shear strength of the rock far exceeds the drilling fluid pressures downhole. Downhole drilling fluid pressures can easily exceed the shear strength of soil formations. In general, fine-grained soils such as silt and clays have a relatively moderate to high risk of hydraulic fracture, whereas granular soils such as sands have a relatively low risk of hydraulic fracture. In general, we expect that there is a relatively low risk of hydraulic fracture occurring during HDD installation because much of the HDD profile passes through sandy soils and potentially bedrock; however, this estimate of risk is contingent on the HDD contractor maintaining drilling fluid returns during all phases of drilling activities.

We anticipate a relatively low risk of hydraulic fracture and drilling fluid surface releases occurring along most of the HDD alignment during construction. We expect that there is a high risk of hydraulic fracture and drilling fluid surface release within about 150 feet of either end of the HDD due to the anticipated loose sand and decreased depth of cover. As previously indicated, installation of large diameter conductor casing will reduce the risk of drilling fluid surface releases near entry.

Workspace Considerations

The locations for both the northwest (exit) and southeast (entry) workspaces are relatively flat and open such that adequate workspace will be available for drilling and installation operations. Grading will not be required to prepare entry and exit workspaces in these areas. Because of the loose sandy soils, it may be necessary to provide a stable working platform such as a timber matted or gravel workspace and an entrance road during construction, particularly if construction is completed during the wet winter season, or when heavy prolonged precipitation occurs. In addition, construction roads will be required to access the entry and exit points and the product pipe stringing area.

CONCLUSIONS

The following summarizes the primary considerations for the Coos Bay West HDD.

1. Additional subsurface exploration and laboratory testing is required to confirm the construction considerations and feasibility conclusions presented in this report, and to provide subsurface information required for final design of the conceptual HDD. Proposed boring locations and depths are shown in Figure 2A.
2. The railroad trestle foundation data will need to be obtained and considered for the HDD design.
3. Due to the substantial length of the HDD, we anticipate that it will be completed using pilot hole intersect methods.
4. It will be necessary to design the HDD to maximize the amount of drill path within bedrock.
5. Oversized casing may need to be installed at both ends of the HDD path to assist in efficiently transferring axial loads to the drill bit, and to mitigate against hydraulic fracture and drilling fluid surface releases within the loose sand anticipated in the upper 30 feet.

LIMITATIONS

We have prepared this report for use by PCGP and the design team, their authorized agents and other approved members of the design team involved with this project. The report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. The conclusions and recommendations in this report should be applied in their entirety.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. The conclusions, recommendations, and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, express or implied, should be understood.

REFERENCES

Baldwin, E.M., et al. 1973. Geology and Mineral Resources of Coos County, Oregon. Department of Geology and Mineral Industries, Bulletin 80.

Bourgoyne, A.T., et al. 1991. "Applied Drilling Engineering," Society of Petroleum Engineers.

Duncan, D.C. 1953. U.S. Geological Survey Bulletin 982-B, Geology and Coal Deposits in Part of the Coos Bay Coal Field, Coos Bay, Oregon.

Pipeline Research Committee International (PRCI) of the American Gas Association. April 15, 1995. "Installation of Pipelines by Horizontal Directional Drilling, An Engineering Design Guide," Contract No. PR-227-9424.

CLOSING

We appreciate the opportunity to provide services to PCGP. Please call if you have any questions concerning this report or if we can be of further assistance.

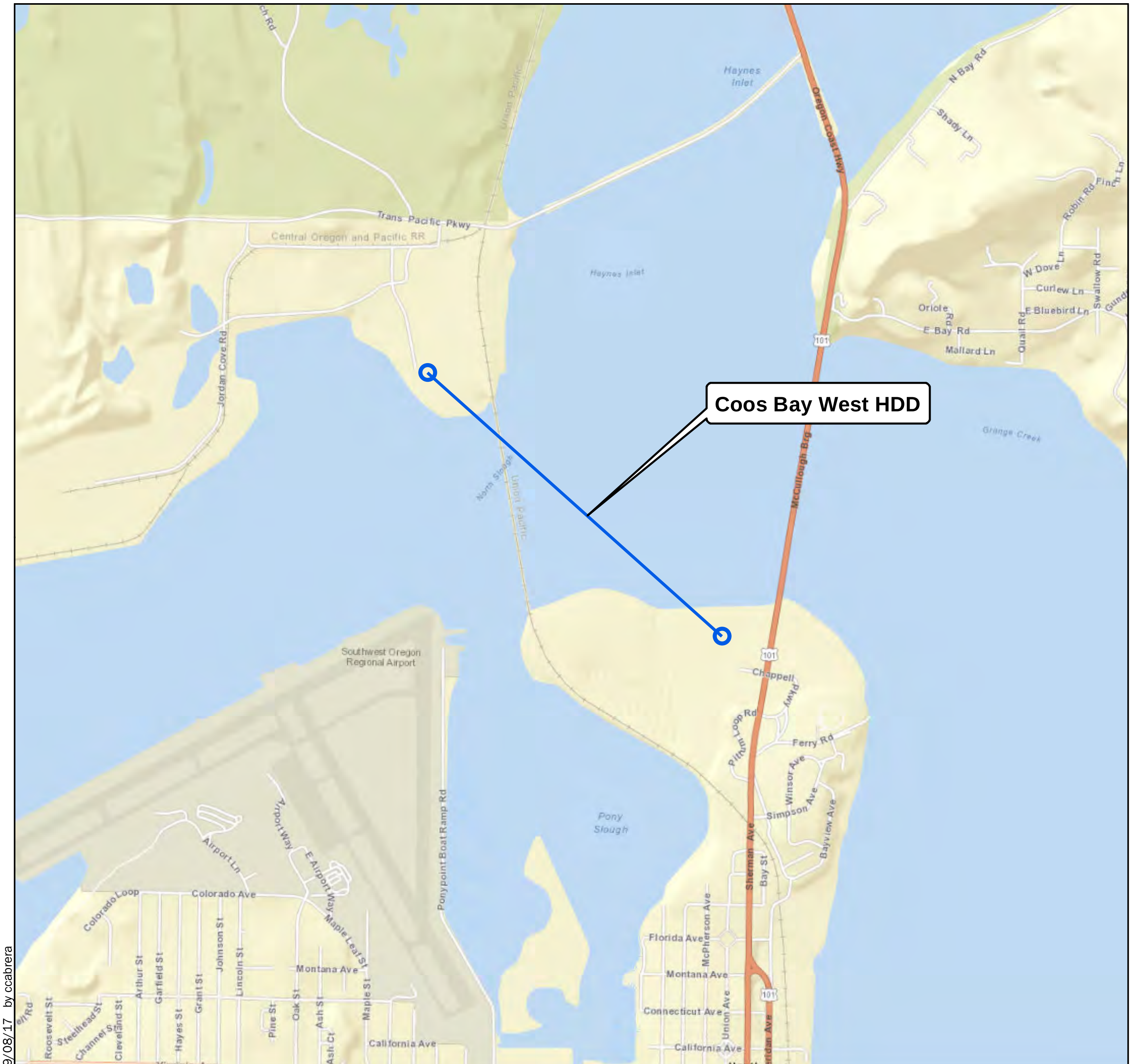
Sincerely,
GeoEngineers, Inc.

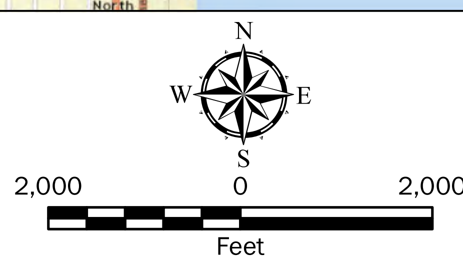
Brian Ranney
Senior Engineering Geologist

Trevor N. Hoyles, PE
Principal

BCR:TNH:cje

List of Figures:





Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Mapbox Open Street Map, 2017

Projection: NAD 1983 UTM Zone 10N

Vicinity Map

COOS BAY WEST HDD
COOS COUNTY, OREGON

GEOENGINEERS

Figure 1

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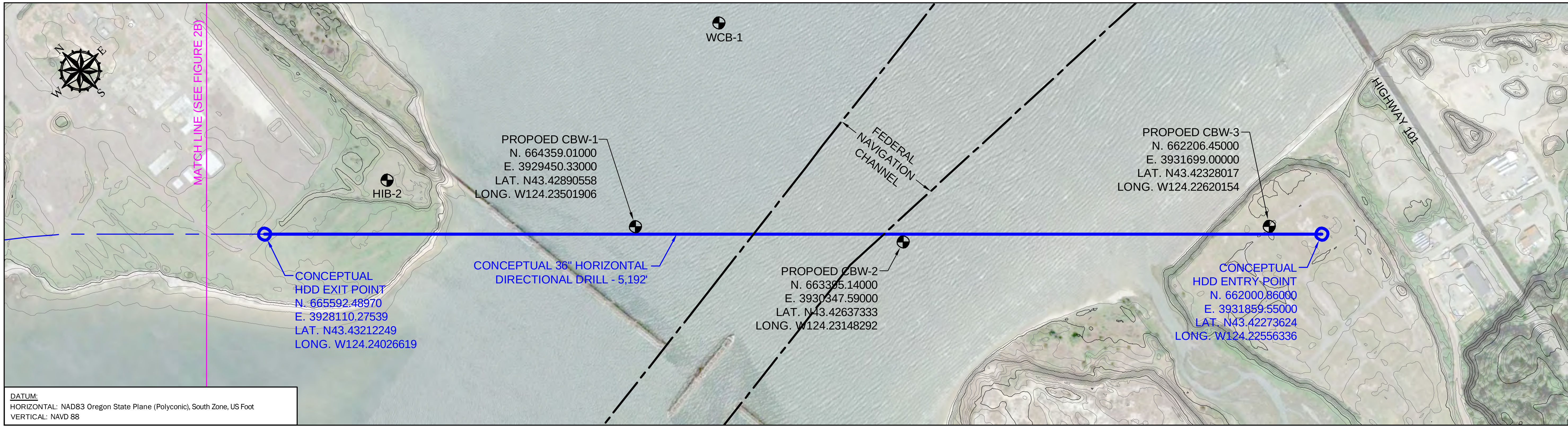
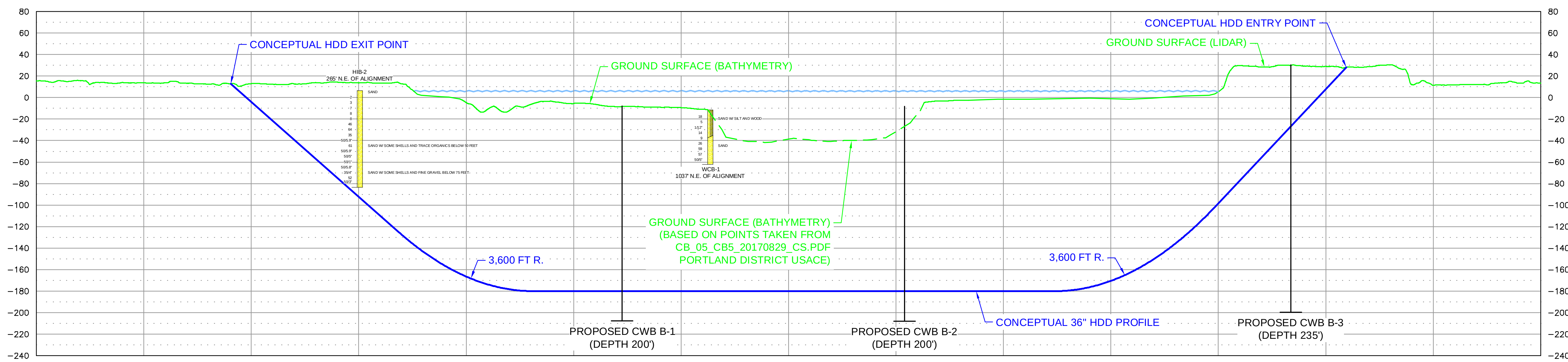
TNH : RBM





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Reference: Ground surface Lidar downloaded from http://www.oregongeology.org/dogamilidarviewer/. Aerial image taken From Google Earth Pro © 2016, licensed to GeoEngineers, Inc., image dated 01/15/16.
Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

Legend

- Proposed Boring Profile
- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

500 0 500
Horizontal Scale in Feet
100 0 100
Vertical Scale in Feet
Vertical Exaggeration: 5X

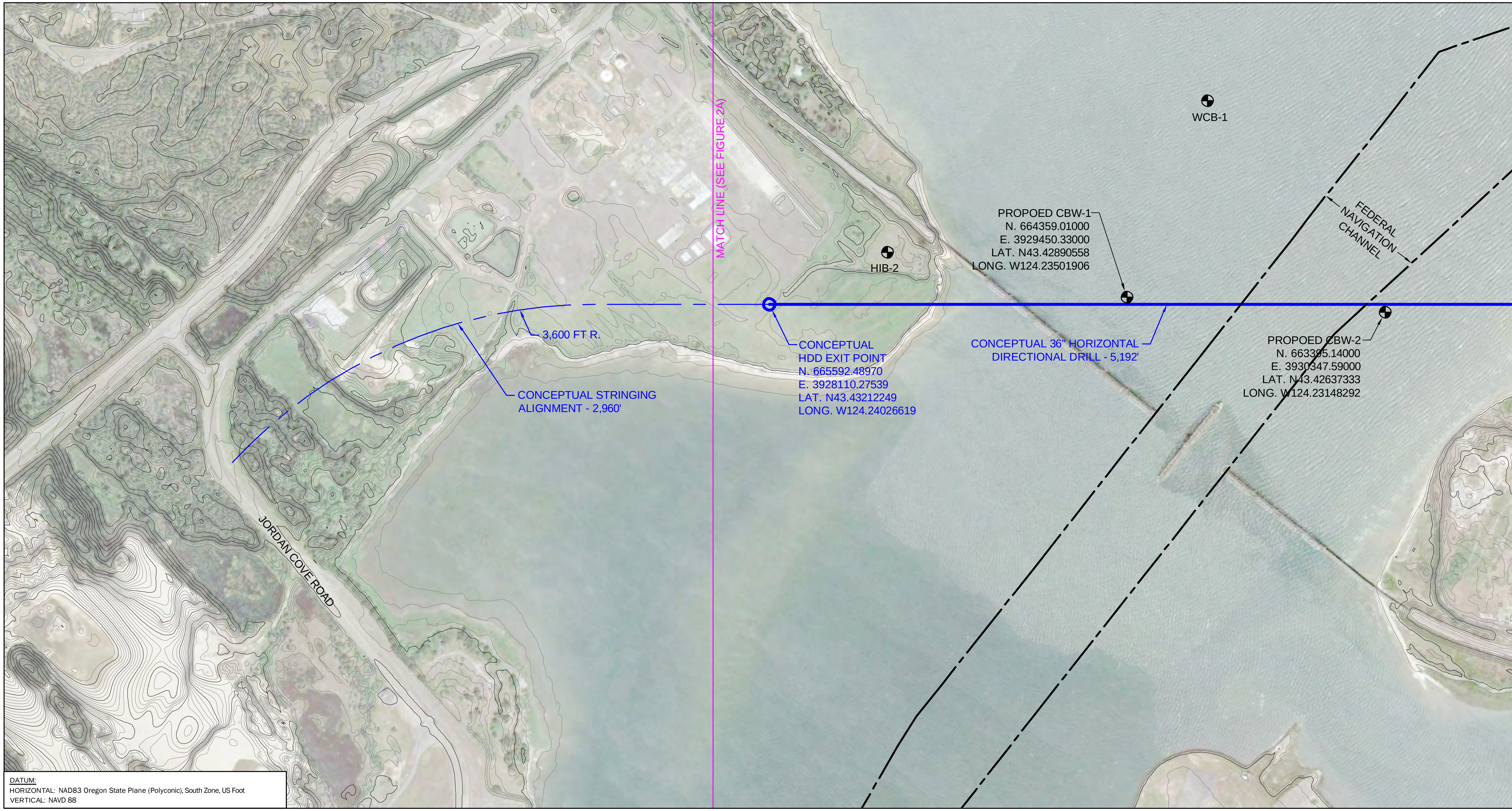
CONCEPTUAL SITE PLAN AND PROFILE

COOS BAY WEST HDD
COOS COUNTY, OREGON

GEOENGINEERS

FIGURE 2A

P:\22\2708001\CAD\Crossings\Coos Bay West HDD\Coos Bay West HDD.dwg\TAB:Figure 2A modified on Sep 14, 2017 - 3:41pm



Notes:
1. The locations of all features shown are approximate.
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Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

Legend

- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

N E S W

500 0 500
Feet

CONCEPTUAL STRINGING WORKSPACE

COOS BAY WEST HDD
COOS COUNTY, OREGON

GEOENGINEERS

FIGURE 2B

P:\22\22708001\CAD\Crossings\Coos Bay West HDD\Coos Bay West HDD.dwg\TAB:Figure 2B modified on Sep 14, 2017 - 3:42pm

TNH : RBM

Date(s) Drilled	11/02/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Subsurface Technologies, Inc.	Drilling Method	Mud Rotary	Sampling Methods	SPT / Coring
Auger Data		Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Diedrich D-50 Track
Total Depth (ft)	90	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Interval	SAMPLES: Recovered (in)	SAMPLES: Blows/foot	SAMPLES: Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0							SP	Gray fine to medium sand (loose, wet)			
5		8	2	1							
10		10	3	2							
15		10	7	3							
20		14	8	4							
25		12	8	5							
30		18	46	6				Dense below 30 feet			
35											

Note: See Figure A-1 for explanation of symbols.

LOG OF BORING HIB-2

GeoEngineers

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 27708-001-01

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample	Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35		18	64		7				Very dense below 35 feet			
40		18	35		8				Dense below 40 feet			
45		18	50/5.9"		9							
50		18	61		10				Very dense; with some shells and trace organics below 50 feet			
55		12	50/5.9"		11							
60		18	50/5"		12							
65		18	50/1"		13							
70		12	50/5.8"		14							
75		10	35/4"		15				Becomes medium sand with some shells and occasional fine gravel below 75 feet			

V6_GTBORING P:\8\8169021\00\FINALS\816902100_HAYNES INLET.GPJ GEIV6_1.GDT 11/16/06

LOG OF BORING HIB-2 (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 27708-001-01

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80		18	52	16							
85											skipped sample #17
90		18	50/3"	18				Bottom of hole at 90 feet Groundwater not encountered during drilling			
95											
100											
105											
110											
115											
120											

V6_GTBORING P:\8169021\00\FINALS\816902100_HAYNES INLET.GPJ GEIV6_1.GDT 11/16/06

LOG OF BORING HIB-2 (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 27708-001-01

Figure: 3
Sheet 3 of 3

Date(s) Drilled	12/18/06	Logged By	John Lawes	Checked By	SRR
Drilling Contractor	Crux	Drilling Method	Mud Rotary	Sampling Methods	SPT
Auger Data	HWT/HQ-3 casing advancer	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	DWM-6500 Barge-mounted drilling
Total Depth (ft)	51.5	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0							SP-SM	Dark gray poorly graded fine sand with silt and trace wood and shell fragments (very loose, wet) Alluvium bay flat deposit			
5											
~6	■	Trace	18	1							
10											
~11	■	NR	5	2				Becomes loose			
15											
~16	■	5	1/12"	3				Becomes very loose	29		SA %F=7.4
20											
~22.5	■	5	14	4				Becomes medium dense	32		pH=6.1 Resistivity=620 ohm-cm
25							SP	Dark gray poorly graded fine sand (loose, wet)			
~28	■	9	9	5					26		SA %F=3.9
30											
~34	■	10	26	6				Becomes medium dense	28		
35											

Note: See Figure A-1 for explanation of symbols.

LOG OF BORING WCB-1

GeoEngineers

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 27708-001-01

Figure 4
Sheet 1 of 2

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35											
40		10	59	7				Becomes very dense			
45		14	57	8							
50		17	50/5"	9							

Heaving sand generally encountered in loose and very loose sand deposits

55

60

65

70

75

LOG OF BORING WCB-1 (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 27708-001-01

Figure 4
Sheet 2 of 2

GeoEngineers
317 East Main Street
American Fork, Utah 84003
801.307.0216

September 6, 2017

Pacific Connector Gas Pipeline, LP
5615 Kirby Drive, Suite 500
Houston, Texas 77004

Attention: John Walls

Subject: HDD Feasibility Evaluation
Coos Bay East Crossing
Pacific Connector Gas Pipeline Project
Coos County, Oregon
File No. 22708-001-01

INTRODUCTION AND PROJECT UNDERSTANDING

GeoEngineers, Inc. (GeoEngineers) is pleased to present this horizontal directional drilling (HDD) feasibility evaluation for the proposed 36-inch-diameter pipeline installation beneath Coos Bay in Coos Bay, Oregon. The proposed Coos Bay East HDD crossing will be a part of the 229-mile-long Pacific Connector Gas Pipeline (PCGP), beginning at the proposed Jordan Cove Liquefied Natural Gas (LNG) Terminal near Coos Bay, Oregon and terminating near Malin, Oregon. The site is shown with respect to the surrounding area in the Vicinity Map, Figure 1.

Our feasibility evaluation of the proposed Coos Bay East HDD is based on limited subsurface data. Our conclusions should be considered preliminary pending completion of a subsurface exploration program. Table 1 below provides our understanding of the design basis for the proposed HDD.

TABLE 1. BASIS OF DESIGN FOR THE COOS BAY HDD

Product Pipe Data	Design Parameter
Product Pipe Specifications	36 inches x 0.823 inches w.t.[a] API-5L X-70 Steel Pipe
Approximate Horizontal Crossing Length	8,972 feet
Maximum Allowable Operating Pressure	1,600 psig[b]
Maximum Operating Temperature	100 degrees F

Product Pipe Data	Design Parameter
Tie-In Temperature	70 degrees F
Design Factor[c]	0.5

Notes:

[a] w.t. – wall thickness

[b] psig – pounds per square inch gauge

[c] As defined in 49 CFR Parts 195.106 and 192.111

PURPOSE AND SCOPE OF SERVICES

The purpose of our services was to utilize existing subsurface and site survey information in order to evaluate the feasibility of the proposed HDD installation. Our specific scope of services included the following:

1. Reviewed geologic maps and boring logs of previously completed borings in the project area to evaluate geologic conditions along the HDD alignment.
2. Evaluated the feasibility of the proposed HDD from the workspace considerations, subsurface considerations and geometric feasibility standpoints.
3. Prepared conceptual HDD plan and profile drawings using AutoCAD files provided by others.
4. Prepared this HDD feasibility report summarizing HDD feasibility and construction considerations.

SURFACE CONDITIONS

The Coos Bay East HDD extends from North Point in North Bend, Oregon eastward across Coos Bay and ends at the mouth of Kentuck Slough as shown in the Vicinity Map, Figure 1. Surface conditions at North Point at the west end of the HDD consists of a relatively flat ground surface covered with fill stockpiles. The east end of the HDD is located within a flat grass vegetated area in Kentuck Slough Valley. The alignment of the HDD would cross the Coos Bay navigation channel and shallow tidal mud flats east of the navigation channel.

SUBSURFACE SOIL AND GROUNDWATER CONDITIONS

Site Geology

Published geologic mapping shows that the shallow subsurface conditions along the HDD alignment is dominated by young alluvium. Alluvium is described as "…variable amounts of clay, silt, sand, and gravel."

Sedimentary bedrock of the Eocene-age Coaledo Formation is mapped by Baldwin and others (1973) as underlying the uplands surrounding Coos Bay. Baldwin and others (1973) notes that "(t)he Coaledo Formation occupies a north-plunging basin surrounding Coos Bay," implying that the Coaledo forms the bedrock within the Bay and is likely underlying the surficial alluvium.

The most detailed structural geology of the Coaledo Formation in north Coos Bay (Duncan, 1953) includes an east-west cross-section through the Bay, 1 mile north of the HDD alignment. It shows the upper contact of the Coaledo Formation beneath the Bay as an irregular basin deepening to the west to as much as -300 feet mean sea level (MSL). The top of the sedimentary rock is shown rising to approximately -150 feet MSL in the eastern half of the Bay.

SUBSURFACE EXPLORATIONS

GeoEngineers has completed a number of exploratory borings in Coos Bay to investigate various PCGP pipeline alignments. The exploratory boring completed closest to the Coos Bay East HDD alignment is WCB-3, which was completed approximately 1,000 feet south of the alignment at the location shown in Figures 2A and 3A. The boring log of WCB-3 is presented in Figure 5.

Boring WCB-3 was completed to a depth of about 50.5 feet below mudline. The boring encountered approximately 27 feet of very loose to medium dense sand overlying dense sand with silt to a depth of 33 feet where dense to very dense sand was encountered to a depth of 50.5 feet, the maximum depth explored.

Geotechnical Resources, Inc. (GRI) completed a subsurface exploration program in Kentuck Slough valley and reported their findings in a Preliminary Geotechnical Report dated July 2, 2010 (GRI, 2010). Boring B-1 of that report was completed approximately 250 feet southwest of the eastern end of the proposed HDD crossing. B-1 encountered about 10 feet of sandy fill (associated with East Bay Road) overlying soft silt to a depth of 15 feet, where very loose sand was encountered to a depth of 20 feet. Below 20 feet, very soft to soft silt with trace wood debris was encountered to a depth of 100 feet where very loose sand was encountered to 101.5 feet, the maximum depth explored.

PRELIMINARY HDD DESIGN CONSIDERATIONS

General

Due to the substantial length of the proposed HDD, GeoEngineers evaluated two potential alternatives for accomplishing the proposed Coos Bay East 36-inch HDD installation; a single 8,972-foot-long alternative and two shorter HDDs connected by an open cut tie-in located within the tidal flats of Coos Bay. The following describes the basis of design for these two alternatives.

Single HDD Option

We developed a conceptual HDD alignment and profile for the Coos Bay East 36-inch diameter HDD as shown in Figure 2A, with a horizontal design length of approximately 8,972 feet. Due to the substantial length of the HDD, we anticipate that it will be completed using pilot hole intersect methods. The conceptual HDD alignment extends eastward from North Point in North Bend, Oregon, crosses the Coos Bay navigation channel and terminates at the mouth of Kentuck Slough east of East Bay Road. For this conceptual design, the carrier pipe would be strung and fabricated along the Kentuck Slough valley floor on the east end of the crossing as shown in Figure 2B. The bottom tangent was designed with a 25.62-degree horizontal curve, in order to accomplish the necessary alignment to facilitate the pipe string laydown area along Kentuck Slough. Because this crossing would be completed using pilot hole intersect methods, both ends are identified as entry points. We chose a 12-degree entry angle on the west end in order to achieve a suitable depth below the navigation channel. A typical angle of 10 degrees was selected for the east side entry angle, and a radius of curvature of 4,000 feet was selected for both vertical curves and the horizontal curve. The bottom tangent was placed at an elevation of -190 feet, with the assumption that the bottom tangent and horizontal curve will be within bedrock at that depth. This assumption is critical for the feasibility of this option.

Dual HDD with Tie-in Option

GeoEngineers developed two HDD profiles, identified as HDD 1 and HDD 2, to accomplish the Coos Bay east crossing as shown in Figures 3A and 4A, respectively. The east entry point of HDD 1 is located within the tidal mud flats of Coos Bay approximately 250 feet south of Glasgow Point. HDD 1 extends westward a horizontal distance of 5,605 feet, crossing the Coos Bay navigation channel and terminating at the west entry point on land within North Point at the same location as the entry point for the single HDD option. The west entry point of HDD 2 is located about 48 feet from the east entry for HDD 1 and extends eastward a distance of 3,500 feet to the mouth of Kentuck Slough about 300 feet east of East Bay Road as shown in Figure 4A.

Typical entry angles of 10 and 12 degrees were selected for the conceptual profiles of East HDD 1 and East HDD 2. As with the single HDD option, the bottom tangent was placed at an elevation of -190 feet. However, depending on the results of the subsurface exploration program and hydraulic fracture analysis, it may not be necessary for the bottom tangent of HDD 1 and HDD 2 to be in bedrock.

The construction considerations for the single HDD and dual HDD with Tie-in Option are presented in the following section. The discussion for the dual HDD option assumes that both of the HDD 1 and HDD 2 segments will also be completed using pilot hole intersect methods. For discussion purposes, the HDD end points will be identified as east entry and west entry (for the single HDD option) or land side entry and water side entry (for the dual HDD option).

HDD CONSTRUCTION CONSIDERATIONS

General

Based on the information available as presented in this report it is our opinion that the proposed Coos Bay East HDD is technically feasible, pending the results of the subsurface exploration program and provided the considerations in this report are addressed in the design, preconstruction and construction phases of the project.

Site Access

Single HDD Option

Access to the conceptual west side workspace can be gained directly from surface streets servicing an industrial area at North Point in North Bend. The east side workspace could be accessed via a temporary entrance and access road off of East Bay Road west of the workspace. Matting or other subgrade stabilization methods will likely be needed to gain access to the east side entry workspace.

Dual HDD with Tie-In Option

Access to the land side entry points of each drill would be the same as described above for the single HDD option.

Because of the location of the shared in-water entry workspace in Coos Bay for the dual HDD option, access to the tie-in workspace location will have to be provided by barges or other marine vessels, and will be much more difficult than a typical land based HDD site. Because of tidal fluctuations, the tidal flats within the in-water workspace will be exposed at times such that dredging will be required between the navigation channel and the workspace area so that equipment barges can access the workspace. There is an existing shallow natural channel extending from the mouth of Kentuck Slough to the navigation channel that may be incorporated into the access route to the shared workspace to reduce the amount of dredging that would be required. A dredging plan will likely be required to address the dimensions and depth of the access channel, the dredging procedures and placement or disposal of spoils. In addition, the dredging plan will likely need to be permitted through the Army Corps of Engineers, Department of State Lands and/or other state and federal agencies. The HDD contractor can provide details of their plan to access the in-water workspaces as part of their HDD drill plan, and provide input regarding areas to be dredged. However, we assume that the project owner would be responsible for permitting dredging activities.

Workspace Considerations

Single HDD Option

The locations for both the east and west side workspaces are relatively flat and open such the adequate workspace will be available for drilling and installation operations. The east side would be located in a relatively flat low-lying area that may be prone to flooding which should be considered when scheduling and planning for construction.

The proposed carrier pipe stringing area would be located northeast of the east entry point along the Kentuck Slough valley floor. Kentuck Slough and Kentuck Way limit the available pipe string length to 5,293 feet so a tie-in weld will be required during pullback operations. The orientation of the HDD alignment would require two horizontal curves in the pull section, making fabricating and handling the pipe more difficult.

Dual HDD with Tie-In Option

The proposed shared water side entry (tie-in) workspace for both HDD installations is located in a tidal flat area south of Glasgow Point as shown in Figure 3A and 4A. The workspace is approximately 200 feet wide and 450 feet long. As mentioned above, the water side entry workspace will likely have to be dredged in order to stage equipment and provide access to support vessels.

Because of the tidal fluctuations, it will be necessary for the HDD contractor to install steel piles (dolphins) and support brackets (goal posts) to support the drill pipe string during HDD drilling operations. The location and depth of the dolphins is typically selected by the HDD contractor based on the configuration of the HDD equipment.

Workspace considerations for the land side entry points of each drill would be the same as described above for the single HDD option.

The proposed carrier pipe stringing area for HDD 1 would be located through the industrial area west of the land side entry point. The pipe string could pass beneath Highway 101, as the highway is on a raised bridge at the crossing location. The available area across North Point is not sufficiently wide to string the carrier pipe in one continuous section which would require a tie-in weld during pullback operations. The proposed carrier pipe stringing area for HDD 2 would be located northeast of the land side entry point along Kentuck

Slough. This area is of sufficient length to string the carrier pipe in one continuous section prior to pullback operations; however, the orientation of the HDD alignment would require two horizontal curves in the pull section, making fabricating and handling the pipe more difficult.

Drilling Fluid Containment

Single HDD Option

Drilling fluid containment for the Single HDD Option will be via relatively small fluid containment pits excavated adjacent to the entry points of the drill. These pits typically measure approximately 6 to 10 feet square and 4 to 6 feet deep. During drilling operations, drilling fluid returns and cuttings from downhole flow into the pits where the fluid is then pumped to a recycling system where most of the cuttings are removed and the drilling fluid can be recirculated downhole.

Dual HDD with Tie-In Option

By virtue of the fact that both conceptual HDD installations will involve entry points located in water, drilling fluids will be released to the Coos Bay tidal flat during normal operations as a result of drilling fluid circulation if containment measures are not implemented. Drilling fluids may be contained at the water side entry points during pilot hole operations through use of small-diameter conductor casing; however, additional measures will need to be implemented at the water side entry points during reaming operations to contain the drilling fluids.

During reaming operations, it will be preferable to promote drilling fluid returns toward land side entry where they can be more easily contained, recycled, and reused. This may be accomplished by not reaming the pilot hole through the last 200 to 250 feet of the entry tangent until the final reaming pass. Once the entry tangent is reamed to its final diameter, a relatively large drilling fluid returns pit and or containment such as sheet piling may be required at entry to contain drilling fluid returns that surface at the entry point. Containment and recycling operations will need to be executed considering tidal fluctuations. Alternatively, large-diameter casing could be installed prior to reaming operations at the water side entry points to contain drilling fluid on the barge or other containment structure.

Drilling fluid at the land side entry points of both drills could be contained conventionally in shallow pits as described above for the long option HDD.

Pilot Hole Considerations

Based on our experience with similar HDD projects of this length and diameter, we anticipate that the pilot bit diameter will likely range from 9.875 to 12.25 inches. We also anticipate that the pilot hole will most likely be advanced using a jetting assembly through the alluvial soils, and a positive displacement mud motor through the underlying dense to very dense sand and sandstone bedrock, if the proposed HDD profile encounters bedrock.

Single HDD Option

Because of the relatively large degree of horizontal curvature in the alignment of the conceptual HDD and the need to complete a pilot hole intersect within the bay, the use of a magnetic based steering tool may be more advantageous than a gyroscopic steering tool. Currently, the gyroscopic steering tool does not have the secondary survey capabilities offered by the magnetic based steering tool systems. The ability to obtain secondary survey data should aid in advancing the pilot hole within acceptable tolerances and help to complete the pilot hole intersect. For this crossing, the installation and survey of the secondary survey coil wire across the tidal flats will be somewhat more difficult because of the tidal fluctuations. The contractor will need to devise a method of installing the wire given the tidal fluctuations and anchor the wire so that it does not move with the currents. If the wire is not sufficiently anchored, the wire can move which would result in inaccurate survey data. It will not be possible to install the survey coil wire across the navigation channel, so the contractor will have to rely on the downhole steering tool data while crossing the channel.

Dual HDD Option

Because of the difficulty in placing a secondary survey coil wire (used with magnetic based steering tools) along the HDD alignment in the navigation channel and across the tidal flat, it may be preferable for the contractor to use a gyroscopic steering tool to complete the pilot hole. However, the gyroscopic steering tool is sensitive to excessive vibration, particularly when drilling through rock, and requires a skilled surveyor to make constant adjustments to maintain accuracy and account for accumulated error in the survey data. It is typically the HDD contractor's responsibility to choose appropriate means and methods to track the pilot hole.

To accommodate forces generated during pilot hole operations and to maintain drilling fluid returns to the drill barge, support structures (dolphins and goal posts) and an appropriately sized steel casing will likely be required between the drill platform and the entry point for both HDDs.

Reaming Considerations

Single HDD Option

Because of the length of the single HDD option, there is an increased risk of drilling fluid surface release during reaming operations. This risk can be reduced by reaming the hole from both ends of the crossing. This methodology helps reduce downhole annular drilling fluid pressures by shortening the flow path of the drilling fluid through the hole. Although this increased risk doesn't necessarily affect the technical feasibility of the proposed HDD, reaming from both sides of the crossing could potentially have cost impacts that may require consideration.

Dual HDD With Tie-In Option

As discussed in the drilling fluid containment section above, the HDD contractor might elect to not ream the last 200 to 250 feet of entry tangent of the drill profile until the hole is reamed to the final diameter to promote the flow of drilling fluid to the land-side containment pit. This will reduce the volume of drilling fluid that needs to be collected, recycled and pumped downhole from the drill and support barges within the bay.

Pullback

Single HDD Option

As previously described, the fabrication and stringing workspace for the single HDD option would be in the Kentuck Slough valley. The pipe could be fabricated along a straight alignment within the valley but because of the orientation of the HDD alignment relative to that of the valley, the pull section for installation would have to have to be positioned with two horizontal curves for pullback operations. In addition, the practical length of the fabrication and stringing workspace is not sufficient to fabricate the pull section into one continuous section which will require that a minimum of one tie-in weld will be required during pullback operations.

Because of the length of the conceptual HDD, the horizontal curvature in the alignment and the need to make at least one tie-in weld during pullback, it may be necessary to utilize a pipe thruster on the east side of the crossing to help assist the installation process if needed.

Dual HDD With Tie-In Option

The fabrication and stringing workspaces for both conceptual HDDs would be on the land side of each crossing. Because of the tidal flat conditions within the bay, attempting to float the pipe in the bay and installing the pipe from the water side to the land side would be more complex and expensive.

For HDD #1, the stringing and fabrication workspace would be located west of the crossing; however, there is not sufficient workspace to fabricate the pull section into one continuous section which will require that a minimum of one tie-in weld will be required during pullback operations.

For HDD #2, the stringing and fabrication workspace would be located east of the crossing with sufficient workspace to fabricate the pull section into one continuous section prior to pullback operations. The pipe could be fabricated along a straight alignment within the valley but because of the orientation of the HDD alignment relative to that of the valley, the pull section for installation would have to have to be positioned with two horizontal curves for pullback operations.

Because both HDD #1 and HDD #2 would install the pipe from land side to water side, the barge would have to be anchored sufficiently to resist the lateral loads imposed by the drill rig during the installation process.

Drill Hole Stability

The stability of the hole during HDD operations is dependent on a number of factors, including the type and composition of the soils, drilling fluid properties, groundwater conditions and the HDD profile geometry. Holes drilled or reamed through loose soil formations, soil formations with significant gravel content, dry hole sections and fractured rock formations with poor rock quality are prone to exhibiting instabilities.

In general, we expect the risk of drill hole instability along the conceptual HDD drill paths (either option) to be relatively low. Minor hole instabilities may be encountered within the very loose to loose soils expected along the upper portions of the HDD profile at the east end near Kentuck Slough, but we do not anticipate that this condition will jeopardize the successful installation of the product pipe. If hole instabilities are anticipated within the shallow portions of the drill profiles, large-diameter casing can be installed through the tangent sections of the drill profiles to stabilize those areas. The casing would need to be sized sufficiently to allow the reaming tools to pass through it. For the proposed 36-inch carrier pipe and anticipated final ream diameter of 48 inches, we anticipate that the large-diameter casing would need to be a minimum of 56 inches in diameter.

Hydraulic Fracture and Drilling Fluid Surface Release

Drilling fluid loss can occur as a result of either formational fluid loss or hydraulic fracture. The loss of drilling fluid downhole is accompanied by either partial or full loss of drilling fluid returns to the entry and/or exit pits.

Formational drilling fluid losses typically occur when the drilling fluid flows through the pore spaces in the surrounding formation. Thus, a formation with a higher porosity can potentially absorb a larger volume of drilling fluid than a formation with a lower porosity. Coarse sands and gravel units with low percentages of silt and clay and fractured rock formations have a moderate to high susceptibility for drilling fluid loss. Without additional subsurface information along the HDD alignment, it is not currently possible to estimate the risk of substantial formational fluid loss.

Hydraulic fracture is a term typically used to describe the condition in which the downhole drilling fluid pressure exceeds the overburden pressure and shear strength of the formation surrounding a drill path. The risk of hydraulically fracturing subsurface formations during the HDD process generally depends on the type and shear strength of the formation and the downhole drilling fluid pressures. Drilling fluid pressures used for HDD construction are not typically high enough to cause hydraulic fracture of intact bedrock because the shear strength of the rock far exceeds the drilling fluid pressures downhole. Downhole drilling fluid pressures can easily exceed the shear strength of soil formations. In general, fine-grained soils such as silt and clays have a relatively moderate to high risk of hydraulic fracture, whereas granular soils such as sands have a relatively low risk of hydraulic fracture. In general, we expect that there is a relatively low risk of hydraulic fracture occurring during HDD installation because much of the HDD profile passes through sandy soils and potentially bedrock; however, this estimate of risk is contingent on the HDD contractor maintaining drilling fluid returns during all phases of drilling activities.

We anticipate a relatively low risk of drilling fluid surface releases occurring along most of the HDD alignment during construction, primarily because the design intent is to place the bottom tangent of either option within bedrock. However, very soft to soft silt is expected to depth of 100 feet at the east end of the crossing approaching Kentuck Slough. We expect that there is a high risk of hydraulic fracture and drilling fluid surface release along the east side entry tangent of the long, single HDD option and HDD 2 of the Dual HDD with Tie-In option. Large-diameter casing can be utilized to mitigate the potential for hydraulic fracturing. The casing would need to be sized sufficiently to allow the reaming tools to pass through it. For the proposed 36-inch carrier pipe and anticipated final ream diameter of 48 inches, we anticipate that the large-diameter casing would need to be a minimum of 56 inches in diameter.

Installation of oversized casing at the east end of the HDD crossing will require that East HDD 2 be completed as a pilot hole intersect, since the west end of the HDD will also likely utilize casing for drilling fluid containment as describe in more detail below.

For the dual HDD option, drilling fluids will be released to the Coos Bay floor at the conceptual entry points at the tie in location in Coos Bay during normal operations of drilling fluid circulation, unless they are. contained at the water side entry points during pilot hole operations through use of a conductor casing.

Additional measures will need to be implemented during reaming operations to contain the drilling fluids. During reaming operations, the volume of drilling fluid that surfaces at the entry point could be reduced by not reaming the pilot hole through the entry tangent until the final reaming pass. Once the entry tangent is reamed to its final diameter, a relatively large drilling fluid returns pit and or containment such as sheet piling may be required at entry to contain drilling fluid returns that surface at the entry point. Leaving the soil plug at entry through much of the reaming operations promotes drilling fluids returns to land side of the crossings where they can be more easily contained, recycled, and reused. Containment and recycling operations will need to be executed considering tidal fluctuations.

CONCLUSIONS

The following summarizes the primary considerations for the Single HDD and Dual HDD with Tie-In Options.

Single HDD Option

1. Additional subsurface exploration and laboratory testing is required to confirm the construction considerations and feasibility conclusions presented in this report, and to provide subsurface information required for final design of the conceptual HDD. Proposed boring locations and depths are shown in Figure 2A.

2. Due to the substantial length of the HDD, we anticipate that it will be completed using pilot hole intersect methods.

3. It will be necessary to design the HDD to maximize the amount of drill path within bedrock.

4. Oversized casing will likely need to be installed at the eastside entry to assist in efficiently transferring axial loads to the drill bit, and to mitigate against hydraulic fracture and drilling fluid surface releases within the soft silts along the east end of the HDD path.

Dual HDD Option with Tie-In

1. Additional subsurface exploration and laboratory testing is required to confirm the construction considerations and feasibility conclusions presented in this report, and to provide subsurface information required for final design of the conceptual HDDs. Proposed boring locations and depths are shown in Figure 3A and 4A.

2. Due to the length of the HDD 1, we anticipate that it will be completed using pilot hole intersect methods.

3. Dredging will likely be required along the tidal mud flats to provide barge access to the water side entry works space for HDD 1 and HDD 2.

4. Drilling fluids will need to be contained at the water side entry of HDD 1 and HDD 2 during pilot hole operations through use of small-diameter conductor casing; however, additional measures will need to be implemented at the water side entry during reaming operations to contain the drilling fluids.

5. Oversized casing will likely need to be installed at the land side entry of HDD 2 to assist in efficiently transferring axial loads to the drill bit, and to mitigate against hydraulic fracture and drilling fluid surface releases within the soft silts along the east end of the HDD path.

6. Due to the need for casing at both ends of HDD 2, we anticipate that it will be completed using pilot hole intersect methods.

REFERENCES

Baldwin, et al. 1973, “Geology and Mineral Resources of Coos County, Oregon.

Duncan, 1953., U.S. Geological Survey Bulletin 982-B, Geology and Coal Deposits in Part of the Coos Bay Coal Field, Coos Bay, Oregon.

Bourgoyne, A.T., et al. 1991. “Applied Drilling Engineering”, Society of Petroleum Engineers.

Pipeline Research Committee International (PRCI) of the American Gas Association. April 15, 1995. “Installation of Pipelines by Horizontal Directional Drilling, An Engineering Design Guide,” Contract No. PR-227-9424.

GRI, July 2, 2010. Preliminary Geotechnical Report, Kentuck Slough Mitigation Site, North Bend, Oregon.

LIMITATIONS

We have prepared this report for use by PCGP and the design team, their authorized agents and other approved members of the design team involved with this project. The report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. The conclusions and recommendations in this report should be applied in their entirety.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. The conclusions, recommendations, and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, express or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments should be considered a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record.

CLOSING

We appreciate the opportunity to provide services to PCGP. Please call if you have any questions concerning this report or if we can be of further assistance.

Sincerely,
GeoEngineers, Inc.

Mark Miller, PE
Principal

Trevor N. Hoyles, PE
Principal

AES:MAM:TNH:cje:mlh

List of Figures:

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Feet

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Mapbox Open Street Map, 2017

Projection: NAD 1983 UTM Zone 10N

Vicinity Map

COOS BAY EAST HDD
COOS COUNTY, OREGON

GEOENGINEERS

Figure 1

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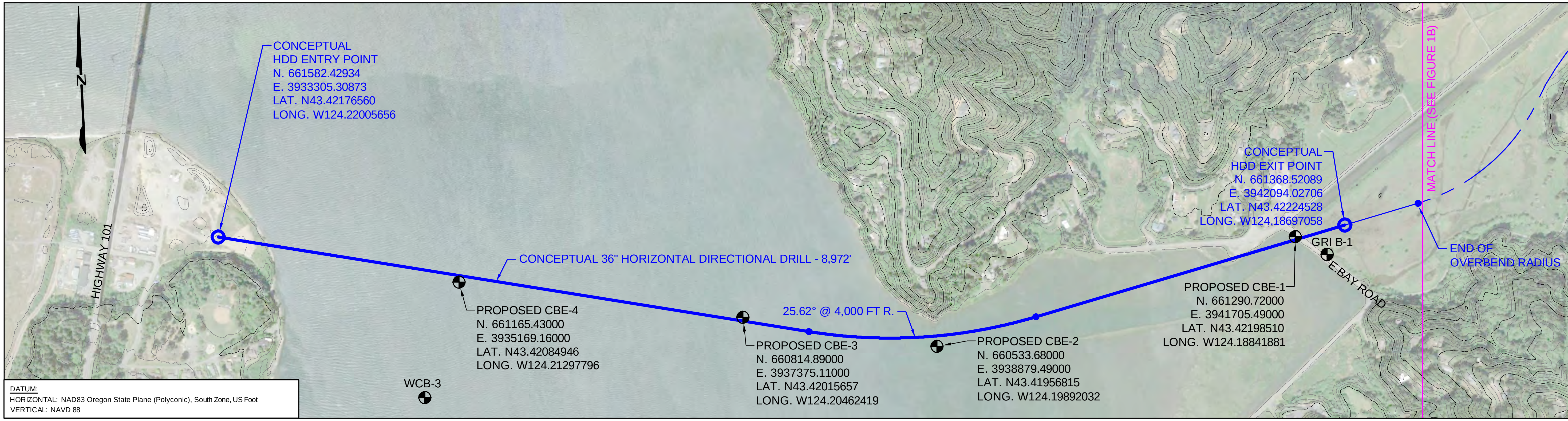

NOT FOR CONSTRUCTION

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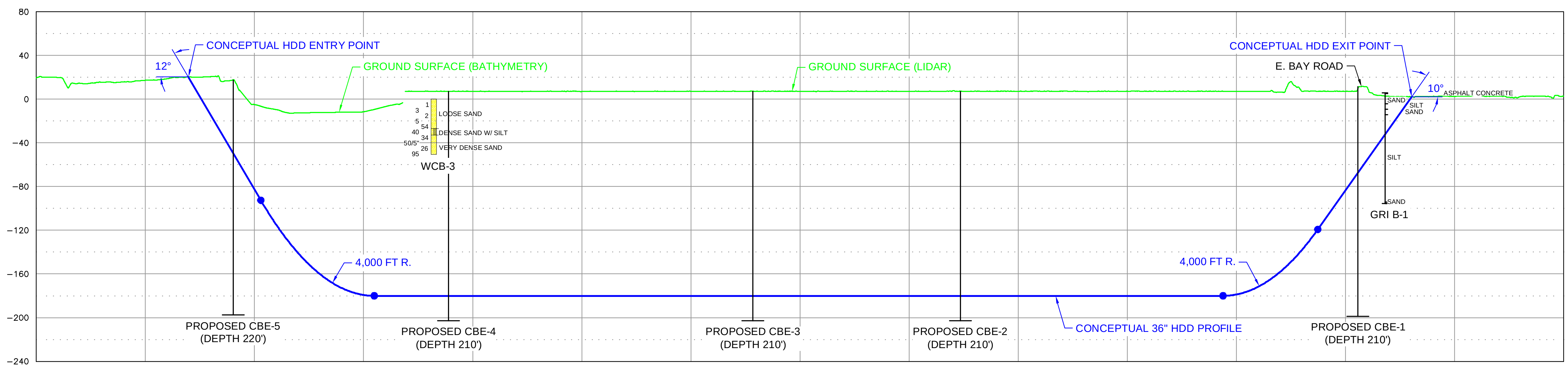

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VERTICAL SCALE IN FEET

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Reference: Ground surface Lidar downloaded from http://www.oregongeology.org/dogamilidarviewer/. Aerial image taken From Google Earth Pro © 2016, licensed to GeoEngineers, Inc., image dated 01/15/16.
Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

LEGEND:
- Proposed Boring Location
- Major Contour - 40' Interval
- Minor Contour - 10' Interval

CONCEPTUAL SITE PLAN AND PROFILE

COOS BAY EAST HDD
COOS COUNTY, OREGON

GEOENGINEERS

FIGURE 2A

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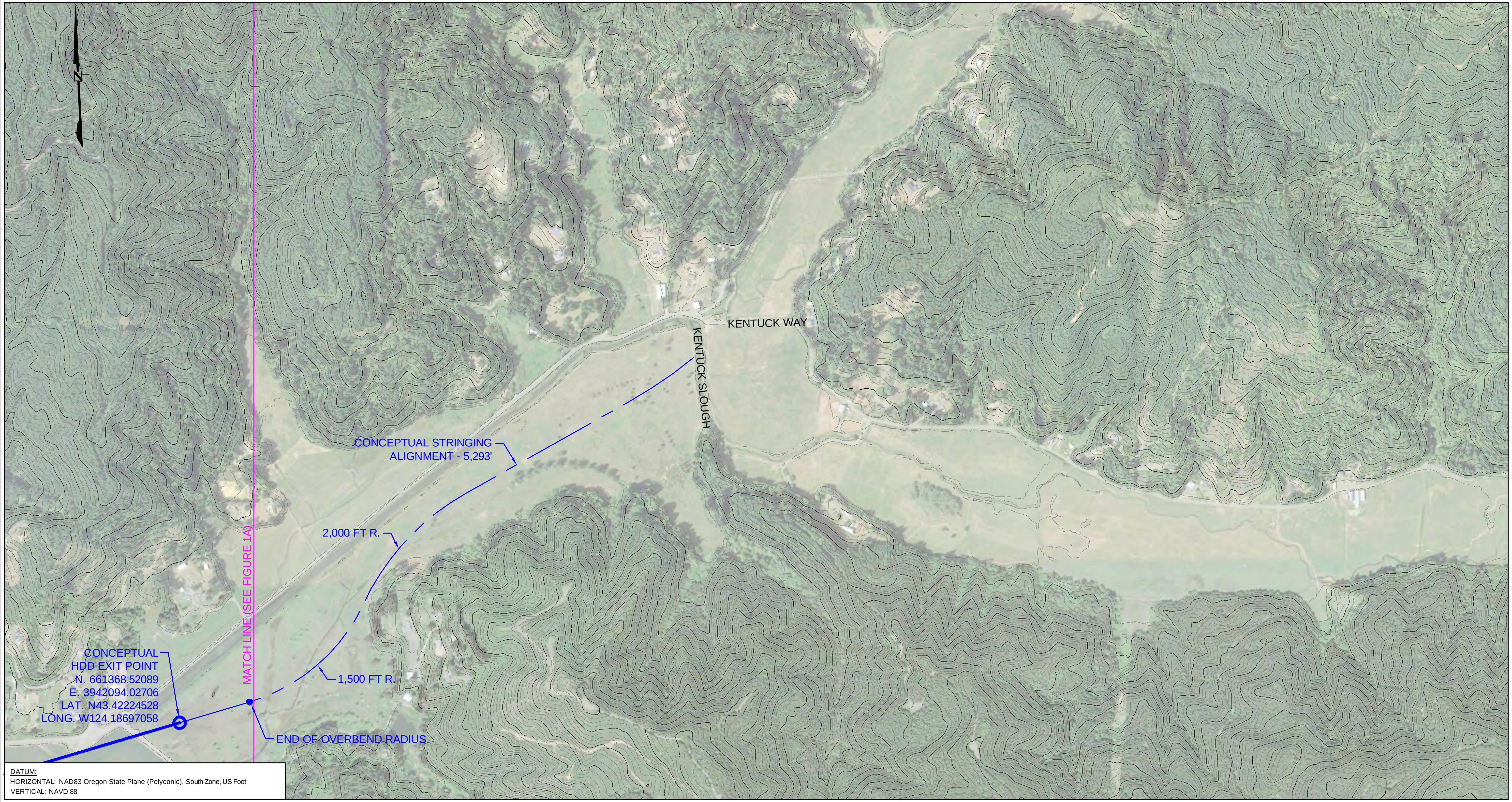
ISSUED DATE: AUGUST, 2017



Notes:
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Reference: Ground surface Lidar downloaded from http://www.oregongeology.org/dogamilidarviewer/. Aerial image taken From Google Earth Pro © 2016, licensed to GeoEngineers, Inc., image dated 01/15/16.

PLAN

800 0 800

SCALE IN FEET

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

LEGEND:

Major Contour - 40' Interval

Minor Contour - 10' Interval

CONCEPTUAL STRINGING WORKSPACE

COOS BAY EAST HDD
COOS COUNTY, OREGON

GEOENGINEERS

FIGURE 2B

ISSUED DATE: AUGUST, 2017

TNH : RBM

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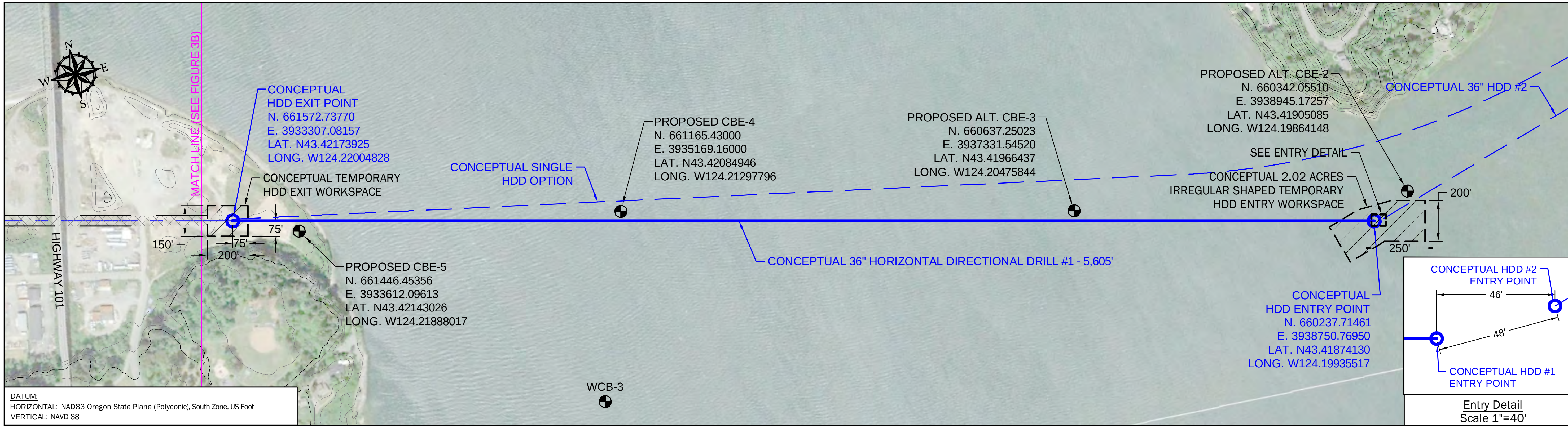
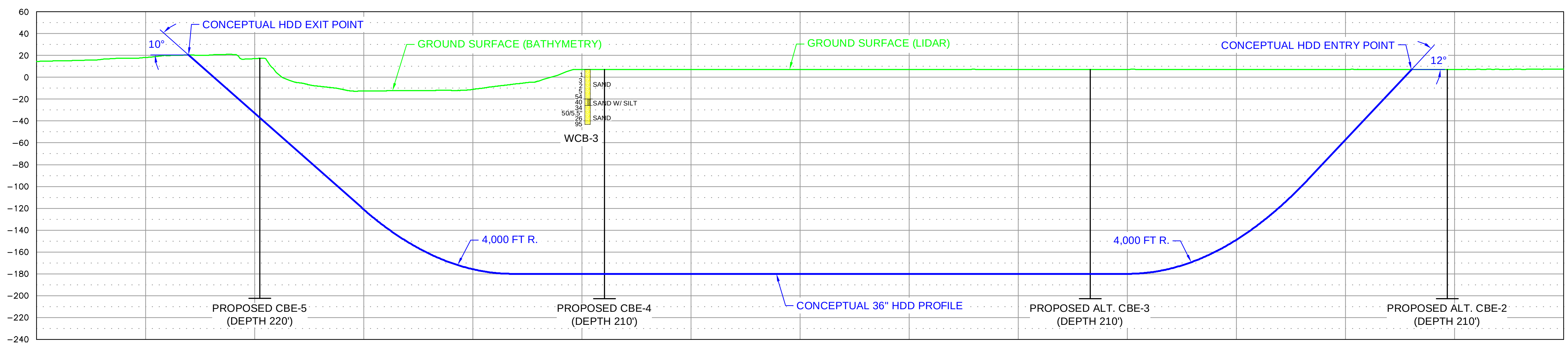


Not For Construction

Plan



Profile

Notes:

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Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

Legend

- Proposed Boring Profile
- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

500 0 500
Horizontal Scale in Feet
100 0 100
Vertical Scale in Feet
Vertical Exaggeration: 5X

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

Conceptual Site Plan and Profile

Coos Bay East HDD #1
Coos County, Oregon

GEOENGINEERS

Figure 3A

Issued Date: August, 2017

TNH : RBM

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Reference: Ground surface Lidar downloaded from http://www.oregongeology.org/dogamilidarviewer/. Aerial image taken From Google Earth Pro © 2016, licensed to GeoEngineers, Inc., image dated 01/15/16.
Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

Legend

- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

N E S W

500 0 500
Feet

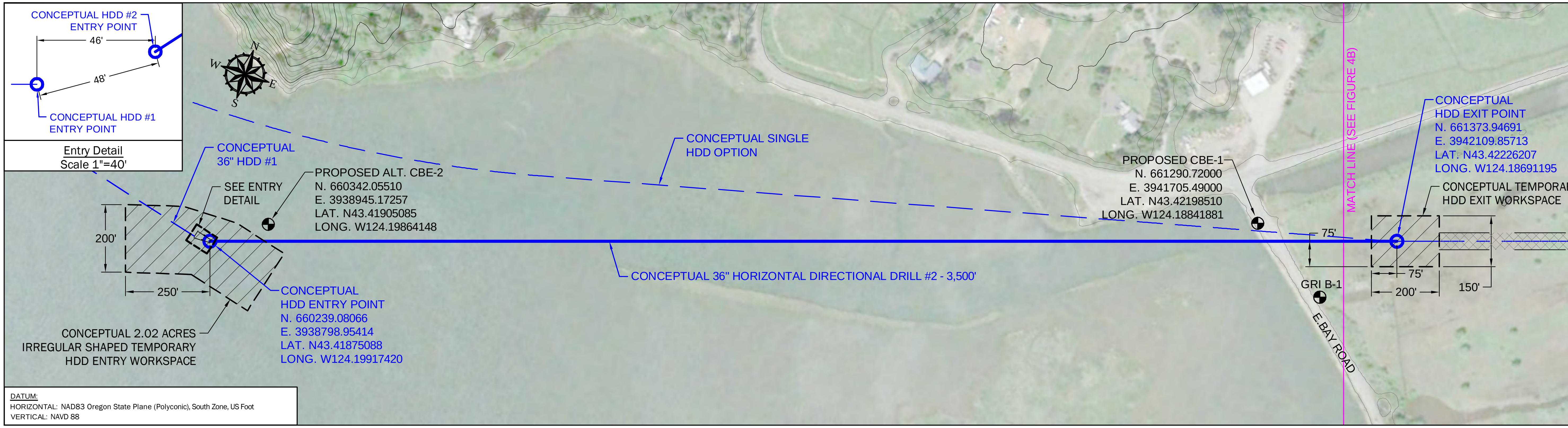
Conceptual Stringing Workspace

Coos Bay East HDD #1
Coos County, Oregon

GEOENGINEERS

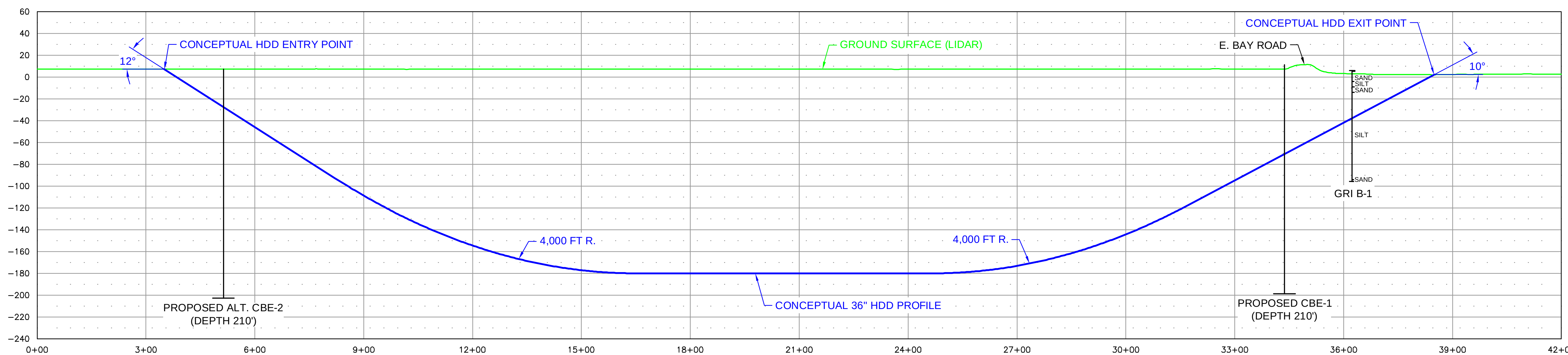
Figure 3B

Issued Date: August, 2017



Not For Construction

Plan



Profile

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

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Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

Legend

- Proposed Boring Profile
- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

300 0 300
Horizontal Scale in Feet
100 0 100
Vertical Scale in Feet
Vertical Exaggeration: 3X

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

Conceptual Site Plan and Profile

Coos Bay East HDD #2
Coos County, Oregon

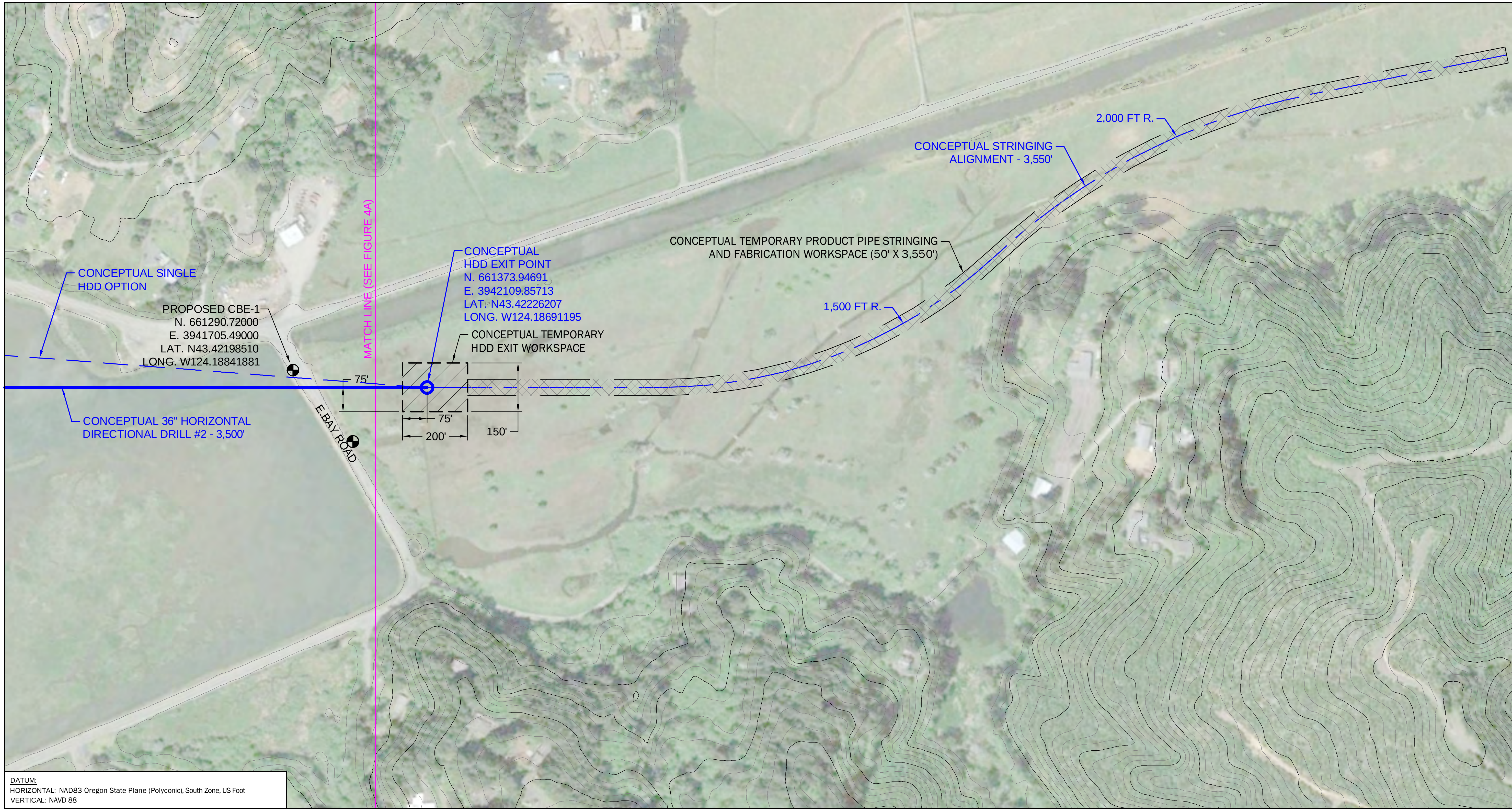
GEOENGINEERS

Figure 4A

Issued Date: August, 2017

TNH : RBM

P:\22\22708001\CAD\Crossings\Kentuck Inlet\Coos Bay East HDD 2.dwg\TAB:Figure 2A modified on Aug 31, 2017 - 9:29am



Notes:
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Ground surface bathymetry downloaded from https://www.ngdc.noaa.gov/nos/H10001-H12000/H11745.html

Legend

- Proposed Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

N W E S

300 0 300
Feet

Conceptual Stringing Workspace

Coos Bay East HDD #2
Coos County, Oregon

GEOENGINEERS

Figure 4B

Issued Date: August, 2017

TNH : RBM

P:\22\2270800\1\CAD\Crossings\Kentuck Inlet\Coos Bay East HDD 2.dwg\TAB:Figure 2B modified on Aug 31, 2017 - 9:30am

Date(s) Drilled	12/18/06	Logged By	John Lawes	Checked By	SRR
Drilling Contractor	Crux	Drilling Method	Mud Rotary	Sampling Methods	SPT/D&M
Auger Data	HWT/HQ-3 casing advancer	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	DWM-6500 Barge-mounted drilling
Total Depth (ft)	50.5	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Recovered (in)	Blows/foot	Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0					SP	Dark gray fine poorly graded sand with trace shell (very loose, wet)			
5	10	1	1				24		SA %F=3.5 pH=7.2
10	9	3	2			Some medium sand with abundant shell and trace wood fragments	30		pH=7.7
15	4	2	3			Fine sand with trace shell			%F=3.6 pH=8.1
20		5	4			Becomes loose with abundant broken shell and trace medium sand	28		pH=5.5 Resistivity=310 ohm-cm
25	10	54	5			Becomes medium dense with trace broken shell			
30	8	40	6		SP-SM	Dark gray fine poorly graded sand with silt with trace shell fragments (dense, wet)			%F=6.0
35	7	34	7		SP	Dark gray fine poorly graded sand (dense, wet)			

Note: See Figure A-1 for explanation of symbols.

V6_GTBORING C:\DOCUME~1\JATKINS\LOCALS~1\TEMPOR~1\OLK8\8169021 07.GPJ GEIV6_1.GDT 2/1/07

LOG OF BORING WCB-3

GeoEngineers

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 8169-021-07 T2

Figure 5
Sheet 1 of 2

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35											
		9	50/5½"	8				Becomes very dense			
40											
45		10	26	9				Becomes medium dense			%F=1.8
50			95	10				Becomes very dense			
								Heaving sand generally encountered in loose and very loose sand deposits			

55

60

65

70

75

LOG OF BORING WCB-3 (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline
Project Location: Coos Bay, Oregon
Project Number: 8169-021-07 T2

Geotechnical Engineering Services and Horizontal Directional Drilling Design

Coos River HDD
Pacific Connector Gas Pipeline Project
Coos County, Oregon

for
Pacific Connector Gas Pipeline, LP

September 1, 2017

GeoEngineers
Earth Science + Technology

Geotechnical Engineering Services and Horizontal Directional Drilling Design

Coos River HDD
Pacific Connector Gas Pipeline Project
Coos County, Oregon

for
Pacific Connector Gas Pipeline, LP

September 1, 2017

GeoEngineers

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503.624.9274

Geotechnical Engineering Services and Horizontal Directional Drilling Design

Coos River HDD
Pacific Connector Gas Pipeline Project
Coos County, Oregon

File No. 22708-001-01

September 1, 2017

Prepared for:

Pacific Connector Gas Pipeline, LP
5616 Kirby Drive, Suite 500
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Attention: John Walls

Prepared by:

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Date: 2017.09.01 17:36:18 -04'00'
OREGON
JULY 09, 2001
TREVOR NATHAN HOYLES
EXP: 6/30/19

Trevor N Hoyles, PE
Principal

APS:BCR:TNH:cje

GeoEngineers

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LIST OF FIGURES

APPENDICES

EXECUTIVE SUMMARY

This report provides geotechnical engineering and horizontal directional drilling (HDD) recommendations and HDD design criteria for the proposed HDD crossing of the Coos River located approximately 4 miles northeast of Coos Bay, Oregon. This HDD crossing consists of installing a new 36-inch-diameter pipeline under the Coos River, Coos River Highway and South Coos River Highway. The river crossing will be a part of the proposed Pacific Connector Gas Pipeline (PCGP).

Based on the results of our site visits, subsurface exploration program, geotechnical engineering evaluations, HDD design, and HDD constructability review, it is our opinion the HDD method of installation is feasible and the proposed crossing of the Coos River can be installed successfully provided the recommendations in this report are incorporated into the installation of the crossing.

The subsurface conditions at the site were evaluated by drilling four borings to depths up to 101.5 feet below the existing ground surface. The soils encountered on the entry (north) side of the river consisted of very soft to stiff fat clay, lean clay, organic clay, organic silt with sand overlying very soft, decomposed to fresh siltstone. Soils encountered on the exit (south) side of the river typically consisted of very soft to soft silt, and very loose to dense fine sand with varying amounts of silt to the maximum depths explored. Soils encountered during exploration had varying amounts of organic matter.

The hydraulic fracture and drilling fluid surface release model indicates the risk of drilling fluid surface release is high along the first approximately 250 feet of the drill path. The risk becomes low from the northern edge of the Coos River Highway and across Coos River to approximate station 17+00. The risk becomes high within approximately 150 feet of the exit point.

The site-specific HDD profile was created utilizing the design guide published by the Pipeline Research Committee International (PRCI) of the American Gas Association. Associated installation and operational stresses were calculated utilizing the PRCI Design Guide and checked to assess compliance with ASTM/ASME B31.8, API Recommended Practice 2A – WSD, and DOT CFR Part 192. The HDD design calculations indicate the stresses incurred during installation and operation should be within the allowable limits.

This Executive Summary should be used only in the context of the full report for which it is intended.

1.0 INTRODUCTION

1.1 General

This report summarizes our geotechnical engineering and HDD design services for the proposed HDD crossing of the Coos River. The site is located approximately 4 miles northeast of Coos Bay, Oregon. The site is shown in the Vicinity Map, Figure 1. The general layout of the site is shown in the Site Plan and Profile, Figure 2.

1.2 Project Description and Basis of Design

The proposed Coos River HDD crossing will be a part of the 229-mile-long PCGP, beginning at the proposed Jordan Cove Liquefied Natural Gas (LNG) Terminal near Coos Bay, Oregon and terminating near Malin, Oregon. The proposed pipeline crossing of the Coos River consists of a single 36-inch-diameter pipe to be installed using HDD installation techniques.

We previously prepared an HDD Feasibility Study for the Coos River HDD in a report titled "HDD Feasibility Study, Coos River HDD, Coos Bay, Oregon," dated January 15, 2013.

The HDD design was completed in accordance with the latest versions of Department of Transportation (DOT) 49 CFR 192, ASME 31.8 and accepted practices within the natural gas industry. The geotechnical and HDD design engineering was completed based on the parameters presented below in Table 1.

TABLE 1. BASIS OF DESIGN FOR THE 36-INCH-DIAMETER COOS RIVER HDD

Product Pipe Data	Design Parameter
Product Pipe Specifications	36 inches x 0.823 inches w.t.[1] API-5L X-70 steel pipe, SAWH or SAWL
Horizontal Crossing Length	1,602 feet
Maximum Allowable Operating Pressure	1,600 psig[2]
Operating Temperature	70 degrees F
Maximum Operating Temperature	100 degrees F
Assumed Tie-In Temperature	50 degrees F

Notes:

[1]w.t. – wall thickness

[2]psig – pounds per square inch gauge

2.0 SCOPE OF SERVICES

The purpose of our services was to evaluate the existing surface and subsurface soil and groundwater conditions and prepare a HDD design for the proposed crossing. The specific scope of services provided by GeoEngineers, Inc. included the following:

1. Prepared preliminary information and maps of the HDD utilizing geographic information system (GIS) data provided by Pacific Gas Connector Pipeline, LP (PCGP, LP) and other available public data sources.

2. Completed a site reconnaissance with PCGP, LP and their authorized representatives to observe surface conditions and locate borings. During our site reconnaissance we collected the following information:
    a. Geologic and environmental surface features that could impact HDD feasibility;
    b. Topography of the site, particularly along the planned alignment;
    c. Potential HDD operational areas such as entry and exit points, staging, site access and pipe stringing;
    d. Number and approximate location of geotechnical borings;
    e. Potential obstacles such as existing utilities, buildings, houses and other surface features within the potential work areas; and
    f. Map surface exposures of geologic materials visible within road cuts and stream banks in order to aid in interpreting potential subsurface conditions along the planned HDD alignment.
3. Coordinated utility locates near the proposed boring locations by the public "One Call" utility locating service.
4. Explored subsurface conditions at the site as follows:
    a. Drilled four brings near the HDD alignment using mud rotary drilling techniques;
    b. Obtained soil samples at representative intervals from the borings using split spoon samples and standard penetration tests (SPT). SPTs were conducted at 5-foot intervals in the soil and soft rock portions of the borings; and
    c. Classified soils encountered in the borings in general accordance with ASTM International (ASTM) Standard Practice D 2488 and maintained a log of the materials encountered in each exploration.
5. Performed index tests necessary to characterize the subsurface materials. Testing included:
    a. Thirteen Atterberg limits determinations in general accordance with ASTM D 4318;
    b. One grain size determination in general accordance with ASTM C 136;
    c. Four percent fines determinations in general accordance with ASTM D 1140; and
    d. Ten sieve analysis in general accordance with ASTM D 422.
6. Prepared and submitted a HDD feasibility study report, which included:
    a. Brief surface description of site conditions that could affect the planned HDD operations;
    b. Summary of subsurface conditions encountered during our fieldwork;
    c. HDD feasibility discussion;
    d. Preliminary HDD profile design length and depth;
    e. Boring logs; and
    f. Site Photographs.
7. Performed a hydraulic fracture and drilling fluid surface release analysis to quantify the risk of hydraulic fracture and drilling fluid surface release.

8. Completed HDD design, including:
    a. Alignment and profile;
    b. Minimum radius;
    c. Installation stresses; and
    d. Operating stresses.
9. Providing this draft HDD design report to the project team for review and comment. The draft report includes:
    a. Analyses and discussion of hydraulic fracture and drilling fluid surface returns potential;
    b. Installation stress calculations;
    c. Operating stress calculations;
    d. HDD design conclusions and recommendations, including:
        i. Drilling fluid loss;
        ii. Minimum allowable product pipe bending radius;
        iii. Pilot hole survey recommendations;
        iv. Anticipated drilling conditions;
        v. Hole collapse conclusions and recommendations;
        vi. Pipe coating specifications conclusions;
        vii. Buoyancy considerations;
        viii. Site access considerations; and
        ix. Noise mitigation techniques.
    e. Geotechnical engineering considerations, including:
        i. Temporary access roads;
        ii. Temporary workspace areas;
        iii. HDD installation
        iv. Temporary excavations;
        v. Construction dewatering; and
        vi. Erosion control.
    f. HDD design drawing, including site-specific construction diagrams that show the location of temporary entry and exit workspaces, pipe assembly areas and areas to be disturbed or cleared for construction.
10. Preparing a final HDD design report incorporating comments from the project team.

3.0 SITE CONDITIONS

3.1 Geologic Setting

3.1.1 Site Geology

The geologic mapping we reviewed (Beaulieu and Baldwin, 1973) shows the site underlain by Quaternary-aged marsh and peat deposits overlying the Tertiary aged Flournoy Formation. The peat and marsh is described as unconsolidated organic soils of silt, clay and sand. The Flournoy Formation is described as rhythmically bedded siltstone and sandstone.

3.2 Surface Conditions

3.2.1 General

We evaluated surface conditions in the vicinity of the site by completing a site reconnaissance during both our preliminary site visits, and our subsurface exploration program conducted on December 6th and 7th, 2012.

3.2.2 Surface Description

The proposed HDD alignment is oriented in a generally northwest-southeast (entry to exit) direction, as shown in Figure 2. The north side (entry) of the proposed HDD is situated on a gently sloping (less than 10 percent) field within the Coos River Valley between approximately Elevation 8 feet and 17 feet above mean sea level (MSL). The south side (exit) is located on a relatively flat alluvial valley floor at about Elevation 5 feet. The north bank of the Coos River is approximately 500 feet south of the entry point and the south bank is approximately 630 feet north of the exit point. Coos River Highway parallels the river on the north side and South Coos River Highway parallels the river on the south side. Both highways are situated on elevated embankments or levees between approximate elevation of 10 to 15 feet.

The open field on the north side of the HDD is located adjacent to the Coos River Highway and is approximately 250 feet wide measured parallel to the highway and is approximately 550 feet long. The proposed entry workspace occupies an irregularly shaped approximately 200-foot by 250-foot area, with the south side of the workspace approximately 100 feet south of the entry point. The area within the entry workspace is vegetated with low grass and a few deciduous trees on the north end. The ground surface at the time of exploration was soft due to recent rains saturating the near surface soils.

The exit workspace occupies an approximately 230-foot by 300-foot area, with the north side of the workspace approximately 125 feet north of the exit point. The area within the exit workspace and stringing area is relatively flat. The ground surface within the stringing area ranges from Elevation 6 feet at the south end to approximately Elevation 3 feet at the west end of the stringing area. The vegetation within the exit workspace and stringing area consists of low grasses.

3.3 Subsurface Conditions

3.3.1 General

We explored subsurface conditions at the site between the dates of December 6th and 7th, 2012 by advancing four drilled borings to maximum depths of 101.5 feet below ground surface (bgs) at the locations shown in Figure 2. A representative from GeoEngineers maintained logs of the materials encountered in each boring and collected disturbed soil samples at 5-foot intervals. Appendix A presents the boring logs and a description of the subsurface exploration and laboratory-testing programs. Laboratory test results are shown in the boring logs in Appendix A.

The materials encountered in our borings were consistent with the geologic mapping for the site. In general, the borings completed on the north side of the crossing encountered fat clay with organic matter, organic clay, and clayey sand overlying siltstone at depths of 48 to 96 feet bgs. The borings completed on the south side of the crossing generally encountered interbedded silt, silty sand, sand with silt, and fat clay to the maximum depths explored. The materials encountered in each boring are described in more detail in the following paragraphs.

3.3.2 Subsurface Conditions Encountered by Borings

Boring CR-1 was completed approximately 125 feet southeast of the entry point and approximately 400 feet northwest of the north bank of the Coos River. Boring CR-1 encountered approximately 48 feet of very soft to stiff fat clay with occasional gravel and varying amounts of organic matter overlying predominantly decomposed, very soft siltstone to a depth of 55.2 feet bgs, the maximum depth explored.

Boring CR-2 was completed approximately 375 feet southeast of the entry point and approximately 150 feet northwest of the north bank of the Coos River. Boring CR-2 encountered 43 feet of very soft organic clay and silt, soft lean clay with sand, and very loose clayey fine to coarse sand overlying soft to very stiff fat clay with varying amounts of sand and gravel to a depth of 96 feet bgs. Very soft, fresh siltstone was encountered from 96 feet bgs to a depth of 101.7 feet bgs, the maximum depth explored.

Boring CR-3 was completed approximately 525 feet northwest of the exit point and approximately 100 feet southeast of the south bank of the Coos River. Boring CR-3 encountered 13 feet of very soft sandy silt and silt with varying amounts of organic matter overlying 10 feet of loose to very loose fine sand with silt. Loose to dense, silty fine sand with trace organic matter was encountered from a depth of 23 feet to a depth of 90 feet bgs, overlying very soft fat clay with trace organic matter to a depth of 101.5 feet bgs, the maximum depth explored.

Boring CR-4 was completed approximately 200 feet northwest of the exit point and approximately 425 feet southeast of the south bank of the Coos River. Boring CR-4 encountered 23 feet of very soft organic clay and very loose silty fine sand overlying very soft to soft, fine sandy silt with loose silty fine sand layers to a depth of about 63 feet, where very loose to medium dense fine sand with varying amounts of silt was encountered to a depth of 76.5 feet bgs, the maximum depth explored.

The subsurface materials encountered in the borings are described in more detail in the boring logs included in Appendix A.

3.3.3 Groundwater Conditions

During our borings, we were not able to measure groundwater levels due to the presence of drilling fluid. However, based on the observed relative moisture content of the samples, and the locations and elevations of the borings relative to the Coos River, we estimate that groundwater was at or near the ground surface at the time of drilling. We anticipate that groundwater levels will fluctuate with precipitation, site utilization and other factors. During heavy prolonged precipitation, and probably during most of the winter months, we expect that groundwater will be near or at the surface of the site.

4.0 HDD ENGINEERING ANALYSES

4.1 Hydraulic Fracture and Drilling Fluid Surface Release Evaluation

4.1.1 Model Input Parameters

The HDD geometry used for our analyses of the Coos River HDD is shown in the HDD Design Drawing in Appendix B. The horizontal length of the HDD is 1,602 feet. The soil units encountered in the vicinity of the HDD are characterized by borings CR-1 through CR-4. A general description of the subsurface conditions encountered in the borings is presented in Section 3.3.2, and the boring logs are presented in Appendix A. Generally, the soils encountered in the borings to the north of Coos River consisted of fat clay with organic matter, organic clay, and clayey sand overlying siltstone. The borings completed on the south side of the crossing generally encountered interbedded silt, silty sand, sand with silt, and fat clay to the maximum depths explored.

Based on the results of the exploration program and subsequent laboratory-testing program, the soil properties used in the evaluation are presented in Table 2 below.

TABLE 2. ESTIMATED SOIL PROPERTIES

Soil Description	Unit Weight (pcf)	Friction Angle (degrees)	Cohesion (psf)
Very Soft Silt and Organic Silt	90	0	100
Soft Fat Clay	90 – 100	0	100 – 350
Medium Stiff to Stiff Fat Clay	100 – 105	0	750 – 1,000
Stiff Fat Clay	105 – 110	0	1,000 – 1,500
Very Stiff Fat Clay	115 – 120	0	2,000 – 3,000
Soft Sandy Silt	100	20	200
Loose Clayey Sand/Soft Sandy Clay	100	24	200
Loose Silty Sand	100 – 110	26 – 28	0
Medium Dense Silty Sand	110 – 115	30 – 32	0

Notes:

pcf = pounds per cubic foot; psf = pounds per square foot

Based on available information and common HDD construction procedures, the tool dimensions and rheological properties used in the evaluation are summarized in Table 3. Because these parameters are dependent upon the HDD contractor’s means and methods, the hydraulic fracture and drilling fluid surface release evaluation should be refined during construction of the HDD installations.

TABLE 3. ESTIMATED TOOL DIMENSIONS AND RHEOLOGICAL PROPERTIES

Parameter	Value
Pilot Hole Bit Diameter	9.875 inches
Drill Pipe Diameter	5.0 inches
Drilling Fluid Weight	9.5 ppg
Plastic Viscosity	8 CP
Yield Point	20 lb/100 sf

Notes:

ppg = pounds per gallon; CP = centipoise; lb/100 sf = pounds per 100 square feet

4.1.2 Discussion of Hydraulic Fracture and Drilling Fluid Surface Release

4.1.2.1 GENERAL

During HDD installation, drilling fluid is transported under pressure through the drill pipe string to the cutting tool. For HDD installations like the Coos River HDD, pump pressures of several hundred pounds per square inch (psi) and pump rates of 150 to 400 gallons per minute (gpm) are typical. The drilling fluid typically has a specific gravity ranging from 1.1 to 1.2 (approximately 69 to 75 pounds per cubic foot).

The total drilling fluid pressure at the cutting tool is a function of pumping pressures, the elevation difference between the drill rig and the cutting tool and friction losses. Soil and rock formations along the drill path experience maximum drilling fluid pressures in the immediate proximity of the drill bit or reaming tools. The energy (pressure) of the drilling fluid is steadily diminished along its path from the drill rig to the cutting tool and back to the rig through the annulus of the hole. Thus, the pumping pressure required to circulate the drilling fluid increases as the drill bit advances farther from the drill rig. Typically, the annular drilling fluid pressure at the cutting tool can range from 15 to 25 percent of the pump pressure.

4.1.2.2 DRILLING FLUID LOSS

Drilling fluid circulation may be reduced or lost during HDD operations by drilling fluid loss to the surrounding soil or by the accumulation of cuttings downhole that create a blockage, which may result in hydraulic fracture. These two processes are discussed below:

1. Formational fluid loss occurs when drilling fluid flows into surrounding permeable soil units either within the pore spaces of the soil or along preexisting fractures or voids in the formation.
2. Hydraulic fracturing and subsequent loss of drilling fluid can occur where the combined resisting force of the available overburden pressure and the shear strength of the overburden soil is less than the hydrostatic drilling fluid pressure and the pressures applied to the surrounding soil from the drilling fluid at the cutting tool.

Formational drilling fluid losses typically occur when the drilling fluid flows through the pore spaces in the soil through which the HDD profile passes. Thus, a formation with a higher porosity can potentially absorb a larger volume of drilling fluid than a formation with a lower porosity. Silty sands, silts and clays typically have a low susceptibility to formational drilling fluid losses. Coarse sand and gravel units with low percentages of silt and clay have a moderate to high susceptibility for drilling fluid loss. The proper management of the drilling fluid properties can reduce the volume of formational drilling fluid loss.

4.1.2.3 HYDRAULIC FRACTURE

Hydraulic fracture is a term typically used to describe the condition in which the downhole drilling fluid pressure exceeds the overburden pressure and shear strength of the soil surrounding a drill path. Soils that are most vulnerable to hydraulic fracture include relatively weak cohesive soils or loose granular soils with low shear strength. Medium dense to very dense sands and very stiff to hard silts and clays have a low to moderate hydraulic fracture potential. HDD installations with greater depth or drill paths in formations with higher shear strength may reduce the potential for hydraulic fracturing.

4.1.2.4 DRILLING FLUID SURFACE RELEASE

Drilling fluid surface releases, commonly referred to as "Frac-Outs," occur when drilling fluid emerges at the ground surface or in any other undesired location such as wetlands, utility trenches, basements, roads, railroads, and waterbodies (Photograph 1). In practice, drilling fluid surface releases typically occur in proximity to the entry and exit points where annular pressures are high and soil cover is thin. Drilling fluid surface releases can also occur at locations along a drill path where there are low shear strength soils, where soil cover is relatively thin or along preexisting fractures or voids. Other locations where drilling fluid surface releases can occur are along preferential pathways such as exploratory boring locations, within utility trenches, or along the edges of existing subsurface structures such as piles or utility poles.

The HDD contractor's construction procedures constitute another important factor influencing when and where drilling fluid loss occurs. If the contractor operates with insufficient drilling fluid flow rates, inadequate drilling fluid properties or excessive rates of penetration, the annulus may become blocked through an accumulation of drill cuttings falling out of suspension. This can occur within formations that typically have a low potential for hydraulic fracture. If the accumulation of cuttings creates a blockage downhole, the annulus may become over-pressurized, leading to hydraulic fracturing and potentially drilling fluid surface releases. Our analysis does not account for this over-pressurized condition.

Photograph 1 - Example of Drilling Fluid Surface Release

4.1.2.5 HYDRAULIC FRACTURE CALCULATIONS

The procedures used to evaluate the potential for drilling fluid loss through hydraulic fracturing are based primarily on research completed by Delft Geotechnics, as discussed in Appendix B of the USACE Report CPAR-GL-98 (Staheli, et al., 1998). The methodologies used to estimate the hydraulic fracture potential outlined in the research are based on cavity expansion theory. The cavity expansion model is used to estimate the maximum effective pressure in the drill hole before plastic deformation of the drill hole occurs.

In order to evaluate the hydraulic fracture and drilling fluid surface releases potential for a HDD installation, assumptions must be made when selecting the input parameters. The assumptions used in the model include the extent and uniformity of soil layers, hydrostatic groundwater pressures, drilling fluid properties, penetration rates and drilling fluid flow rates. The soil strength properties are estimated based on interpretations of the boring logs and laboratory test results. The drilling fluid properties, penetration rates and pump rates are estimated based on generally accepted best management practices (BMPs) of the HDD industry. Consequently, the results of the evaluation are only estimates of the potential for hydraulic fracture and drilling fluid surface releases.

In addition, the drilling fluid properties are dependent on the field conditions and the construction practices of the HDD contractor and drilling fluid engineer. Changes in these properties can significantly affect the potential for hydraulic fracture and drilling fluid surface releases.

Based on the soil properties, rheological parameters and anticipated tool dimensions, the model considers the total and effective overburden stresses, shear strengths of the soil, and the estimated drilling fluid pressures along the drill path. A comparison is then made of the estimated drilling fluid pressures immediately behind the drill bit and the ability of the soil to resist plastic deformation. The evaluation considers only the hydraulic fracture potential during pilot hole operations assuming the drilling fluid returns are continuously maintained to the entry point.

The factor of safety against hydraulic fracturing of the soil surrounding the drill bit is defined as the ratio of the formation limit pressure to the estimated annular drilling fluid pressure. The factor of safety against drilling fluid surface releases is defined as the maximum factor of safety against hydraulic fracture calculated for all of the soil units above specified points along the drill path.

In some cases, the evaluation may indicate a high potential for, or a low factor of safety against, hydraulic fracture in the soils surrounding the drill bit; however, a higher-strength layer may be present above the weaker layer that may reduce the migration of drilling fluid toward the ground surface, thus providing a higher factor of safety against drilling fluid surface releases.

Table 4 below shows the relative risk associated with the estimated factors of safety against hydraulic fracture and drilling fluid surface releases.

TABLE 4. RELATIVE HYDRAULIC FRACTURE AND DRILLING FLUID SURFACE RELEASE RISK

Factor of Safety	Relative Risk
Less than 1	Very High
Between 1 and 1.5	High
Between 1.5 and 2	Moderate
Greater than 2	Low

4.1.3 Results of Hydraulic Fracture and Drilling Fluid Surface Release Evaluation

The results of the hydraulic fracture evaluation are presented in Figures 5 through 7. The formation limit pressure, presented in Figure 5, is the ability of the soil to resist plastic deformation and is a function of the shear strength of the soil through which the HDD profile passes. Based on the HDD design, the proposed HDD profile passes through layers of very soft to medium stiff fat clay, organic silt and clay, fine sandy silt and very loose to medium dense silty fine sand. As a result, the formation limit pressure varies depending on the soil encountered along the HDD profile as shown in Figure 5 as the green line. In general, the areas with the higher formation limit pressures are the silty sand and sandy silt soils. The estimated drilling fluid pressure is also shown in Figure 5 as the red line and represents the drilling fluid pressure along the HDD profile based on the anticipated drilling fluid properties shown in Table 3.

When evaluating the risk of hydraulic fracture and drilling fluid surface releases, the analysis computes two types of factors of safety. These are:

- Factor of Safety against localized hydraulic fracture; and
- Factor of Safety against drilling fluid surface release.

Local Hydraulic Fracture: The factor of safety against hydraulic fracture is the ratio of the formation limit pressure to the estimated drilling fluid pressure along the profile, shown as the green line in Figure 6. This represents the factor of safety against hydraulic fracture of the soil immediately surrounding the HDD profile and is a localized condition.

Drilling Fluid Surface Release: The factors of safety against drilling fluid surface release considers the strength of the soil column above the HDD profile that resists drilling fluid migrating to the ground surface. It is computed by comparing the formation limit pressure of the soil units above a specific location along the planned HDD alignment to the anticipated drilling fluid pressure at the same location. The factors of safety against drilling fluid surface releases are shown in Figure 6 at selected points shown as red triangles.

The model indicates that the risk of drilling fluid surface release is generally low when the HDD profile is located within the silty sand units, with calculated factors of safety generally greater than 2, see Figure 6. The factors of safety, however, drop significantly when the HDD passes through the fat clay, organic silt and clay, and shallow sandy silt units as shown in Figure 6 between Stations 4+00 (Entry) and 7+00 and 17+00 and 20+00 (Exit). Figure 6 also shows the factors of safety against hydraulic fracture generally decrease as the HDD progresses towards the exit point as the required drilling fluid pressure increases with length. Most importantly, the factors of safety against drilling fluid surface release are greater than 2 (low risk) along the portion of the HDD path located beneath Coos River.

4.2 Installation Stresses

The analyses of installation loads and stresses are based on the product pipe being installed along the designed path using the BMPs of the HDD industry. The addition of water into the product pipe is the standard method that contractors typically use to control buoyancy of the product pipe during the installation procedure. The proposed 36-inch-diameter product pipe will be positively buoyant in the anticipated drilling fluid weights. Therefore, our analyses include five cases with differing levels of buoyancy and drilling fluid weights.

The five cases analyzed are as follows:

1. The annulus contains 9.5 lb/gal drilling fluid and product pipe is empty.
2. The annulus contains 9.5 lb/gal drilling fluid and product pipe is full of water.
3. The annulus contains 12 lb/gal drilling fluid and product pipe is empty.
4. The annulus contains 12 lb/gal drilling fluid and product pipe is full of water.
5. The annulus contains 10.5 lb/gal drilling fluid and product pipe is filled such that neutral buoyancy is achieved.

The analyses are based upon the methods developed by the Pipeline Research Committee International (PRCI) of the American Gas Association (PR-227-9424, 1995). The only deviation from this guide in calculating the installation stresses is a more conservative allowable tensile stress (F_t).

The equation recommended in the PRCI Design Guide is shown in below in **Equation 1**:

F_t = 0.9 *SMYS (Specified Minimum Yield Strength)

The allowable tensile stress used for our analyses is derived from Sections 2.4.1, 3.1.2 and 3.2 of the American Petroleum Institute (API) Recommended Practice 2A – WSD (WSD Recommended Practice 2A-WSD, 1993).

Section 3.2 of the API Recommended Practice defines the allowable tensile stress of cylindrical members as shown below in **Equation 2**:

F_t = 0.6 *SMYS

Sections 2.4.1 and 3.1.2 of the API Recommended Practice permit the allowable tensile stress, defined in Equation 2, to be increased by one-third, yielding a design factor of 0.8, which is more conservative than 0.9 as listed in the PRCI Design Guide.

The equation used in our analyses is shown below in **Equation 3**:

F_t = 0.8 *SMYS

The following table presents a summary of the calculated installation loads for the HDD.

TABLE 5. INSTALLATION LOADS FOR THE 36-INCH-DIAMETER COOS RIVER HDD[1]

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Effective Pipe Weight[2] (lb/ft)	Pullback Force[3] (lb)
9.5	Empty	-192	240,000
9.5	Full	209	207,000
12	Empty	-325	316,000
12	Full	77	135,000
10.5	Neutral Buoyancy	0	127,000

Notes:

[1]See Appendix B for detailed calculations.

[2]Negative values indicate upward force (positive buoyancy).

[3]Assumes a fully open drilled hole.

4.3 Operating Stresses

The operating stresses on a pipeline installed by directional drilling include hoop stress from the maximum allowable operating pressure (MAOP), hoop stress from external pressure applied by the groundwater acting on the outside of the product pipe, elastic bending as the product pipe conforms to the shape of the drilled hole, and thermal expansion and contraction stresses resulting from the difference between the constructed temperature and the operating temperature. The following table presents a summary of the operating stresses based on the product pipe specifications and the HDD profile as shown on the HDD Design Drawing in Appendix B.

TABLE 6. SUMMARY OF OPERATING STRESSES FOR THE 36-INCH-DIAMETER COOS RIVER HDD*

Stress Component	Stress (psi)	Percent SMYS[1] (%)	Maximum Allowable Percent SMYS (%)
Longitudinal Bending Stress	16,900	24	-
Hoop Stress	34,990	50	50[2]
Longitudinal Tensile Stress from Hoop Stress	10,500	15	-
Longitudinal Stress from Thermal Expansion	9,500	14	90[3]
Maximum Net Longitudinal Stress	17,900	26	90[4]
Maximum Shear Stress	25,500	36	45[5]
Maximum Combined Effective Stress	50,960	73	90[6]

Notes:

*Operating stress calculations are based on the specified minimum radius of curvature of 2,600 feet and assumed installation and maximum operating temperatures of 50 degrees and 100 degrees Fahrenheit, respectively.

[1]Specified Minimum Yield Strength

[2]Limited by design factor from DOT regulations, Title 49 CFR Part 192.111 for gas.

[3]Limited by Section 402.3.2 of ASME B31.4.

[4]Limited by Section 833.3 of ASME B31.8 for gas.

[5]Limited by Section 402.3.1 of ASME B31.4.

[6]Limited by Section 833.4 of ASME B31.8 for gas.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 HDD Design Considerations and Recommendations

5.1.1 General

The contractor's means and methods during construction are critical to the successful completion of the HDD. Specifically, during pilot hole drilling, only small deviations from the design for horizontal and vertical curvature should be allowed so that pull load forces similar to those estimated by the calculations can be maintained. The HDD contractor's ability to maintain drilling fluid returns, proper drilling fluid properties with appropriate penetration rates, and drilling fluid flow rates will also be important factors to consider during drilling because hole conditions will be directly affected by these operations.

We recommend that PCGP, LP retain a qualified representative to observe and document the drilling process and to advise the project team on areas of concern and recommended actions during drilling activities. We also recommend that PCGP, LP require that a qualified drilling fluid engineer or technician evaluate the drilling fluid properties on a continuous basis during the entire drilling and installation process. Close coordination between the contractor and the drilling fluid engineer or technician to maintain proper drilling fluid properties, penetration rates and drilling fluid flow rates will be instrumental to effectively remove cuttings from the pilot hole and reamed hole.

5.1.2 Drill Hole Stability

In general, the alluvial soils encountered by our borings along the proposed HDD alignment have a low risk of hole instability. However, if hole instability or steering difficulty occur, installation of casing at the entry and exit points can serve to maintain drill hole stability. If casing is utilized, upon completion of the pilot hole or prior to reaming the cased section of the hole, the casing is typically removed but could remain in place through product pipe pullback to maintain drill hole stability within the entry tangent. The specific casing diameter and installation method should be determined by the HDD contractor.

5.1.3 Cuttings Removal

Based on our experience, cuttings removal in fat clay like that encountered by borings underlying the HDD alignment is typically more challenging than in other non-cohesive soils. In some cases, relatively dry fat clays may swell and block the drill hole or the clay cuttings may "ball up" forming large diameter particles that fall out of suspension and are more difficult to remove than smaller clay particles that remain in suspension. Therefore, the potential for the hole to become plugged with cuttings is elevated along the proposed HDD crossing where the drill path is within the fat clay observed in the borings. In the event that the hole becomes plugged, and drilling fluid circulation ceases, downhole annular pressures can increase dramatically. This temporary spike in downhole annular pressure can dramatically increase the risk of hydraulic fracture and drilling fluid surface release. In addition, if cuttings are not effectively removed from the hole during HDD operations, pullback forces could be excessively high during pullback of the 36-inch-diameter product pipe, or the product pipe could become lodged in the hole. The failure to effectively remove cuttings from the hole could potentially result in failure of the HDD installation. Therefore, we recommend that the drilling contractor maintain drilling fluid returns at all times, and use appropriate means and methods (appropriate penetration rates, drilling fluid management, mechanical methods) to ensure that cuttings are adequately removed from the hole during the HDD process.

5.1.4 Drilling Fluid Loss and Drilling Fluid Surface Release

It is our opinion that there is a relatively high risk of hydraulic fracture and drilling fluid surface releases along the first 500 feet and last 300 feet of the HDD, respectively. However, based on our analyses, the risk of drilling fluid surface release to the Coos River is relatively low. As is typical with all HDDs, the risk of drilling fluid surface release is becomes high within approximately 150 feet of the exit. Drilling fluid surface releases may occur within these high risk zones even if the contractor maintains drilling fluid returns during construction and also maintains drilling fluid properties that are conducive to cuttings removal and formation of a "wall cake" to help stabilize the borehole and limit fluid interaction between the borehole and surrounding soils.

Because of the elevated risk of drilling fluid surface release occurring near the entry and exit points during construction, we recommend that the contractor establish a contingency and mitigation plan in the event that drilling fluid surface releases occur; these plans should be reviewed and approved by the project team prior to the start of construction. We recommend the annular drilling fluid pressures be closely monitored during drilling to help identify when the potential for a surface release of drilling fluid may be possible. Annular pressures can be monitored through the use of an annular pressure tool as part of the bottom hole assembly (BHA).

5.1.5 Workspace Considerations

There is not adequate area for a pipe stringing and fabrication workspace on the northwest side of the proposed HDD. Therefore, the Coos River HDD can be drilled from the northwest (entry) side to the southeast (exit) side so that the stringing area will be to the southeast. Depending on temporary workspace that can be obtained on the southeast side of the conceptual HDD, there may be enough linear area for a pipe stringing and fabrication workspace that will allow assembly of a single product pipe string. However, in order to achieve pullback with a single product pipe string, it will need to be curved slightly to the south.

There is adequate area for workspaces at the entry and exit points as shown in Figure 2. Minor grading may be required to prepare entry workspace, but grading is not likely required for the exit workspace. Near the entry and exit points, it will likely be necessary to provide a stable working platform such as a timber matted or gravel workspace and an entrance road during construction, particularly if construction is completed during the wet season, or when heavy prolonged precipitation occurs. In addition, construction roads will be required to access the entry and exit points and the product pipe stringing area, unless construction is completed during the latter part of the dry summer months when precipitation has not recently occurred and groundwater levels are at their lowest point throughout the year.

5.1.6 Minimum Allowable Product Pipe Bending Radius

The design radii for the entry and exit vertical curves are 3,600 feet. The design radii of the vertical curves were chosen based on the industry standard of the design radii being least 100 times the product pipe diameter in inches (for example, 36-inch-diameter pipe x 100 = 3,600-foot design radius), and to provide a reasonable separation of the design radii and the absolute minimum allowable radius calculated based on the product pipe specifications and the anticipated operating conditions. We recommend that the three-joint radius be calculated for each three-joint section of drill pipe during pilot hole operations. Based on the design geometry, subsurface conditions encountered, and proposed product pipe specifications, the minimum allowable three-joint radius over any consecutive three-joint section of drill pipe should not be less than 2,600 feet.

5.1.7 Pilot Hole Survey

We recommend that a secondary survey system (TruTracker, ParaTrack or equivalent) be used along the entire length of the HDD. If the HDD contractor elects to use the wire coil grids with these secondary survey systems, we recommend that the wire grids be placed at least as wide as the survey probe is deep. The placement of the coils is limited to areas where ground surface conditions and agreements with landowners allow.

The HDD design drawing in Appendix B shows two approximate configurations for secondary surface survey coil wires that may be used to track the bottom hole assembly during pilot hole operations. One of the configurations is for the ParaTrack survey system, and the other is for the TruTracker survey system. The secondary surface survey coil wire layouts shown in the design drawing are intended to show the general layout of typical survey coil configurations and are not intended to direct the HDD contractor as to the exact placement of the secondary surface survey coil wires. The final placement of secondary surface survey coil wires is the contractor’s responsibility and may vary from what is shown depending on ground surface conditions at the time of HDD installation, and the HDD contractor’s means and methods. We recommend that the contractor review the project plans and workspace limitations to determine the most appropriate configuration for the secondary survey system.

If secondary surface survey coils will be installed across or within water bodies, we recommend that the HDD contractor sufficiently anchor the coil wires such that the wire does not deviate from the installed location. If the coils are not sufficiently anchored, currents, boat traffic or other influences may deform the coil configuration, resulting in inaccurate downhole survey shots. In addition, accurate downhole survey shots may not be obtained if the coil corners are not properly surveyed.

For pilot hole operations, we recommend that the HDD contractor drill the pilot hole as closely as possible to the designed HDD profile while still maintaining three-joint horizontal and vertical radii equal to or greater than 2,600 feet. We recommend a horizontal tolerance of 5 feet left and 5 feet right of the designed alignment and a vertical tolerance of 2 feet above and 10 feet below the designed profile. We also recommend that, upon completion of the pilot hole, GeoEngineers have the opportunity to review the pilot hole survey data prior to the start of hole opening operations. The contractor should be responsible for producing an as-built drawing of the pilot hole survey data and providing it to PCGP, LP within 2 weeks of the completion of the pilot hole. This as-built drawing should be kept in the project file for future reference as to the location of the installed pipeline.

5.1.8 Product Pipe Coating Specifications

The proposed product pipe coating specifications provided by PCGP, LP specify a nominal thickness of 8 to 10 mils of external Fusion Bonded Epoxy (FBE), and 40 mil thick Abrasion Resistant Overlay (ARO).

5.1.9 Installation Load Considerations

For the proposed HDD crossing, we analyzed the anticipated pull loads based upon different drilling fluid weights in the drilled hole and the proposed pipe specifications. We also evaluated the anticipated pull loads based on using or not using buoyancy control. We recommend that the contractor utilize a rig that provides a factor of safety between the rig capacity and the anticipated pull loads. In addition, the contractor should install a deadman anchor of sufficient capacity to withstand the anticipated pull loads; these aspects are generally left to the contractor's discretion as approved by the owner. Based on our analysis of the installation stresses (see Table 6, in Section 4.3), the pullback force may be as high as 240,000 pounds, without the use of some form of buoyancy control and drilling fluid management. The calculations suggest that the pullback force required to install the product pipe may be reduced to approximately 127,000 pounds, if buoyancy control is used and neutral buoyancy is achieved, and drilling fluid weight is properly managed during construction.

5.1.10 Site Access

Access to the entry workspace can be gained from a gravel drive located southeast of the workspace, which connects with Coos River Highway approximately 0.9 miles northeast of the Chandler Bridge, east of Coos Bay, Oregon. Access to the exit workspace could be gained from a gravel road located off of South Coos River Highway approximately 0.7 miles northeast of Chandler Bridge. We anticipate construction of temporary access roads to the entry and exit workspaces will be necessary, depending on PCGP, LP's approved construction access routes. Recommendations for construction of access roads are provided in Section 5.2.1 below.

5.1.11 Water Sources

A reliable source of water for drilling operations is required during the HDD installation process. In addition, water is also required for the hydrostatic testing of the product pipe. Provided permits can be obtained, the HDD contractor may be able to use water from the Coos River or nearby streams for drilling operations. If local water sources are not available or permissible for access, the water for drilling operations will likely have to be obtained from an approved off-site source and transported to the site.

5.1.12 Noise Mitigation Techniques

Residences are located as close as approximately 300 feet the proposed entry workspace and 700 feet from the exit workspace. We do not anticipate that noise mitigation will be required for exit space operations. However, noise mitigation may be required for entry workspace operations. If noise mitigation is required, diesel power units associated with heavy equipment may be outfitted with noise-reducing mufflers. In addition, the contractor may need to place baffles around the equipment to further reduce noise emissions. The actual placement of the noise reduction measures should be implemented by the selected HDD contractor, when necessary.

5.2 Geotechnical Engineering Considerations

5.2.1 Temporary Site Access

If ground disturbance must be reduced to the extent possible, we recommend the construction of temporary access roads to the HDD work areas. The temporary access roads should consist of either board roads or a minimum 12-inch-thick layer of 4-inch-diameter quarry spalls. If soft or wet near surface soils are encountered, these measures may need to be augmented. If board roads are used, several layers of mats may be necessary to provide adequate support for the heavy equipment entering the site. If quarry spalls are used, the quarry spall thickness may need to be increased or a layer of woven geotextile fabric (TC Mirafi 600X or equivalent) or biaxial geogrid (Tensar BX 1200 or equivalent) may be placed below the quarry spalls. The temporary roads should be constructed with culverts and other improvements necessary to allow surface water runoff to drain without ponding or changing off-site drainage patterns.

5.2.2 Temporary Workspace Areas

Temporary work pad areas for staging drilling equipment, pipeline materials and excavation equipment may be necessary at the entry and exit points depending on the conditions at the time of construction. The size and location of workspace areas to accommodate the HDD and pipeline tie-in activities depend on the available space and right-of-way constraints. The proposed temporary entry, exit and product pipe stringing workspaces for the project are shown in Figure 2.

If necessary, we recommend that the workspace areas be protected with either board mats or a minimum 12-inch-thick layer of 4-inch-diameter quarry spalls. If soft or wet near-surface soils are encountered, these measures may need to be augmented. If board mats are used, several layers of mats may be necessary to provide adequate support for the heavy equipment entering the site. If quarry spalls are used, quarry spall thickness may need to be increased or a layer of woven geotextile fabric (TC Mirafi 600X or equivalent) or biaxial geogrid (Tensar BX 1200 or equivalent) may be placed below the quarry spalls. We also recommend placing an additional 2-inch-thick layer of ¾-inch crushed rock on top of the quarry spalls, which should improve the overall site safety and provide a level surface for light-duty vehicles and foot traffic. The temporary work pads should be removed upon completion of the product pipe installation, and the areas should be restored in accordance with the project site restoration plan.

5.2.3 HDD Installation

Drilling fluid containment pits will be required at the drill entry and exit work areas. Depending on the practices of the HDD contractor, drilling fluid containment pit excavations are typically constructed adjacent to the centerline near the entry and exit point locations and are approximately 20 feet long by 10 feet wide by 6 feet deep.

Based on the completed explorations, soil within the planned excavation depths is anticipated to consist of very soft fat clay and organic silt. Conventional equipment, such as backhoes or excavators, should be suitable for excavation of these soils.

5.2.4 Temporary Excavations

Maintenance of safe working conditions, including temporary excavation stability, is the responsibility of the contractor. All temporary cuts in excess of 4 feet in height should be shored or sloped in accordance with OSHA regulation 1926 Subpart P, Appendix B – Sloping and Benching. For planning purposes, soils encountered within the exploratory borings in the vicinity of the excavation areas should be classified as Type C Soil. Temporary excavations in Type C soil should be inclined no steeper than 1.5H:1V (horizontal to vertical). However, if caving occurs in excavation sidewalls, temporary excavations may need to be laid back to a shallower inclination. These cut slope inclinations are applicable to excavations above the groundwater table only. Dewatering may be required to lower the groundwater table below the base of the excavations. Steeper temporary slope inclinations may be allowed if soil conditions are determined to be suitable by the field geotechnical engineer. For open cuts, we recommend that:

1. No traffic, construction equipment, stockpiles or supplies should be allowed within a distance of at least 5 feet from the top of the cut;
2. Construction activities should be scheduled to reduce the length of time the cuts are left open;
3. Erosion control measures should be implemented as appropriate to limit runoff from the site; and
4. Surface water should be diverted away from the excavations.

5.2.5 Construction Dewatering

The contractor should have the responsibility of determining whether dewatering measures are needed at the time of work. Based on the explorations completed to date, we anticipate that very soft fat clay and organic silt could be encountered in shallow excavations at entry and exit. Groundwater seepage through low plasticity or granular soils may cause caving, making it difficult to keep the excavations open to the required depths. If granular soils and high groundwater conditions are encountered, the contractor may need to implement a well point or pumping well dewatering system. The construction of low berms around excavations should help reduce the volume of surface water runoff entering the excavations.

The contractor should be prepared to handle the effluent that will be generated during any dewatering operations. The effluent may need to be treated in a settlement tank, sediment trap or basin in order to meet discharge permit requirements for sediment content. Additionally, filter bags or filter socks might be necessary at the end of the outfall pipe or hose to reduce sediment discharge.

5.2.6 Erosion Control

To reduce the potential for migration of sediment off site and into adjacent receiving waters during HDD operations, we recommend that state and local regulations be followed during and after construction operations. Proper BMP should be implemented in accordance with the PCGP Project's Erosion Control and Revegetation Plan (ECRP).

6.0 LIMITATIONS

We have prepared this report for use by PCGP, LP. GeoEngineers' report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. The conclusions and recommendations in this report should be applied in their entirety.

Variations in subsurface conditions are possible between the explorations. Subsurface conditions may also vary with time. A contingency for unanticipated conditions should be included in the project budget and schedule for such an occurrence. We recommend that sufficient monitoring, testing and consultation be provided by GeoEngineers during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether earthwork and pipeline installation activities comply with contract plans and specifications.

The scope of our services does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractor's methods, techniques, sequences or procedures, except as specifically described in our report for consideration in design.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. No warranty or other conditions, express, written or implied, should be understood.

Please refer to Appendix C, titled "Report Limitations and Guidelines for Use," for additional information pertaining to use of this report.

7.0 REFERENCES

American Petroleum Institute, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design, API Recommended Practice 2A-WSD, July 1, 1993.

Beaulieu, J.D. and E.M. Baldwin, Geologic Map of the Coos Bay Quadrangle, Oregon. Included in Bulletin 87, Environmental Geology of Western Coos and Douglas Counties, Oregon. State of Oregon Department of Geology and Mineral Industries, Scale 1:62,500, 1973.

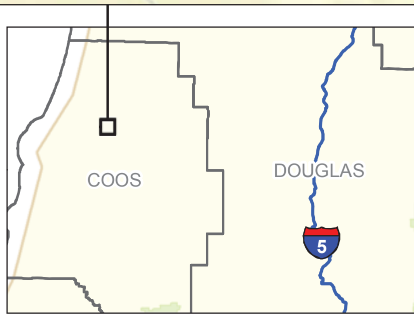
Installation of Pipelines by Horizontal Directional Drilling, an Engineering Design Guide, and Contract No. PR-227-9424, May 3, 1995.

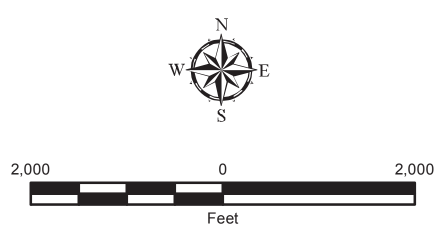
Oregon Department of Transportation Highway Division, Oregon Department of Transportation Soil and Rock Classification Manual, 1987.

Staheli, K., Bennett, D., O'Donnell, H.W., and Hurley, T.J., Installation of Pipelines beneath levees using horizontal directional drilling, Technical Report CPAR-GL-98-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 1998.

USGS, Spatial Digital Database for the Geologic Map of Oregon. Geology compiled by George W. Walker and Norman S. MacLeod. Spatial database by Robert J. Miller, Gary L. Raines and Katherine A. Connors. United States Geological Survey Open File Report 03-67, 2002.

FIGURES





Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
Data Sources: ESRI Data & Maps, Street Maps 2008.
Base map from ESRI Data Online.
Projection: NAD 1983, UTM Zone 10 North.

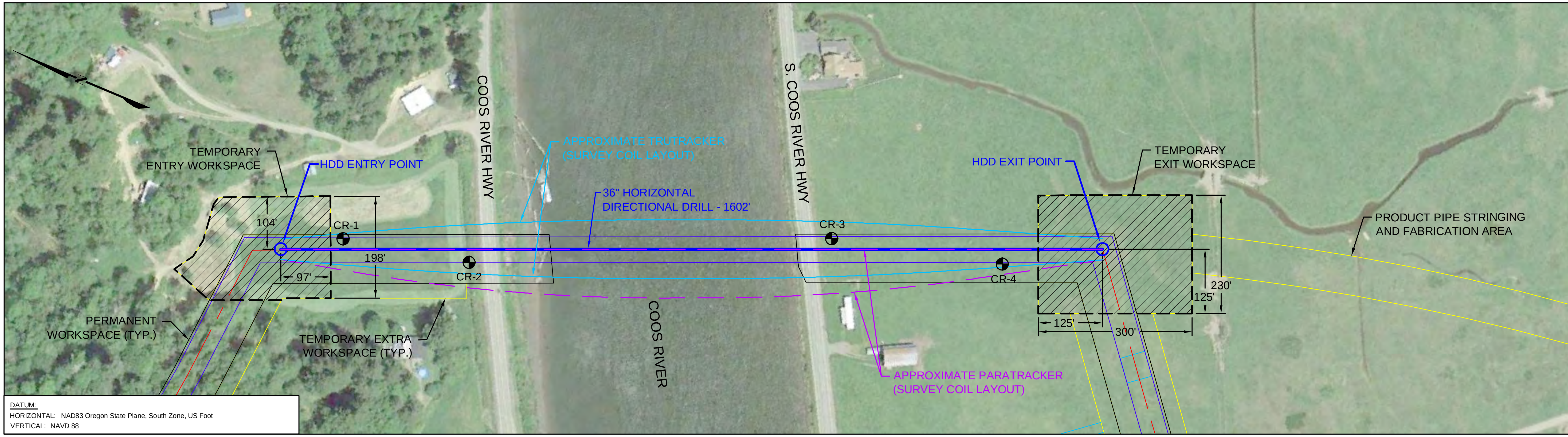
Vicinity Map

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure 1

Office: PORT Path: P:\16\1672400200\GIS\MXD\Task300\1672400200_Tsk300_CoosR_HDD_VM.mxd Map Revised: 21 July 2014 ccabrera

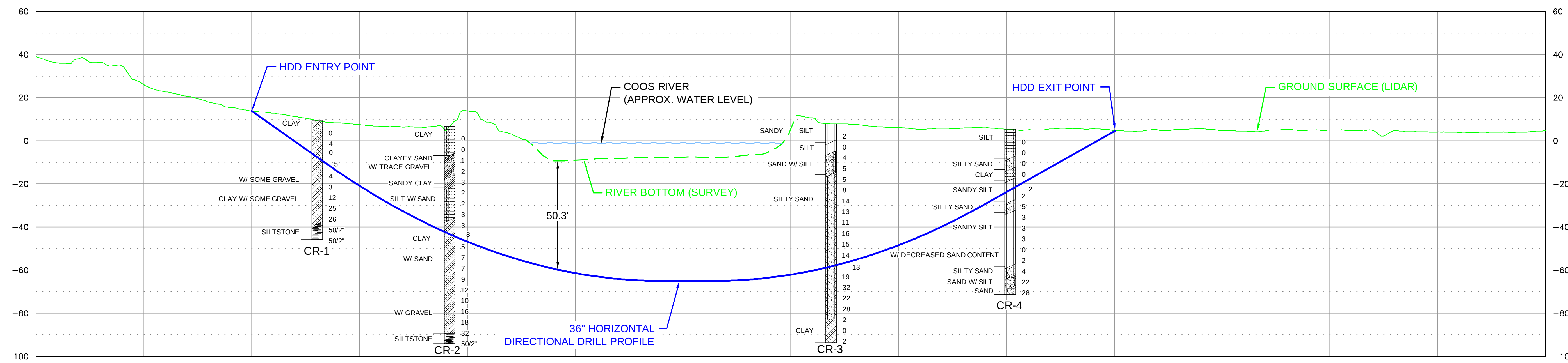


NOT FOR CONSTRUCTION

PLAN

200' 0 200'

SCALE IN FEET



PROFILE

200' 0 200'

HORIZONTAL SCALE IN FEET

50' 0 50'

VERTICAL SCALE IN FEET

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Refer to the boring logs in the accompanying report for more detailed soil descriptions.
4. GeoEngineers, Inc. has not verified the field location of the existing utilities.

Reference: Aerial image taken from Google Earth Pro, licensed to GeoEngineers, Inc., dated 05-03-13.
Surface lidar data generated from: edited lidar elevation data, downloaded from http://www.oregongeology.org
River bottom survey provided by Williams Northwest Pipeline, LLC.

LEGEND:

TYPE OF SOIL — SPT (N)

TYPE OF ROCK — RQD/%REC

Boring Location

SITE PLAN AND PROFILE

COOS RIVER HDD
COOS COUNTY, OREGON

GEOENGINEERS

FIGURE 2

AES : RBM

P:\16\1672400\00\CAD\Coos River HDD\Coos River HDD_IFP_Figure 2.dwg\TAB:Figure 2 modified on Dec 08, 2014 - 3:06pm

Entry Looking Southeast Toward Exit

Exit Looking Northwest Toward Entry

GEOENGINEERS

Pacific Connector Gas Pipeline Project
Coos River HDD Site Photos

FIGURE 3

SP:\16742002000|\Working\Task 0300-Coos River HDD\Coos River HDD_Site Photos

RTB: 072114

Boring CR-4 Looking Toward Exit

West of Exit Looking Toward Stringing Area

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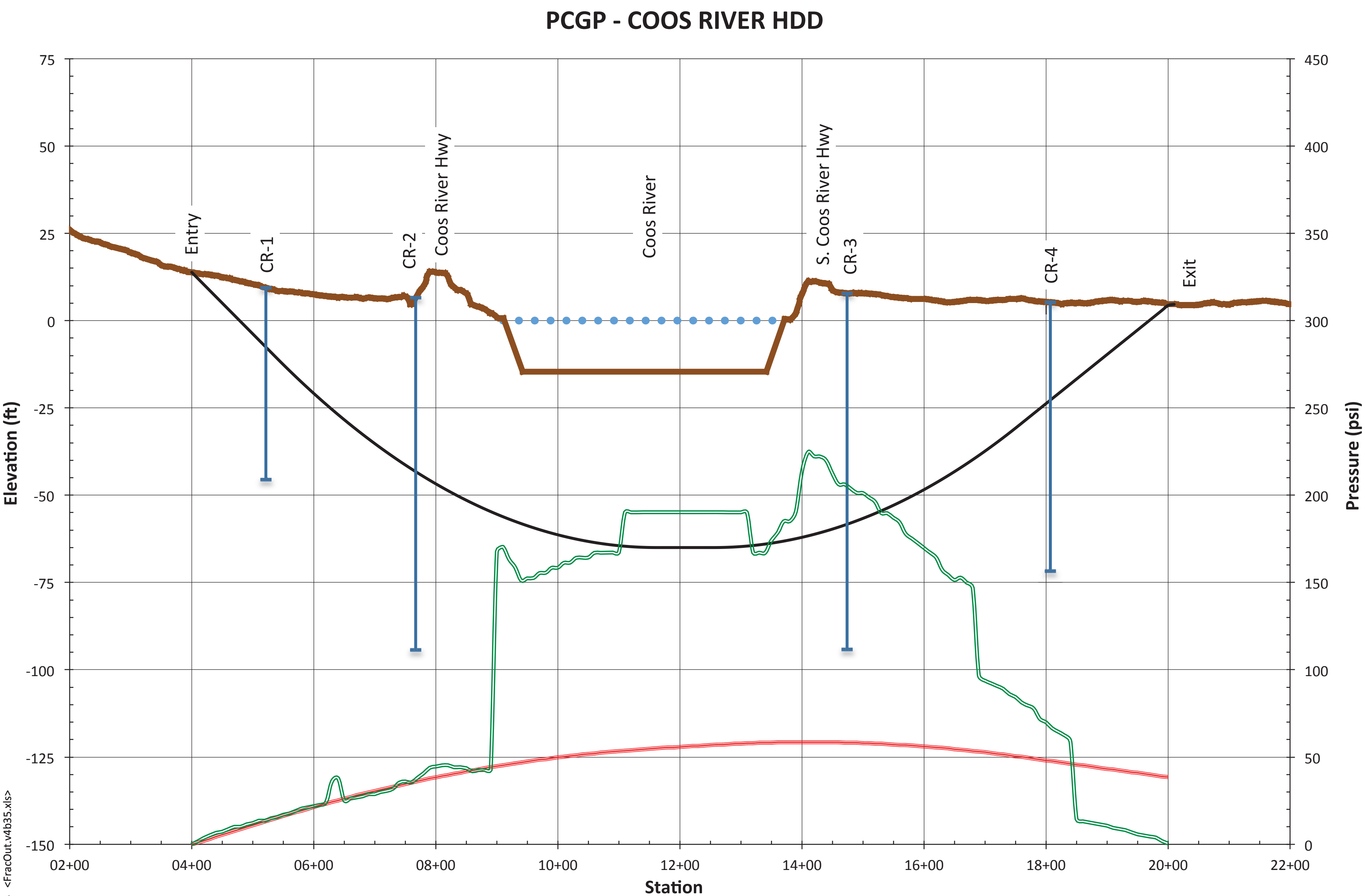
Pacific Connector Gas Pipeline Project
Coos River HDD Site Photos

FIGURE 4

SP:\1674200200|\Working\Task 0300-Coos River HDD\Coos River HDD_Site Photos

RTB: 072114



Crossing Length (ft)	1602
Hole Diameter (in)	9.875
Drill Pipe O.D. (in)	5.000
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	8
Yield Point (lb/100 ft)	20

Ground Surface Elevation (ft)
HDD Profile (ft)
Estimated Annular Drilliing Fluid Pressure (psi) for Pilot Hole
Formation Limit Pressure (psi)

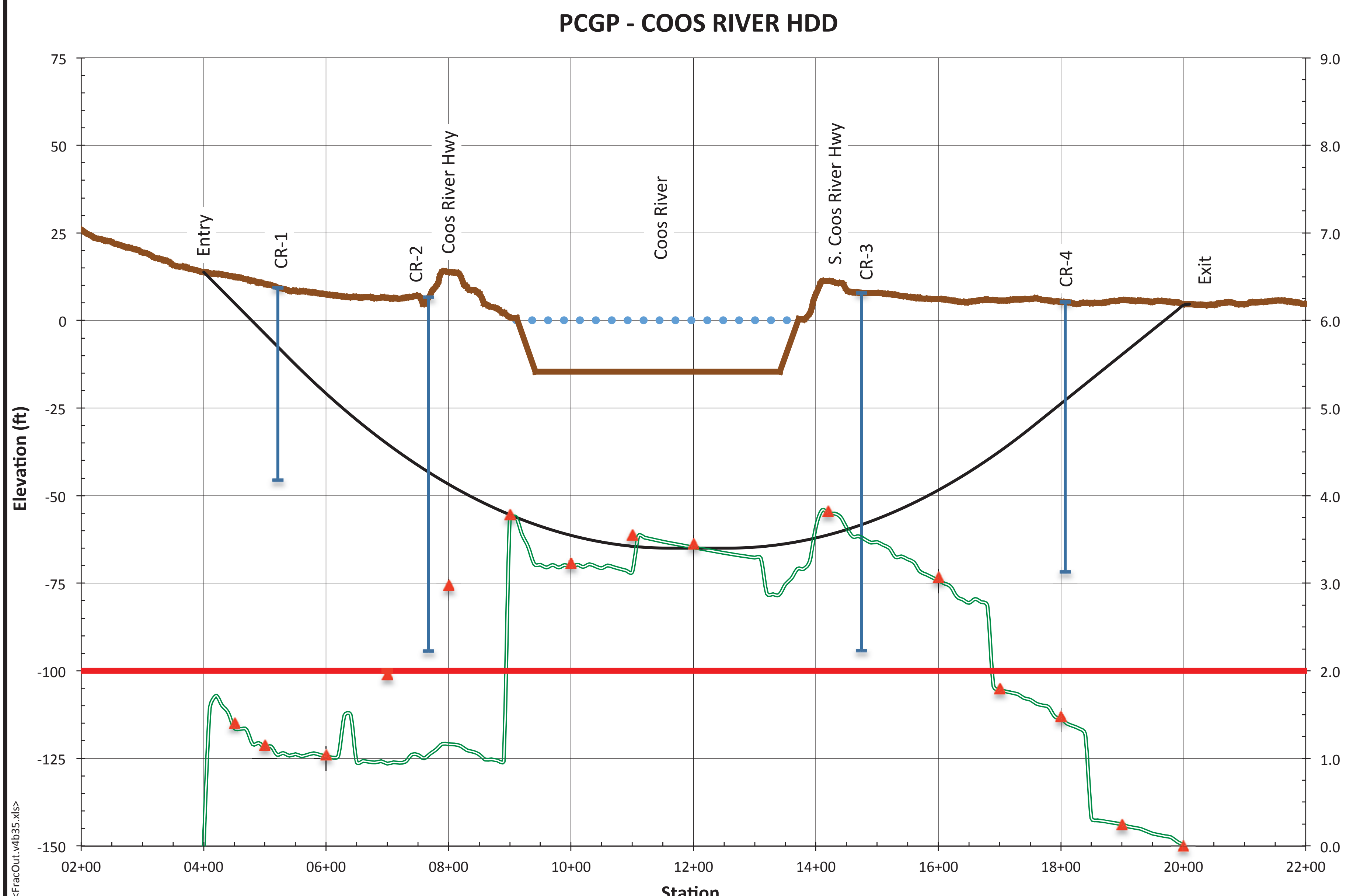
ESTIMATED ANNULAR DRILLING FLUID AND FORMATION LIMIT PRESSURES

PCGP - COOS RIVER HDD

GEOENGINEERS

FIGURE 5

16724-002-00 AES 120414 <FracOut.v4b35.xls>



Crossing Length (ft)	1602
Hole Diameter (in)	9.875
Drill Pipe O.D. (in)	5.000
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	8
Yield Point (lb/100 ft)	20

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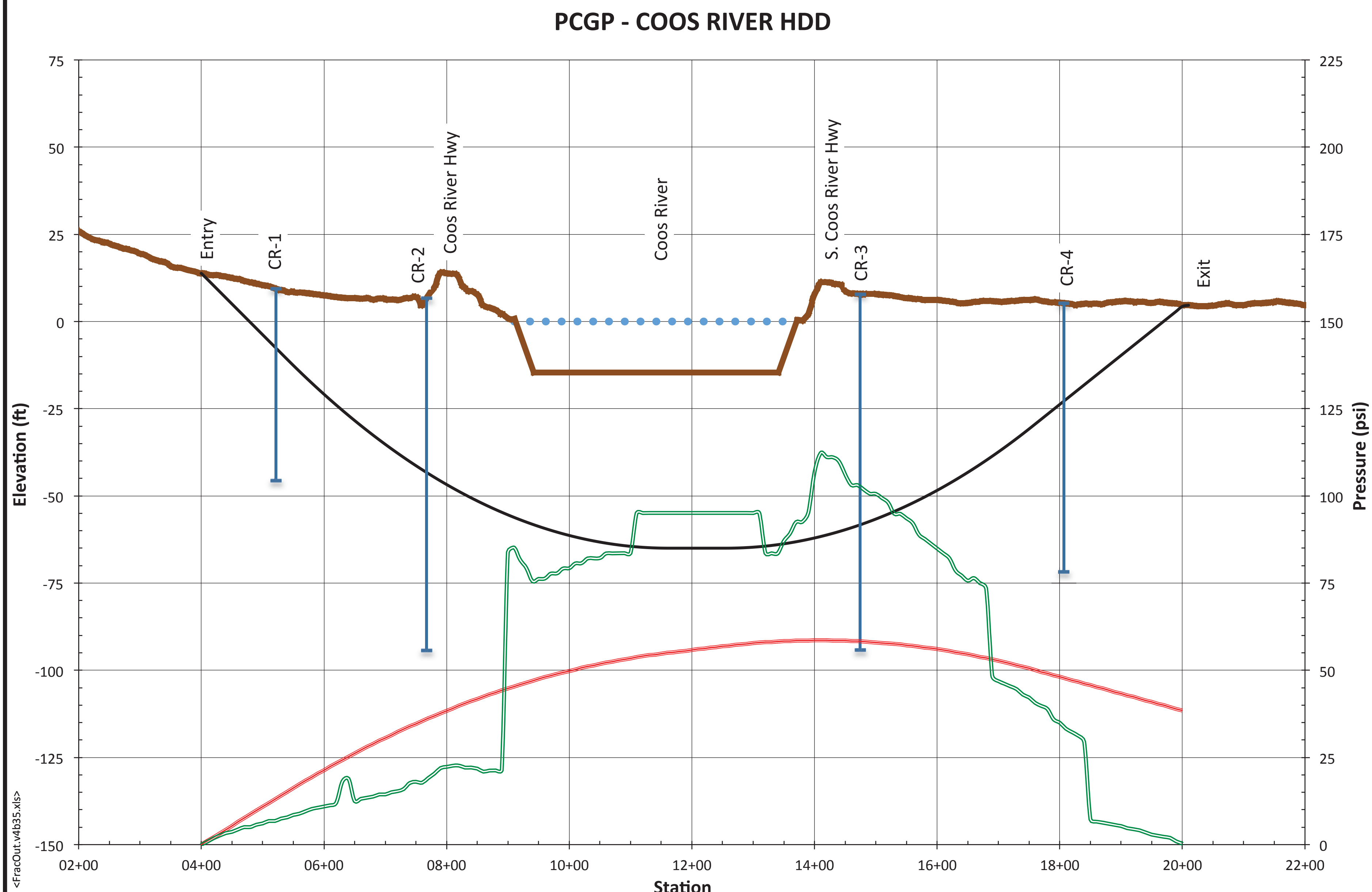
HYDRAULIC FRACTURE AND DRILLING FLUID SURFACE RELEASE FACTORS OF SAFETY

PCGP - COOS RIVER HDD

GEOENGINEERS

FIGURE 6



Crossing Length (ft)	1602
Hole Diameter (in)	9.875
Drill Pipe O.D. (in)	5.000
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	8
Yield Point (lb/100 ft)	20

Ground Surface Elevation (ft)
HDD Profile (ft)
Estimated Annular Drilliing Fluid Pressure (psi) for Pilot Hole
Allowable Drilling Fluid Pressure (psi) for FS=2

ESTIMATED AND ALLOWABLE ANNULAR DRILLING FLUID PRESSURES

PCGP - COOS RIVER HDD

GEOENGINEERS

FIGURE 7

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APPENDICES

APPENDIX A
Field Explorations and Laboratory-Testing Program

APPENDIX A
FIELD EXPLORATION AND LABORATORY-TESTING PROGRAM

We explored subsurface conditions at the site by drilling four borings with a truck-mounted drill rig using mud rotary drilling methods. Western States Drilling of Hubbard, Oregon drilled the borings to depths of up to 101.5 feet bgs. Figure 2 shows the approximate boring locations. A representative from our office observed field activities, classified the soil and rock encountered, obtained representative samples, observed groundwater conditions where possible and prepared a log of each exploration. The borings were backfilled with a bentonite and cement grout mixture at the conclusion of each exploration.

Soil samples were obtained by performing SPTs in general accordance with ASTM Test Method D 1586. The sampler was driven with a 140-pound hammer falling 30 inches. The number of blows required to drive the sampler 1 foot, or as otherwise indicated, into the soils is shown adjacent to the sample symbols on the boring logs. Disturbed samples were obtained from the split barrel sampler for subsequent classification and index testing.

Soils encountered in the borings were classified in the field by a GeoEngineers representative in general accordance with ASTM D 2488, the Standard Practice for the Classification of Soils (Visual-Manual Procedure) which is described in Figure A-1. Rock encountered in the borings was classified in general accordance with the ODOT rock classification system (ODOT, 1987), which is described in Figure A-2. The boring logs are presented in Figures A-3 through A-6. Soil and rock classification and sampling intervals are shown in the boring logs. Inclined lines at the material contacts shown on the log indicate uncertainty as to the exact contact elevation, rather than the inclination of the contact itself.

The relative density of the SPT samples recovered at each interval was evaluated based on correlations with lab and field observations in general accordance with the values outlined in Table A-1 below.

TABLE A-1. CORRELATION BETWEEN BLOW COUNTS AND RELATIVE DENSITY *

Cohesive Soils (Clay/Silt)						
Parameter	Very Soft	Soft	Medium Stiff	Stiff	Very Stiff	Hard
Blows, N	< 2	2 – 4	4 - 8	8 – 16	16 - 32	>32

Cohesionless Soils (Gravel/Sand/Silty Sand) **					
Parameter	Very Loose	Loose	Medium Dense	Dense	Very Dense
Blows, N	0 – 4	4 – 10	10 – 30	30 - 50	> 50

Notes:

*After Terzaghi, K and Peck, R.B., "Soil Mechanics in Engineering Practice," John Wiley & Sons, Inc., 1962.

**Classification applies to soils containing additional constituents; that is, organic clay, silty or clayey sand, etc.

Laboratory Testing

General

Samples obtained from the explorations were transported to our Portland, Oregon laboratory and examined to confirm or modify field classifications, as well as to evaluate engineering properties of the samples. Representative samples were selected for laboratory testing consisting of moisture content determinations, sieve analyses, fines content, and Atterberg limits tests. The laboratory-testing procedures are discussed in more detail below.

Moisture Content Testing

Moisture content tests were completed for representative samples obtained from the explorations. The results of these tests are presented on the exploration logs in Figures A-3 through A-6 at the depths at which the samples were obtained.

Fines Content Determinations

Fines content determinations were performed on selected soil samples in general accordance with ASTM D 1140. The results of the fines content determinations are shown on the attached boring logs at the depths at which the samples were obtained.

Sieve Analyses

Sieve analyses were performed on selected coarse-grained samples in general accordance with ASTM D 422. The results of the sieve analyses were plotted and classified in general accordance with the Unified Soil Classification System (USCS) and are presented in Figures A-7 through A-11. The percentage passing the U.S. No. 200 sieve is shown on the boring logs at the respective sample depths.

Atterberg Limits Testing

Atterberg Limits tests were performed on selected fine-grained soil samples in general accordance with ASTM D 4318. The tests were used to classify the soil as well as to evaluate its index properties. The results of the Atterberg Limits testing are shown in Figures A-12 through A-17.

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% RETAINED ON NO. 200 SIEVE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	AC	Asphalt Concrete
	CC	Cement Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Groundwater Contact

Measured groundwater level in exploration, well, or piezometer

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

Laboratory / Field Tests

%F	Percent fines
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
OC	Organic content
PM	Permeability or hydraulic conductivity
PI	Plasticity index
PP	Pocket penetrometer
PPM	Parts per million
SA	Sieve analysis
TX	Triaxial compression
UC	Unconfined compression
VS	Vane shear

Sheen Classification

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
NT	Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

GEOENGINEERS

FIGURE A-1

Scale of Relative Rock Weathering (ODOT, 1987)

Designation	Field Identification
Fresh	Crystals are bright. Discontinuities may show some minor surface staining. No discoloration in rock fabric.
Slightly Weathered	Rock mass is generally fresh. Discontinuities are stained and may contain clay. Some discoloration in rock fabric. Decomposition extends up to 1 inch into rock.
Moderately Weathered	Rock mass is decomposed 50% or less. Significant portions of rock show discoloration and weathering effects. Crystals are dull and show visible chemical alteration. Discontinuities are stained and may contain secondary mineral deposits.
Predominantly Decomposed	Rock mass is more than 50% decomposed. Rock can be excavated with geologist's pick. All discontinuities exhibit secondary mineralization. Complete discoloration of rock fabric. Surface of core is friable and usually pitted due to washing out of highly altered minerals by drilling water.
Decomposed	Rock mass is completely decomposed. Original rock "fabric" may be evident. May be reduced to soil with hand pressure.

Scale of Relative Rock Hardness (ODOT, 1987)

Term	Hardness Designation	Field Identification	Approximate Unconfined Compressive Strength
Extremely Soft	R0	Can be indented with difficulty by thumbnail. May be moldable or friable with finger pressure.	< 100 psi
Very Soft	R1	Crumbles under firm blows with point of a geology pick. Can be peeled by a pocket knife. Scratched with fingernail.	100-1000 psi
Soft	R2	Can be peeled by a pocket knife with difficulty. Cannot be scratched with fingernail. Shallow indentation made by firm blow of geology pick.	1000-4000 psi
Medium Hard	R3	Can be scratched by knife or pick. Specimen can be fractured with a single firm blow of hammer/geology pick.	4000-8000 psi
Hard	R4	Can be scratched with knife or pick only with difficulty. Several hard hammer blows required to fracture specimen.	8000-16000 psi
Very Hard	R5	Cannot be scratched by knife or sharp pick. Specimen requires many blows of hammer to fracture or chip. Hammer rebounds after impact.	> 16000 psi

Rock Quality Designation (RQD)

RQD (Percent)	Description of Rock Quality
0 to 25	Very Poor
25 to 50	Poor
50 to 75	Fair
75 to 90	Good
90 to 100	Excellent

RQD is a modified core recovery measurement which expresses the number of hard and sound rock pieces of 4" or more in size as a percentage of the total length of core run.

Discontinuity Spacing (ODOT, 1987)

Description for Bedding, Foliation, or Flow Banding	Spacing	Description of Joints, Faults, or Other Fractures
Very Thickly	>10 feet	Very Widely
Thickly	3-10 feet	Widely
Medium	1-3 feet	Moderately Close
Thinly	2-12 inches	Closely
Very Thinly	< 2 inches	Very Closely

EXPLANATION OF BEDROCK TERMS

GeoEngineers

FIGURE A-2

Drilled	Start 12/6/2012	End 12/7/2012	Total Depth (ft) 55.2	Logged By KWW Checked By AES	Driller Western States Drilling	Drilling Method Mud Rotary

Surface Elevation (ft) Vertical Datum: 24	Hammer Data: Auto 140 (lbs) / 30 (in) Drop	Drilling Equipment: CME 75	
Latitude: 43° 22' 32.016" N Longitude: 124° 8' 28.968" W	System: Geographic Datum: WGS84	Groundwater	

Groundwater:

Date Measured	Depth to Water (ft)	Elevation (ft)
	Not encountered	

Notes: Boring backfilled with cement-bentonite grout upon completion.

FIELD DATA

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample / Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0						CH	Grayish brown fat clay with occasional organic matter (very soft, wet)			
20											
	5	12	0	1 AL					52		AL; PI = 31
15											
	10	6	4	2				Becomes soft			
10											
	15	12	0	3 AL				With trace organic matter, very soft	51		AL; PI = 44
5											
	20	18	5	4				Becomes medium stiff			
0											
	25	12	4	5 AL					45		AL; PI = 28
								Becomes blue-gray with occasional gravel, soft			
-5											
	30	12	3	6							
-10											
	35										

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-1

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Recovered (in)	Blows/foot	Sample Name / Testing	Water Level	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35	6	12	7		CH	Blue-gray fat clay with occasional gravel and organic matter (stiff, wet)			
-15							Becomes orange-gray-blue mottled, very stiff (weakly to moderately cemented)			
	40	12	25	8 / AL				37		AL; PI = 38
-20										
	45	12	26	9						
-25						SLST	Orange-gray siltstone; predominantly decomposed, very soft			
	50	2	50/2"	10						
-30										
	55	2	50/2"	11			Becomes gray, fresh			

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-1 (continued)

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Drilled	Start 12/7/2012	End 12/7/2012	Total Depth (ft) 100.7	Logged By KWW / Checked By AES	Driller Western States Drilling	Drilling Method Mud Rotary

Surface Elevation (ft) / Vertical Datum: 14	Hammer Data: Auto, 140 (lbs) / 30 (in) Drop	Drilling Equipment: CME 75	
Latitude: 43° 22' 29.564" N / Longitude: 124° 8' 28.108" W	System: Geographic / Datum: WGS84	Groundwater — Date Measured / Depth to Water (ft) / Elevation (ft)	Not encountered

Notes: Boring backfilled with cement-bentonite grout upon completion.

Elevation (feet)	Depth (feet)	Recovered (in)	Blows/foot	Sample Name / Testing	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0				OH	Dark brown organic clay (very soft, wet)			
10									
	5	12	0	1 / AL			138		AL; PI = 188
5									
	10	12	0	2		Woody debris from 10 to 11 feet			
0					SC	Gray clayey fine to coarse sand with trace fine gravel (very loose, wet)			
	15	12	1	3 / SA			59		SA; %F = 47 %Gravel = 1
-5									
	20	12	2	4					
-10					CL	Gray fine to coarse sandy lean clay (soft, wet)			
	25	18	3	5 / %F			85		%F = 56
-15					OH	Dark brown organic silt with sand (woody debris) (soft, wet)			
	30	18	2	6					burn?
-20									
	35								

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-2

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Figure A-4
Sheet 1 of 3

Elevation (feet)	Depth (feet)	Recovered (in)	Blows/foot	Sample Name / Testing	Water Level	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35	3	2	7		OH	Dark brown organic silt with sand (woody debris) (soft, wet)			
-25										
	40	18	3	8 / AL				94		AL; PI = 67
-30						CH	Gray fat clay with trace organic matter (soft, wet)			
	45	18	3	9						
-35										
	50	8	8	10 / AL			Becomes medium stiff	41		AL; PI = 36
-40										
	55	18	5	11						
-45										
	60	18	7	12 / AL			With fine sand	44		AL; PI = 34
-50										
	65	18	7	13						
-55										
	70	12	9	14			Becomes orange-gray mottled, stiff (weakly to moderately cemented)			
-60										
	75	12	12	15 / AL				39		AL; PI = 35

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-2 (continued)

GEOENGINEERS

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Figure A-4
Sheet 2 of 3

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
									OH	Orange-gray mottled fat clay with fine sand and trace organic matter (stiff, wet) (weakly to moderately cemented)			
-65													
	80		12	10		16							
-70													
	85		5	16		17 / AL				With gravel, very stiff			AL; PI = 40
-75													
	90		10	18		18				Becomes gray			
-80													
	95		12	32		19							
									SLST	Brown-gray siltstone; fresh, very soft			
-85													
	100		2	50/2"		20							

Note: See Figure A-1 for explanation of symbols

Portland: Date:10/2/14 Path:C:\USERS\KJANCI\DESKTOP\1672400200.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Log of Boring CR-2 (continued)

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Drilled	Start 12/7/2012	End 12/7/2012	Total Depth (ft)	101.5	Logged By KWW	Checked By AES	Driller	Western States Drilling	Drilling Method	Mud Rotary

Surface Elevation (ft) / Vertical Datum	2	Hammer Data	Auto 140 (lbs) / 30 (in) Drop	Drilling Equipment	CME 75
Latitude / Longitude	43° 22' 23.484" N / 124° 8' 23.352" W	System / Datum	Geographic / WGS84	Groundwater	

Groundwater — Date Measured | Depth to Water (ft) | Elevation (ft): Not encountered

Notes: Boring backfilled with cement-bentonite grout upon completion.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0								ML	Brown sandy silt with organic matter (woody debris) (very soft, wet)			
0													
	5		6	2		1							
-5													
									ML	Brownish gray silt with occasional organic matter (very soft, wet)			
	10		18	0		2							
-10													
									SP-SM	Gray fine sand with silt (loose, wet)			
	15		12	4		3 / SA					34		SA; %F = 12
-15													
	20		8	5		4				With organic matter (woody debris)			
-20													
									SM	Gray silty fine sand with trace organic matter (loose, wet)			
	25		10	5		5							
-25													
	30		12	8		6 / SA					42		SA; %F = 40
-30													
	35												

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-3

GEOENGINEERS

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35		12	14		7			SM	Gray silty fine sand with trace organic matter (medium dense, wet)			
-35													
	40		12	13		8 / SA				Lacks organic matter	34		SA; %F = 19
-40													
	45		12	11		9							
-45													
	50		12	16		10 / SA					36		SA; %F = 19
-50													
	55		18	15		11							
-55													
	60		18	14		12 / SA					46		SA; %F = 29
-60													
	65		18	13		13							
-65													
	70		12	19		14 / SA					33		SA; %F = 23
-70													
	75		12	32		15				Becomes dense			

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-3 (continued)

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
-75									SM	Gray silty fine sand (dense, wet)			
	80		12	22		16 / SA				Becomes medium dense	37		SA; %F = 19
-80													
	85		18	28		17							
-85													
	90		12	2		18							
									CH	Grayish brown fat clay with trace organic matter (very soft, wet)			
-90													
	95		18	0		19 / AL					55		AL; PI = 32
-95													
	100		18	2		20							

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-3 (continued)

GEOENGINEERS

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Figure A-5

Drilled	Start 12/7/2012	End 12/7/2012	Total Depth (ft)	76.5	Logged By KWW / Checked By AES	Driller	Western States Drilling	Drilling Method	Mud Rotary

Surface Elevation (ft) / Vertical Datum	8	Hammer Data	Auto 140 (lbs) / 30 (in) Drop	Drilling Equipment	CME 75
Latitude / Longitude	43° 22' 20.316" N / 124° 8' 21.984" W	System / Datum	Geographic / WGS84	Groundwater	Date Measured / Depth to Water (ft) / Elevation (ft)
Notes: Boring backfilled with cement-bentonite grout upon completion.					Not encountered

Elevation (feet)	Depth (feet)	Interval / Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0							OH	Dark brown organic clay (very soft, wet)			
		14	0		1							
5												
	5											
0												
	10	18	0		2 / AL					111		AL; PI = 102
-5												
								SM	Gray silty fine sand with trace organic matter (very loose, wet)			
	15	18	0		3 / SA					56		SA; %F = 41
-10												
								OH	Brownish gray organic clay (very soft, wet)			
	20	18	0		4 / AL					106		AL; PI = 78
-15												
								ML	Gray fine sandy silt with trace organic matter (very soft to soft, wet)			
	25	18	2		5							
-20												
	30	18	2		6 / %F					52		%F = 58
-25												
								SM	Gray silty fine sand with trace organic matter (loose, wet)			
	35											

Note: See Figure A-1 for explanation of symbols

Log of Boring CR-4

GEOENGINEERS

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Depth (feet)	Interval Recovered (in)	Blows/foot	Sample Name / Testing	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
35	18	5	7 / SA	SM	Gray silty fine sand with trace organic matter (loose, wet)	53		SA; %F = 49
~38.5				ML	Gray fine sandy silt (soft, wet)			
40	18	3	8					
45	18	3	9 / %F			53		%F = 53
50	18	3	10					
55	18	0	11 / %F		Becomes very soft with decreased sand content	57		%F = 76
~58.5					Becomes brownish gray			
60	18	2	12					
~63.5				SM	Gray silty fine sand (very loose, wet)			
65	18	4	13					
~68.5				SP-SM	Gray fine sand with silt (medium dense, wet)			
70	18	22	14					
~73.5				SP	Gray fine to medium sand (medium dense, wet)			
75	12	28	15					

Elevation (feet): -30, -35, -40, -45, -50, -55, -60, -65

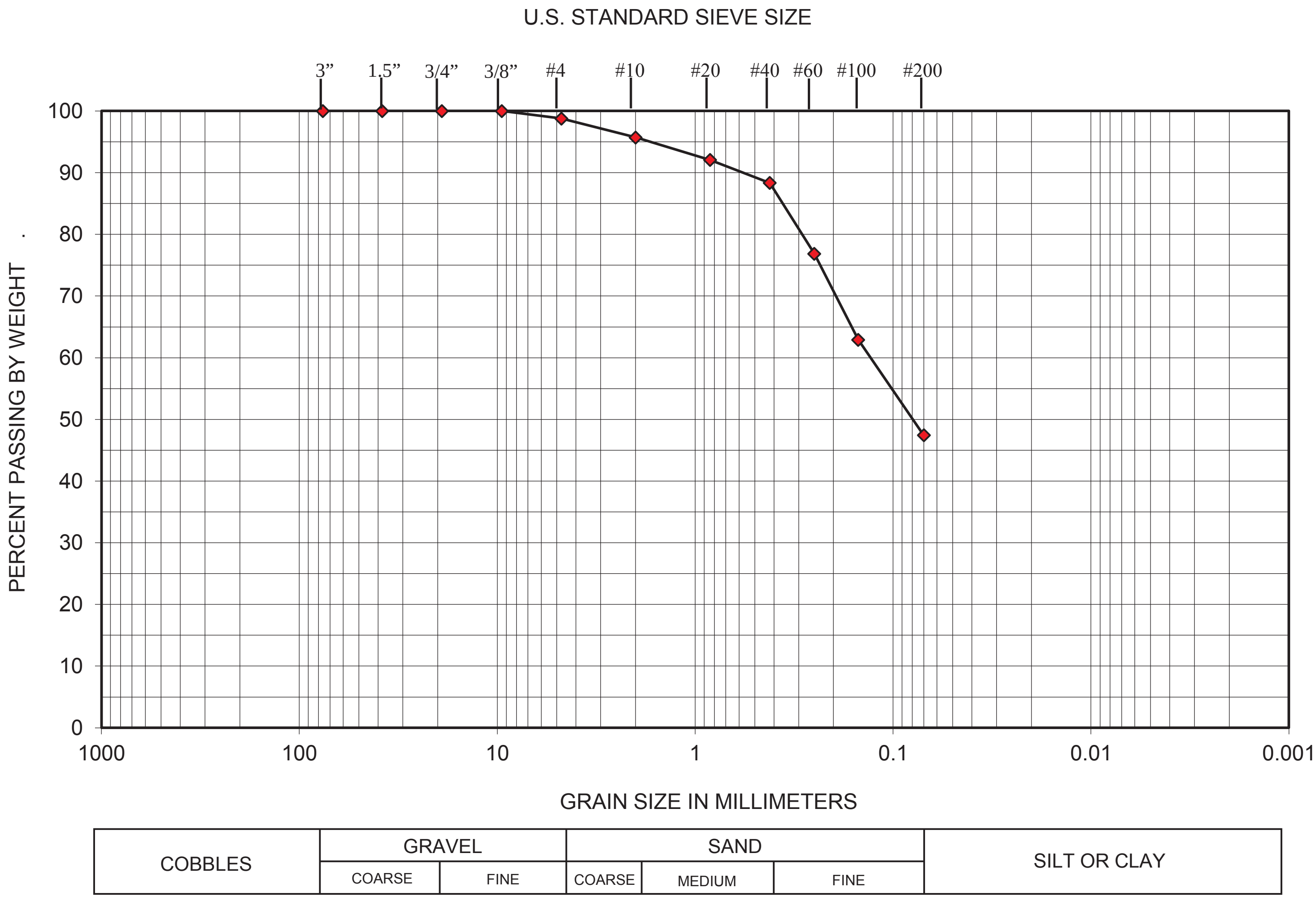
Note: See Figure A-1 for explanation of symbols

Log of Boring CR-4 (continued)

GeoEngineers

Project: PCGP Pacific Connector Pipeline
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Figure A-6
Sheet 2 of 2



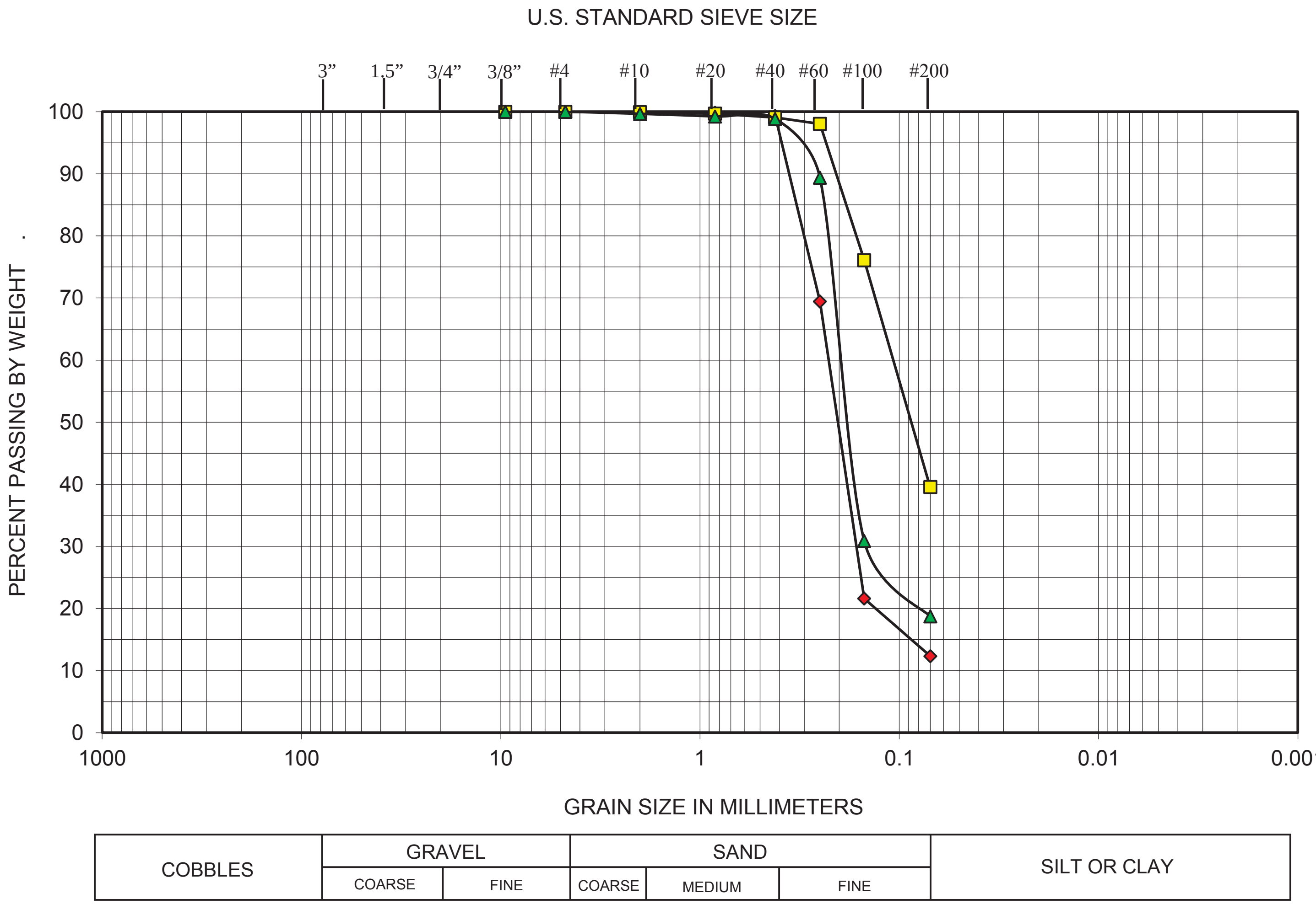
Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	CR-2	15.0 – 16.5	Gray Clayey Fine To Coarse SAND With Trace Fine Gravel (SC)

Sieve Analysis Results

Coos River HDD
Coos County, Oregon

GEOENGINEERS

Figure A-7



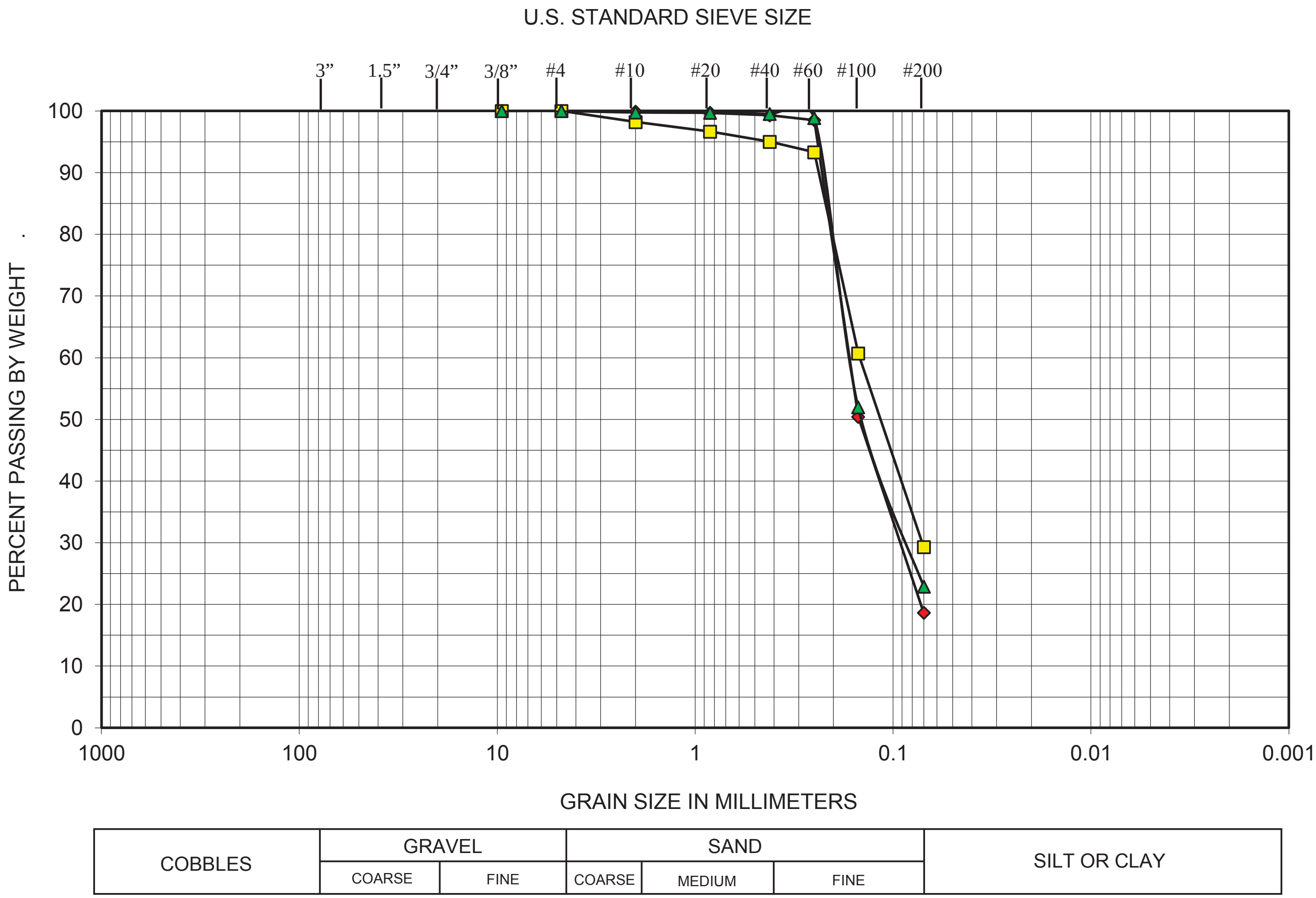
Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆ (red diamond)	CR-3	15.0 – 16.5	Gray Fine SAND With Silt (SP-SM)
■ (yellow square)	CR-3	30.0 – 31.5	Gray Silty Fine SAND (SM)
▲ (green triangle)	CR-3	40.0 – 41.5	Gray Silty Fine SAND (SM)

Sieve Analysis Results

Coos River HDD
Coos County, Oregon

GEOENGINEERS

Figure A-8



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆ (red diamond)	CR-3	50.0 – 51.5	Gray Silty Fine SAND (SM)
■ (yellow square)	CR-3	60.0 – 61.5	Gray Silty Fine SAND (SM)
▲ (green triangle)	CR-3	70.0 – 71.5	Gray Silty Fine SAND (SM)

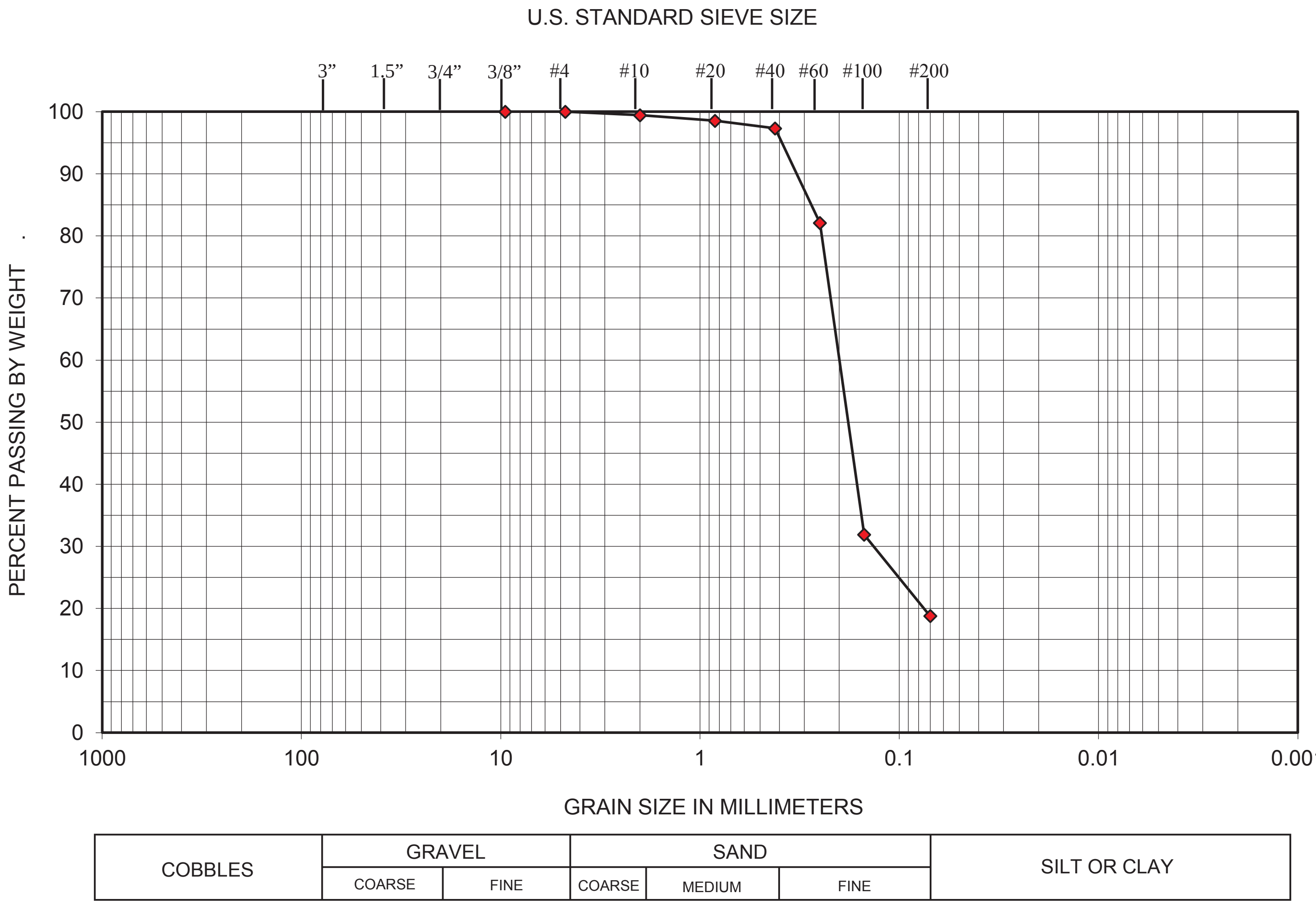
Sieve Analysis Results

Coos River HDD
Coos County, Oregon

GEOENGINEERS

Figure A-9

projects\sites\16724-002-00\Laboratory Data\Task 0300\SA 1672400200_Figures.ppt RTB 072114



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	CR-3	80.0 – 81.5	Gray Silty Fine SAND (SM)

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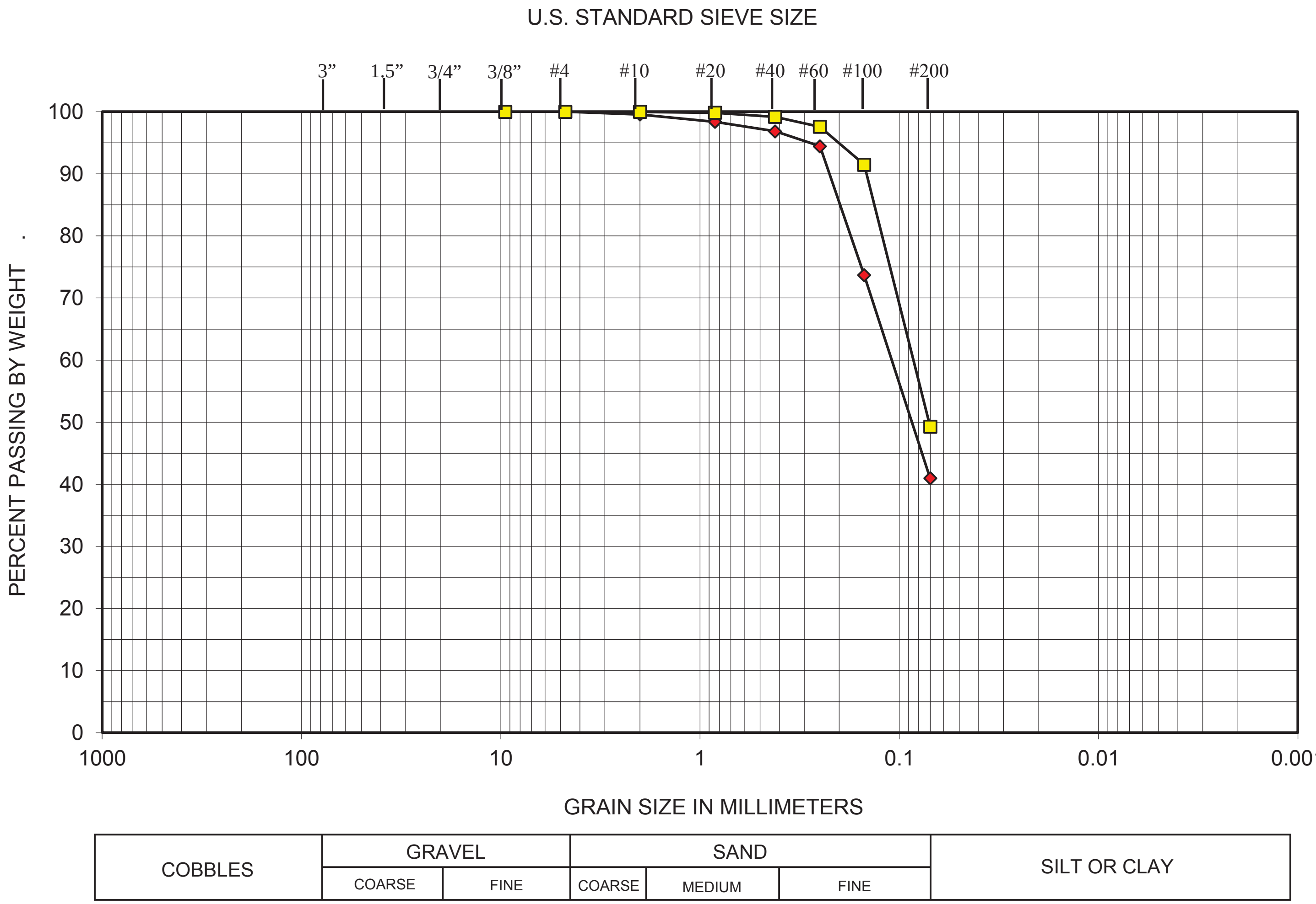
Sieve Analysis Results

Coos River HDD
Coos County, Oregon

GEOENGINEERS

Figure A-10

projects\sites\16724-002-00\Laboratory Data\Task 0300\SA 1672400200_Figures.ppt RTB 072114



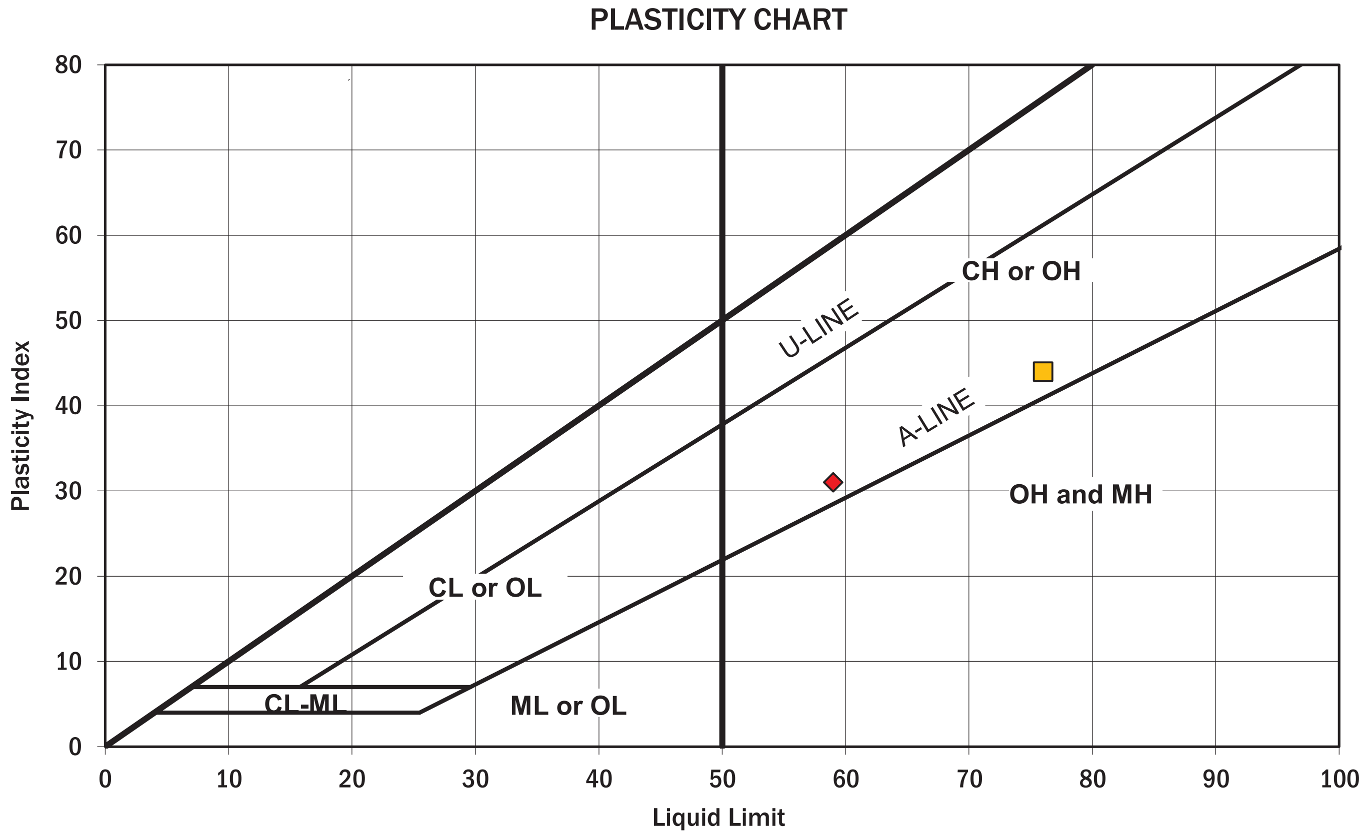
Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	CR-4	15.0 – 16.5	Gray Silty Fine SAND (SM)
□	CR-4	35.0 – 36.5	Gray Silty Fine SAND (SM)

Sieve Analysis Results

Coos River HDD
Coos County, Oregon

GEOENGINEERS

Figure A-11



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
◆	CR-1	5.0 – 6.5	52	59	31	Grayish Brown Fat CLAY (CH)
■	CR-1	15.0 – 16.5	51	76	44	Grayish Brown Fat CLAY (CH)

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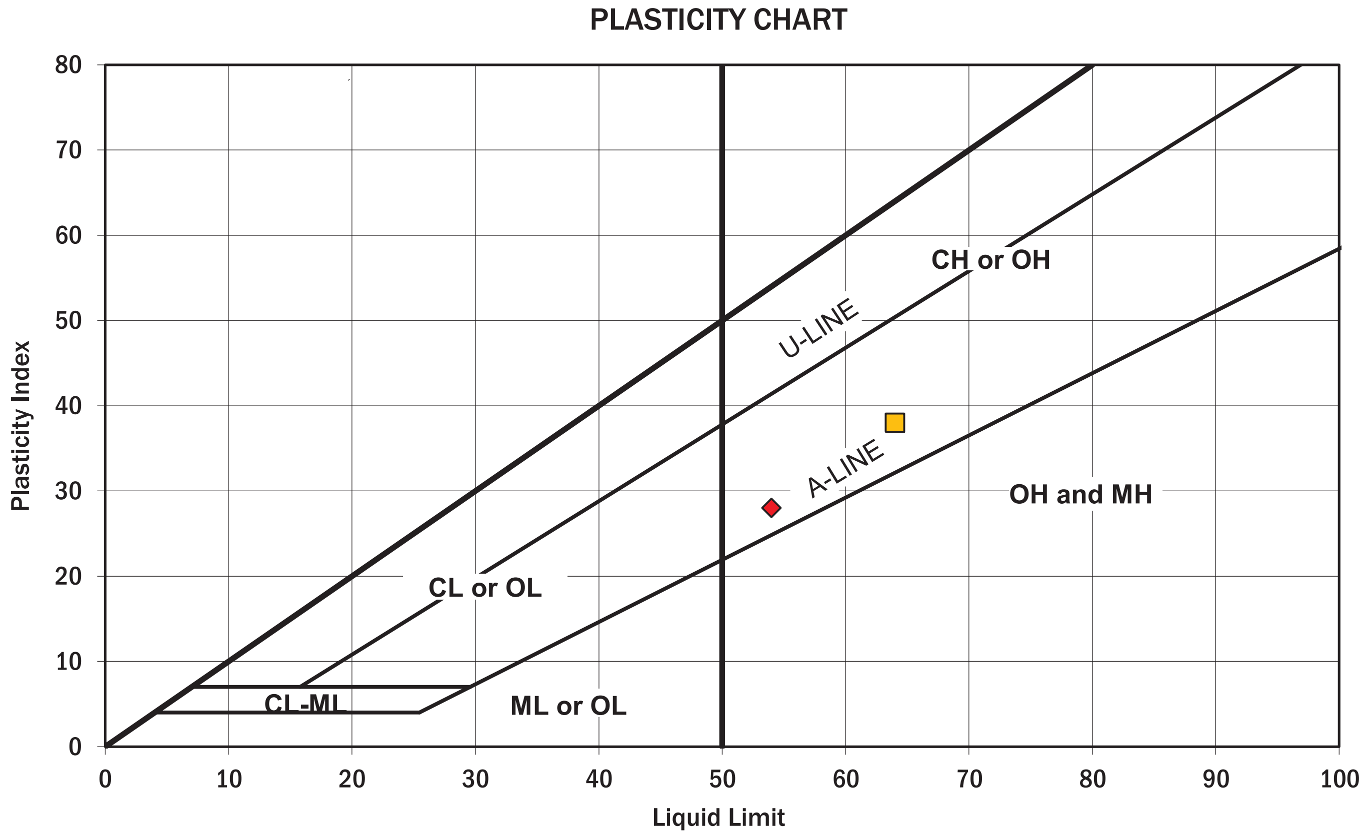
Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-12



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
♦ (red diamond)	CR-1	25.0 – 26.5	45	54	28	Blue-Gray Fat CLAY With Occasional Gravel (CH)
■ (yellow square)	CR-1	40.0 – 41.5	37	64	38	Orange-Gray-Blue Mottled Fat CLAY With Occasional Gravel (CH)

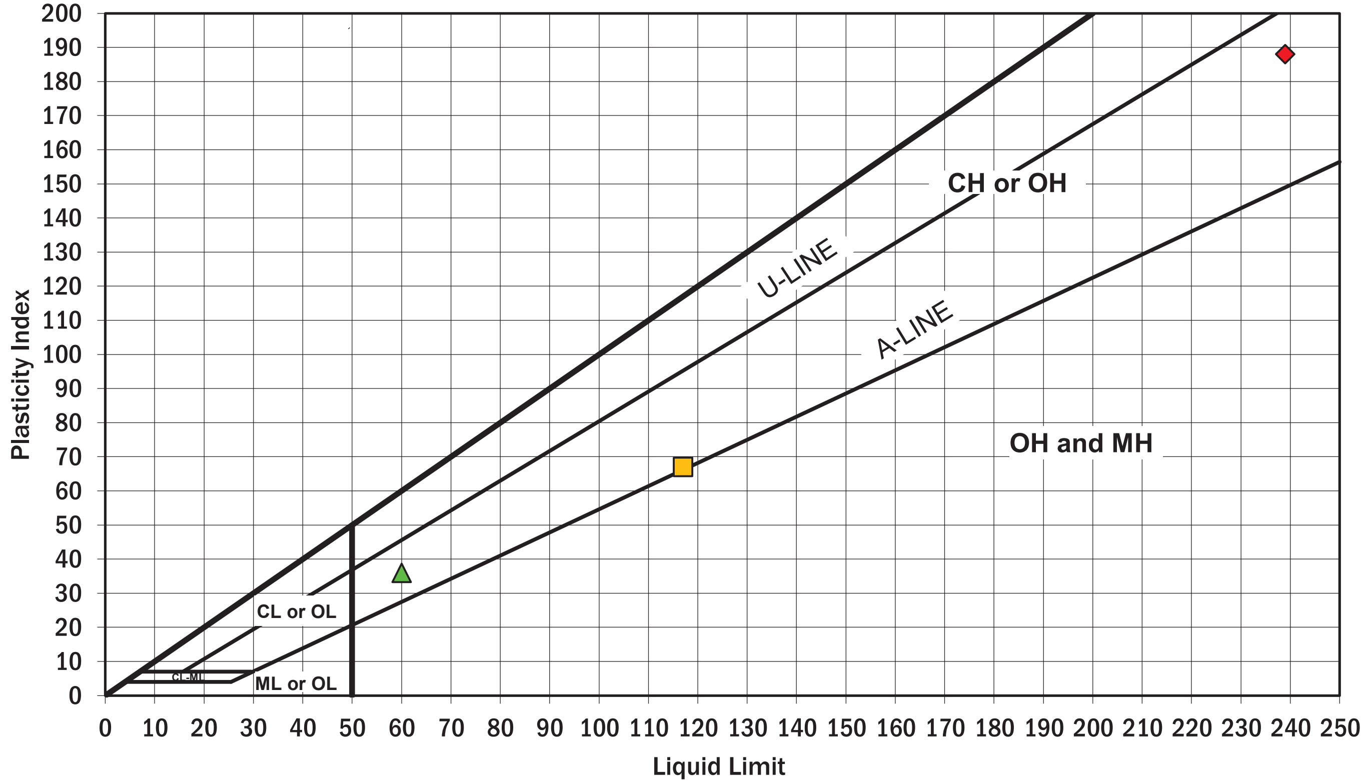
Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-13

PLASTICITY CHART



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
◆ (red diamond)	CR-2	5.0 – 6.5	138	239	188	Dark Brown Organic CLAY (OH)
■ (yellow square)	CR-2	40.0 – 41.5	94	117	67	Dark Brown Organic SILT With Sand (OH)
▲ (green triangle)	CR-2	50.0 – 51.5	41	60	36	Gray Fat CLAY (CH)

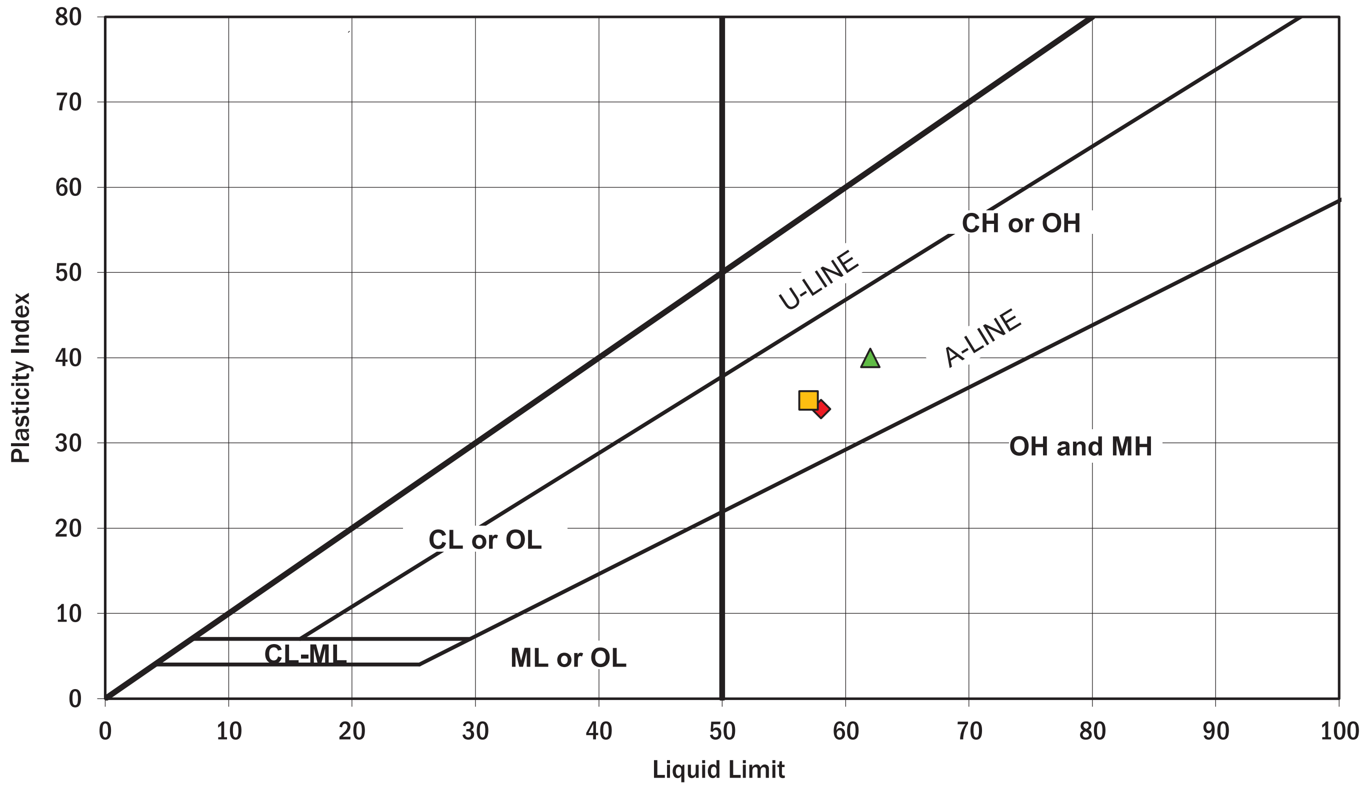
Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GEOENGINEERS

Figure A-14

PLASTICITY CHART



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
◆	CR-2	60.0 – 61.5	44	58	34	Gray Fat CLAY With Fine Sand (CH)
■	CR-2	75.0 – 76.5	39	57	35	Orange-Gray Mottled Fat CLAY With Fine Sand (CH)
▲	CR-2	85.0 – 86.5	-	62	40	Orange-Gray Mottled Fat CLAY With Fine Sand And Gravel (CH)

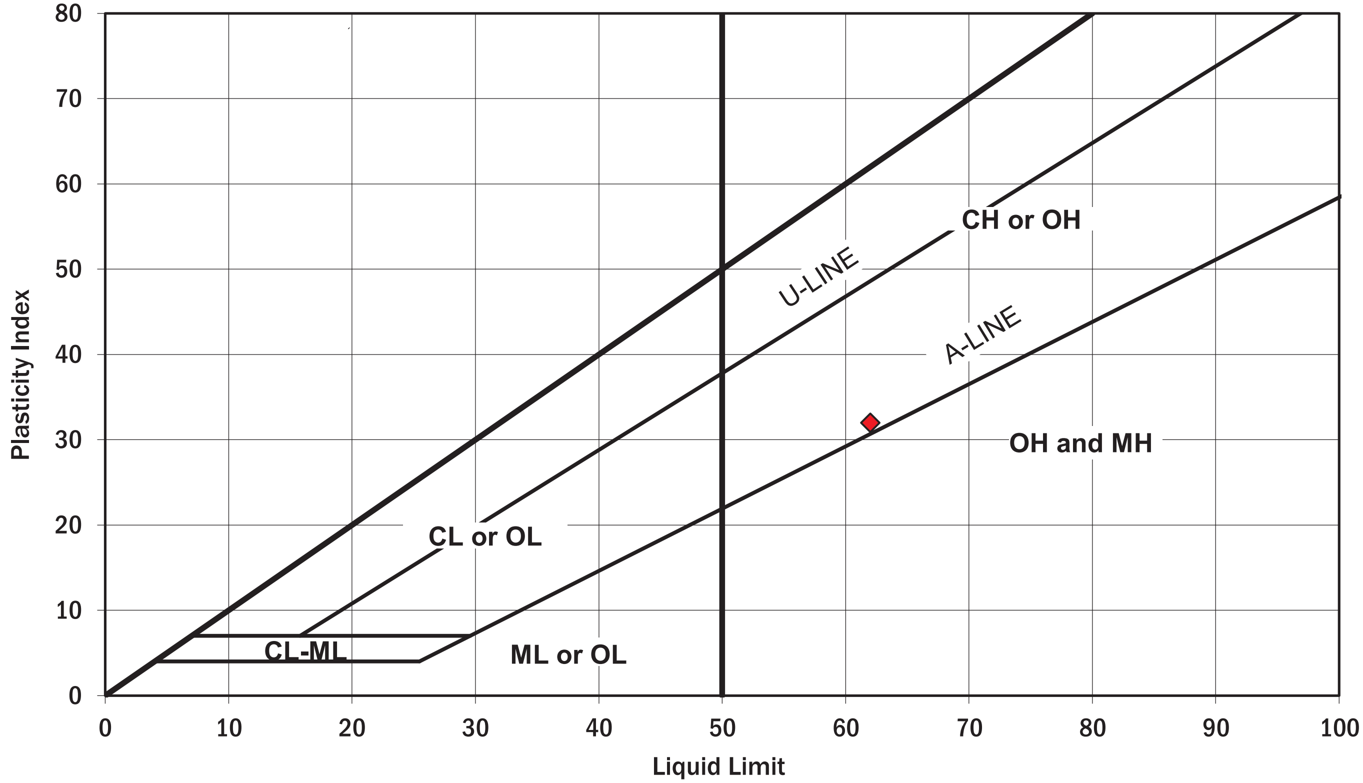
Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-15

PLASTICITY CHART



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
♦	CR-3	95.0 – 96.5	55	62	32	Grayish Brown Fat CLAY (CH)

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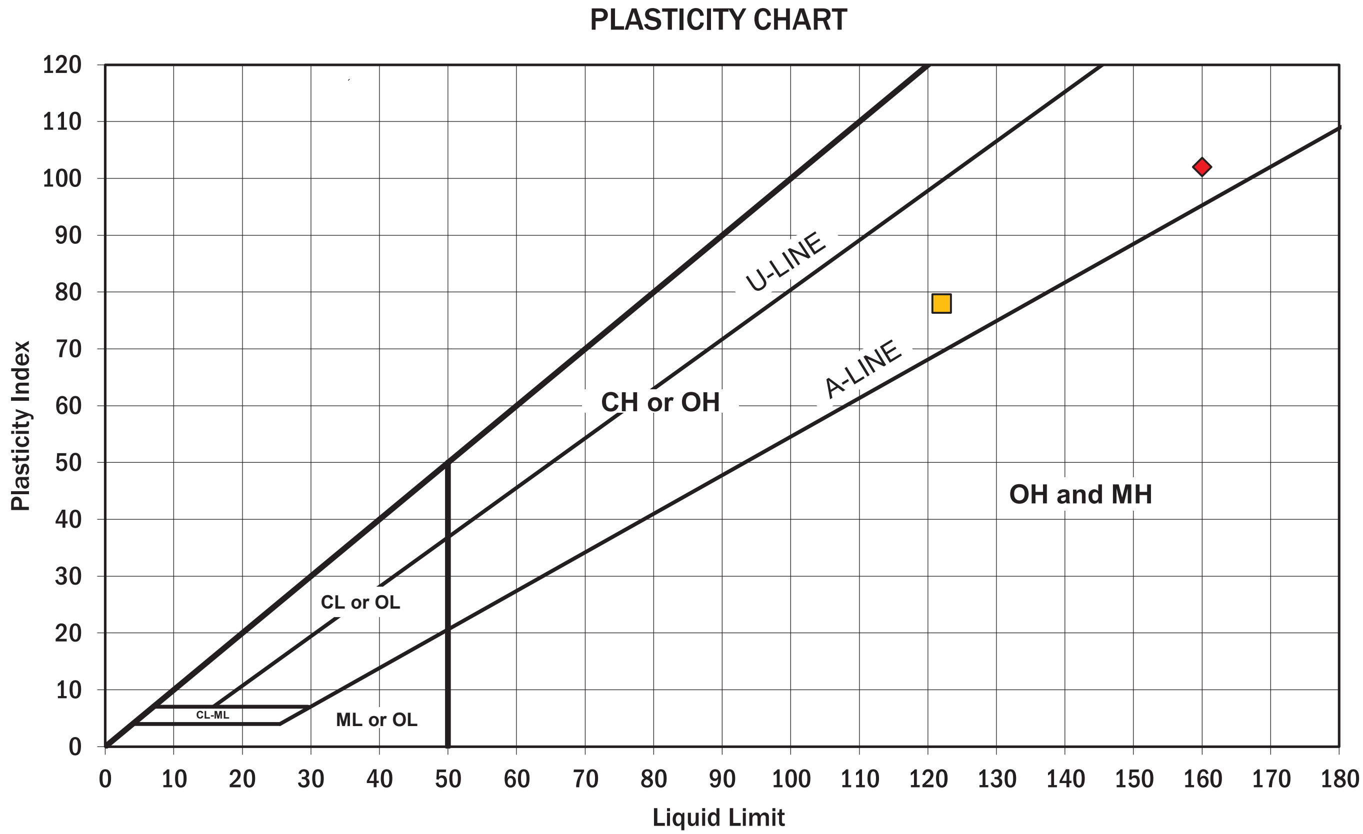
Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GEOENGINEERS

Figure A-16



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
◆	CR-4	10.0 – 11.5	111	160	102	Dark Brown Organic CLAY (OH)
■	CR-4	20.0 – 21.5	106	122	78	Brownish Gray Organic CLAY (OH)

Atterberg Limits Test Results

Coos River HDD
Coos County, Oregon

GeoEngineers

Figure A-17

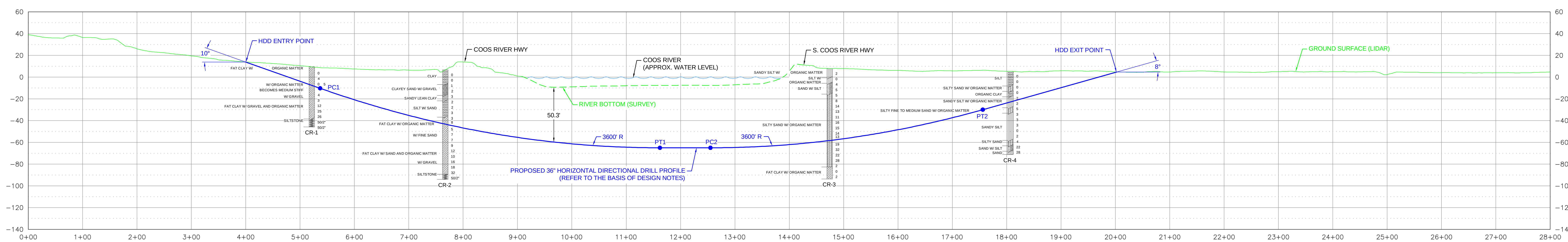
APPENDIX B
HDD Design Drawing and Calculations

DATUM:
HORIZONTAL: NAD83 Oregon State Plane, South Zone, US Foot
VERTICAL: NAVD 88

NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN

100 0 100
SCALE IN FEET



DIRECTIONAL DRILL DATA COOS RIVER HDD		
DESCRIPTION	STATION * (FT)	ELEVATION (FT)
ENTRY @ 10°	4+00.00	13.84
P C 1 (10.00° @ 3,600 FT R.)	5+36.92	-10.31
P T 1	11+62.05	-65.00
P C 2 (8.00° @ 3,600 FT R.)	12+54.98	-65.00
P T 2	17+56.00	-29.97
EXIT @ 8°	20+02.24	4.64
HORIZONTAL DISTANCE = 1,602.24 FT		
DIRECTIONAL DRILL PIPE LENGTH = 1,611.59 FT		

* THE STATIONING IS BASED ON AN ARBITRARY REFERENCE POINT

RECOMMENDED TOLERANCES	
ITEM	TOLERANCE
PILOT HOLE ENTRY ANGLE	INCREASE ANGLE UP TO 1º (STEEPER), BUT NO DECREASE IN ANGLE ALLOWED.
PILOT HOLE ENTRY LOCATION	AS PER COORDINATES PROVIDED BY COMPANY WITH NO CHANGES WITHOUT COMPANY APPROVAL.
PILOT HOLE EXIT ANGLE	INCREASE ANGLE UP TO 1º (STEEPER) OR DECREASE UP TO 2º (FLATTER).
PILOT HOLE EXIT LOCATION	UP TO 20 FEET BEYOND OR 10 FEET SHORT OF THE EXIT STAKE. BETWEEN 5 FEET LEFT AND 5 FEET RIGHT OF CENTERLINE.
PILOT HOLE DEPTH	UP TO 2 FEET ABOVE THE DESIGN DRILL PROFILE ALLOWED. UP TO 10 FEET BELOW THE DESIGN DRILL PROFILE ALLOWED.
PILOT HOLE ALIGNMENT	SHALL REMAIN WITHIN 5 FEET LEFT OR RIGHT OF THE HDD ALIGNMENT.

BORING LEGEND

TYPE OF SOIL — SPT (N)
TYPE OF ROCK — RQD/%REC
Boring Location

PROFILE

100 0 100
HORIZONTAL SCALE IN FEET
50 0 50
VERTICAL SCALE IN FEET

BASIS OF DESIGN:

1. PRODUCT PIPE WILL CONSIST OF 36" O.D. X 0.823" W.T., API-5L X-70 SAWL OR SAWH PIPE WITH 8-10 MILS OF FUSION BONDED EPOXY (FBE) AND A MINIMUM OF 40 MILS OF ABRASION RESISTANT OVERLAY (ARO).
2. MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP) = 1,600 psi
3. ASSUMED MAXIMUM OPERATING TEMPERATURE = 100° FAHRENHEIT.
4. ASSUMED AVERAGE OPERATING TEMPERATURE = 70° FAHRENHEIT.
5. THE MINIMUM ALLOWABLE THREE JOINT RADIUS SHALL NOT BE LESS THAN 2,600 FEET.

ISSUED FOR PERMIT

NOTES:

1. CONTRACTOR SHALL ADHERE TO THE SPECIFICATIONS AND REQUIREMENTS PER PACIFIC CONNECTOR GAS PIPELINE, LP SPECIFICATIONS, CONTRACT DOCUMENTS AND SPECIAL PERMIT CONDITIONS, EXCEPT AS NOTED ON THIS DRAWING.
2. CONTRACTOR IS RESPONSIBLE FOR CALLING OREGON ONE-CALL AND LOCATING ALL UNDERGROUND UTILITIES PRIOR TO BEGINNING CONSTRUCTION. IF ANY UTILITY IS LOCATED WITHIN 15 FEET OF THE DESIGNED HDD PROFILE AND ALIGNMENT, CONTRACTOR SHALL OBTAIN APPROVAL FROM PACIFIC CONNECTOR GAS PIPELINE, LP PRIOR TO INITIATING HDD OPERATIONS.
2. IT IS THE CONTRACTORS RESPONSIBILITY TO IDENTIFY AND PROTECT ANY FOREIGN UTILITY THAT MAY BE AFFECTED BY THE HDD OPERATIONS.
3. PLACEMENT OF THE HDD RIG IS NOT FIXED BY THE DESIGNATION OF THE ENTRY AND EXIT POINTS. THE USE OF DUAL HDD RIGS DURING CONSTRUCTION MAY BE AT THE DISCRETION OF THE HDD CONTRACTOR, TO BE APPROVED BY THE PROJECT TEAM.
4. ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY OR FROM APPROVED ACCESS ROADS.
5. WORK SPACE: MAXIMUM WORK SPACE LIMITS ARE DEPICTED. RESTRICT CLEARING TO THE WORK SPACE INDICATED AT THE ENTRY AND EXIT POINTS AND PRODUCT PIPE STRINGING AND FABRICATION AREA ALONG THE CONSTRUCTION RIGHT-OF-WAY. CLEARING BETWEEN THE ENTRY AND EXIT POINTS REQUIRES PRIOR APPROVAL FROM THE ENVIRONMENTAL INSPECTOR AND IS LIMITED TO THE AMOUNT NECESSARY TO STRING SURVEY WIRES AND INSTALL PUMPS AND PIPING TO OBTAIN WATER (WHERE APPROVED).
6. WATER SOURCE: DRILL WATER AND HYDROSTATIC TEST WATER SHALL BE OBTAINED FROM AN APPROVED SOURCE.
7. HYDROSTATIC TEST: PRE-INSTALLATION AND POST-INSTALLATION HYDROSTATIC TESTS SHALL BE CONDUCTED IN ACCORDANCE WITH THE HYDROSTATIC TEST PLAN. TEST WATER SHALL BE SAMPLED AND TESTED IN ACCORDANCE WITH PERMIT REQUIREMENTS. THE TEST WATER SHALL BE DISCHARGED IN AN UPLAND AREA INTO AN EROSION CONTROL STRUCTURE OF STRAW BALES AND/OR SILT FENCES, GEOTEXTILE FILTER BAG, OR COLLECTED IN A TRUCK AND HAULED TO AN APPROVED DISPOSAL SITE. UPON COMPLETION OF DEWATERING AND DRYING, A CALIPER PIG SURVEY SHALL BE COMPLETED IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.
8. SPILL-PREVENTION: REFUELING OF ALL EQUIPMENT SHALL BE COMPLETED IN ACCORDANCE WITH THE SPCC PLAN.
9. EROSION AND SEDIMENT CONTROL: CONTRACTOR SHALL SUPPLY, INSTALL AND MAINTAIN SEDIMENT CONTROL STRUCTURES IN ACCORDANCE WITH CONTRACT DOCUMENTS. CONTRACTOR SHALL INSTALL ADDITIONAL EROSION CONTROL STRUCTURES AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
10. INSTALLATION: THE PIPE SECTION FOR THE DRILLED CROSSING SHALL BE MADE UP WITHIN THE APPROVED CONSTRUCTION RIGHT-OF-WAY AT THE DRILL EXIT POINT AS SHOWN. AFTER THE PILOT HOLE IS COMPLETE, CONTRACTOR'S ACTUAL DRILL PROFILE SHALL BE SUBMITTED TO PACIFIC CONNECTOR GAS PIPELINE, LP FOR APPROVAL. CONTRACTOR SHALL ASSESS THE NEED FOR AND SUPPLY APPROPRIATE BALLAST DURING PULLBACK.
11. DRILLING FLUID DISPOSAL: CONTRACTOR SHALL DISPOSE OF EXCESS DRILLING FLUID AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS. UNDER NO CIRCUMSTANCES SHALL DRILLING FLUID BE DISPOSED OF IN WATER BODIES OR WETLANDS. ANY DRILLING FLUID WHICH INADVERTENTLY SURFACES AT POINTS OTHER THAN THE ENTRY OR EXIT POINTS SHALL BE CONTAINED AND COLLECTED TO THE EXTENT PRACTICAL AND DISPOSED OF AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS.
12. CLEANUP/STABILIZATION/RESTORATION: ALL DISTURBED AREAS SHALL BE RETURNED TO THE ORIGINAL CONTOURS. DISTURBED AREAS SHALL BE SEEDED AS SPECIFIED IN THE CLEAN-UP AND RESTORATION REQUIREMENTS. IF THE TERRAIN ALLOWS AND ACCESS IS PERMITTED, CONTRACTOR SHALL UTILIZE LOW GROUND PRESSURE EQUIPMENT OR OTHER EQUIPMENT APPROVED BY OWNER, TO FACILITATE CONTAINMENT AND CLEAN-UP OF ANY INADVERTENT RETURNS THAT OCCUR DURING THE HDD INSTALLATION PROCESS.
13. GEOTECHNICAL DATA: BORE HOLES ARE OFFSET FROM THE PIPELINE CENTERLINE AS SHOWN ON THE PLAN VIEW. THE GEOTECHNICAL INFORMATION PROVIDED ON THIS DRAWING IS A GENERAL SUMMARY. REFER TO THE APPLICABLE GEOTECHNICAL REPORT IN THE CONTRACT DOCUMENTS FOR MORE DETAILED INFORMATION.
14. GROUND SURFACE LIDAR DATA GENERATED FROM: EDITED LIDAR ELEVATION DATA, DOWNLOADED FROM HTTP://WWW.OREGONGEOLOGY.ORG. AERIAL IMAGE TAKEN FROM GOOGLE EARTH PRO, LICENSED TO GEOENGINEERS, INC., DATED 05-03-13.
15. RIVER BOTTOM SURVEY PROVIDED BY WILLIAMS NORTHWEST PIPELINE, LLC.
16. THE SECONDARY SURFACE SURVEY COIL LAYOUTS SHOWN ON THIS DRAWING ARE APPROXIMATE AND INTENDED TO SHOW THE GENERAL LAYOUT OF TYPICAL SECONDARY SURFACE SURVEY COIL WIRES THAT MAY BE PLACED TO TRACK THE BOTTOM HOLE ASSEMBLY DURING PILOT HOLE OPERATIONS. THE APPROXIMATE LOCATIONS OF THE COIL WIRES SHOWN ON THIS DRAWING ARE NOT INTENDED TO DIRECT THE HDD CONTRACTOR AS TO THE EXACT PLACEMENT OF THE COIL WIRES. THE FINAL PLACEMENT OF SOIL WIRES IS THE CONTRACTOR'S RESPONSIBILITY AND MAY VARY FROM WHAT IS SHOWN DEPENDING ON GROUND SURFACE CONDITIONS AT THE TIME OF HDD INSTALLATION, AND THE HDD CONTRACTORS MEANS AND METHODS.

REFERENCES

DRAWING NUMBER	REFERENCE DRAWING TITLE
	PCGP_IP_Right_of_Way.dwg

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
0	ISSUED FOR PERMIT (MODIFIED PIPE SPECS)	RBM	08/24/17	BCR	TNH

AES Design	03/05/14 Date
RBM Drawn	03/04/17 Date
BCR Checked	07/09/15 Date
TNH Approved	08/24/17 Date

GEOENGINEERS
317 East Main Street,
American Fork, UT 84003
Telephone (801) 307-0216

36" PACIFIC CONNECTOR GAS PIPELINE PROJECT

COOS RIVER HDD
COOS COUNTY, OREGON

Project No. 22708-001-01
Drawing No. P1-000-CIV-HDD-GEI-00003-01
Sheet 1 of 1

HDD Design Summary

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Coos River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Coos County, Oregon **Date:** Friday, September 1, 2017

Design Parameters

Pipe Diameter = 36.000 in

Pipe Material = Steel

Yield Stress = 70,000 psi

Wall Thickness = 0.823 in

Assumed Installation Temp = 50 °F

Assumed Operating Temp= 100 °F

Design Factor = 0.5

MAOP = 1,600 psi

Drill Data Box

Point	Station (ft)	Elevation (ft)
ENTRY @ 10°	400.00	13.84
P C 1 (10.00° @ 3,600 ft R.)	536.92	-10.31
P T 1	1,162.05	-65.00
P C 2 (8.00° @ 3,600 ft R.)	1,254.98	-65.00
P T 2	1,756.00	-29.97
EXIT @ 8°	2,002.24	4.64

Horizontal Alignment Length = 1,602.24 ft

Profile Segment Information

Segment Name	Segment Type	Segment Length (ft)
ENTRY TANGENT	Straight	139.03
ENTRY CURVE	Vertical Curve	628.32
BOTTOM TANGENT	Straight	92.92
EXIT CURVE	Vertical Curve	502.65
EXIT TANGENT	Straight	248.66

Pipe Length = 1,611.59 ft

Installation Load Summary

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Buoyancy Control (lb/ft)	Effective Pipe Weight (lb/ft)	Total Installation Force (lb)
9.50	Empty	0.00	-192.37	240,000
9.50	Full	401.67	209.30	207,000
12.00	Empty	0.00	-324.56	316,000
12.00	Full	401.67	77.11	135,000
10.50	Neutral	245.24	0.00	127,000

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Minimum Radius Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Coos River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Coos County, Oregon	**Date:**	Friday, September 1, 2017

Design Parameters:

Pipe Diameter = 36.000 in

Wall Thickness = 0.823 in

D/t Ratio = 43.74

MAOP = 1,600 psi

SMYS = 70,000 psi

Modulus of Elasticity (E) = 2.93E+007 psi

Factor of Safety = 2.00

Hoop Stress:

Calculated Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness) = 34,994 psi

Longitudinal Stress:

Calculated Longitudinal Stress = Hoop Stress / 2 = 17,497 psi

Allowable Stress:

Calculated Allowable Stress = SMYS / Factor of Safety = 35,000 psi

Bending Stress:

Calculated Bending Stress = Allowable Stress - Longitudinal Stress = 17,503 psi

Minimum Radius:

Calculated Minimum Radius = (E * Pipe Diameter) / (2 * Bending Stress) = 2,485 ft

Operating Stress Summary

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Coos River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Coos County, Oregon **Date:** Friday, September 1, 2017

Design Parameters

Pipe diameter = 36.000 in

Wall Thickness = 0.823 in

SMYS = 70,000 psi

MAOP = 1,600 psi

Poissons's Ratio = 0.30

Young's Modulus (E) = 2.93E+007 psi

Design Factor = 0.5

Minimum Radius of Curvature = 2,600 ft

Coefficient of Thermal Expansion = 6.5E-06 in/in/°F

Assumed Installation Temperature = 50 °F

Assumed Operating Temperature = 100 °F

Temperature Derating Factor = 1.00

Groundwater Table Head = 0.00 ft

Stress Analyses

Longitudinal Stress from Bending = 16,929 psi

Percent SMYS = 24.18 %

Hoop Stress = 34,994 psi

Percent SMYS = 49.99 % Limited by Design Factor (0.5) according to 49 CFR 192.111

Longitudinal Tensile Stress from Hoop Stress = 10,498 psi

Percent SMYS = 15.00 %

Longitudinal Stress from Thermal Expansion = -9,537 psi

Percent SMYS = 13.62 % Limited to 90% SMYS by ASME/ANSI B31.4 section 402.3.2

Net Longitudinal Stress (Comp. side of Curve) = -15,968 psi

Percent SMYS = 22.81 % Limited to 90% SMYS by ASME/ANSI B31.8 section 833.3

Net Longitudinal Stress (Tension side of Curve) = 17,891 psi

Percent SMYS = 25.56 % Limited to 90% SMYS by ASME/ANSI B31.8 section 833.3

Maximum Shear Stress = 25,481 psi

Percent SMYS = 36.40 % Limited to 45% SMYS by ASME/ANSI B31.4 section 402.3.1

Combined Biaxial Stress Check = 50,962 psi

Percent SMYS = 72.80 % Limited to 90% SMYS by ASME/ANSI B31.8 section 833.4

Operating Stress Summary

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Coos River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Coos County, Oregon **Date:** Friday, September 1, 2017

Installation Load Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Coos River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Coos County, Oregon	**Date:**	Friday, September 1, 2017

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	1,612 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	502.33 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	-192.37 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters			
Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	248.66 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	16,874 lb
Friction Force =	14,211 lb
Segment Weight =	6,657 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	37,742 lb
Cumulative Force =	**37,742 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	415 psi	
Cumulative Axial Stress =	415 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	473 psi	8,892 psi
Combined Stress =	0.0074	< 1.0
Total Stress =	0.0029	< 1.0

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Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	502.65 ft	Center Displacement =	8.77 ft

Segment Force Components

Normal Force =	75,730 lb
Drag Force =	34,109 lb
Friction Force =	22,719 lb
Segment Weight =	6,745 lb
Tension =	124,034 lb
Average Tension =	80,888 lb
Segment Force =	86,292 lb
Cumulative Force =	**124,034 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	949 psi	
Cumulative Axial Stress =	1,364 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	851 psi	8,892 psi
Combined Stress =	0.3872	< 1.0
Total Stress =	0.1268	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	92.92 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	6,306 lb
Friction Force =	5,363 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	11,668 lb
Cumulative Force =	**135,702 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	128 psi	
Cumulative Axial Stress =	1,492 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	851 psi	8,892 psi
Combined Stress =	0.0266	< 1.0
Total Stress =	0.0106	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty **Segment 4 of 5**

Segment Parameters

Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	628.32 ft	Center Displacement =	13.70 ft

Segment Force Components

Normal Force =	98,840 lb
Drag Force =	42,637 lb
Friction Force =	29,652 lb
Segment Weight =	-10,534 lb
Tension =	227,109 lb
Average Tension =	181,406 lb
Segment Force =	91,407 lb
Cumulative Force =	**227,109 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,005 psi	
Cumulative Axial Stress =	2,497 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	851 psi	8,892 psi
Combined Stress =	0.4074	< 1.0
Total Stress =	0.1412	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty **Segment 5 of 5**

Segment Parameters

Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	139.03 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	9,435 lb
Friction Force =	7,902 lb
Segment Weight =	-4,644 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	12,692 lb
Cumulative Force =	**239,801 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	140 psi	
Cumulative Axial Stress =	2,637 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	261 psi	8,892 psi
Combined Stress =	0.0471	< 1.0
Total Stress =	0.0036	< 1.0

Installation Load Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Coos River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Coos County, Oregon	**Date:**	Friday, September 1, 2017

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	1,612 ft
Moment of Inertia =	14,076 in^4
Pipe Face Area =	90.95 in^2
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft^3
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft^3
Pipe Exterior Volume =	7.07 ft^3/ft
Displaced Fluid Weight =	502.33 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft^3/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft^3
Effective Weight of Pipe =	209.30 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters			
Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	248.66 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	16,874 lb
Friction Force =	15,461 lb
Segment Weight =	-7,243 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	25,092 lb
Cumulative Force =	**25,092 lb**

Segment Installation Stress Checks		
Stress Component	Calculated	Allowable
Segment Axial Stress =	276 psi	
Cumulative Axial Stress =	276 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	145 psi	8,892 psi
Combined Stress =	0.0049	< 1.0
Total Stress =	0.0003	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — **Segment 2 of 5**

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	502.65 ft	Center Displacement =	8.77 ft

Segment Force Components

Normal Force =	-51,211 lb
Drag Force =	34,109 lb
Friction Force =	15,363 lb
Segment Weight =	-7,339 lb
Tension =	82,590 lb
Average Tension =	53,841 lb
Segment Force =	57,497 lb
Cumulative Force =	**82,590 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	632 psi	
Cumulative Axial Stress =	908 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	191 psi	8,892 psi
Combined Stress =	0.3790	< 1.0
Total Stress =	0.1026	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — **Segment 3 of 5**

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	92.92 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	6,306 lb
Friction Force =	5,835 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	12,140 lb
Cumulative Force =	**94,730 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	133 psi	
Cumulative Axial Stress =	1,042 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	191 psi	8,892 psi
Combined Stress =	0.0186	< 1.0
Total Stress =	0.0010	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters			
Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	628.32 ft	Center Displacement =	13.70 ft

Segment Force Components	
Normal Force =	-57,925 lb
Drag Force =	42,637 lb
Friction Force =	17,378 lb
Segment Weight =	11,462 lb
Tension =	183,583 lb
Average Tension =	139,157 lb
Segment Force =	88,854 lb
Cumulative Force =	**183,583 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	977 psi	
Cumulative Axial Stress =	2,018 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	191 psi	8,892 psi
Combined Stress =	0.3989	< 1.0
Total Stress =	0.1157	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters			
Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	139.03 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	9,435 lb
Friction Force =	8,597 lb
Segment Weight =	5,053 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	23,085 lb
Cumulative Force =	**206,668 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	254 psi	
Cumulative Axial Stress =	2,272 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	119 psi	8,892 psi
Combined Stress =	0.0406	< 1.0
Total Stress =	0.0021	< 1.0

Installation Load Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Coos River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Coos County, Oregon	**Date:**	Friday, September 1, 2017

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters

Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	1,612 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	634.52 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	-324.56 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	248.66 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	16,874 lb
Friction Force =	23,976 lb
Segment Weight =	11,232 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	52,082 lb
Cumulative Force =	**52,082 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	573 psi	
Cumulative Axial Stress =	573 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	597 psi	8,892 psi
Combined Stress =	0.0102	< 1.0
Total Stress =	0.0047	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	502.65 ft	Center Displacement =	8.77 ft

Segment Force Components

Normal Force =	118,745 lb
Drag Force =	34,109 lb
Friction Force =	35,623 lb
Segment Weight =	11,380 lb
Tension =	168,818 lb
Average Tension =	110,450 lb
Segment Force =	116,736 lb
Cumulative Force =	**168,818 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,284 psi	
Cumulative Axial Stress =	1,856 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,075 psi	8,892 psi
Combined Stress =	0.3960	< 1.0
Total Stress =	0.1419	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	92.92 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	6,306 lb
Friction Force =	9,048 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	15,353 lb
Cumulative Force =	**184,172 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	169 psi	
Cumulative Axial Stress =	2,025 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	1,075 psi	8,892 psi
Combined Stress =	0.0362	< 1.0
Total Stress =	0.0172	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty **Segment 4 of 5**

Segment Parameters			
Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	628.32 ft	Center Displacement =	13.70 ft

Segment Force Components	
Normal Force =	153,970 lb
Drag Force =	42,637 lb
Friction Force =	46,191 lb
Segment Weight =	-17,773 lb
Tension =	301,417 lb
Average Tension =	242,794 lb
Segment Force =	117,245 lb
Cumulative Force =	**301,417 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,289 psi	
Cumulative Axial Stress =	3,314 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	1,075 psi	8,892 psi
Combined Stress =	0.4220	< 1.0
Total Stress =	0.1612	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty **Segment 5 of 5**

Segment Parameters			
Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	139.03 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	9,435 lb
Friction Force =	13,332 lb
Segment Weight =	-7,836 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	14,931 lb
Cumulative Force =	**316,348 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	164 psi	
Cumulative Axial Stress =	3,478 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	329 psi	8,892 psi
Combined Stress =	0.0621	< 1.0
Total Stress =	0.0062	< 1.0

Installation Load Calculations

Project Name: Pacific Connector Gas Pipeline **HDD Name:** Coos River HDD **Owner:** PCGP, LP

Project No: 22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH **Location:** Coos County, Oregon **Date:** Friday, September 1, 2017

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters

Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	1,612 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	634.52 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	77.11 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters

Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	248.66 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	16,874 lb
Friction Force =	5,696 lb
Segment Weight =	-2,668 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	19,901 lb
Cumulative Force =	**19,901 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	219 psi	
Cumulative Axial Stress =	219 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	269 psi	8,892 psi
Combined Stress =	0.0039	< 1.0
Total Stress =	0.0009	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	502.65 ft	Center Displacement =	8.77 ft

Segment Force Components

Normal Force =	-11,408 lb
Drag Force =	34,109 lb
Friction Force =	3,422 lb
Segment Weight =	-2,704 lb
Tension =	58,152 lb
Average Tension =	39,027 lb
Segment Force =	38,251 lb
Cumulative Force =	**58,152 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	421 psi	
Cumulative Axial Stress =	639 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	415 psi	8,892 psi
Combined Stress =	0.3742	< 1.0
Total Stress =	0.1047	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	92.92 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	6,306 lb
Friction Force =	2,150 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	8,455 lb
Cumulative Force =	**66,607 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	93 psi	
Cumulative Axial Stress =	732 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	415 psi	8,892 psi
Combined Stress =	0.0131	< 1.0
Total Stress =	0.0025	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters

Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	628.32 ft	Center Displacement =	13.70 ft

Segment Force Components

Normal Force =	-12,405 lb
Drag Force =	42,637 lb
Friction Force =	3,722 lb
Segment Weight =	4,223 lb
Tension =	120,910 lb
Average Tension =	93,758 lb
Segment Force =	54,303 lb
Cumulative Force =	**120,910 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	597 psi	
Cumulative Axial Stress =	1,329 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	415 psi	8,892 psi
Combined Stress =	0.3866	< 1.0
Total Stress =	0.1127	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters

Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	139.03 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	9,435 lb
Friction Force =	3,167 lb
Segment Weight =	1,862 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	14,464 lb
Cumulative Force =	**135,373 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	159 psi	
Cumulative Axial Stress =	1,488 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	187 psi	8,892 psi
Combined Stress =	0.0266	< 1.0
Total Stress =	0.0014	< 1.0

Installation Load Calculations

Project Name:	Pacific Connector Gas Pipeline	**HDD Name:**	Coos River HDD	**Owner:**	PCGP, LP
Project No:	22708-001-01 **By:** AES **Ck'd By:** BCR/ JAH	**Location:**	Coos County, Oregon	**Date:**	Friday, September 1, 2017

Installation Case:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy

Product Pipe Parameters	
Pipe Diameter =	36.000 in
Wall Thickness =	0.823 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	1,612 ft
Moment of Inertia =	14,076 in⁴
Pipe Face Area =	90.95 in²
D/t Ratio =	43.74
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	309.96 lb/ft
Pipe Interior Volume =	6.44 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	7.07 ft³/ft
Displaced Fluid Weight =	555.21 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	0.00 lb/ft

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 1 of 5

Segment Parameters			
Segment Name =	EXIT TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	248.66 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	16,874 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	16,874 lb
Cumulative Force =	**16,874 lb**

Stress Component	Calculated	Allowable
Segment Axial Stress =	186 psi	
Cumulative Axial Stress =	186 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	523 psi	8,892 psi
Combined Stress =	0.0033	< 1.0
Total Stress =	0.0035	< 1.0

Installation Load Calculations

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 2 of 5

Segment Parameters			
Segment Name =	EXIT CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	502.65 ft	Center Displacement =	8.77 ft

Segment Force Components

Normal Force =	12,567 lb
Drag Force =	34,109 lb
Friction Force =	3,770 lb
Segment Weight =	0 lb
Tension =	58,523 lb
Average Tension =	37,699 lb
Segment Force =	41,650 lb
Cumulative Force =	**58,523 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	458 psi	
Cumulative Axial Stress =	643 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	940 psi	8,892 psi
Combined Stress =	0.3743	< 1.0
Total Stress =	0.1215	< 1.0

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 3 of 5

Segment Parameters			
Segment Name =	BOTTOM TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	92.92 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	6,306 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	6,306 lb
Cumulative Force =	**64,829 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	69 psi	
Cumulative Axial Stress =	713 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	940 psi	8,892 psi
Combined Stress =	0.0127	< 1.0
Total Stress =	0.0115	< 1.0

Installation Load Calculations

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 4 of 5

Segment Parameters

Segment Name =	ENTRY CURVE	Radius of Curvature =	3,600 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	628.32 ft	Center Displacement =	13.70 ft

Segment Force Components

Normal Force =	16,931 lb
Drag Force =	42,637 lb
Friction Force =	5,079 lb
Segment Weight =	0 lb
Tension =	117,624 lb
Average Tension =	91,227 lb
Segment Force =	52,795 lb
Cumulative Force =	**117,624 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	580 psi	
Cumulative Axial Stress =	1,293 psi	56,000 psi
Bending Stress =	16,731 psi	46,113 psi
Hoop Stress =	940 psi	8,892 psi
Combined Stress =	0.3859	< 1.0
Total Stress =	0.1293	< 1.0

Installation:10.50 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 5 of 5

Segment Parameters

Segment Name =	ENTRY TANGENT	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	139.03 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	9,435 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	9,435 lb
Cumulative Force =	**127,059 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	104 psi	
Cumulative Axial Stress =	1,397 psi	56,000 psi
Bending Stress =	0 psi	46,113 psi
Hoop Stress =	288 psi	8,892 psi
Combined Stress =	0.0249	< 1.0
Total Stress =	0.0020	< 1.0

APPENDIX C
Report Limitations and Guidelines for Use

APPENDIX C
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

Geotechnical Services Are Performed for Specific Purposes, Persons and Projects

This report has been prepared for the exclusive use of PCGP, LP and their authorized agents. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared. This report should not be applied for any purpose or project except the one originally contemplated.

A Geotechnical Engineering or Geologic Report Is Based on a Unique Set of Project-specific Factors

This report has been prepared for PCGP, LP for the Coos River HDD in Coos County, Oregon. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you.
- not prepared for your project.
- not prepared for the specific site explored.
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure.
- elevation, configuration, location, orientation or weight of the proposed structure.
- composition of the design team.
- project ownership.

---

[1] Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

Subsurface Conditions Can Change

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

Most Geotechnical and Geologic Findings Are Professional Opinions

Our interpretations of subsurface conditions are based on field observations from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

Geotechnical Engineering Report Recommendations Are Not Final

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient observation, testing and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A Geotechnical Engineering or Geologic Report Could Be Subject to Misinterpretation

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also, retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Exploration Logs

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

Give Contractors a Complete Report and Guidance

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

Contractors Are Responsible for Site Safety on Their Own Construction Projects

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

Read These Provisions Closely

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

Geotechnical, Geologic and Environmental Reports Should Not Be Interchanged

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

Biological Pollutants

GeoEngineers' Scope of Work specifically excludes the investigation, detection, prevention or assessment of the presence of Biological Pollutants. Accordingly, this report does not include any interpretations, recommendations, findings, or conclusions regarding the detecting, assessing, preventing or abating of Biological Pollutants and no conclusions or inferences should be drawn regarding Biological Pollutants, as they may relate to this project. The term "Biological Pollutants" includes, but is not limited to, molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts.

If Client desires these specialized services, they should be obtained from a consultant who offers services in this specialized field.

Have we delivered World Class Client Service?

Please let us know by visiting **www.geoengineers.com/feedback**.

GeoEngineers

Geotechnical Engineering Services and Horizontal Directional Drilling Design

MP 25 HDD

Pacific Connector Gas Pipeline Project

Coos County, Oregon

for

Willbros Professional Services – West Region

May 11, 2015

GeoEngineers
Earth Science + Technology

Geotechnical Engineering Services and Horizontal Directional Drilling Design

MP 25 HDD
Pacific Connector Gas Pipeline Project
Coos County, Oregon

for
Willbros Professional Services – West Region

May 11, 2015

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Geotechnical Engineering Services and Horizontal Directional Drilling Design

MP 25 HDD
Pacific Connector Gas Pipeline Project
Coos County, Oregon

File No. 16724-002-00

May 11, 2015

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EXECUTIVE SUMMARY

This report provides geotechnical engineering and horizontal directional drilling (HDD) recommendations and HDD design criteria for the proposed Milepost (MP) 25 HDD, located approximately 2 miles southeast of Fairview, Oregon. This HDD installation consists of installing a new 36-inch-diameter pipeline beneath steep side slopes in the area where conventional open trench construction would be difficult, and would also present long-term, right-of-way (ROW) maintenance problems. The MP 25 HDD is part of the proposed Pacific Connector Gas Pipeline (PCGP) project.

Based on the results of our site visits, subsurface exploration program, geotechnical engineering evaluations, HDD design, and HDD constructability review, it is our opinion that the HDD method of installation is feasible and that the proposed 36-inch pipeline can be successfully installed using HDD installation methods provided the recommendations in this report are incorporated into construction.

The subsurface conditions at the site were evaluated by drilling two borings to depths ranging between 100 feet below ground surface (bgs) and 120 feet bgs. In general, the borings encountered about 45 feet of elastic silt, fat clay and lean clay overlying siltstone and sandstone bedrock that was generally soft and ranged from slightly weathered to predominately decomposed.

The hydraulic fracture and drilling fluid surface release model indicates that the risks of localized hydraulic fracture and drilling fluid surface release are generally low throughout the HDD profile. However, as is typical with HDD installations, we consider the risk of drilling fluid surface release to be relatively high within about 100 feet of the entry point.

The HDD alignment traverses moderately to steeply sloping terrain from southeast to northwest (entry to exit). The pipe stringing and fabrication area extends northwestward along the proposed pipeline ROW. There is approximately 100 feet of elevation gain between the proposed entry point (low side) and proposed exit point (high side). The difference in elevation between the entry (low side) and exit point (high side) will cause the drilling fluid within the hole to drain to the point of equilibrium equal to the elevation of the entry point. Any section of the hole above the point of equilibrium is commonly referred to as "dry hole," and will not have the benefit of being filled with or supported by drilling fluid. This dry hole condition can increase the risk of hole collapse, groundwater intrusion and poor cuttings removal from the annulus, which, in turn may lead to additional risks (ground settlement, loss of drilling fluid returns, and hole flushing. These risks are discussed in Section 5.1.5 of this report. We recommend that the HDD contractor advance tooling during pilot hole, reaming and swabbing operations from the entry point towards the exit point to promote drilling fluid returns to the entry point and reduce the risk of drilling fluid flushing.

The site-specific HDD profile was created utilizing the design guide published by the Pipeline Research Committee International (PRCI) of the American Gas Association. Associated installation and operational stresses were calculated utilizing the PRCI Design Guide and checked to assess compliance with ASTM International (ASTM)/American Society of Mechanical Engineers (ASME) B31.8, API Recommended Practice 2A – WSD, and DOT CFR Part 192. The HDD design calculations indicate the stresses incurred during installation and operation should be within the allowable limits.

This Executive Summary should be used only in the context of the full report for which it is intended.

1.0 INTRODUCTION

1.1 General

This report summarizes our geotechnical engineering and HDD design services for the proposed MP 25 HDD installation. The site is located approximately 2 miles southeast of Fairview, Oregon. The site location is shown with respect to the surrounding area in the Vicinity Map, Figure 1. The general layout of the site is shown in the Site Plan and Profile, Figures 2A and 2B.

1.2 Project Description and Basis of Design

The proposed MP 25 HDD will be a part of the 232-mile-long PCGP, beginning at the proposed Jordan Cove Liquefied Natural Gas (LNG) Terminal near Coos Bay, Oregon and terminating near Malin, Oregon. The proposed MP 25 HDD installation consists of a single 36-inch-diameter pipe to be installed beneath steep terrain where conventional open trench construction would be difficult, and would also present long-term ROW maintenance problems.

The HDD design was completed in accordance with the latest versions of Department of Transportation (DOT) 49 CFR 192, ASME 31.8 and accepted practices within the natural gas industry. The geotechnical and HDD design engineering was completed based on the parameters presented below in Table 1.

TABLE 1. BASIS OF DESIGN FOR THE 36-INCH-DIAMETER MP 25 HDD

Product Pipe Data	Design Parameter
Product Pipe Specifications	36 inches x 0.762 inches w.t.[1] API-5L X-70 steel pipe, SAWH or SAWL
Horizontal Crossing Length	3,520 feet
Maximum Allowable Operating Pressure	1,480 psig[2]
Average Operating Temperature	70 degrees F
Maximum Operating Temperature	100 degrees F
Assumed Tie-In Temperature	50 degrees F

Notes:

[1]w.t. – wall thickness

[2]psig – pounds per square inch gauge

2.0 SCOPE OF SERVICES

The purpose of our services was to evaluate the existing surface and subsurface soil and groundwater conditions in order to evaluate the feasibility of the HDD installation and prepare a HDD design for the proposed HDD installation. The specific scope of services provided by GeoEngineers, Inc. (GeoEngineers) included the following:

2.1 Phase 1 – Geometric Feasibility

The purpose of our Phase 1 services was to utilize site-specific topographic survey to evaluate the geometric feasibility of the proposed HDD. Our specific Phase 1 scope of services included:

1. Conducting a site visit to evaluate potential entry and exit points for the proposed HDD installation and observe surface conditions along the proposed alignment.
2. Developing a preliminary HDD plan and profile drawing using site-specific topographic information provided by Williams Pipeline – West (Williams) for the purposes of evaluating the geometric feasibility of the proposed HDD.
3. Meeting with Williams to discuss our findings.

2.2 Phase 2 – Subsurface Conditions Feasibility

The purpose of our Phase 2 services was to explore subsurface conditions along the proposed HDD alignment in order to provide a HDD design for installation of the 36-inch-diameter product pipe. Our specific phase 2 scope of services included:

1. Conducting a site visit to evaluate access to potential boring locations and mark the borings.
2. Reviewing geologic maps from our files to evaluate geologic materials in the area.
3. Exploring subsurface conditions along the proposed HDD alignment by means of two drilled borings to depths of 100 feet bgs and 120 feet bgs using mud-rotary and rock coring techniques, as appropriate. While observing the borings we:
    a. Obtained soil samples at representative intervals from the borings during standard penetration testing (SPT samples);
    b. Obtained continuous rock core within bedrock, where applicable;
    c. Classified the materials encountered in the borings in general accordance with ASTM International (ASTM) Standard Practices D 2488 (soil), and the Oregon Department of Transportation (ODOT) rock classification system (rock); and
    d. Maintained a detailed log of each boring.
4. Performing index tests necessary to characterize subsurface conditions for use in crossing design. Testing included:
    a. Six Atterberg limits determinations in general accordance with ASTM D 4318;
    b. One sieve analyses in general accordance with ASTM C 136; and
    c. Six unconfined compressive strength tests in general accordance with ASTM D 7012.

2.3 Phase 3 – HDD Design

Our specific Phase 3 scope of services included:

1. Performing a hydraulic fracture and drilling fluid surface release analysis to characterize the risk of hydraulic fracture and drilling fluid surface releases.
2. Completing a HDD design in accordance with applicable pipeline design codes, including:
    d. Alignment and profile of the HDD;
    e. Minimum pipeline installation radius;
    f. Installation stresses during HDD pullback; and

    g. Operating stresses on the pipe.

5. Preparing a preliminary design drawing in AutoCAD format (24-inch x 36-inch). The drawing included the following:
    a. Required temporary workspace;
    b. Identification of existing utilities (located by others) crossed by the HDD path; and
    c. Locations of the borings with respect to the HDD alignment and profile.
6. Providing this HDD design report and design drawing to the project team for review. Our report includes the following:
    a. A summary of our site reconnaissance, including a surface description along the proposed alignment;
    b. A summary of our field explorations, subsurface materials and laboratory testing;
    c. A summary of our HDD engineering analyses, including drilling fluid losses, and quantitative hydraulic fracture evaluation and drilling fluid surface release evaluation;
    d. Proposed entry, exit and pipe stringing workspace size and location;
    e. Minimum allowable pipe bending radius;
    f. Installation loads and operating stresses;
    g. Site access, water sources and noise mitigation, as appropriate;
    h. HDD conclusions and construction considerations, including workspace layout, risk of hydraulic fracture, drilling fluid surface release, hole instability, cuttings removal; and
    i. Geotechnical engineering considerations for temporary roads and workspaces, temporary excavations, construction dewatering and erosion control.
7. Preparing a final HDD design report and HDD design drawing (issued for construction) incorporating review comments (not yet completed).

3.0 SITE CONDITIONS

3.1 Geologic Setting

3.1.1 Site Geology

Geologic mapping we reviewed indicates that the site is underlain by sedimentary deposits of the Tertiary-aged Roseburg Formation (Beaulieu and Baldwin, 1973). These sedimentary deposits are described as rhythmically bedded hard sandstone and siltstone. The mapping indicates that bedding planes within the sedimentary rocks typically dip to the southeast at angles generally ranging between 25 and 50 degrees.

3.2 Surface Conditions

3.2.1 General

We evaluated surface conditions in the vicinity of the site during an initial site reconnaissance in May of 2014, and also while conducting our subsurface exploration program in December 2014 and February 2015.

3.2.2 Surface Description

The proposed HDD alignment is oriented southeast to northwest (entry to exit) as shown in Figure 2. The southeast side (entry) of the proposed HDD is located on a gently sloping ground on the crest of a ridge at approximately elevation 579 feet above mean sea level (MSL). The northwest side (exit) is located on a moderately sloping northwest facing ridge flank just below the crest of the ridge. Beginning at the entry point (station 38+62) and heading northwestward, the HDD alignment traverses steep east to northeast facing slopes ascending to a high ridgeline at a maximum elevation of about 850 feet MSL (station 21+00). Northwest of Station 21+00, the HDD alignment descends the steep northwest facing ridge flank, then crosses several smaller spur ridges before exiting on the northwest flank of a ridge, just below its crest at an elevation of 701 feet MSL (station 3+42).

The proposed entry workspace is an odd shaped workspace situated on a ridgeline adjacent to and east of a Bonneville Power Administration (BPA) ROW. The workspace measures approximately 150 feet by 300 feet. The workspace is currently vegetated with conifer trees. The ground surface within the workspace is gently to moderately sloping to the northwest.

The exit workspace occupies an approximately 150-foot by 225-foot area, just northwest of an existing gravel road, and on moderately steep northwest facing slopes. The workspace is vegetated with young conifer trees.

The pipe stringing and fabrication workspace extends cross country to the northwest along the proposed pipeline ROW for a distance of 2,210 feet to Lone Pine Road. The first approximately 400 feet of the pipe stringing and fabrication workspace descends moderate to steep slopes to the northwest, then traverses gentle to moderate terrain to Lone Pine Road. Vegetation within the workspace typically consists of young conifer trees. However, there is a patch of mature conifer trees located about 600 feet northwest of the exit point that is crossed by the workspace.

3.3 Subsurface Conditions

3.3.1 General

We explored subsurface conditions at the site on December 9 and 10, 2014 and between February 10 and 12, 2015 by advancing two drilled borings to a depth of 100 feet bgs (B25.09-1) and 120 feet bgs (B25.6-1). The approximate boring locations are presented in Figure 2A. A representative from GeoEngineers maintained logs of the materials encountered in each boring and collected samples at 5-foot intervals in soil using split spoon samplers during standard penetration testing (SPT). In bedrock, cores were obtained using an HQ-3 core barrel. Appendix A presents the boring logs, a description of the subsurface exploration, and laboratory-testing programs. Laboratory test results are shown in the boring logs and laboratory test result figures in Appendix A.

The materials encountered in our borings were generally consistent with the geologic mapping for the site. In general, borings encountered approximately 45 feet of stiff to very stiff elastic silt, fat clay and lean clay residual soil overlying bedded extremely soft to soft siltstone with subordinate amounts of interbedded sandstone. The siltstone ranged from moderately weathered to predominately decomposed, and extremely soft to soft. Rock Quality Designation (RQD) values within the siltstone generally ranged between 65 and 100 percent, although zones of zero to 43 percent RQD were also observed. The sandstone was generally slightly weathered and ranged from soft to extremely soft. Unconfined compressive strength tests (UC tests) conducted on select samples of the siltstone were highly variable, ranging between 22 pounds per square inch (psi) to 1,178 psi. UC tests conducted on select samples of the sandstone were also quite variable ranging between 27 psi and 618 psi. During the UC testing we observed that the siltstone and sandstone appeared internally fissured, and likely broke along pre-existing fractures, which may indicate misleading (low) rock shear strength.

The subsurface materials encountered in the borings are described in more detail in the boring logs included in Appendix A.

3.3.2 Groundwater Conditions

We could not measure groundwater levels upon completion of the borings because of the presence of drilling fluid in the holes at the time of drilling. We anticipate that static groundwater levels may be tens to hundreds of feet below the ground surface in the mountainous terrain. However, perched groundwater may be encountered by the HDD alignment, particularly at the contact of the residual soil and underlying bedrock, and within sandstone layers. Additional risks and considerations regarding groundwater are presented in Section 5.1.6 of this report.

4.0 HDD ENGINEERING ANALYSES

4.1 Hydraulic Fracture and Drilling Fluid Surface Release Evaluation

4.1.1 Model Input Parameters

The HDD geometry used for our analyses of the MP 25 HDD installation is shown in the HDD Design Drawing in Appendix B. The horizontal length of the HDD is 3,520 feet. The soil and rock units encountered in the vicinity of the HDD are characterized by borings B-25.09-1 and B-25.6-1. A general description of the subsurface conditions encountered in the borings is presented in Section 3.3.1, and the boring logs are presented in Appendix A.

Based on the results of the exploration program and subsequent laboratory-testing program, the soil properties used in the evaluation are presented in Table 2 below.

TABLE 2. ESTIMATED SOIL PROPERTIES

Soil Description	Unit Weight (pcf)	Friction Angle (degrees)	Cohesion (psf)
Stiff Elastic Silt, Fat Clay and Lean Clay	120	0	750
Very Stiff Elastic Silt, Fat Clay and Lean Clay	130	0	1500
Very Soft to Soft Siltstone/Sandstone	140	30	5220

Notes:
pcf = pounds per cubic foot; psf = pounds per square foot

Based on available information and common HDD construction procedures, the tool dimensions and rheological properties used in the evaluation are summarized in Table 3. Because these parameters are dependent upon the HDD contractor's means and methods, the hydraulic fracture and drilling fluid surface release evaluation should be refined during construction of the HDD installations.

TABLE 3. ESTIMATED TOOL DIMENSIONS AND RHEOLOGICAL PROPERTIES

Parameter	Value
Pilot Hole Bit Diameter	12.25 inches
Drill Pipe Diameter	5.5 inches
Drilling Fluid Weight	9.5 ppg
Plastic Viscosity	10 CP
Yield Point	20 lb/100 sf

Notes:
ppg = pounds per gallon; CP = centipoise; lb/100 sf = pounds per 100 square feet

4.1.2 Discussion of Hydraulic Fracture and Drilling Fluid Surface Release

4.1.2.1 GENERAL

During HDD installation, drilling fluid is transported under pressure through the drill pipe string to the cutting tool. For HDD installations like the MP 25 HDD installation, pump pressures of several hundred psi and pump rates of 300 to 600 gallons per minute (gpm) are typical. The drilling fluid typically has a specific gravity ranging from 1.1 to 1.2 (approximately 69 to 75 pounds per cubic foot).

The total drilling fluid pressure at the cutting tool is a function of pumping pressures, the elevation difference between the drill rig and the cutting tool and friction losses. Soil and rock formations along the drill path experience maximum drilling fluid pressures in the immediate proximity of the drill bit or reaming tools. The energy (pressure) of the drilling fluid is steadily diminished along its path from the drill rig to the cutting tool and back to the rig through the annulus of the hole. Thus, the pumping pressure required to circulate the drilling fluid increases as the drill bit advances farther from the drill rig. Typically, the annular drilling fluid pressure at the cutting tool can range from 15 to 25 percent of the pump pressure.

4.1.2.2 DRILLING FLUID LOSS

Drilling fluid circulation may be reduced or lost during HDD operations by drilling fluid loss to the surrounding soil or by the accumulation of cuttings downhole that create a blockage, which may result in hydraulic fracture. These two processes are discussed below:

1. Formational fluid loss occurs when drilling fluid flows into surrounding permeable soil units either within the pore spaces of the soil or along preexisting fractures or voids in the formation.
2. Hydraulic fracturing and subsequent loss of drilling fluid can occur where the combined resisting force of the available overburden pressure and the shear strength of the overburden soil is less than the hydrostatic drilling fluid pressure and the pressures applied to the surrounding soil from the drilling fluid at the cutting tool.

Formational drilling fluid losses typically occur when the drilling fluid flows through the pore spaces in the soil through which the HDD profile passes. Thus, a formation with a higher porosity can potentially absorb a larger volume of drilling fluid than a formation with a lower porosity. Silty sands, silts and clays typically have a low susceptibility to formational drilling fluid losses. Coarse sand and gravel units with low percentages of silt and clay have a moderate to high susceptibility for drilling fluid loss. The proper management of the drilling fluid properties can reduce the volume of formational drilling fluid loss.

4.1.2.3 HYDRAULIC FRACTURE

Hydraulic fracture is a term typically used to describe the condition in which the downhole drilling fluid pressure exceeds the overburden pressure and shear strength of the soil surrounding a drill path. Soils that are most vulnerable to hydraulic fracture include relatively weak cohesive soils or loose granular soils with low shear strength. Medium dense to very dense sands and very stiff to hard silts and clays have a low to moderate hydraulic fracture potential. Rock, due to its high shear strength, typically has a low potential for hydraulic fracture. HDD installations with greater depth or drill paths in formations with higher shear strength may reduce the potential for hydraulic fracturing.

4.1.2.4 DRILLING FLUID SURFACE RELEASE

Drilling fluid surface releases, commonly referred to as “Frac-Outs,” occur when drilling fluid emerges at the ground surface or in any other undesired location such as wetlands, utility trenches, basements, roads, railroads, and waterbodies (Photograph 1). In practice, drilling fluid surface releases typically occur in proximity to the entry and exit points where annular pressures are high and soil cover is thin. Drilling fluid surface releases can also occur at locations along a drill path where there are low shear strength soils, where soil cover is relatively thin or along preexisting fractures or voids. Other locations where drilling fluid surface releases can occur are along preferential pathways such as exploratory boring locations, within utility trenches, or along the edges of existing subsurface structures such as piles or utility poles.

The HDD contractor’s construction procedures constitute another important factor influencing when and where drilling fluid loss occurs. If the contractor operates with insufficient drilling fluid flow rates, inadequate drilling fluid properties or excessive rates of penetration, the annulus may become blocked through an accumulation of drill cuttings falling out of suspension. This can occur within formations that typically have a low potential for hydraulic fracture. If the accumulation of cuttings creates a blockage downhole, the annulus may become over-pressurized, leading to hydraulic fracturing and potentially drilling fluid surface releases. Our analysis does not account for this over-pressurized condition.

Photograph 1 - Example of Drilling Fluid Surface Release

4.1.2.5 HYDRAULIC FRACTURE CALCULATIONS

The procedures used to evaluate the potential for drilling fluid loss through hydraulic fracturing are based primarily on research completed by Delft Geotechnics, as discussed in Appendix B of the USACE Report CPAR-GL-98 (Staheli, et al., 1998). The methodologies used to estimate the hydraulic fracture potential outlined in the research are based on cavity expansion theory. The cavity expansion model is used to estimate the maximum effective pressure in the drill hole before plastic deformation of the drill hole occurs.

In order to evaluate the hydraulic fracture and drilling fluid surface releases potential for a HDD installation, assumptions must be made when selecting the input parameters. The assumptions used in the model include the extent and uniformity of soil layers, hydrostatic groundwater pressures, drilling fluid properties, penetration rates and drilling fluid flow rates. The soil strength properties are estimated based on interpretations of the boring logs and laboratory test results. The drilling fluid properties, penetration rates and pump rates are estimated based on generally accepted best management practices (BMPs) of the HDD industry. Consequently, the results of the evaluation are only estimates of the potential for hydraulic fracture and drilling fluid surface releases.

In addition, the drilling fluid properties are dependent on the field conditions and the construction practices of the HDD contractor and drilling fluid engineer. Changes in these properties can significantly affect the potential for hydraulic fracture and drilling fluid surface releases.

Based on the soil properties, rheological parameters and anticipated tool dimensions, the model considers the total and effective overburden stresses, shear strengths of the soil, and the estimated drilling fluid pressures along the drill path. A comparison is then made of the estimated drilling fluid pressures immediately behind the drill bit and the ability of the soil to resist plastic deformation. The evaluation considers only the hydraulic fracture potential during pilot hole operations assuming the drilling fluid returns are continuously maintained to the entry point.

The factor of safety against hydraulic fracturing of the soil surrounding the drill bit is defined as the ratio of the formation limit pressure to the estimated annular drilling fluid pressure. The factor of safety against drilling fluid surface releases is defined as the maximum factor of safety against hydraulic fracture calculated for all of the soil units above specified points along the drill path.

In some cases, the evaluation may indicate a high potential for, or a low factor of safety against, hydraulic fracture in the soils surrounding the drill bit; however, a higher-strength layer may be present above the weaker layer that may reduce the risk of drilling fluid migration toward the ground surface, thus providing a higher factor of safety against drilling fluid surface releases.

Table 4 below shows the relative risk associated with the estimated factors of safety against hydraulic fracture and drilling fluid surface releases.

TABLE 4. RELATIVE HYDRAULIC FRACTURE AND DRILLING FLUID SURFACE RELEASE RISK

Factor of Safety	Relative Risk
Less than 1	Very High
Between 1 and 1.5	High
Between 1.5 and 2	Moderate
Greater than 2	Low

4.1.3 Results of Hydraulic Fracture and Drilling Fluid Surface Release Evaluation

The results of the hydraulic fracture evaluation are presented in Figures 3 and 4. The formation limit pressure, presented in Figure 3, is the ability of the soil and rock to resist plastic deformation and is a function of the shear strength of the soil through which the HDD profile passes. Based on subsurface conditions encountered in the borings and the HDD design geometry, the proposed HDD profile passes through stiff to very stiff elastic silt, lean clay and fat clay, and layered siltstone and sandstone bedrock. As a result, the formation limit pressure varies depending on the soil and rock encountered along the HDD profile as shown in Figure 3 as the green line. The areas with the higher formation limit pressures are where the profile passes through the sandstone and siltstone. The estimated drilling fluid pressure is also shown in Figure 3 as the red line and represents the drilling fluid pressure along the HDD profile based on the anticipated drilling fluid properties shown in Table 3. As seen in Figure 3, the estimated annular drilling fluid pressure drops to zero approximately at station 10+50. This decrease in estimated annular drilling fluid pressure corresponds with the drilling fluid equilibrium point, above which will be “dry hole” (drilling fluid does not fill the drill hole).

When evaluating the risk of hydraulic fracture and drilling fluid surface releases, the analysis computes two types of factors of safety. These are:

- Factor of Safety against localized hydraulic fracture; and
- Factor of Safety against drilling fluid surface release.

<u>Local Hydraulic Fracture</u>: The factor of safety against hydraulic fracture is the ratio of the formation limit pressure to the estimated drilling fluid pressure along the profile, shown as the green line in Figure 4. This represents the factor of safety against hydraulic fracture of the soil immediately surrounding the HDD profile and is a localized condition.

<u>Drilling Fluid Surface Release</u>: The factors of safety against drilling fluid surface release considers the strength of the soil/rock column above the HDD profile that resists drilling fluid migrating to the ground surface. It is computed by comparing the formation limit pressure of the soil and rock units above a specific location along the planned HDD alignment to the anticipated drilling fluid pressure at the same location. The factors of safety against drilling fluid surface releases are shown in Figure 4 at selected points shown as red triangles.

The model indicates that the risks of localized hydraulic fracture and drilling fluid surface release are very low when the HDD profile is located within the sandstone and siltstone bedrock, with calculated factors of safety generally greater than 20 (see Figure 4), and low when the HDD profile is located within the stiff to very stiff elastic silt, lean clay and fat clay with factors of safety greater than 2.0. Factors of safety against drilling fluid release were not computed to the northwest of station 10+50 along the dry hole section.

In general, we consider that the risk of hydraulic fracture and drilling fluid surface release is high within approximately 100 feet of the HDD entry point. This is a result of relatively thin soil cover near the entry point.

4.2 Installation Stresses

The analyses of installation loads and stresses are based on the product pipe being installed along the designed path using the BMPs of the HDD industry. The addition of water into the product pipe is the standard method that contractors typically use to control buoyancy of the product pipe during the installation procedure. The proposed 36-inch-diameter product pipe will be positively buoyant in the anticipated drilling fluid weights. Therefore, our analyses include five cases with differing levels of buoyancy and drilling fluid weights.

The five cases analyzed are as follows:

1. The annulus contains 9.5 pounds per gallon (lb/gal) drilling fluid and product pipe is empty.
2. The annulus contains 9.5 lb/gal drilling fluid and product pipe is full of water.
3. The annulus contains 12 lb/gal drilling fluid and product pipe is empty.
4. The annulus contains 12 lb/gal drilling fluid and product pipe is full of water.
5. The annulus contains 10.5 lb/gal drilling fluid and product pipe is filled such that neutral buoyancy is achieved.

The analyses are based upon the methods developed by the PRCI of the American Gas Association (PR-227-9424, 1995). The only deviation from this guide in calculating the installation stresses is a more conservative allowable tensile stress (F_t).

The equation recommended in the PRCI Design Guide is shown in below in **Equation 1**:

$$F_t = 0.9 * SMYS \text{ (Specified Minimum Yield Strength)}$$

The allowable tensile stress used for our analyses is derived from Sections 2.4.1, 3.1.2 and 3.2 of the American Petroleum Institute (API) Recommended Practice 2A – WSD (WSD Recommended Practice 2A-WSD, 1993).

Section 3.2 of the API Recommended Practice defines the allowable tensile stress of cylindrical members as shown below in **Equation 2**:

$$F_t = 0.6 * SMYS$$

Sections 2.4.1 and 3.1.2 of the API Recommended Practice permit the allowable tensile stress, defined in Equation 2, to be increased by one-third, yielding a design factor of 0.8, which is more conservative than 0.9 as listed in the PRCI Design Guide.

The equation used in our analyses is shown below in **Equation 3**:

$$F_t = 0.8 * SMYS$$

The following table presents a summary of the calculated installation loads for the HDD installation.

TABLE 5. INSTALLATION LOADS FOR THE 36-INCH-DIAMETER MP 25 HDD[1]

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Effective Pipe Weight[2] (lb/ft)	Pullback Force[3] (lb)
9.5	Empty	-215	551,000
9.5	Full	190	398,000
12	Empty	-347	726,000
12	Full	57	287,000
10.5	Neutral Buoyancy	0	265,000

Notes:

[1]See Appendix B for detailed calculations; [2]Negative values indicate upward force (positive buoyancy); and

[3]Assumes a fully open drilled hole drilled along the designed HDD profile.

4.3 Operating Stresses

The operating stresses on a pipeline installed by directional drilling include hoop stress from the maximum allowable operating pressure (MAOP), hoop stress from external pressure applied by the groundwater acting on the outside of the product pipe, elastic bending as the product pipe conforms to the shape of the drilled hole, and thermal expansion and contraction stresses resulting from the difference between the constructed temperature and the operating temperature. The following table presents a summary of the operating stresses based on the product pipe specifications and the HDD profile as shown on the HDD Design Drawing in Appendix B.

TABLE 6. SUMMARY OF OPERATING STRESSES FOR THE 36-INCH-DIAMETER MP 25 HDD*

Stress Component	Stress (psi)	Percent SMYS[1] (%)	Maximum Allowable Percent SMYS[1] (%)
Longitudinal Bending Stress	16,929	24	-
Hoop Stress	34,961	50	50[2]
Longitudinal Tensile Stress from Hoop Stress	10,488	15	-
Longitudinal Stress from Thermal Expansion	-9,537	14	90[3]
Maximum Net Longitudinal Stress	17,881	26	90[4]
Maximum Shear Stress	25,469	36	45[5]
Maximum Combined Effective Stress	50,939	73	90[6]

Notes:

*Operating stress calculations are based on the specified minimum radius of curvature of 2,600 feet and assumed installation and operating temperatures of 50 degrees and 100 degrees Fahrenheit, respectively.

[1]Specified Minimum Yield Stress

[2]Limited by design factor from DOT regulations, Title 49 CFR Part 192.111 for gas.

[3]Limited by Section 402.3.2 of ASME B31.4.

[4]Limited by Section 833.3 of ASME B31.8 for gas.

[5]Limited by Section 402.3.1 of ASME B31.4.

[6]Limited by Section 833.4 of ASME B31.8 for gas.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 HDD Design Considerations and Recommendations

5.1.1 General

The contractor's means and methods during construction are critical to the successful completion of the HDD. Specifically, during pilot hole drilling, only small deviations from the design for horizontal and vertical curvature should be allowed so that pull load forces similar to those estimated by the calculations can be maintained. The HDD contractor's ability to maintain drilling fluid returns, proper drilling fluid properties with appropriate penetration rates, and drilling fluid flow rates will also be important factors to consider during drilling because hole conditions will be directly affected by these operations.

Based on geologic mapping, subsurface materials encountered in the borings and our laboratory testing, the HDD pilot hole will encounter layered sedimentary rocks with bedding planes dipping to the southeast, roughly the same direction as the exit tangent. The various rock layers may have different shear strengths. We anticipate that the contractor may experience some steering difficulty as the drill bit encounters the contacts of these bedding planes, particularly between contacts of softer and harder rocks. These conditions will likely encourage the bottom hole assembly to preferentially follow along the bedding planes. The contractor should be prepared to encounter some steering difficulties due to these conditions and mitigate them by adjusting steering patterns and/or downhole tooling to alleviate steering difficulties.

We recommend that Williams retain a qualified representative to observe and document the drilling process and to advise the project team on areas of concern and recommended actions during drilling activities. We also recommend that Williams require that a qualified drilling fluid engineer evaluate the drilling fluid properties on a continuous basis during the entire drilling and installation process. Close coordination between the contractor and the drilling fluid technician to maintain proper drilling fluid properties, penetration rates and drilling fluid flow rates will be instrumental to effectively remove cuttings from the pilot hole and reamed hole.

5.1.2 Drill Hole Stability

In general, the residual soils and bedrock encountered by our borings along the proposed HDD alignment present a relatively low risk of hole instability during HDD operations. However, the dry hole condition produces a greater risk of hole instability by virtue of the fact that it is not supported by drilling fluid. Groundwater seepage (if encountered) into the hole could also contribute to hole instability.

5.1.3 Cuttings Removal

Based on our experience, cuttings removal in elastic silt and fat clay like that encountered by borings completed along the HDD alignment, is typically more challenging than in other non-cohesive soils. In some cases, relatively dry elastic silts may swell and block the drill hole or the high plasticity cuttings may "ball up" forming large diameter particles that fall out of suspension and are more difficult to remove than smaller clay particles that remain in suspension. Therefore, the potential for the hole to become plugged with cuttings is elevated along the soil portions of the proposed HDD profile. In the event that the hole becomes plugged, and drilling fluid circulation ceases, downhole annular pressures can increase dramatically. This temporary spike in downhole annular pressure can dramatically increase the risk of hydraulic fracture and drilling fluid surface release, as well as increasing the risk of hole flushing. In addition, if cuttings are not effectively removed from the hole during HDD operations, pullback forces could be excessively high during pullback of the 36-inch-diameter product pipe, or the product pipe could become lodged in the hole. The failure to effectively remove cuttings from the hole could potentially result in failure of the HDD installation. Therefore, we recommend that the drilling contractor maintain drilling fluid returns at all times, and use appropriate means and methods (appropriate penetration rates, drilling fluid pump rates, drilling fluid management, and mechanical methods) to ensure that cuttings are adequately removed from the hole during the HDD process.

5.1.4 Soil/Bedrock Interface

During the reaming process, the soil/bedrock interface can be a location where an excessive vertical offset (dogleg) in the hole profile can form as a result of the heavy rock hole openers over-mining the bottom portion of the hole. If not properly mitigated, this condition can induce excessive stresses in the downhole tooling, increasing the risk for stuck tooling, a twist-off downhole and stuck pipe during pullback operations. This risk will likely be most pronounced within the entry tangent or the first few joints of the entry curve, and within the exit tangent of the HDD profile, where we expect that the soil/bedrock interface will be contacted during HDD operations.

The contractor should take care when reaming the pilot hole to reduce the risk of vertical offset at the soil/bedrock interface adversely affecting pullback operations. If it is suspected that a severe hole offset exists at the soil/bedrock interface, the hole can be reamed to a larger diameter than typically required to allow more annular space for the carrier pipe to conform to the hole and pass through the interface without becoming lodged in the hole. We recommend that the HDD contractor be required to submit with their HDD Work Plan an assessment of the potential for excessive hole offset at the soil/bedrock interface and their proposed mitigation procedures to reduce this risk.

5.1.5 Hole Flushing

If the hole becomes obstructed with cuttings generated during pilot hole or reaming operations, the drilling fluid level in the hole can begin to rise above the drilling fluid equilibrium point into the "dry" portion of the hole. The drilling fluid may continue to rise in the "dry" section of the hole until the hydrostatic pressures within the hole causes a breach in the obstruction, at which point the drilling fluid will rapidly flow from the entry point. This occurrence is commonly referred to as a "hole flush." Depending on the diameter of the hole and the height of the drilling fluid above the low side of the crossing when the hole flushes, the volume of drilling fluid that is expelled from the hole can be extremely large. If the HDD contractor is not prepared to collect and contain the volume of drilling fluid generated during a hole flush, the drilling fluid can impact sensitive areas outside of the designated workspace areas.

The HDD contractor can take steps to both prevent hole flushes and prepare for them in the event that they do occur. We recommend that the HDD contractor submit with their HDD Work Plan the precautions that will be taken to both prevent the occurrence of hole flushes and to reduce the impacts of hole flushes should they occur. These precautions could include the following:

- Employing a drilling fluids ("Mud") engineer to test the drilling fluid properties and implement methods to optimize the drilling fluid properties through the use of additives, as necessary.

- Making attempts to restore drilling fluid returns should drilling fluid returns begin to slow. The slowing of drilling fluid returns may indicate that drilled cuttings are accumulating in the hole, restricting the flow and that fluid is beginning to back up within the "dry" portion of the hole. Proactive methods to prevent a hole flush can include the use of "weeper" subs, swabbing the hole to help entrain drilled cuttings into the drilling fluid and transport them out of the hole, or tripping out tooling to the entry point to mechanically remove cuttings from the hole.
- The use of multiple high-pressure drilling fluid pumps to allow for high drilling fluid flow rates and higher annular velocities, which helps to transport drilled cuttings from the hole.
- To prepare for a possible hole flush, the contractor can excavate a drilling fluid returns pit that is larger than normally required to help contain drilling fluid during a hole flush as well as stage 21,000-gallon mobile storage tanks (frac tanks) on site to allow for the storage of a large volume of drilling fluid. Discharge rates during a flush can be significant and may require multiple pumps to transfer the fluid to the frac tanks at a sufficient rate.

5.1.6 Groundwater

Although not specifically identified at the MP 25 HDD site, groundwater can introduce substantial risk during pilot hole operations if the HDD path crosses a water table that is higher in elevation than the low side of the crossing. If this occurs, a significant influx of groundwater may enter the pilot hole and dilute the drilling fluid. Depending on the nature of the formation containing groundwater and the volume of water stored in the water zone, the rate and volume of groundwater influx into the hole may be significant. In some instances this groundwater may dissipate after a short period of time without causing any long-term negative impacts to the project; however, under certain circumstances the groundwater influx could persist throughout the entirety of drilling operations

Groundwater may also pose long-term concerns with groundwater flow continuing through the annulus of the hole after the installation of the pipe. The potential impacts of long-term groundwater flow through the hole should be considered and a plan to mitigate this situation developed if it is deemed necessary to prevent this occurrence.

5.1.7 Drilling Fluid Loss and Drilling Fluid Surface Release

It is our opinion that little formational fluid loss should be expected within the subsurface materials encountered along the crossing. The total volume of formational fluid loss should be small relative to the total volume of fluid required for the project.

Our analysis indicates a generally low risk of hydraulic fracture and drilling fluid surface releases along the design HDD profile. However, we typically consider the risk to be relatively high within 100 feet of the entry point because of reduced soil cover. However, there will be very little risk near the exit point of this HDD crossing due to the dry hole condition at exit.

Because of the elevated risk of drilling fluid surface release occurring near the entry point, we recommend that the contractor establish a contingency and mitigation plan in the event that drilling fluid surface releases occur; these plans should be reviewed and approved by the project team prior to the start of construction.

5.1.8 Workspace Considerations

The entry workspace is situated within a sloping area that is vegetated with tall conifer trees. Therefore, we anticipate that vegetation removal, removal of stumps (grubbing) and grading will be required to prepare the entry workspace prior to the mobilization of HDD equipment to the site.

The exit workspace is situated in an area that slopes moderately to steeply to the northwest. This area is within the proposed Pipeline ROW. The workspace is occupied by young conifer trees and stumps. We anticipate that vegetation removal, removal of stumps (grubbing) and grading will be also required to prepare the exit workspace.

The first 400 feet of the proposed pipe stringing area northwest of the exit point slopes relatively moderately to steeply. We anticipate that grading will be required along the entire proposed pipe stringing and fabrication area. In addition, removal of relatively short, young conifer trees (0-20 year old) and a group of tall, mature (+40 year) conifer trees will be required to prepare the workspace.

As shown in Figure 2B and in Sheet 2 of the HDD design drawings in Appendix B, we laid out the approximate centerline of the proposed product pipe fabrication string with 1,500-foot radius curves that allow the pipe string to remain within Williams' PCGP workspace. As currently envisioned, an approximately 2,200-foot-long pipe string could be assembled within the workspace. Because the proposed pipe length of the HDD installation is 3,534 feet, two pipe strings will be required to be assembled, and one tie-weld will be required to be completed during pullback. Assuming the contractor assembles two pipe strings with lengths of approximately 2,200 feet and 1,415 feet (total length assumes an additional 2 pipe joint lengths or 80 extra feet), we recommend pulling in the shorter of the two pipe strings first, making the tie-in weld between the two product pipe strings, and then pulling in the longer of the two strings.

Stabilization of the ground surface within the entry, exit and pipe stringing workspaces will likely be required to provide a stable working platform for HDD and pipe fabrication operations. Ground surface stabilization can be accomplished by placing timber mats within the workspaces. Recommendations for stabilization of the ground surface are provided in Section 5.2 of this report.

5.1.9 Minimum Allowable Product Pipe Bending Radius

The design radii for the entry and exit vertical curves are 3,600 feet. The design radii of the vertical curves were chosen based on the industry standard of the design radii being at least 100 times the product pipe diameter in inches (for example, 36-inch-diameter pipe x 100 = 3,600-foot design radius), and to provide a reasonable separation of the design radii and the minimum allowable radius calculated based on the product pipe specifications and the anticipated operating conditions. We recommend that the three-joint radius be calculated for each three-joint section advanced during pilot hole operations. Based on the design geometry, subsurface conditions encountered, and proposed product pipe specifications, the minimum allowable three-joint radius over any consecutive three-joint section of drill pipe should not be less than 2,600 feet.

5.1.10 Pilot Hole Survey

We recommend that a secondary survey system (TruTracker, ParaTrack or equivalent) be used along the entire length of the HDD. If the HDD contractor elects to use the wire coil grids with these secondary survey systems, we recommend that the wire grids be placed at least as wide as the survey probe is deep. The placement of the coils is limited to areas where ground surface conditions and agreements with landowners allow.

For pilot hole operations, we recommend that the HDD contractor drill the pilot hole as closely as possible to the designed HDD profile while still maintaining three-joint horizontal and vertical radii equal to or greater than 2,600 feet. We recommend a horizontal tolerance of 5 feet left and 5 feet right of the designed alignment and a vertical tolerance of 2 feet above and 10 feet below the designed profile. We also recommend that, upon completion of the pilot hole, GeoEngineers have the opportunity to review the pilot hole survey data prior to the start of hole opening operations. The contractor should be responsible for producing an as-built drawing of the pilot hole survey data and providing it to Williams within 2 weeks of the completion of pullback operations. This as-built drawing should be kept in the project file for future reference as to the location of the installed pipeline.

5.1.11 Product Pipe Coating Specifications

The proposed product pipe coating specifications provided by Williams specify a nominal thickness of 8-10 mils of external Fusion Bonded Epoxy (FBE), and 40 mil thick Abrasion Resistant Overlay (ARO). In our opinion, the ARO thickness should be increased to provide added protection for the product pipe during pullback where the product pipe passes through the rock formations expected along the HDD profile.

5.1.12 Installation Load Considerations

For the proposed HDD crossing, we analyzed the anticipated pull loads based upon different drilling fluid weights in the drilled hole and the proposed pipe specifications. We also evaluated the anticipated pull loads based on using or not using buoyancy control. We recommend that the contractor utilize a drill rig that provides a factor of safety between the drill rig capacity and the anticipated pull loads. In addition, the contractor should install a deadman anchor of sufficient capacity to withstand the anticipated pull loads; these aspects are generally left to the contractor's discretion as approved by the owner. Based on our analysis of the installation stresses (see Table 5, in Section 4.2), the pullback force may be as high as 551,000 pounds, without the use of some form of buoyancy control. The calculations suggest that the pullback force required to install the product pipe may be reduced to approximately 265,000 pounds, if buoyancy control is used.

5.1.13 Site Access

Access to the entry, exit and pipe stringing workspaces can be obtained from existing gravel roads that meet with Lone Pine Road approximately 1 mile north of the site. We anticipate that improvement of the gravel roads may be necessary to provide a stable access route for heavy construction equipment entering the workspaces.

5.1.14 Water Sources

A reliable source of water for drilling operations is required during the HDD installation process. In addition, water is also required for the hydrostatic testing of the product pipe. There are no natural water sources at the site and as such, water for drilling operations will have to be obtained from an approved off-site source and transported to the site.

5.1.15 Noise Mitigation Techniques

The proposed workspaces are located several miles from the nearest residences. We do not anticipate that noise mitigation will be required. If noise suppression is required for permitting, diesel power units associated with heavy equipment may be outfitted with noise reducing mufflers. In addition, the workspace can be muffled by strategically placed baffles to further reduce noise emissions. The actual placement of the noise reduction measures should be implemented by the selected HDD contractor, when necessary.

5.2 Geotechnical Engineering Considerations

5.2.1 Temporary Site Access

If ground disturbance must be reduced to the extent possible, we recommend the construction of temporary access roads to the HDD work areas. The temporary access roads should consist of either board roads or a minimum 12-inch-thick layer of 4-inch-diameter quarry spalls. If soft or wet near surface soils are encountered, these measures may need to be augmented. If board roads are used, several layers of mats may be necessary to provide adequate support for the heavy equipment entering the site. If quarry spalls are used, the quarry spall thickness may need to be increased or a layer of woven geotextile fabric (TC Mirafi 600X or equivalent) or biaxial geogrid (Tensar BX 1200 or equivalent) may be placed below the quarry spalls. The temporary roads should be constructed with culverts and other improvements necessary to allow surface water runoff to drain without ponding or changing off-site drainage patterns.

5.2.2 Temporary Workspace Areas

Temporary work pad areas for staging drilling equipment, pipeline materials and excavation equipment may be necessary at the entry and exit points depending on the conditions at the time of construction. The size and location of workspace areas to accommodate the HDD and pipeline tie-in activities depend on the available space and right-of-way constraints. The proposed temporary entry, exit and product pipe stringing workspaces for the project are shown in Figures 2A and 2B.

If necessary, we recommend that the workspace areas be protected with either board mats or a minimum 12-inch-thick layer of 4-inch-diameter quarry spalls. If soft or wet near-surface soils are encountered, these measures may need to be augmented. If board mats are used, several layers of mats may be necessary to provide adequate support for the heavy equipment entering the site. If quarry spalls are used, quarry spall thickness may need to be increased or a layer of woven geotextile fabric (TC Mirafi 600X or equivalent) or biaxial geogrid (Tensar BX 1200 or equivalent) may be placed below the quarry spalls. We also recommend placing an additional 2-inch-thick layer of ¾-inch crushed rock on top of the quarry spalls, which should improve the overall site safety and provide a level surface for light-duty vehicles and foot traffic. The temporary work pads should be removed upon completion of the product pipe installation, and the areas should be restored in accordance with the project site restoration plan.

5.2.3 HDD Installation

Drilling fluid containment pits will be required at the drill entry and exit work areas. Depending on the practices of the HDD contractor, drilling fluid containment pit excavations are typically constructed adjacent to the centerline near the entry and exit point locations and are approximately 20 feet long by

10 feet wide by 6 feet deep. However, because of the elevated risk of hole flushing occurring during HDD operations, the contractor may choose to excavate a larger than typical entry pit.

Based on the completed explorations, soil within the planned excavation depths is anticipated to consist of elastic silt. Conventional equipment, such as backhoes or excavators, should be suitable for excavation of these soils.

5.2.4 Temporary Excavations

Maintenance of safe working conditions, including temporary excavation stability, is the responsibility of the contractor. All temporary cuts in excess of 4 feet in height should be shored or sloped in accordance with OSHA regulation 1926 Subpart P, Appendix B – Sloping and Benching. For planning purposes, soils encountered within the exploratory borings in the vicinity of the excavation areas should be classified as Type C Soil. Temporary excavations in Type C soil should be inclined no steeper than 1.5H:1V (horizontal to vertical). However, if caving occurs in excavation sidewalls, temporary excavations may need to be laid back to a shallower inclination. These cut slope inclinations are applicable to excavations above the groundwater table only. Dewatering may be required to lower the groundwater table below the base of the excavations. Steeper temporary slope inclinations may be allowed if soil conditions are determined to be suitable by the field geotechnical engineer. For open cuts, we recommend that:

1. No traffic, construction equipment, stockpiles or supplies should be allowed within a distance of at least 5 feet from the top of the cut;
2. Construction activities should be scheduled to reduce the length of time the cuts are left open;
3. Erosion control measures should be implemented as appropriate to limit runoff from the site; and
4. Surface water should be diverted away from the excavations.

5.2.5 Construction Dewatering

The contractor should have the responsibility of determining whether dewatering measures are needed at the time of work. Based on the explorations completed to date, we anticipate that elastic silt will be encountered in shallow excavations at entry and exit. However, if low plasticity silt or granular materials are encountered, groundwater seepage through the low plasticity or granular soils may cause caving, making it difficult to keep the excavations open to the required depths. If granular soils and high groundwater conditions are encountered, the contractor may need to implement a well point or pumping well dewatering system. The construction of low berms around excavations should help reduce the volume of surface water runoff entering the excavations.

The contractor should be prepared to handle the effluent that will be generated during any dewatering operations. The effluent may need to be treated in a settlement tank, sediment trap or basin in order to meet discharge permit requirements for sediment content. Additionally, filter bags or filter socks might be necessary at the end of the outfall pipe or hose to reduce sediment discharge.

5.2.6 Erosion Control

To reduce the potential for migration of sediment off site and into adjacent receiving waters during HDD operations, we recommend that state and local regulations be followed during and after construction operations. Proper BMPs should be implemented in accordance with the PCGP Project's Erosion Control and Revegetation Plan (ECRP).

Potential sources or causes of erosion and sedimentation depend upon construction methods, slope length and gradient, amount of soil exposed and/or disturbed, soil type, construction sequencing and weather. We recommend that the following erosion control measures be included in construction planning:

- Scheduling excavation and construction to minimize soil exposure;
- Retaining existing vegetation whenever feasible;
- Revegetating or mulching denuded areas;
- Directing runoff away from denuded areas;
- Preparing drainage ways and outlets to handle concentrated or increased runoff;
- Using sediment traps/stilling basins/filter socks to collect, detain, and settle sediment from surface water runoff or water pumped from the exit and entry pit excavations;
- Confining sediment to the project site with silt fences and straw bales;
- Inspecting and maintaining control measures frequently;
- Temporarily covering soil stockpiles during construction when necessary;
- Conducting routine inspections of the construction site to ensure effectiveness of the measures and to determine the need for maintenance or additional measures;
- Collecting, containing, and disposing of drilling spoil at a predetermined approved site; and
- Re-vegetating all disturbed surfaces to provide erosion protection after construction is complete.

Construction procedures should be designed to minimize the opportunity for erosion to occur. Clearing, excavation and grading should be limited to those areas necessary for construction of temporary improvements. The construction limits should be clearly marked in the field and equipment should not be allowed outside the work area. Prompt grading, mulching and revegetation will help to limit erosion.

Silt fences should be constructed around the perimeter of the work areas to reduce the possibility of transport of sediment off site. Straw bales should also be incorporated as necessary to augment the silt fences.

Stockpiles of excavated materials or erodible raw material such as soil, sand, backfill and drill cutting materials should be covered during wet weather and small diversion berms used to prevent stormwater runoff from entering or eroding stockpiles. Excavated soil should be reused as much as possible. After final grading is complete, soil in graded or disturbed areas should be tracked in place with the equipment running perpendicular to slope contours so that the track grouser marks provide a texture to help resist erosion. Any excess material disposed of offsite should be handled in accordance with applicable regulations at authorized disposal facilities.

The drilling fluid containment pits should be configured to reduce the potential of transport of sediment off site. Any excess excavated or drilling materials to be disposed of offsite should be handled in accordance with applicable regulations.

Until permanent erosion protection is established and stabilized, periodic monitoring should be performed to evaluate the effectiveness of post-construction erosion control measures and repair and/or modify them as appropriate. Areas of observed significant erosion should be repaired using an appropriate combination of the methods discussed above.

6.0 LIMITATIONS

We have prepared this report for use by Willbros Professional Services - West (Willbros) and Williams. GeoEngineers' report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. The conclusions and recommendations in this report should be applied in their entirety.

Variations in subsurface conditions are possible between the explorations. Subsurface conditions may also vary with time. A contingency for unanticipated conditions should be included in the project budget and schedule for such an occurrence. We recommend that sufficient monitoring, testing and consultation be provided by GeoEngineers during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether earthwork and pipeline installation activities comply with contract plans and specifications.

The scope of our services does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractor's methods, techniques, sequences or procedures, except as specifically described in our report for consideration in developing a drill plan.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. No warranty or other conditions, express, written or implied, should be understood.

Please refer to Appendix C, titled "Report Limitations and Guidelines for Use," for additional information pertaining to use of this report.

7.0 REFERENCES

American Petroleum Institute, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design, API Recommended Practice 2A-WSD, July 1, 1993.

Beaulieu, J.D. and Baldwin, E.M. Geologic Map of the Coquille Quadrangle, Oregon. Included in Bulletin 87, Environmental Geology of Western Coos and Douglas Counties, Oregon. Published by the State of Oregon Department of Geology and Mineral Industries Scale 1:62,500, 1973.

Installation of Pipelines by Horizontal Directional Drilling, an Engineering Design Guide, and Contract No. PR-227-9424, May 3, 1995.

Oregon Department of Transportation Highway Division, Oregon Department of Transportation Soil and Rock Classification Manual, 1987.

Staheli, K., Bennett, D., O'Donnell, H.W., and Hurley, T.J., Installation of Pipelines beneath levees using horizontal directional drilling, Technical Report CPAR-GL-98-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 1998.

Walker, G. and N. MacLeod, Spatial Digital Database for the Geologic Map of Oregon. Geology compiled by George W. Walker and Norman S. MacLeod. Spatial database by Robert J. Miller, Gary L. Raines and Katherine A. Connors. United States Geological Survey Open File Report 03-67, 2002, 1991.

FIGURES

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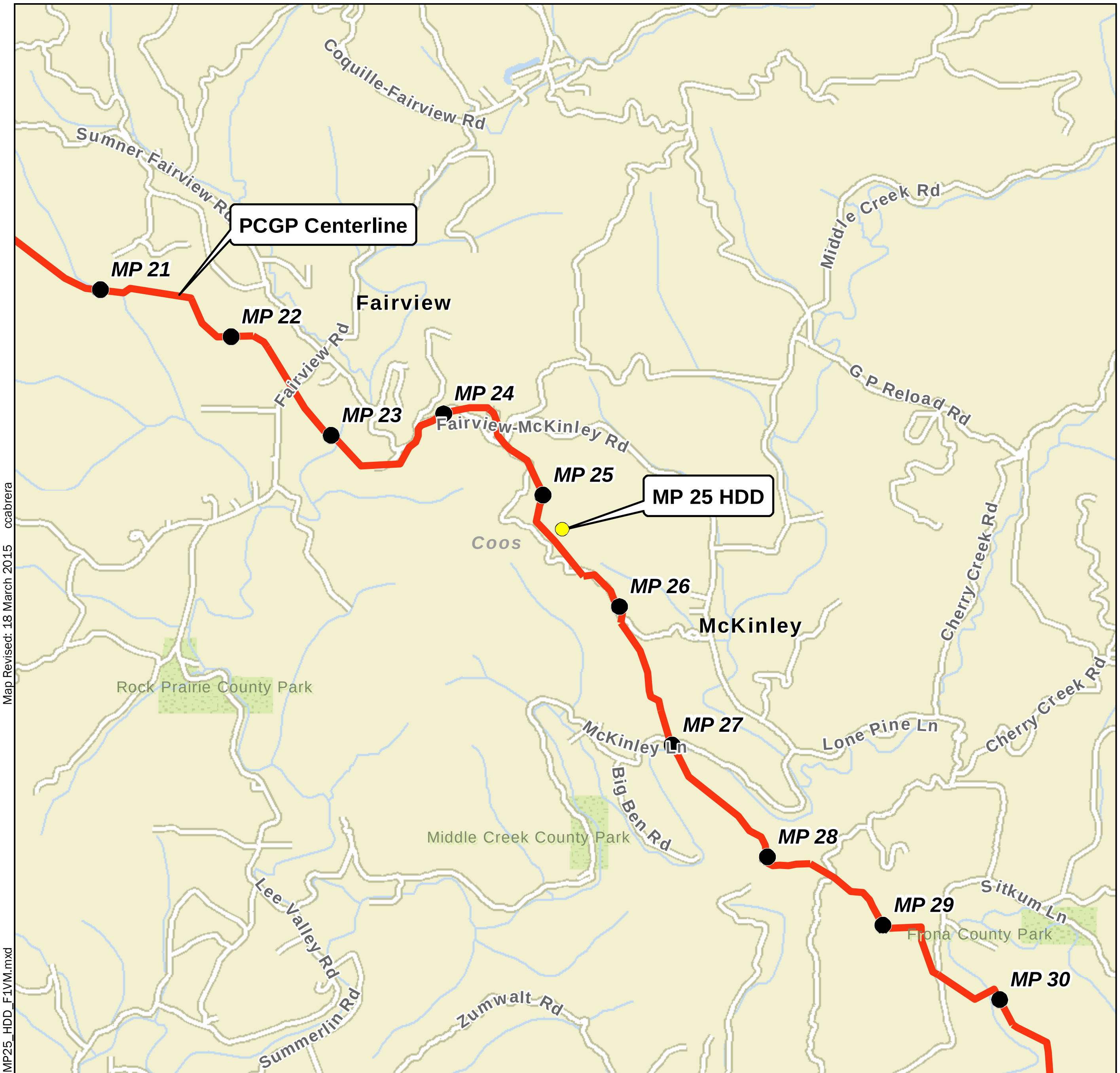

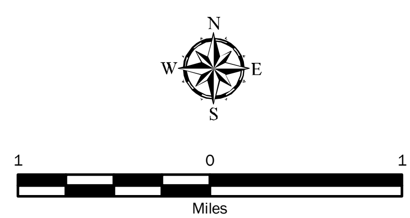

Data Sources: ESRI Data & Maps
PCGP centerline dated September, 2014.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Projection: NAD 1983 UTM Zone 10N

Vicinity Map

MP 25 HDD
Pacific Connector Gas Pipeline Project
Coos County, Oregon

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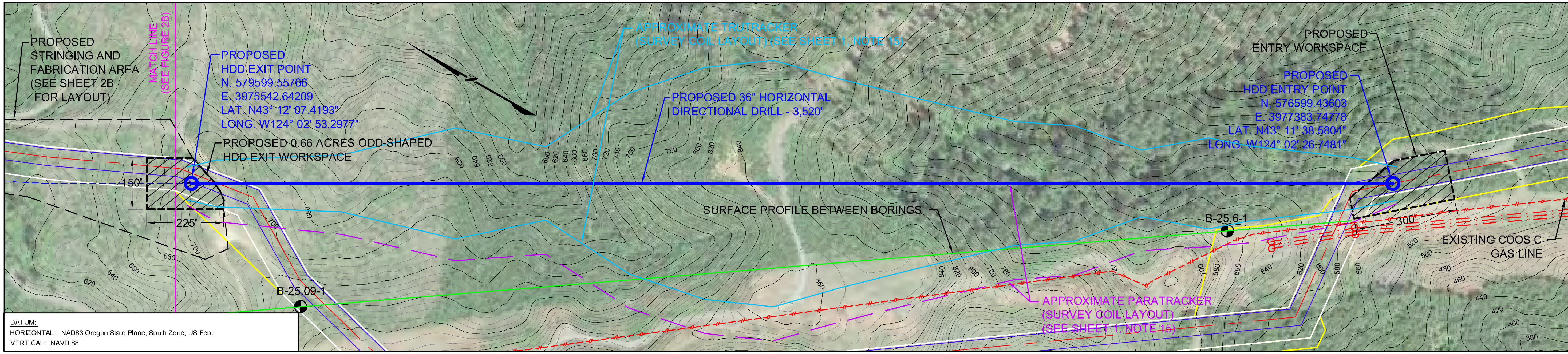
Figure 1

Office: PORT Path: P:\16\16724002\GIS\MXD\Task1700\1672400200_MP25_HDD_F1VM.mxd Map Revised: 18 March 2015 ccabrera

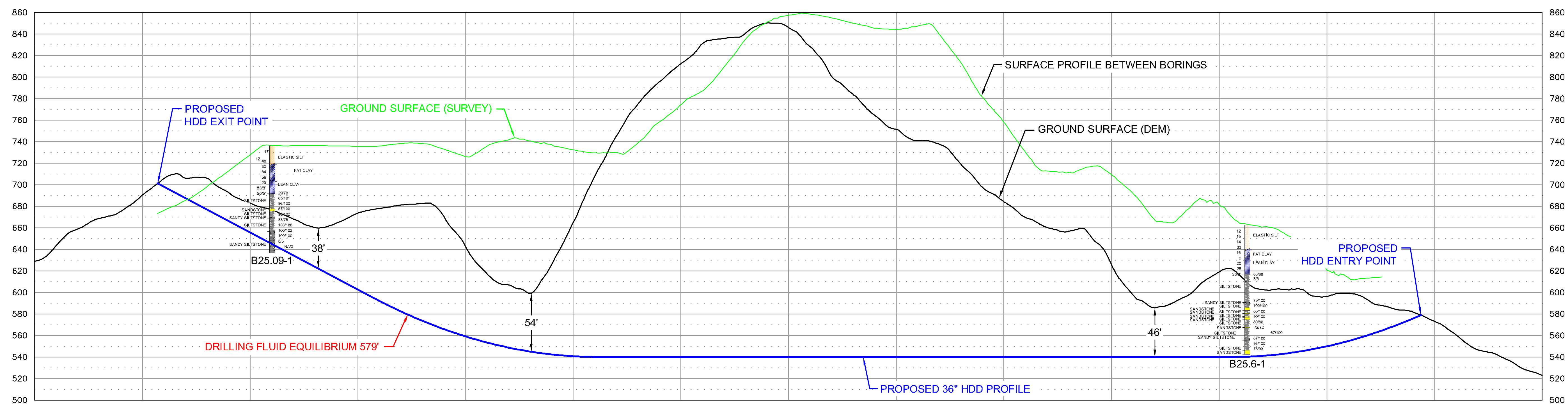


NOT FOR CONSTRUCTION

PLAN

300' 0 300'

SCALE IN FEET



Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication. .
3. GeoEngineers, Inc. has not verified the field location of the existing utilities.
4. Boring offset based along ridgeline rather than perpidicular to the HDD alignment in order to infer subsurface conditions more accurately. However, it should be noted that offsetting by this method requires that the boring be shown at a different elevation (lower) than which it was completed.

Reference: Aerial photo taken from Google Earth Pro © 2015, licensed to GeoEngineers, Inc., dated 05-03-13. Ground surface DEM (1/ 9 arc second) downloaded from http:/NationalMap.Gov/Viewer.

PROFILE

300' 0 300'

HORIZONTAL SCALE IN FEET

100' 0 100'

VERTICAL SCALE IN FEET

LEGEND:

SPT (N) — TYPE OF SOIL

TYPE OF ROCK — RQD/%REC

Boring Location

Major contours= 20'

Minor contours= 5'

SITE PLAN AND PROFILE

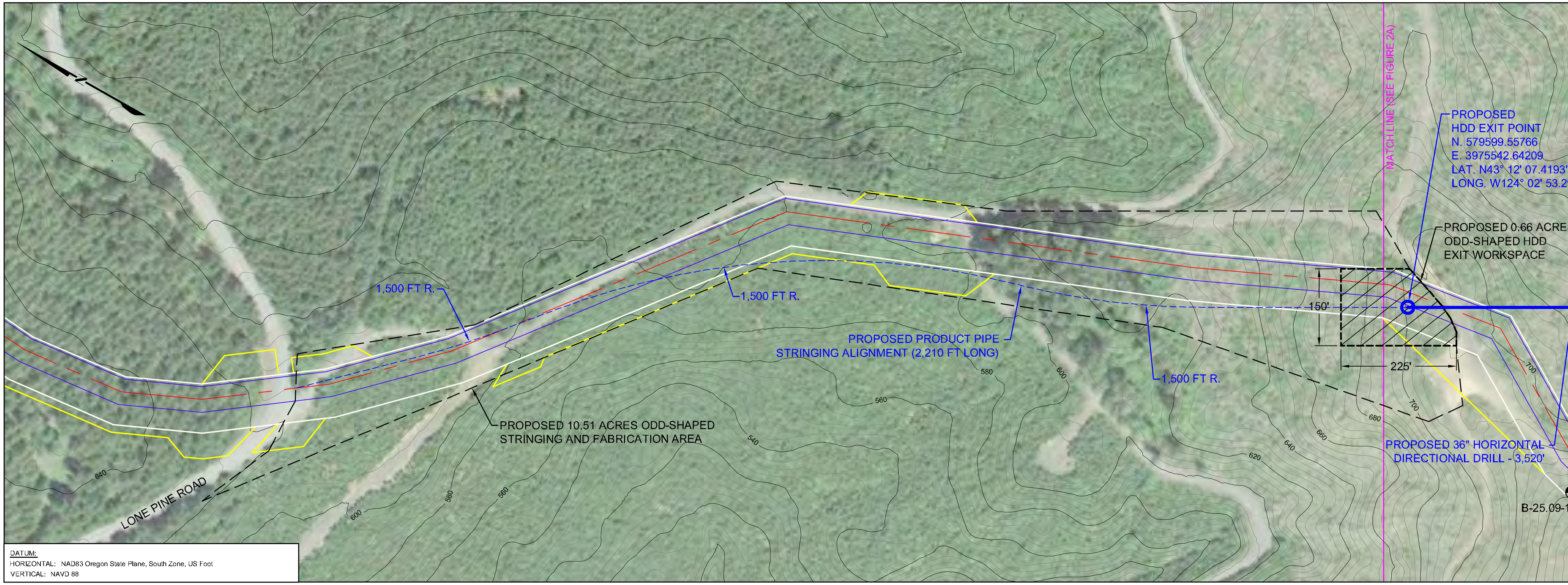
ALTERNATE MP 25 HDD
COOS COUNTY, OREGON

GEOENGINEERS

FIGURE 2A

TNH : RBM

P:\16\1672400\100\CAD\MP 25 HDD\CAD\Sheet Files\Alt MP 25 HDD_Figure 2A.dwg\TAB:Figure 2A modified on May 04, 2015 - 7:56am

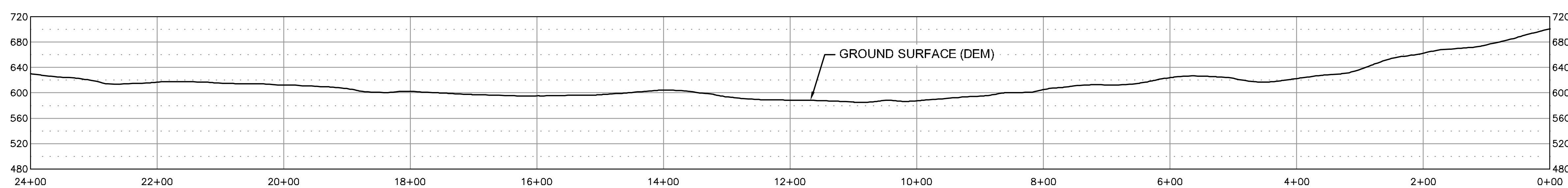


NOT FOR CONSTRUCTION

PLAN

200' 0 200'

SCALE IN FEET



PROFILE

200' 0 200'

HORIZONTAL SCALE IN FEET

200' 0 200'

VERTICAL SCALE IN FEET

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication. .
3. GeoEngineers, Inc. has not verified the field location of the existing utilities.

Reference: Aerial photo taken from Google earth pro, licensed to GeoEngineers, Inc., dated 05-03-13.Ground surface DEM (1/ 9 arc second) downloaded from http:/NationalMap.Gov/Viewer.

LEGEND:

- Boring Location
- Major contours= 20'
- Minor contours= 5'

STRINGING WORKSPACE

ALTERNATE MP 25 HDD
COOS COUNTY, OREGON

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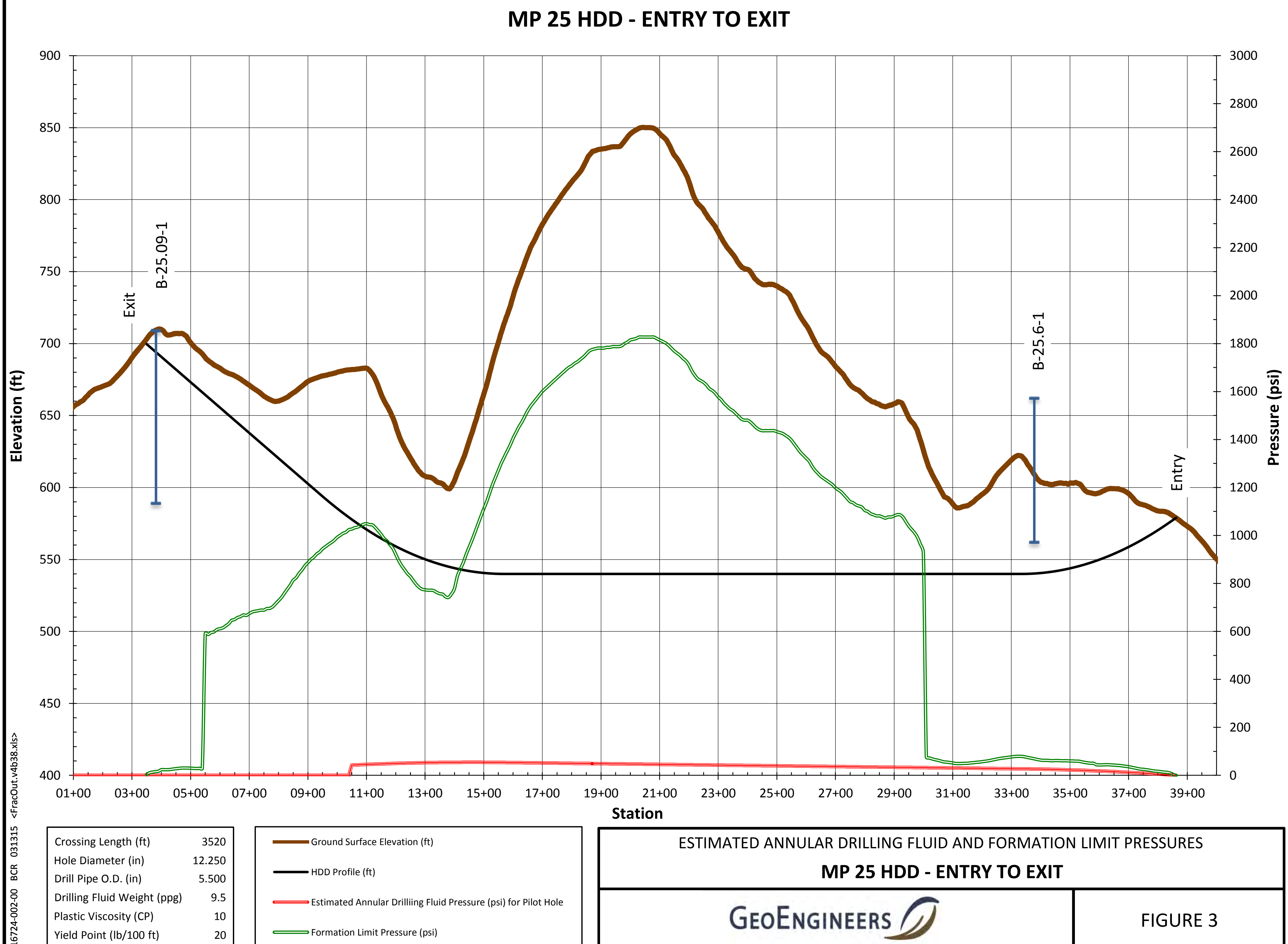
FIGURE 2B

TNH : RBM

E:\Blakes\16\16724002\MP 25 HDD\CAD\Sheet Files\Alt MP 25 HDD_Figure 2B.dwg\TAB:Figure 2B modified on May 01, 2015 - 11:49am



Crossing Length (ft)	3520
Hole Diameter (in)	12.250
Drill Pipe O.D. (in)	5.500
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	10
Yield Point (lb/100 ft)	20

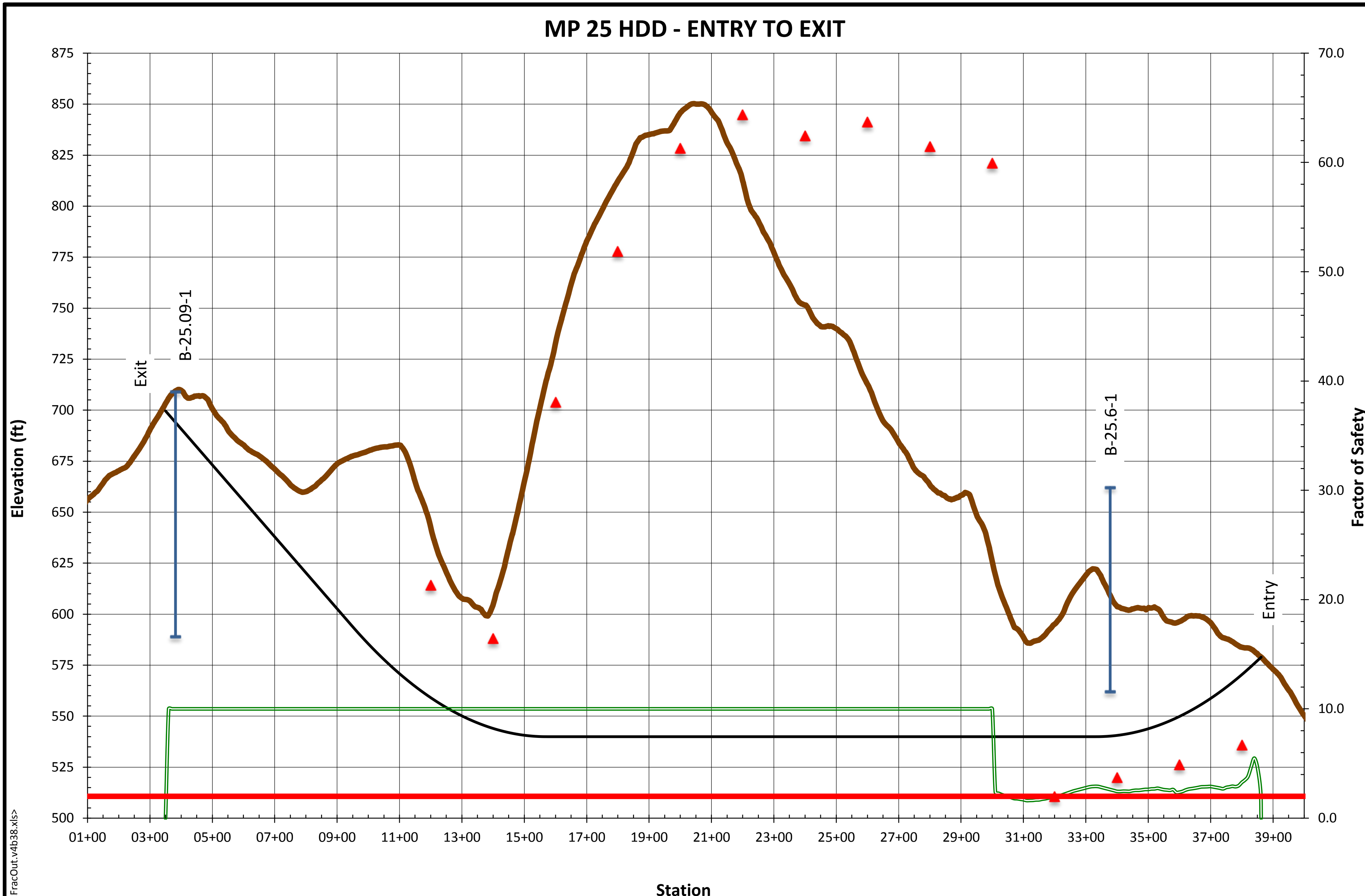
ESTIMATED ANNULAR DRILLING FLUID AND FORMATION LIMIT PRESSURES

MP 25 HDD - ENTRY TO EXIT

GEOENGINEERS

FIGURE 3

16724-002-00 BCR 031315 <FracOut.v4b38.xls>



16724-002-00 BCR 031315 <FracOut.v4b38.xls>

Crossing Length (ft)	3520
Hole Diameter (in)	12.250
Drill Pipe O.D. (in)	5.500
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	10
Yield Point (lb/100 ft)	20

Ground Surface Elevation (ft)
HDD Profile (ft)
Drilling Fluid Surface Release Factor of Safety for Pilot Hole
Hydraulic Fracture Factor of Safety for Pilot Hole
Factor of Safety = 2

HYDRAULIC FRACTURE AND DRILLING FLUID SURFACE RELEASE FACTORS OF SAFETY

MP 25 HDD - ENTRY TO EXIT

GEOENGINEERS

FIGURE 4

APPENDICES

GeoEngineers

APPENDIX A
Field Explorations and Laboratory-Testing Program

APPENDIX A
FIELD EXPLORATION AND LABORATORY-TESTING PROGRAM

We explored subsurface conditions at the site by drilling two borings to depths of up to 120 feet bgs using mud rotary and HQ rock coring drilling techniques, as appropriate. Subsurface Technologies of North Plains, Oregon drilled the borings. Figure 2A shows the approximate boring locations. A representative from our office observed field activities, classified the soil and rock encountered, obtained representative samples, observed groundwater conditions where possible and prepared a log of each exploration. The borings were backfilled with a bentonite and cement grout mixture at the conclusion of each exploration.

Soil samples were obtained by performing SPTs in general accordance with ASTM Test Method D 1586. The sampler was driven with a 140-pound hammer falling 30 inches. The number of blows required to drive the sampler 1 foot, or as otherwise indicated, into the soils is shown adjacent to the sample symbols on the boring logs. Disturbed samples were obtained from the split barrel sampler for subsequent classification and index testing.

When bedrock was encountered in the borings, rock core samples were taken using a HQ rock core barrel. The rock core samples were examined and classified in the field before being transported to our laboratory facilities for testing. RQD values also were measured in the field prior to transport.

Soils encountered in the borings were classified in the field by a GeoEngineers representative in general accordance with ASTM D 2488, the Standard Practice for the Classification of Soils (Visual-Manual Procedure) which is described in Figure A-1. Rock encountered in the borings was classified in general accordance with the ODOT rock classification system (ODOT, 1987), which is described in Figure A-2. The boring logs are presented in Figures A-3 and A-4. Soil classifications and sampling intervals are shown in the boring logs. Inclined lines at the material contacts shown on the log indicate uncertainty as to the exact contact elevation, rather than the inclination of the contact itself.

The relative density of the SPT samples recovered at each interval was evaluated based on correlations with lab and field observations in general accordance with the values outlined in Table A-1 below.

TABLE A-1. CORRELATION BETWEEN BLOW COUNTS AND RELATIVE DENSITY *

Cohesive Soils (Clay/Silt)						
Parameter	Very Soft	Soft	Medium Stiff	Stiff	Very Stiff	Hard
Blows, N	< 2	2 – 4	4 - 8	8 – 16	16 - 32	>32

Cohesionless Soils (Gravel/Sand/Silty Sand) **					
Parameter	Very Loose	Loose	Medium Dense	Dense	Very Dense
Blows, N	0 – 4	4 – 10	10 – 30	30 - 50	> 50

Notes:

*After Terzaghi, K and Peck, R.B., "Soil Mechanics in Engineering Practice," John Wiley & Sons, Inc., 1962.

**Classification applies to soils containing additional constituents; that is, organic clay, silty or clayey sand, etc.

Laboratory Testing

General

Samples obtained from the explorations were transported to our Portland, Oregon laboratory and examined to confirm or modify field classifications, as well as to evaluate engineering properties of the samples. Representative samples were selected for laboratory testing consisting of sieve analysis, Atterberg limits tests, and unconfined compression test. The laboratory-testing procedures are discussed in more detail below.

Atterberg Limits Testing

Atterberg Limits tests were performed on selected fine-grained soil samples in general accordance with ASTM D 4318. The tests were used to classify the soil as well as to evaluate its index properties. The results of the Atterberg Limits testing are shown in Figures A-5 and A-6.

Sieve Analyses

Sieve analyses were performed on selected coarse-grained samples in general accordance with ASTM D 422. The results of the sieve analyses were plotted and classified in general accordance with the Unified Soil Classification System (USCS) and are presented in Figure A-7. The percentage passing the U.S. No. 200 sieve is shown on the boring logs at the respective sample depths.

Unconfined Compression Test

Unconfined compression (UC) tests were completed on six rock core samples obtained from borings in general accordance with ASTM D 7012-04. The results of these tests are presented on the exploration logs in Figures A-3 and A-4 at the depths at which the samples were obtained.

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% RETAINED ON NO. 200 SIEVE	SAND AND SANDY SOILS	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	AC	Asphalt Concrete
	CC	Cement Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Groundwater Contact

Measured groundwater level in exploration, well, or piezometer

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

Laboratory / Field Tests

%F	Percent fines
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
OC	Organic content
PM	Permeability or hydraulic conductivity
PI	Plasticity index
PP	Pocket penetrometer
PPM	Parts per million
SA	Sieve analysis
TX	Triaxial compression
UC	Unconfined compression
VS	Vane shear

Sheen Classification

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
NT	Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

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FIGURE A-1

Scale of Relative Rock Weathering (ODOT, 1987)

Designation	Field Identification
Fresh	Crystals are bright. Discontinuities may show some minor surface staining. No discoloration in rock fabric.
Slightly Weathered	Rock mass is generally fresh. Discontinuities are stained and may contain clay. Some discoloration in rock fabric. Decomposition extends up to 1 inch into rock.
Moderately Weathered	Rock mass is decomposed 50% or less. Significant portions of rock show discoloration and weathering effects. Crystals are dull and show visible chemical alteration. Discontinuities are stained and may contain secondary mineral deposits.
Predominantly Decomposed	Rock mass is more than 50% decomposed. Rock can be excavated with geologist's pick. All discontinuities exhibit secondary mineralization. Complete discoloration of rock fabric. Surface of core is friable and usually pitted due to washing out of highly altered minerals by drilling water.
Decomposed	Rock mass is completely decomposed. Original rock "fabric" may be evident. May be reduced to soil with hand pressure.

Scale of Relative Rock Hardness (ODOT, 1987)

Term	Hardness Designation	Field Identification	Approximate Unconfined Compressive Strength
Extremely Soft	R0	Can be indented with difficulty by thumbnail. May be moldable or friable with finger pressure.	< 100 psi
Very Soft	R1	Crumbles under firm blows with point of a geology pick. Can be peeled by a pocket knife. Scratched with fingernail.	100-1000 psi
Soft	R2	Can be peeled by a pocket knife with difficulty. Cannot be scratched with fingernail. Shallow indentation made by firm blow of geology pick.	1000-4000 psi
Medium Hard	R3	Can be scratched by knife or pick. Specimen can be fractured with a single firm blow of hammer/geology pick.	4000-8000 psi
Hard	R4	Can be scratched with knife or pick only with difficulty. Several hard hammer blows required to fracture specimen.	8000-16000 psi
Very Hard	R5	Cannot be scratched by knife or sharp pick. Specimen requires many blows of hammer to fracture or chip. Hammer rebounds after impact.	> 16000 psi

Rock Quality Designation (RQD)

RQD (Percent)	Description of Rock Quality
0 to 25	Very Poor
25 to 50	Poor
50 to 75	Fair
75 to 90	Good
90 to 100	Excellent

RQD is a modified core recovery measurement which expresses the number of hard and sound rock pieces of 4" or more in size as a percentage of the total length of core run.

Discontinuity Spacing (ODOT, 1987)

Description for Bedding, Foliation, or Flow Banding	Spacing	Description of Joints, Faults, or Other Fractures
Very Thickly	>10 feet	Very Widely
Thickly	3-10 feet	Widely
Medium	1-3 feet	Moderately Close
Thinly	2-12 inches	Closely
Very Thinly	< 2 inches	Very Closely

EXPLANATION OF BEDROCK TERMS

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FIGURE A-2

Drilled	Start 12/9/2014	End 12/10/2014	Total Depth (ft)	100	Logged By MK / Checked By BCR	Driller	Subsurface Technologies, Inc.	Drilling Method	Mud Rotary/Rock Core

Surface Elevation (ft) / Vertical Datum	740	Hammer Data	140 (lbs) / 30 (in) Drop	Drilling Equipment	Track Mounted Drill Rig
Latitude / Longitude	43.20078 / -124.04859	System / Datum	Geographic / WGS84	Groundwater	
Notes:				Date Measured / Depth to Water (ft) / Elevation (ft)	Not Measured

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0								MH	Light brown and red elastic silt (very stiff, moist) (Residual Soil)			
735	5		18	1	17						39		Visible layering PI = 25
730	10		13	2	12					Becomes stiff			
725	15		18	3	48					Becomes very stiff			
									CH	Tan and orange fat clay (very stiff, moist) (Residual Soil)			
720	20		14	4	30					Becomes sandy	36	70	PI = 41 SA; %Gravel = 0
715	25		18	6	34					Becomes hard			
710	30												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B25.09-1

GeoEngineers

Project: PCGP - MP 25
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Figure A-3
Sheet 1 of 3

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	30		18	5	56				CH	Tan and orange sandy fat clay (hard, moist) (Residual Soil)			Moved boring 5 feet North, conditions appear similar based on cuttings
									CL	Dark gray lean clay (very stiff, moist) (residual soil)			
705	35		18	7	23						21		PI = 24
700	40		17	8	50/5"					Becomes gravelly and hard (weathered bedrock)			
695	45		5	9	50/5"				Siltstone	Siltstone; dark gray, moderately weathered, closely fractured, soft			Breaks along preferential weakness planes
			70	R1		29							
690	50		101	R2		65							
685	55		100	R3		96							
													UC = 1,178 psi
									Sandstone	Sandstone; dark gray, slightly weathered, moderately close fractured, soft			
680	60		100	R4		67							
									Siltstone	Siltstone; dark gray, moderately weathered, very widely fractured, very soft			
675	65		102	R5		90							

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B25.09-1 (continued)

GeoEngineers

Project: PCGP - MP 25
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
									Sandy Siltstone	Sandy Siltstone; slightly weathered, moderately close fractured, soft			
									Siltstone	Siltstone; dark gray, moderately weathered, closely fractured, soft			
670	70		75	R6		83							
665	75		100	R7		100				Becomes predominantly decomposed and extremely soft			
660	80		102	R8		100			Sandy Siltstone	Sandy Siltstone; dark gray, moderately weathered, moderately close fractured, soft			
										Becomes predominantly decomposed, massive and extremely soft			
655	85		100	R9		100							
													UC = 22 psi
650	90		5	R10		0							
645	95		0	R11		NA							No recovery
640	100												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B25.09-1 (continued)

GeoEngineers

Project: PCGP - MP 25
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	2/10/2015	2/12/2015	120	MK	BCR	Subsurface Technologies, Inc.	Mud Rotary/Rock Core

Surface Elevation (ft) Vertical Datum	662	Hammer Data	140 (lbs) / 30 (in) Drop	Drilling Equipment	Track Mounted Drill Rig
Latitude Longitude	43.19504 -124.04224	System Datum	Geographic WGS84	Groundwater	
Notes:				Date Measured / Depth to Water (ft) / Elevation (ft)	Not Measured

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0								MH	Red elastic silt (stiff, moist) (Residual soil)			
660													
	5		18	1	12								Slow drilling
655													
	10		18	2	15					Becomes red and light brown mottled	46		PI = 32
650													
	15		18	3	14								Visible layering
645													
	20		18	4	33					Becomes light brown and red and very stiff			
640													
										Becomes orange and tan, stiff			
	25		18	5	16						34		PI = 20 Fast drilling
635													
	30												

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B25.6-1

GEOENGINEERS

Project: PCGP - MP 25
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	30	18	6	9			MH	Orange and tan elastic silt (medium stiff, moist) (Residual soil)			
							CL	Dark gray lean clay (very stiff, moist) (residual soil)			
630											
	35	18	7	20					24		PI = 24
625											
	40	18	8	25							
620											
	45	9	9	50/3"				Becomes hard			
		88	R1		88		Siltstone	Siltstone; gray, moderately weathered, moderately close fractured, very soft			
615											Very weak rock
	50	5	R2		5						Inner core barrel unlatched while drilling. Core recovery was from outer barrel.
610											
	55	10	R3		10			Becomes soft			
605											
	60	93	R4		93			Becomes extremely soft			UC = 62 psi
600											
	65	92	R5		43						

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B25.6-1 (continued)

GEOENGINEERS

Project: PCGP - MP 25

Project Location: Coos County, Oregon

Project Number: 16724-002-00

Figure A-4
Sheet 2 of 4

Elevation (feet)	Depth (feet)	Interval / Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
595								Siltstone	Siltstone; gray, moderately weathered, closely fractured, very soft			Breaks along preferential weakness planes
									Becomes soft at 69 feet			
	70	100	R6		70				Becomes very soft			Fast drilling
590								Sandy Siltstone	Sandy Siltstone; gray, slightly weathered, moderately close fractured, soft			
	75	100	R7		100			Siltstone	Siltstone; gray, moderately weathered, closely fractured, soft			
585								Sandstone	Sandstone; gray, slightly weathered, clay filled fractures, moderately close fractured, very soft			UC = 618 psi
	80	100	R8		86			Siltstone	Siltstone; gray, slightly weathered, closely fractured, moderately hard			
580								Sandstone	Sandstone; gray, slightly weathered, moderately close fractured, medium hard			
								Siltstone	Siltstone; gray, slightly weathered, moderately close fractured, soft			
	85	100	R9		90			Sandstone	Sandstone; gray, slightly weathered, moderately close fractured, medium hard			
								Siltstone	Siltstone; gray, predominantly decomposed, moderately close fractured, very soft			
575								Sandstone	Sandstone; gray, slightly weathered, moderately close fractured, soft			
								Siltstone	Siltstone; gray, slightly weathered, moderately close fractured, soft			
	90	80	R10		80							
570												
	95	72	R11		72			Sandstone	Sandstone; gray, slightly weathered, moderately close fractured, soft			
565								Siltstone	Siltstone; gray, moderately weathered, closely fractured, very soft			
	100	100	R12		67				Becomes moderately close fractured and extremely soft			

Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B25.6-1 (continued)

GeoEngineers

Project: PCGP - MP 25
Project Location: Coos County, Oregon
Project Number: 16724-002-00

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Sample/Run	Blows/foot	RQD %	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
560									Siltstone	Siltstone; gray, moderately weathered, moderately close fractured, extremely soft			UC = 70 psi
	105		100	R13		87			Sandy Siltstone	Sandy Siltstone: gray, slightly weathered, moderately close fractured, medium hard			
555									Siltstone	Siltstone; gray, moderately weathered, medium close fractured, soft			
	110		100	R14		86							
550										Becomes predominantly decomposed and very soft at 112.5 feet			
	115		93	R15		75							
545									Sandstone	Sandstone; gray, slightly weathered, moderately close fractured, extremely soft			UC = 27 psi
	120												

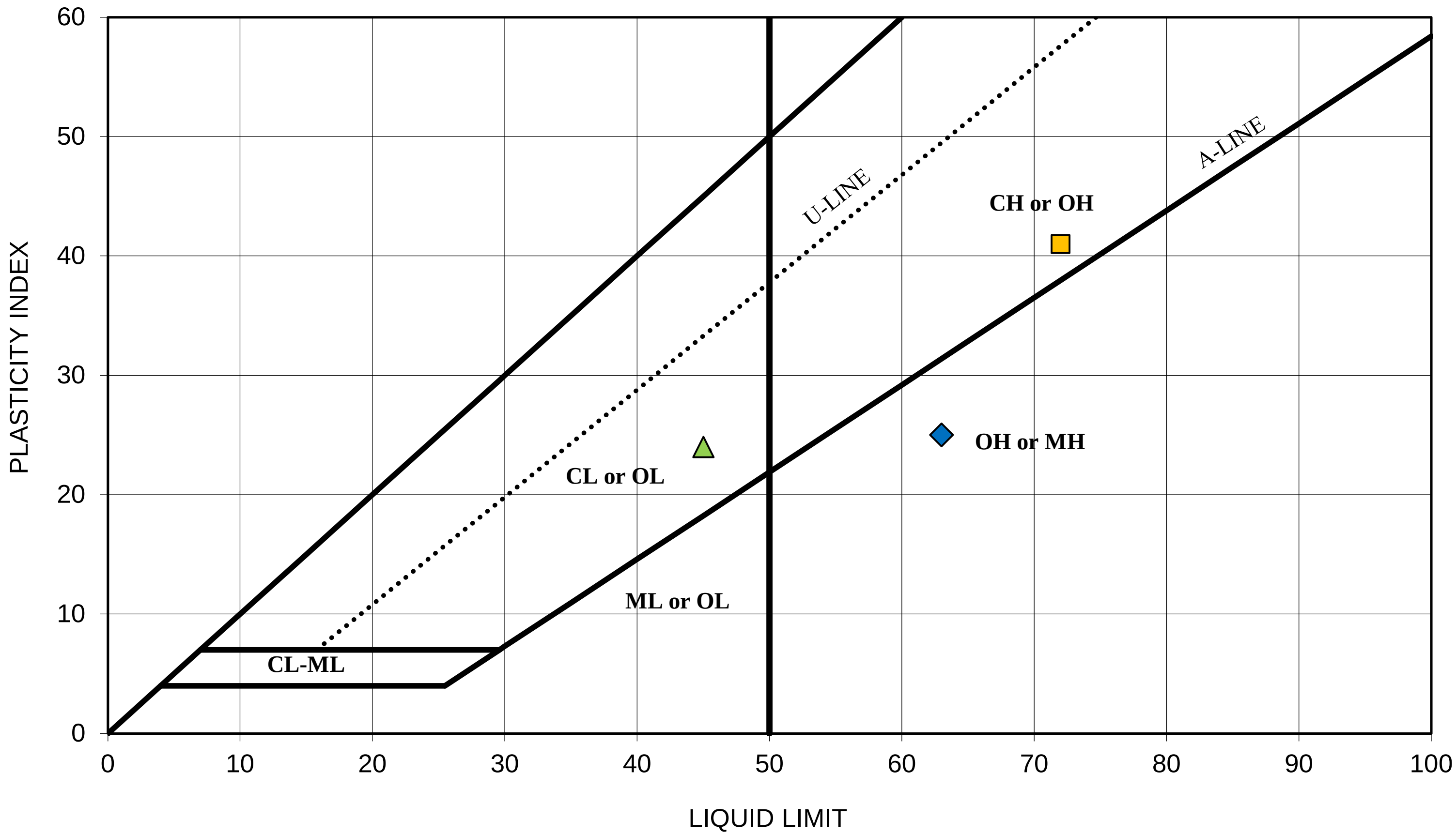
Note: See Figure A-1 for explanation of symbols and Figure A-2 for explanation of rock terms.

Log of Boring B25.6-1 (continued)

GeoEngineers

Project: PCGP - MP 25
Project Location: Coos County, Oregon
Project Number: 16724-002-00

PLASTICITY CHART



Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	USCS	Soil Description
◆	B-25.09-1 S-1	5	39	63	25	MH	Elastic silt with trace fine sand
■	B-25.09-1 S-4	20	36	72	41	CH	Fat clay
▲	B-25.09-1 S-7	35	21	45	24	CL	Lean clay

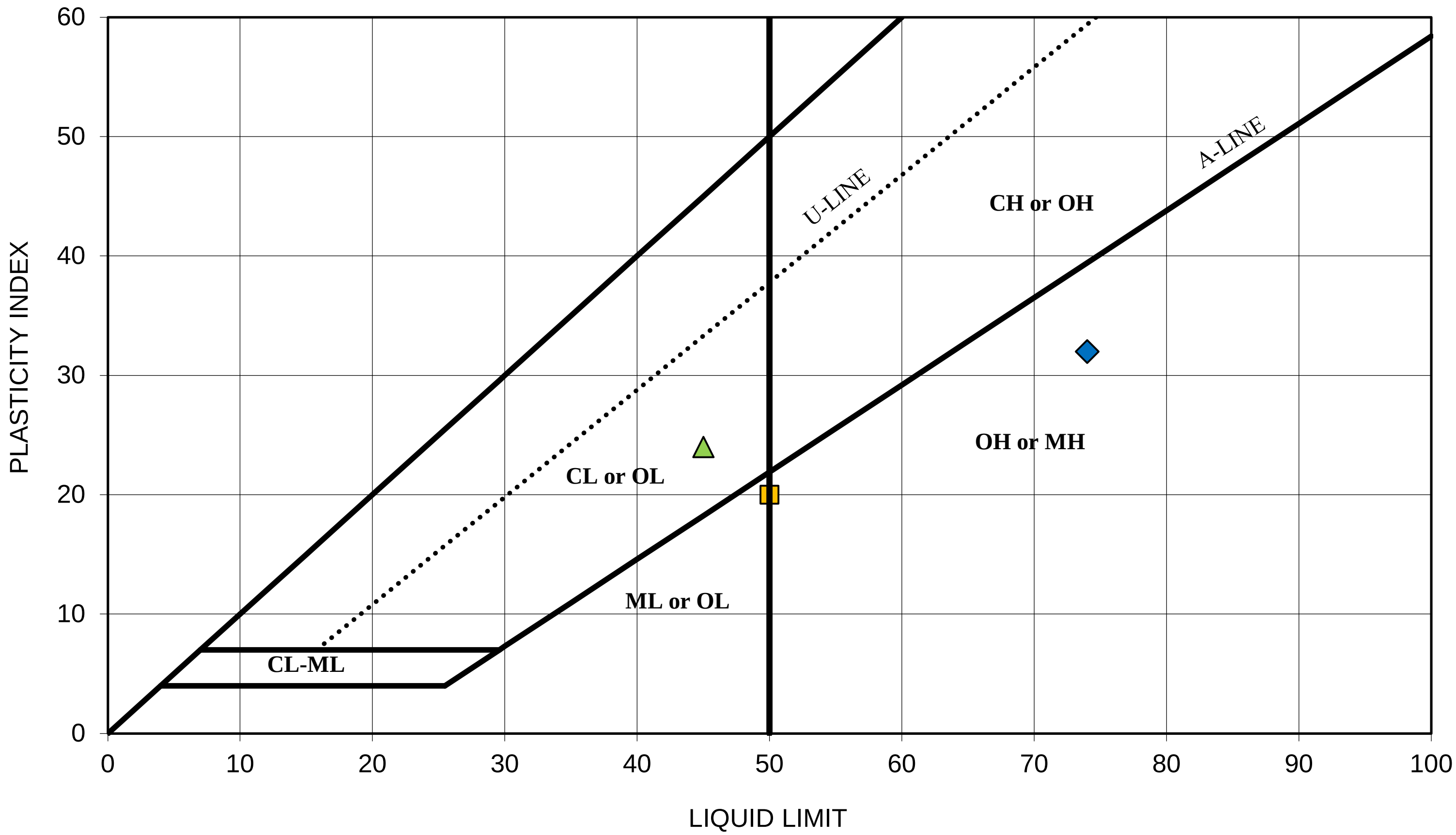
Atterberg Limits Test Results

PCGP- MP 25
Coos County, Oregon

GeoEngineers

Figure A-5

PLASTICITY CHART



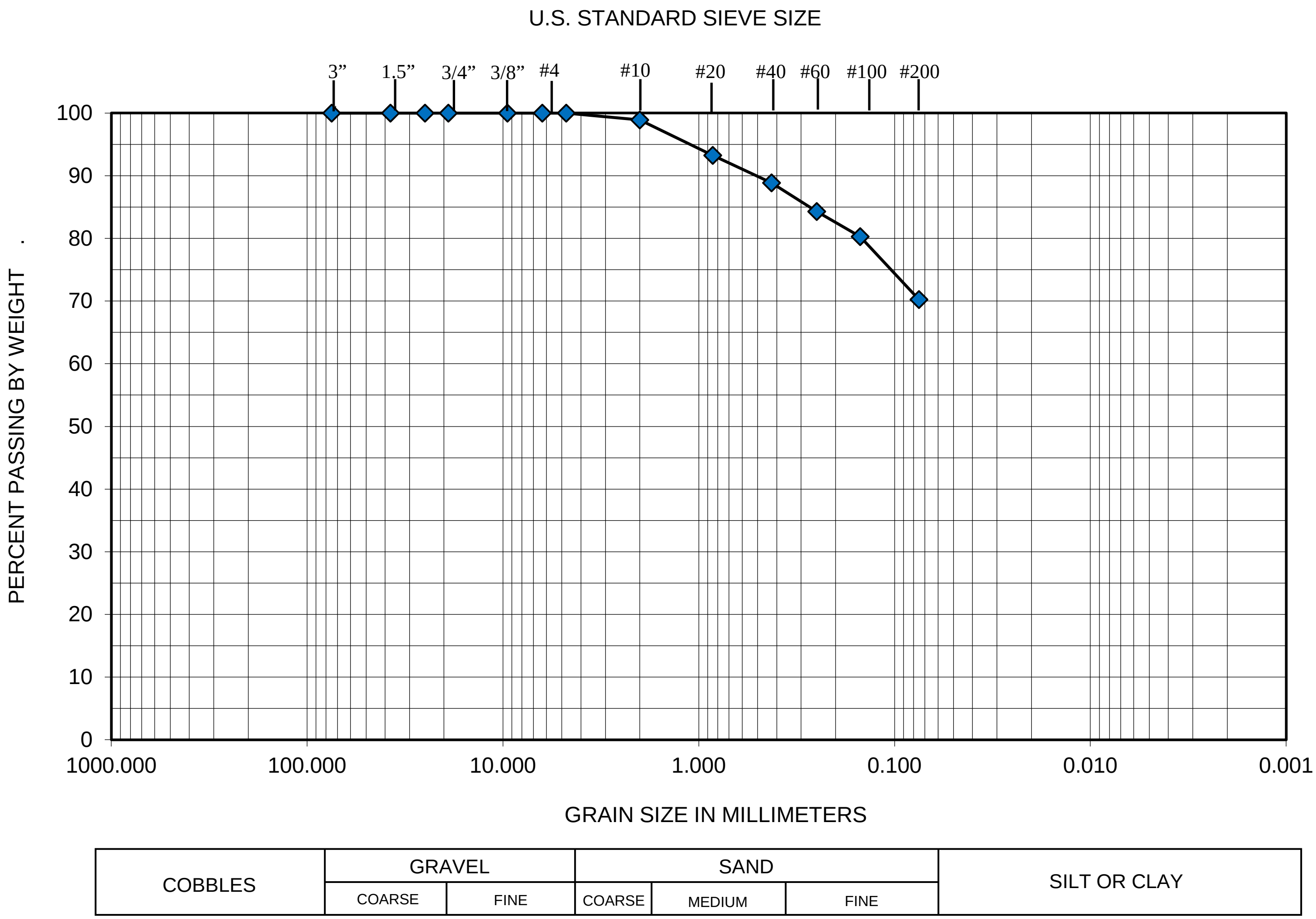
Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	USCS	Soil Description
◆	B-25.6-1 S-1	10	46	74	32	MH	Elastic silt
■	B-25.6-1 S-5	25	34	50	20	MH	Elastic silt
▲	B-25.6-1 S-7	35	24	45	24	CL	Lean clay

Atterberg Limits Test Results

PCGP- MP 25
Coos County, Oregon

GeoEngineers

Figure A-6



Symbol	Sample ID	Sample Depth (feet)	Moisture Content (%)	Gravel (%)	Sand (%)	Fines (%)	USCS	Soil Description
◆	B25.09-1 S-4	20	32	0	30	70	CH	Sandy fat clay

Sieve Analysis Results

PCGP- MP 25
Coos County, Oregon

GEOENGINEERS

Figure A-7

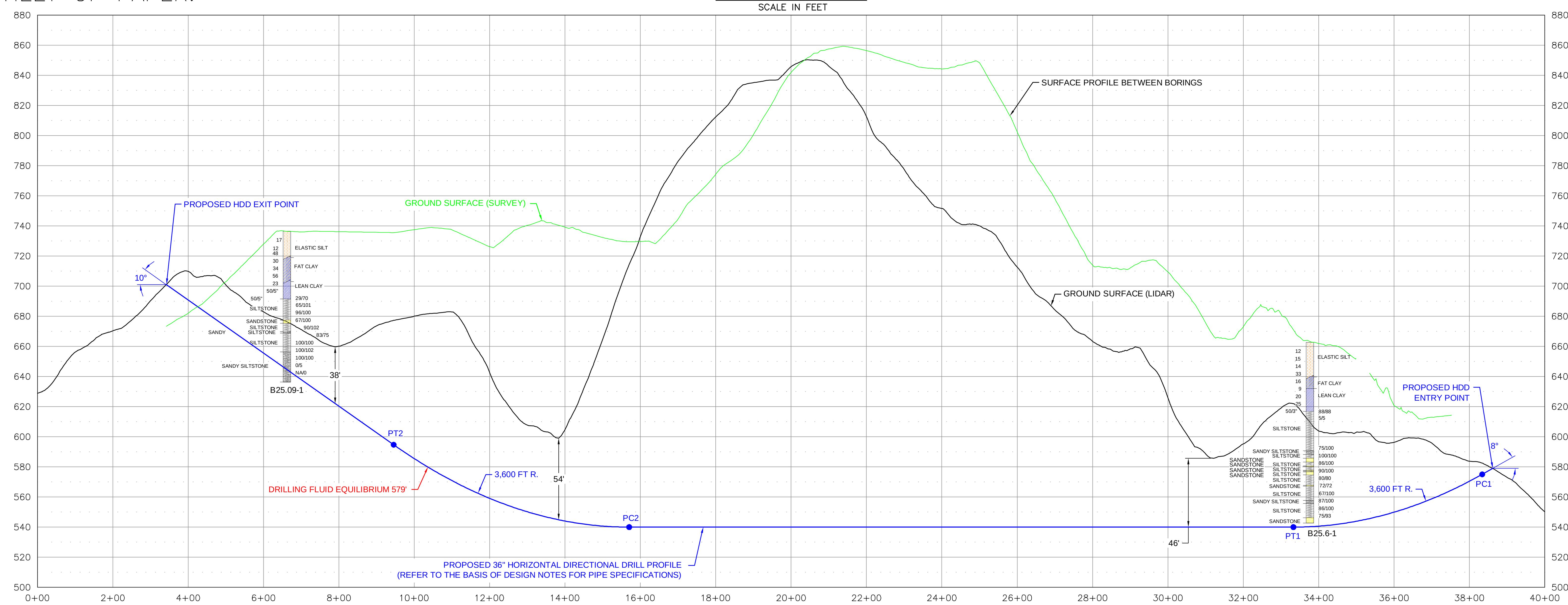
APPENDIX B
HDD Design Drawing and Calculations

NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN

200' 0 200'
SCALE IN FEET

MAJOR CONTOURS= 20'
MINOR CONTOURS= 5'



PROFILE

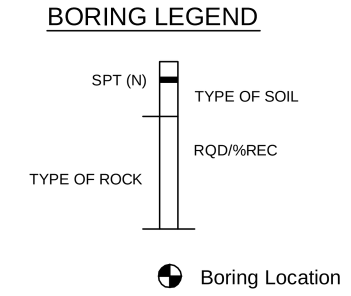
200' 0 200'
HORIZONTAL SCALE IN FEET
50' 0 50'
VERTICAL SCALE IN FEET

DIRECTIONAL DRILL DATA ALT MP 25 HDD		
DESCRIPTION	STATION * (FT)	ELEVATION (FT)
ENTRY @ 8°	38+62.00	578.95
P C 1 (8.00° @ 3,600 FT R.)	38+34.11	575.03
P T 1	33+33.09	540.00
P C 2 (10.00° @ 3,600 FT R.)	15+70.37	540.00
P T 2	9+45.24	594.69
EXIT @ 10°	3+42.00	701.06
HORIZONTAL DISTANCE = 3,520.00 FT		
DIRECTIONAL DRILL PIPE LENGTH = 3,534.40 FT		

* THE STATIONING IS BASED ON AN ARBITRARY REFERENCE POINT

RECOMMENDED TOLERANCES	
ITEM	TOLERANCE
PILOT HOLE ENTRY ANGLE	INCREASE ANGLE UP TO 1° (STEEPER), BUT NO DECREASE IN ANGLE ALLOWED.
PILOT HOLE ENTRY LOCATION	AS PER COORDINATES PROVIDED BY COMPANY WITH NO CHANGES WITHOUT COMPANY APPROVAL.
PILOT HOLE EXIT ANGLE	INCREASE ANGLE UP TO 1° (STEEPER) OR DECREASE UP TO 2° (FLATTER).
PILOT HOLE EXIT LOCATION	UP TO 20 FEET BEYOND OR 10 FEET SHORT OF THE EXIT STAKE. BETWEEN 5 FEET LEFT AND 5 FEET RIGHT OF CENTERLINE.
PILOT HOLE DEPTH	UP TO 2 FEET ABOVE THE DESIGN DRILL PROFILE ALLOWED. UP TO 10 FEET BELOW THE DESIGN DRILL PROFILE ALLOWED.
PILOT HOLE ALIGNMENT	SHALL REMAIN WITHIN 5 FEET LEFT OR RIGHT OF THE HDD ALIGNMENT.

BORING LEGEND



BASIS OF DESIGN:

1. PRODUCT PIPE WILL CONSIST OF 36" O.D. X 0.762" W.T., API-5L X-70 SAWL OR SAWH PIPE WITH 8-10 MILS OF FUSION BONDED EPOXY (FBE) AND A MINIMUM OF 40 MILS OF ABRASION RESISTANT OVERLAY (ARO).
2. MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP) = 1,480 psi
3. ASSUMED MAXIMUM OPERATING TEMPERATURE = 100° FAHRENHEIT.
4. ASSUMED AVERAGE OPERATING TEMPERATURE = 70° FAHRENHEIT.
5. THE MINIMUM ALLOWABLE THREE JOINT RADIUS SHALL NOT BE LESS THAN 2,600 FEET.

NOTES:

1. CONTRACTOR SHALL ADHERE TO THE SPECIFICATIONS AND REQUIREMENTS PER PACIFIC CONNECTOR GAS PIPELINE, LP SPECIFICATIONS, CONTRACT DOCUMENTS AND SPECIAL PERMIT CONDITIONS, EXCEPT AS NOTED ON THIS DRAWING.
2. CONTRACTOR IS RESPONSIBLE FOR CALLING OREGON ONE-CALL AND LOCATING ALL UNDERGROUND UTILITIES PRIOR TO BEGINNING CONSTRUCTION. IF ANY UTILITY IS LOCATED WITHIN 15 FEET OF THE DESIGNED HDD PROFILE AND ALIGNMENT, CONTRACTOR SHALL OBTAIN APPROVAL FROM PACIFIC CONNECTOR GAS PIPELINE, LP PRIOR TO INITIATING HDD OPERATIONS.
2. IT IS THE CONTRACTORS RESPONSIBILITY TO IDENTIFY AND PROTECT ANY FOREIGN UTILITY THAT MAY BE AFFECTED BY THE HDD OPERATIONS.
3. PLACEMENT OF THE HDD RIG IS NOT FIXED BY THE DESIGNATION OF THE ENTRY AND EXIT POINTS. THE USE OF DUAL HDD RIGS DURING CONSTRUCTION MAY BE AT THE DISCRETION OF THE HDD CONTRACTOR, TO BE APPROVED BY THE PROJECT TEAM.
4. ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY OR FROM APPROVED ACCESS ROADS.
5. WORK SPACE: MAXIMUM WORK SPACE LIMITS ARE DEPICTED. RESTRICT CLEARING TO THE WORK SPACE INDICATED AT THE ENTRY AND EXIT POINTS AND PRODUCT PIPE STRINGING AND FABRICATION AREA ALONG THE CONSTRUCTION RIGHT-OF-WAY. CLEARING BETWEEN THE ENTRY AND EXIT POINTS REQUIRES PRIOR APPROVAL FROM THE ENVIRONMENTAL INSPECTOR AND IS LIMITED TO THE AMOUNT NECESSARY TO STRING SURVEY WIRES AND INSTALL PUMPS AND PIPING TO OBTAIN WATER (WHERE APPROVED).
6. WATER SOURCE: DRILL WATER AND HYDROSTATIC TEST WATER SHALL BE OBTAINED FROM AN APPROVED SOURCE.
7. HYDROSTATIC TEST: PRE-INSTALLATION AND POST-INSTALLATION HYDROSTATIC TESTS SHALL BE CONDUCTED IN ACCORDANCE WITH THE HYDROSTATIC TEST PLAN. TEST WATER SHALL BE SAMPLED AND TESTED IN ACCORDANCE WITH PERMIT REQUIREMENTS. THE TEST WATER SHALL BE DISCHARGED IN AN UPLAND AREA INTO AN EROSION CONTROL STRUCTURE OF STRAW BALES AND/OR SILT FENCES, GEOTEXTILE FILTER BAG, OR COLLECTED IN A TRUCK AND HAULED TO AN APPROVED DISPOSAL SITE. UPON COMPLETION OF DEWATERING AND DRYING, A CALIPER PIG SURVEY SHALL BE COMPLETED IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.
8. SPILL-PREVENTION: REFUELING OF ALL EQUIPMENT SHALL BE COMPLETED IN ACCORDANCE WITH THE SPCC PLAN.
9. EROSION AND SEDIMENT CONTROL: CONTRACTOR SHALL SUPPLY, INSTALL AND MAINTAIN SEDIMENT CONTROL STRUCTURES IN ACCORDANCE WITH CONTRACT DOCUMENTS. CONTRACTOR SHALL INSTALL ADDITIONAL EROSION CONTROL STRUCTURES AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
10. INSTALLATION: THE PIPE SECTION FOR THE DRILLED CROSSING SHALL BE MADE UP WITHIN THE APPROVED CONSTRUCTION RIGHT-OF-WAY AT THE DRILL EXIT POINT AS SHOWN. AFTER THE PILOT HOLE IS COMPLETE, CONTRACTOR'S ACTUAL DRILL PROFILE SHALL BE SUBMITTED TO PACIFIC CONNECTOR GAS PIPELINE, LP FOR APPROVAL. CONTRACTOR SHALL ASSESS THE NEED FOR AND SUPPLY APPROPRIATE BALLAST DURING PULLBACK.
11. DRILLING FLUID DISPOSAL: CONTRACTOR SHALL DISPOSE OF EXCESS DRILLING FLUID AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS. UNDER NO CIRCUMSTANCES SHALL DRILLING FLUID BE DISPOSED OF IN WATER BODIES OR WETLANDS. ANY DRILLING FLUID WHICH INADVERTENTLY SURFACES AT POINTS OTHER THAN THE ENTRY OR EXIT POINTS SHALL BE CONTAINED AND COLLECTED TO THE EXTENT PRACTICAL AND DISPOSED OF AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS.
12. CLEANUP/STABILIZATION/RESTORATION: ALL DISTURBED AREAS SHALL BE RETURNED TO THE ORIGINAL CONTOURS. DISTURBED AREAS SHALL BE SEEDED AS SPECIFIED IN THE CLEAN-UP AND RESTORATION REQUIREMENTS. IF THE TERRAIN ALLOWS AND ACCESS IS PERMITTED, CONTRACTOR SHALL UTILIZE LOW GROUND PRESSURE EQUIPMENT OR OTHER EQUIPMENT APPROVED BY OWNER, TO FACILITATE CONTAINMENT AND CLEAN-UP OF ANY INADVERTENT RETURNS THAT OCCUR DURING THE HDD INSTALLATION PROCESS.
13. GEOTECHNICAL DATA: BORE HOLES ARE OFFSET FROM THE PIPELINE CENTERLINE AS SHOWN ON THE PLAN VIEW. THE GEOTECHNICAL INFORMATION PROVIDED ON THIS DRAWING IS A GENERAL SUMMARY. REFER TO THE APPLICABLE GEOTECHNICAL REPORT IN THE CONTRACT DOCUMENTS FOR MORE DETAILED INFORMATION
14. GROUND SURFACE SURVEY PROVIDED BY PACIFIC CONNECTOR GAS PIPELINE, LP. GROUND SURFACE LIDAR DOWNLOADED FROM HTTP://WWW.OREGONGEOLOGY.ORG/SUB/DEFAULT.HTM. AERIAL PHOTOS TAKEN FROM GOOGLE EARTH PRO © 2015, LICENSED TO GEOENGINEERS, INC., DATED 05-03-13.
15. THE SECONDARY SURFACE SURVEY COIL LAYOUTS SHOWN ON THIS DRAWING ARE APPROXIMATE AND INTENDED TO SHOW THE GENERAL LAYOUT OF TYPICAL SECONDARY SURFACE SURVEY COIL WIRES THAT MAY BE PLACED TO TRACK THE BOTTOM HOLE ASSEMBLY DURING PILOT HOLE OPERATIONS. THE APPROXIMATE LOCATIONS OF THE SECONDARY SURFACE SURVEY COIL WIRES SHOWN ON THIS DRAWING ARE NOT INTENDED TO DIRECT THE HDD CONTRACTOR AS TO THE EXACT PLACEMENT OF THE SECONDARY SURFACE SURVEY COIL WIRES. THE FINAL PLACEMENT OF SECONDARY SURFACE SURVEY COIL WIRES IS THE CONTRACTOR'S RESPONSIBILITY AND MAY VARY FROM WHAT IS SHOWN DEPENDING ON GROUND SURFACE CONDITIONS AT THE TIME OF HDD INSTALLATION, AND THE HDD CONTRACTOR'S MEANS AND METHODS.

REFERENCES

DRAWING NUMBER	REFERENCE DRAWING TITLE

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
A	ISSUED AS DRAFT	RBM	05/04/15	BCR	

BCR Design	04/03/15 Date
RBM Drawn	04/03/15 Date
BCR Checked	05/04/15 Date
TNH Approved	05/04/15 Date

GEOENGINEERS
3050 South Delaware
Springfield, MO 65804
Telephone (417) 831-9700
Fax (417) 831-9777

36" PACIFIC CONNECTOR GAS PIPELINE PROJECT

ALT MP 25 HDD
COOS COUNTY, OREGON

Project No. 16724-002-00

Drawing No.

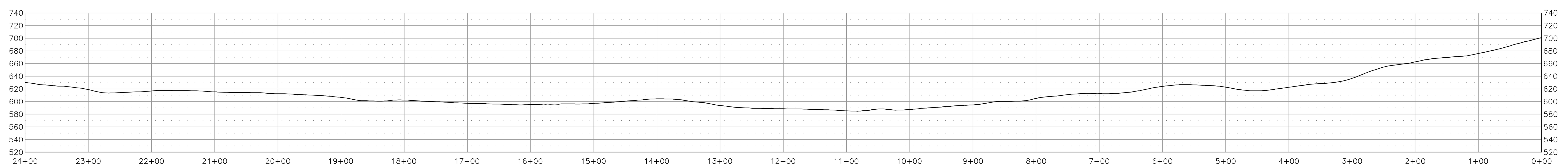
Sheet 1 of 2

DATUM:
HORIZONTAL: NAD83 Oregon State Plane, South Zone, US Foot
VERTICAL: NAVD 88

NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN

100' 0 100'
SCALE IN FEET



PROFILE

100' 0 100'
HORIZONTAL SCALE IN FEET
100' 0 100'
VERTICAL SCALE IN FEET

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8. BASE FILE AND GROUND SURFACE SURVEY PROVIDED BY PACIFIC CONNECTOR GAS PIPELINE, LP. GROUND SURFACE DEM (1/9 ARC SECOND) DOWNLOADED FROM HTTP://VIEWER.NATIONALMAP.GOV/VIEWER/. AERIAL PHOTOS TAKEN FROM GOOGLE EARTH PRO © 2015, LICENSED TO GEOENGINEERS, INC., DATED 05-03-13.

REFERENCES

DRAWING NUMBER	REFERENCE DRAWING TITLE

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
A	ISSUED AS DRAFT	RBM	05/04/15	BCR	

BCR Design	12/01/14 Date
RBM Drawn	03/12/15 Date
BCR Checked	05/04/15 Date
TNH Approved	05/04/15 Date

GEOENGINEERS
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Fax (417) 831-9777

36" PACIFIC CONNECTOR GAS PIPELINE PROJECT

ALT MP 25 HDD STRINGING WORKSPACE
COOS COUNTY, OREGON

Project No. 16724-002-00
Drawing No.

APPENDIX C
Report Limitations and Guidelines for Use

APPENDIX C
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

Geotechnical Services Are Performed for Specific Purposes, Persons and Projects

This report has been prepared for the exclusive use of Willbros, Williams and their authorized agents. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared. This report should not be applied for any purpose or project except the one originally contemplated.

A Geotechnical Engineering or Geologic Report Is Based on a Unique Set of Project-specific Factors

This report has been prepared for Willbros and Williams for the MP 25 HDD in Coos County, Oregon. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- Not prepared for you.
- Not prepared for your project.
- Not prepared for the specific site explored.
- Completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- The function of the proposed structure.
- Elevation, configuration, location, orientation or weight of the proposed structure.
- Composition of the design team.
- Project ownership.

---

[1] Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

Subsurface Conditions Can Change

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

Most Geotechnical and Geologic Findings Are Professional Opinions

Our interpretations of subsurface conditions are based on field observations from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

Geotechnical Engineering Report Recommendations Are Not Final

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient observation, testing and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A Geotechnical Engineering or Geologic Report Could Be Subject to Misinterpretation

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also, retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Exploration Logs

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

Give Contractors a Complete Report and Guidance

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

Contractors Are Responsible for Site Safety on Their Own Construction Projects

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

Read These Provisions Closely

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

Geotechnical, Geologic and Environmental Reports Should Not Be Interchanged

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

Biological Pollutants

GeoEngineers' Scope of Work specifically excludes the investigation, detection, prevention or assessment of the presence of Biological Pollutants. Accordingly, this report does not include any interpretations, recommendations, findings, or conclusions regarding the detecting, assessing, preventing or abating of Biological Pollutants and no conclusions or inferences should be drawn regarding Biological Pollutants, as they may relate to this project. The term “Biological Pollutants” includes, but is not limited to, molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts.

If Client desires these specialized services, they should be obtained from a consultant who offers services in this specialized field.

Have we delivered World Class Client Service?

Please let us know by visiting **www.geoengineers.com/feedback**.

GeoEngineers

Appendix 4
Site-Specific Waterbody Crossing Plans – CZMA

North Fork Coquille River At MP 23.06
East Fork Coquille River At MP 29.88
Typical Bridge Crossing

Pacific Connector
GAS PIPELINE

Site Specific Plan
For
Open Cutting the North Fork Coquille River
At MP 23.06

Pacific Connector Gas Pipeline Project

June 9, 2008

Site Specific Plan For
Open Cutting
The North Fork Coquille River

PRE-CONSTRUCTION

General Description of the Area

The North Fork Coquille River is a perennial river located at approximately MP 23.06 (See North Fork Coquille SSP Drawings 3403-9_052), with a width of approximately 20-feet, in summertime conditions, and a depth ranging from 12 inches to 6 feet depending on the seasonal precipitation.

Vegetation immediately adjacent to the river banks includes primarily myrtle trees, however, Douglas fir and Red Cedar trees may also occur on the south side of the river. Blackberries, vine maple, other shrubs and grasses also occur as understory species along the river bank. The majority of the vegetation located within the confines of the Temporary Extra Work Area (TEWA) on west side of the river crossing is hayfields and pasture used for livestock grazing. TEWA on the east side of the river crossing is heavily forested with Douglas fir and Red Cedar trees.

In the Level 1 Scour Report compiled by GeoEngineers, Inc dated June 6, 2006 indicates the river banks are composed primarily of sand and gravel. The river bed is comprised of erosion resistant sedimentary bedrock. Several gravel bars overlie the bedrock in the channel and along the insides of the bends.

Based on the geologic information provided in the Level 1 Scour Report, as well as onsite investigations to determine conditions on the property immediately adjacent to the crossing, Pacific Connector Gas Pipeline, LP (Pacific Connector) expects a successful dry open cut crossing of the North Fork Coquille River via a flume or dam and pump crossing method.

Schedule

Contractor shall schedule the North Fork Coquille crossing such that all work is accomplished within the “fish window” which is July 1 through September 15. Company estimates the construction contractor will complete work during the Year 2 construction phase of the project. A presumed occupied Marbled Murrelet stand occurs on the forested slopes immediately south of the river crossing and where TEWA 23.09-N is located. This stand has not been surveyed or assessed for suitable nesting habitat, because of denied property access. This stand is not expected to cause seasonal timing conflicts with the proposed crossing schedule because other similar forested stands on BLM lands immediately adjacent to this stand have been surveyed and determined to not be suitable nesting habitat. The non-surveyed stand will be assessed for suitable Marbled Murrelet nesting habitat once access is provided. If the stand is determined to be suitable nesting habitat, consolation with the U.S. Fish and Wildlife Service and NOAA Fisheries will be reinitiated to determine the appropriate crossing schedule for both the stand and the river crossing.

Staking, Flagging and Signage

The right-of-way, TEWA, waterbody ordinary high water mark, and centerline for the pipeline will be staked before the contractor mobilizes to the work area. The contractor shall install signage addressing: fueling areas, waterbody, vehicle speed and access road identification. Wetland boundaries and any sensitive resource locations will also be marked with flagging, signage, and where appropriate, silt fenced.

Access

Contractor access to the west side of the North Fork Coquille Crossing is from Fairview Laverne Park Road to the construction right-of-way. As part of this river crossing a temporary bridge will be installed down stream of the river crossing location to allow construction personnel and equipment access to the east side of the river without creating a large equipment move around and heavy travel on the existing county roads. East side access is through Fisher Private Road to the construction right-of-way. The placement of the temporary access bridge will occur within the designated fish window and will require one pass across the river with installation equipment to place the bridge.

Workspace

TEWAs will be required to successfully construct the pipeline across the river, in addition to the 95 foot wide construction right-of-way on each side of the North Fork Coquille River. Four TEWAs adjacent to the construction right-of-way will be required to construct this crossing. As shown on the North Fork Coquille SSP Drawing 3403-9_052, there are two TEWAs located on the west side of the river. The NW TEWA is 0.59 acres (TEWA 22.59-N) and the SW TEWA is 0.68 acres (TEWA 23.09-W). There are two TEWAs located on the east side of the river crossing. The NE TEWA is 0.56 acres (TEWA 23.09-N) and the SE TEWA is 0.49 acres (TEWA 23.09-W). These TEWAs will be used for material and equipment staging and spoil storage as necessary.

Equipment and Materials

Equipment anticipated to construct the crossing consists of pickups, excavators, loaders, welding rigs, water pumps, bending machine, dozers, side-booms and other associated equipment. This equipment will be on-site when needed and located elsewhere on the project when not needed at this location. Materials will consist primarily of concrete coated pipe, flume pipe, timber mats, straw bales, silt fencing, plastic sheeting and sandbags for the dams. The Environmental Inspector (EI) will inspect all equipment and vehicles prior to entering the construction areas for the river crossing to ensure they are appropriately maintained, clean, are free of leaks and potential weed seed sources.

CONSTRUCTION

Pacific Connector's contractor will comply with the FERC Wetland and Water body Construction and Mitigation Procedures as well as all other federal, state and local permit conditions for both the wetland crossing and the water body crossing. This crossing will be conducted during the fish window and the dry low flow period between July 1 and September 15. This construction period will coincide with the lowest seasonal groundwater levels to minimize potential impacts associated with the river crossing. During the construction of the crossing, water quality monitoring will occur throughout the in-water construction phase as specified according to State and Federal permit conditions.

Environmental Controls

Sediment barriers shall be installed along edges of the right-of-way and the TEWAs to contain sediment and spoil within these workspaces from entering the waterbody. These barriers shall be maintained until revegetation is complete. The Environmental Inspector (EI) will be responsible for appropriate sediment barrier placement and maintenance during construction.

Clearing, Stripping and Grading

All brush and trees within the construction corridor will be cut at ground level. Stumps and root wads will be removed from the pipe ditch alignment. Any stumps in the workspace other than trench line will be cut to ground level. The topsoil will be segregated and stockpiled separately from the subsoil. The ordinary high water mark of the waterbody and any sensitive resource locations will also be marked with flagging, signage, and where appropriate, silt fences will be installed prior to grading activities.

Fluming North Fork Coquille River

Material

Steel pipe, plastic sheeting and sandbags will be the primary materials used in fluming of the North Fork Coquille River. The flume pipe will span the work area, have wings on upstream end sized appropriately for the river and will be clean and free of debris. Plastic sheeting will be at lease 10 mils thick and will have a width of at least 8 feet. The burlap sandbags will be filled with clean sand.

Flume Design

The flume pipe will incorporate wings welded on the upstream end to funnel the water flow into the flume pipe. The wings will extend to each bank and will be angled slightly upstream. The flume pipe will be approximately 95 feet in length with the pipe diameter to be determined in the field being based upon stream flow at the time of construction and anticipated seasonal storm events. The two ends of the flume pipe will be sandbagged and lined with plastic sheeting to seal the dam, as necessary. Sandbag material shall be a non-leachable material. A temporary equipment bridge will be installed downstream of the flume to allow equipment and personnel to access both sides of the river crossing during the construction window.

Flume Installation

The contractor will install 3 to 4 rows of sandbags on the upstream and downstream river beds, each with two sandbag layers. Sandbags will be packed as tightly as is possible. Once these first sandbags are in place, the flume pipe will be lowered into position.

After the flume pipe is laid on the sandbags, the contractor shall begin to build the upstream dam. The winged portion of the pipe will be pushed into the banks with sandbags put on each side of the wings to provide an adequate seal. The dams should extend three feet above water level of the river. Once the upstream and downstream flume dams have been installed and the work area has been isolated from river flow, fish salvaging efforts and dewatering of the isolated work area will commence. All dewater pumps will be appropriately screened according to ODFW and NOAA standards to prevent fish entrainment. Fish salvage efforts will be conducted by an ODFW certified biological contractor. Because of the potential presence of migrating adult spring chinook at the time of the crossing, the work area will be flushed out prior to installation of the flume to ensure adults are not initially trapped within the initial flume dams as requested by ODFW during a site visit in early 2008.

Pump containment will consist of an impervious straw bale structure, or other appropriate containment structure, surrounding the pumps. The bales will be secured to the ground with wooden stakes to secure the structure. The pumps will remove water from between the flume dams and discharge the water through hose pipe into a dewatering structure.

The dewatering structure will be constructed of straw bales and is designed to diffuse the energy in the pump discharge, filter the water, and create a sheet flow discharge of the water over the structure walls. The dewatering structure will be located so that discharge from the structure does not flow to work areas or to the river.

Trenching, Pipe Installation and Backfilling

Pipeline trenching will begin with a track hoe/excavator on each side of the river bank trenching under the flume and proceeding through the banks. Bedrock may be encountered on the river bed based on the information contained in the scour report compiled by GeoEngineers. A hard plug will be maintained near the river bank to maintain separation of the open trench and river channel. The drag section for the river crossing will placed under the flume as soon after the trench has been excavated to design depths as specified to accommodate potential scour. The drag section will be prefabricated and readied for installation prior to any in-stream trenching operations.

Spoil from the trenching to install the initial drag section under the flume will be stockpiled in the TEWAs. Since the topography of the TEWAs are flat, spoil storage runoff should not be an issue but silt fence and straw bales will be installed to contain the excavated river spoil.

Pumping of water from the trench may become necessary to avoid overflow from the two flume dams. Discharge will be through a discharge structure in an upland area to assure filtered dissipation back to the ground.

Backfilling with the stored spoil will begin under the flume pipe proceeding simultaneously through the river banks toward the ends of the pipe section. The backfilling will be restricted to assure the displaced water in the ditch can be adequately handled by the pumps. As the river is backfilled, the river bed will be recontoured and compacted to its preconstruction condition. Impermeable trench plugs will be installed and the river banks will be stabilized. The top one foot of the trench will be backfilled with washed gravel appropriately sized for spawning habitat.

Flume Removal

The downstream sandbags covering the flume pipe will be removed first shortly after completing the crossing. Sandbags under the flume pipe on the downstream end will be left in place until the flume pipe is removed. The sandbags covering the upstream end of the flume pipe will then be removed slowly by hand. After the water flow through the construction area is reconnected, the remainder of the sandbags and the flume pipe will be removed. The flume pipe will be lifted from its perch, not drug or pulled from its location.

Alternate Dam and Pump Option

It should be noted that if the seasonal flows are low enough, the construction contractor may choose to dam and pump this river crossing. Should this type of crossing be chosen, the contractor would install a temporary dam on the upstream side of the construction right-of-way and then install an isolation dam on the downstream side of the construction right-of-way. These isolation dams may be constructed of steel plates, sandbags, porta-dams, aqua dams or other similar devices that provide the same function and would be sited at the same location as the flume entrance and exit spots.

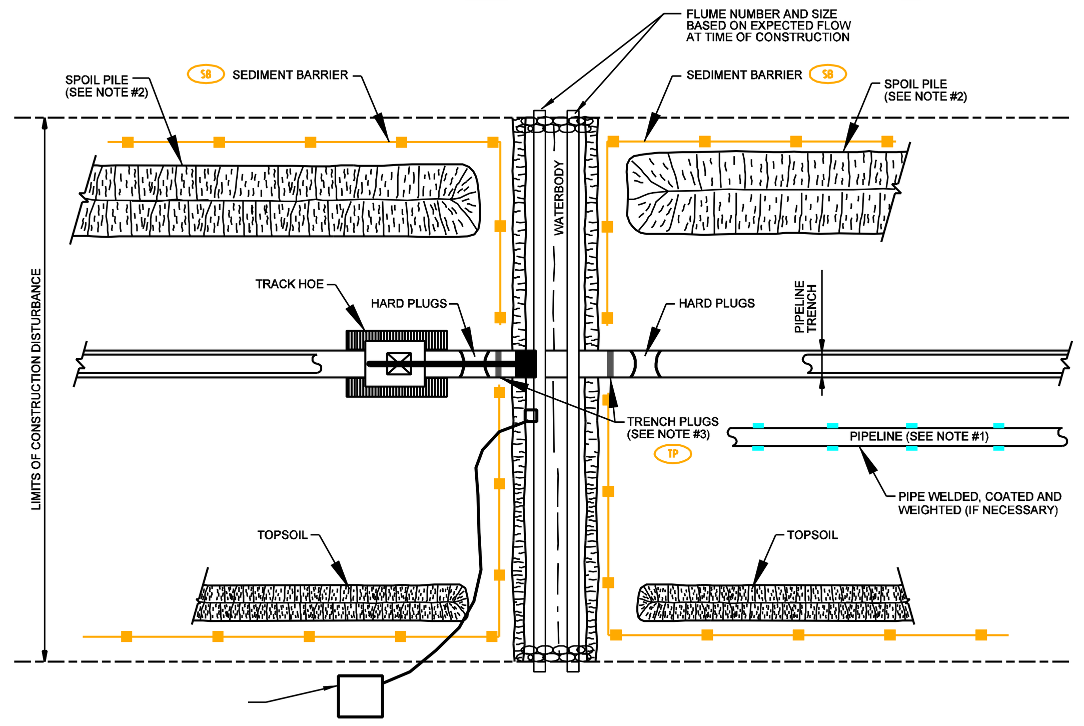
After the isolation dams have been installed, fish salvaging efforts will be completed within the isolation dams and the isolated area dewatered. Fish salvage efforts will be conducted by an ODFW certified biological contractor, as with a flumed crossing method

As soon as the work area is appropriately isolated, the pipeline trench will be excavated across the river. The pipeline trench will be excavated to design depths as specified to accommodate potential scour. If bedrock is encountered during excavation; the top of pipe will be buried 24 inches below the top of bedrock.

After the pipe strings have been tied-in, the pipeline trench will be backfilled with the native material excavated from the trench and the contours of the river bed and river banks will be restored to approximate preconstruction contours. The top one foot of the trench will be backfilled with washed gravel appropriately sized for spawning habitat. The isolation dams will be removed with the downstream dam being removed prior to the upstream dam.

Restoration and Habitat Improvements

During clean up, the river banks will be returned to approximate preconstruction contours or to a stable slope (i.e., 3:1) and stabilized with erosion control fabric as necessary. River banks will be reseeded and the river banks and riparian areas will be planted with appropriate riparian tree and shrub species using the procedures outlined in the Pacific Connectors Erosion Control and Revegetation and in accordance with the FERC Wetland and Waterbody Construction and Mitigation Procedures as well as applicable federal, state, and local permit conditions. Shrub cuttings will be planted on 3-4 foot centers except for a 10-foot corridor center over the pipeline to facilitate operational surveys. Final soil erosion measures will be installed and maintained until the area is successfully revegetated.



TYPICAL DRY OPEN-CUT (FLUMED) WATERBODY CROSSING

OPEN CUT NOTES:

1. Designated workspace shown on the site specific plans is for spoil storage located on either side of the waterbody crossing adjacent to the proposed pipeline alignment. Additional Temporary Extra Work Area (TEWA) is necessary for support equipment/vehicles, supplies and materials, access to construction areas, including the temporary diversion channel and in stream diversion structures. Sediment barriers will be installed around workspace areas and spoil storage areas, where necessary to protect the waterbody from surface runoff.
2. The waterbody crossing will be installed as expeditiously as possible to minimize impacts to the waterway. The pipe trench will be backfilled using the native material excavated from the trench. Trench plugs will be installed at the banks on either side of the waterway.
3. If the waterway is navigable or used by recreational boaters, a mitigation plan for traffic interruption will be prepared.
4. Erosion and sediment control measures shall be inspected daily and repaired if necessary.
5. Schedule crossing during ODFW designated in water work window period between July 1 and September 15.
6. No refueling of mobile equipment within 100 feet of stream bank. Place sign posts 100 feet back from wetland boundary and advise no refueling. Refuel stationary equipment as per SPCC plan.
7. Leave hard plugs at the stream bank edge, until just prior to pipe installation.
8. Maintain stream flow throughout crossing construction.
9. Restore watercourse channel to approximate pre-construction profile and substrate.
10. This typical drawing is preliminary. Site specific design details will be completed prior to construction, based on site specific conditions at the time of construction. Construction phase sequence and specific details outlined in the site-specific plan may be approved in writing based on contractors written recommendations.

DEWATER NOTES:

1. Dewater structure shall be placed on a level, well vegetated site such that filtered water will flow away from structure and any work areas.
2. Flow rates into the discharge shall be such that water will be filtered through the structure and allowed to overflow.
3. Contractor shall utilize certified noxious weed free hay for structure.
4. Dewatering structures will be constructed and maintained according to the dewatering structure typical drawings found in the Erosion Control & Revegetation Plan (ECRP).

LEGEND

- 36-inch Proposed PCGP Project
- Construction Right-of-Way
  - Temporary Construction Right-of-Way (Shown as white on photography)
  - Temporary Extra Work Area
- Uncleared Storage Area
- Access Road
- Drivable Berm or Straw Bales
- Silt Fence

REFERENCE DRAWINGS

DRAWING NO.	TITLE
3430.29-023	CONSTRUCTION ALIGNMENT

REVISIONS

NO.	DATE	BY	DESCRIPTION	W.O. NO.	CHK.	APP.
1	JUNE-2007	KLL	PREFILING 3rd DRAFT			
2	SEPTEMBER-2007	KLL	ISSUED FOR FERC FILING			

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP
NORTH FORK OF COQUILLE RIVER - OPEN CUT
MILE POST 23.06
SEC. 25, T-27-S, R-12-W
COOS COUNTY, OREGON

Pacific Connector GAS PIPELINE

DRAWN BY: KLL / JST	DATE: 5-29-2008	ISSUED FOR BID:	SCALE: 1" = 100'
CHECKED BY:	DATE:	ISSUED FOR CONSTRUCTION:	
APPROVED BY:	DATE:	DRAWING NUMBER: 3430.9-052	SHEET
WO:		6/9/2008 %DATE% Q:\Oregon_gas\Mapping\Waterbodies\3430_9-052.dgn	OF

Site Specific Plan
For
Open Cutting East Fork Coquille River
At MP 29.88

Pacific Connector Gas Pipeline Project

June 9, 2008

Site Specific Plan For
Open Cutting
The East Fork Coquille River

PRE-CONSTRUCTION

General Description of the Area

The East Fork Coquille River is a perennial river located at approximately MP 29.88 (See East Fork Coquille SSP Drawings 3403-9_053), with a width of approximately 30-feet, in summertime conditions, and a depth ranging from a few inches to 6 feet depending on the seasonal precipitation.

Vegetation immediately adjacent to the west river bank includes blackberry thickets along with several smaller sized, alder and Red Cedar trees. Vegetation immediately adjacent to the east river bank includes blackberry thickets willow and dogwood shrubs, Douglas fir and Red Cedar trees of various sizes. The majority of the vegetation located within the confines of the Temporary Extra Work Area (TEWA) on both sides of the river crossing is farm hayfields and pasture used for livestock grazing.

Two soil borings were taken on the west side of the East Fork Coquille crossing location. The soil analysis indicated alluvial soils generally consisting of medium stiff silts and loose to medium dense sands to a depth of approximately 15-feet. Weak to moderately strong siltstone was discovered below the alluvial soils in each of the borings down approximately 100-feet according to the GeoEngineers, Inc East Fork Coquille River-Feasibility Report dated June 19, 2006.

To facilitate the dry open cut of the East Fork Coquille River, the pipeline alignment was modified from Environmental Alignment Sheet 29 to the current layout on shown on the East Fork Coquille SSP Drawings 3403-9_053. The change was made to allow for a perpendicular crossing of the river which will help mitigate disturbances to the river, minimize riparian vegetation removal, and ensure a successful crossing. This realignment also avoids wetland BW250 and two potential Marbled Murrelet stands (G46 G47) which have not been surveyed because of denied access. Based on the geologic information provided in the GeoEngineers East Fork Coquille River-Feasibility Report dated June 19, 2006, as well as onsite investigations to determine conditions on the property immediately adjacent to the crossing, Pacific Connector Gas Pipeline, LP (Pacific Connector) expects a successful dry open cut crossing of the East Fork Coquille River via a flume or dam and pump crossing method.

Schedule

Contractor shall schedule the East Fork Coquille crossing such that all work is accomplished within the “fish window” which is July 1 through September 15. Company estimates the construction contractor will complete work during the Year 2 construction phase of the project.

Staking, Flagging and Signage

The right-of-way, TEWA, the waterbody ordinary high water mark, and centerline for the pipeline will be staked before the contractor mobilizes to the work area. The contractor shall install signage addressing: fueling areas, waterbody, vehicle speed and access road identification. Wetland boundaries and any sensitive resource locations will also be marked with flagging, signage, and where appropriate, silt fenced.

Access

Contractor access to the west side of the East Fork Coquille Crossing is from the Myrtle Point-Sitkum Road to the construction right-of-way. As part of this river crossing, a temporary bridge will be installed down stream of the river crossing location to allow construction personnel and equipment access to the east side of the river without creating a large equipment move around and heavy travel on the existing county roads. The placement of the temporary access bridge will occur within the designated fish window and will require one pass across the river with installation equipment to place the bridge.

Workspace

TEWAs will be required to successfully construct the pipeline across the river in addition to the 95 foot wide construction right-of-way on each side of East Fork Coquille River. Four TEWAs adjacent to the construction right-of-way will be required to construct the crossing. As shown on the East Fork Coquille SSP Drawing 3403-9_053, there are two TEWAs located on the west side of the river. The NW parcel is 0.74 acres (32,234 ft^2) and the SW parcel is 0.38 acres (16,552 ft^2). There are two TEWAs located on the east side of the river crossing. The NE parcel is 0.64 acres (27,878 ft^2) and the SE parcel is 0.48 acres (20,908 ft^2). These parcels will be used for material and equipment staging and spoil storage as necessary.

Equipment and Materials

Equipment anticipated to construct the crossing consists of pickups, excavators, loaders, welding rigs, water pumps, bending machine, dozers, side-booms and other associated equipment. The Environmental Inspector (EI) will inspect all equipment and vehicles prior to entering the construction areas for the river crossing to ensure they are appropriately maintained, clean, are free of leaks and potential weed seed sources. This equipment will be on-site when needed and located elsewhere on the project when not needed at this location. Materials will consist primarily of concrete coated pipe, flume pipe, timber mats, straw bales, silt fencing, plastic sheeting and sandbags for the dams.

CONSTRUCTION

Pacific Connector's contractor will comply with the FERC's Wetland and Water body Construction and Mitigation Procedures as well as all other federal, state and local permit conditions for both the wetland and the waterbody crossings. This crossing will be conducted during the fish window and the dry low flow period between July 1 and September 15. This construction period will also coincide with the lowest seasonal groundwater levels to minimize potential impacts associated with the river crossing.

Environmental Controls

Sediment barriers shall be installed along edges of the right-of-way and the TEWAs to contain sediment and spoil within these workspaces from entering the waterbody. These barriers shall be maintained until revegetation is complete. The EI will be responsible for appropriate sediment barrier placement and maintenance during construction. During the construction of the crossing, water quality monitoring will occur throughout the in-water construction phase as specified according to State and Federal permit conditions.

Clearing, Stripping and Grading

All brush and trees within the construction corridor will be cut at ground level. Stumps and root wads will be removed from the pipe ditch alignment. Any stumps in the workspace other than trench line will be cut to ground level. The topsoil will be segregated and stockpiled separately from the subsoil.

Fluming East Fork Coquille River

Material

Steel pipe, plastic sheeting and sandbags will be the primary materials used in fluming of the East Fork Coquille River. The flume pipe will span the work area, have wings on upstream end sized appropriately for the river and will be clean and free of debris. Plastic sheeting will be at lease 10 mils thick and will have a width of at least 8 feet. The burlap sandbags will be filled with clean sand.

Flume Design

The flume pipe will incorporate wings welded on the upstream end to funnel the water flow into the flume pipe. The wings will extend to each bank and will be angled slightly upstream. The flume pipe will be approximately 95 feet in length with the pipe diameter to be determined in the field being based upon stream flow at the time of construction and anticipated seasonal storm events. The two ends of the flume pipe will be sandbagged and lined with plastic sheeting to seal the dam. Sandbag material shall be a non-leachable material. A temporary equipment bridge will be installed downstream of the flume to allow equipment and personnel to access both sides of the river crossing during the construction window.

Flume Installation

The contractor will install 3 to 4 rows of sandbags on the upstream and downstream river beds, each with two sandbag layers. Sandbags will be packed as tightly as is possible. Once these first sandbags are in place, the flume pipe will be lowered into position.

After the flume pipe is laid on the sandbags, the contractor shall begin to build the upstream dam. The winged portion of the pipe will be pushed into the banks with sandbags put on each side of the wings to provide an adequate seal. The dams should extend three feet above water level of the river. Once the upstream and downstream flume dams have been installed and the work area has been isolated from river flow, fish salvaging efforts and dewatering of the isolated work area will commence. All dewater pumps will be appropriately screened according to ODFW and NOAA standards to prevent fish entrainment. Fish salvage efforts will be conducted by an ODFW certified biological contractor. Because of the potential presence of migrating adult spring chinook at the time of the crossing, the work area will be flushed out prior to installation of the flume to ensure adults are not initially trapped within the initial flume dams as requested by ODFW during a site visit in early 2008.

Pump containment will consist of an impervious straw bale structure, or other appropriate containment structure, surrounding the pumps. The bales will be secured to the ground with wooden stakes to secure the structure. The pumps will remove water from between the flume dams and discharge the water through hose pipe into a dewatering structure.

The dewatering structure will be constructed of straw bales and is designed to diffuse the energy in the pump discharge, filter the water, and create a sheet flow discharge of the water after traveling through the structure walls and into the ground. The dewatering structure will be located so that discharge from the structure does not flow to work areas or to the river.

Attached to this document are typical drawings depicting flumed stream crossing, pump containment structure, dewater structure, pipe placement plan view, sand bag dam, flume wings, and diversion structures.

Trenching, Pipe Installation and Backfilling

Pipeline trenching will begin with a track hoe/excavator on each side of the river bank trenching under the flume and proceeding through the banks. No bedrock is anticipated under the river per the information contained in the geotechnical report compiled by GeoEngineers. A hard plug will be maintained near the river bank to maintain separation of the open trench and river channel. The drag section for the river crossing will placed under the flume as soon after the trench has been excavated to design depths as specified to accommodate potential scour. The drag section will be prefabricated and readied for installation prior to any in-stream trenching operations.

Spoil from the trenching to install the initial drag section under the flume will be stockpiled in the TEWAs. Since the topography of the TEWAs are flat, spoil storage runoff should not be an issue but silt fence and straw bales will be installed to contain the excavated river spoil.

Pumping of water from the trench may become necessary to avoid overflow from the two flume dams. Discharge will be through a discharge structure in an upland area to assure filtered dissipation back to the ground.

Backfilling with the stored spoil will begin under the flume pipe proceeding simultaneously through the river banks toward the ends of the pipe section. The backfilling will be restricted to assure the displaced water in the ditch can be adequately handled by the pumps. As the river is backfilled, the river bed will be recontoured and compacted to its preconstruction condition. Impermeable trench plugs will be installed and the river banks will be stabilized. The top one foot of the trench will be backfilled with washed gravel appropriately sized for spawning habitat.

Flume Removal

The downstream sandbags covering the flume pipe will be removed first shortly after completing the crossing. Sandbags under the flume pipe on the downstream end will be left in place until the flume pipe is removed. The sandbags covering the upstream end of the flume pipe will then be removed slowly by hand. After the water flow through the construction area is reconnected, the remainder of the sandbags and the flume pipe will be removed. The flume pipe will be lifted from its perch, not drug or pulled from its location.

Alternate Dam and Pump Option

It should be noted that if the seasonal flows are low enough, the construction contractor may choose to dam and pump this river crossing. Should this type of crossing be chosen, the contractor would install a temporary dam on the upstream side of the construction right-of-way and then installing an isolation dam on the downstream side of the construction right-of-way. These isolation dams may be constructed of steel plates, sandbags, porta-dams, aqua dams or other similar devices that provide the same function and would be sited at the same location as the flume entrance and exit spots.

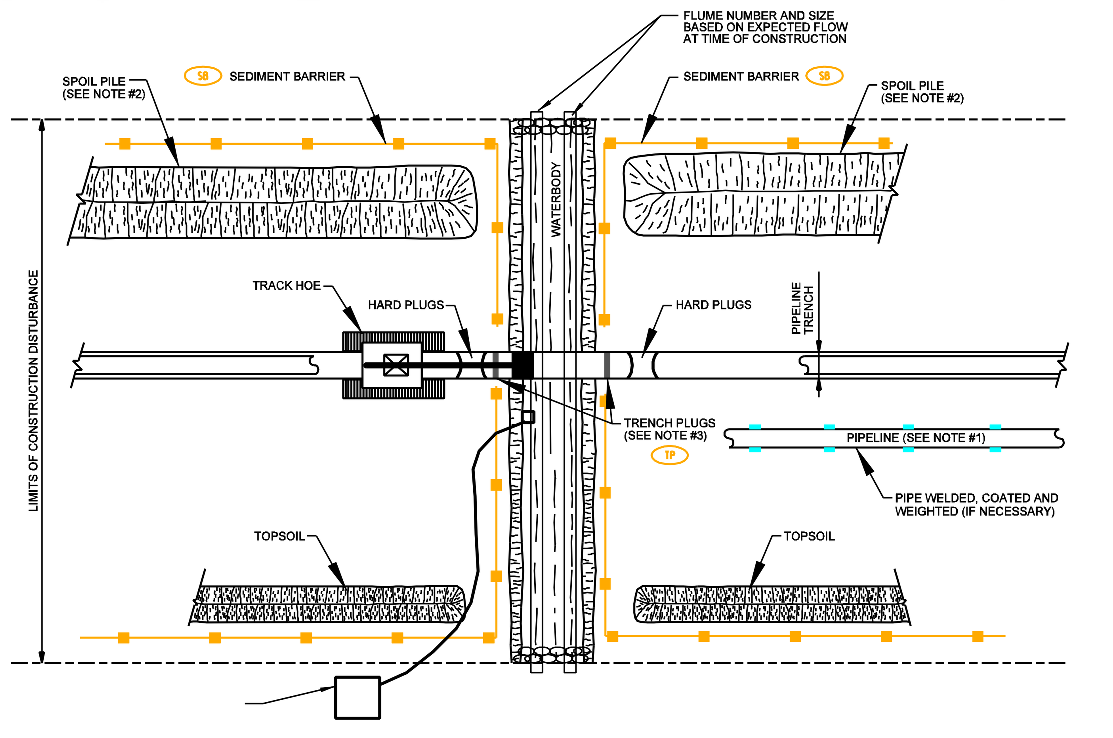
After the isolation dams have been installed, fish salvaging efforts will be completed within the isolation dams and the isolated area dewatered. Fish salvage efforts will be conducted by an ODFW certified biological contractor, as specified for the flumed crossing method.

As soon as the work area is appropriately isolated, the pipeline trench for the will be excavated across the river. The pipeline trench will be excavated to design depths as specified to accommodate potential scour. If bedrock is encountered during excavation; the top of pipe will be buried 24 inches below the top of bedrock.

After the pipe strings have been tied-in, the pipeline trench will be backfilled with the native material excavated from the trench and the contours of the river bed and river banks will be restored to approximate preconstruction contours. The top one-foot of the trench will be backfilled with washed gravel appropriately sized for spawning habitat. The isolation dams will be removed with the downstream dam being removed prior to the upstream dam.

Habitat Improvements

During clean up, the river banks will be returned to approximate preconstruction contours or to a stable slope (i.e., 3:1) and stabilized with erosion control fabric as necessary. River banks will be reseeded and the river banks and riparian areas will be planted with appropriate riparian tree and shrub species using the procedures outlined in Pacific Connectors Erosion Control and Revegetation Plan and in accordance with the FERC Wetland and Waterbody Construction and Mitigation Procedures as well as applicable federal, state, and local permit conditions. Shrub cuttings will be planted on 3-4 foot centers except for a 10-foot corridor center over the pipeline to facilitate operational surveys. Final soil erosion measures will be installed and maintained until the area is successfully revegetated.



TYPICAL DRY OPEN-CUT (FLUMED) WATERBODY CROSSING

OPEN CUT NOTES:

1. Designated workspace shown on the site specific plans is for spoil storage located on either side of the waterbody crossing adjacent to the proposed pipeline alignment. Additional Temporary Extra Work Area (TEWA) is necessary for support equipment/vehicles, supplies and materials, access to construction areas, including the temporary diversion channel and in stream diversion structures. Sediment barriers will be installed around workspace areas and spoil storage areas, where necessary to protect the waterbody from surface runoff.
2. The waterbody crossing will be installed as expeditiously as possible to minimize impacts to the waterway. The pipe trench will be backfilled using the native material excavated from the trench. Trench plugs will be installed at the banks on either side of the waterway.
3. If the waterway is navigable or used by recreational boaters, a mitigation plan for traffic interruption will be prepared.
4. Erosion and sediment control measures shall be inspected daily and repaired if necessary.
5. Schedule crossing during ODFW designated in water work window period between July 1 and September 15.
6. No refueling of mobile equipment within 100 feet of stream bank. Place sign posts 100 feet

   back from wetland boundary and advise no refueling. Refuel stationary equipment as per SPCC plan.
7. Leave hard plugs at the stream bank edge, until just prior to pipe installation.
8. Maintain stream flow throughout crossing construction.
9. Restore watercourse channel to approximate pre-construction profile and substrate.
10. This typical drawing is preliminary. Site specific design details will be completed prior to construction, based on site specific conditions at the time of construction. Construction phase sequence and specific details outlined in the site-specific plan may be approved in writing based on contractors written recommendations.

DEWATER NOTES:

1. Dewater structure shall be placed on a level, well vegetated site such that filtered water will flow away from structure and any work areas.
2. Flow rates into the discharge shall be such that water will be filtered through the structure and allowed to overflow.
3. Contractor shall utilize certified noxious weed free hay for structure.
4. Dewatering structures will be constructed and maintained according to the dewatering structure typical drawings found in the Erosion Control & Revegetation Plan (ECRP).

LEGEND

- 36-inch Proposed PCGP Project
- Original Alignment
- Construction Right-of-Way
- Temporary Construction Right-of-Way (Shown as white on photography)
- Temporary Extra Work Area
- Uncleared Storage Area
- Access Road
- Drivable Berm or Straw Bales
- Silt Fence

REFERENCE DRAWINGS

DRAWING NO.	TITLE
3430.29-029 & 030	CONSTRUCTION ALIGNMENT

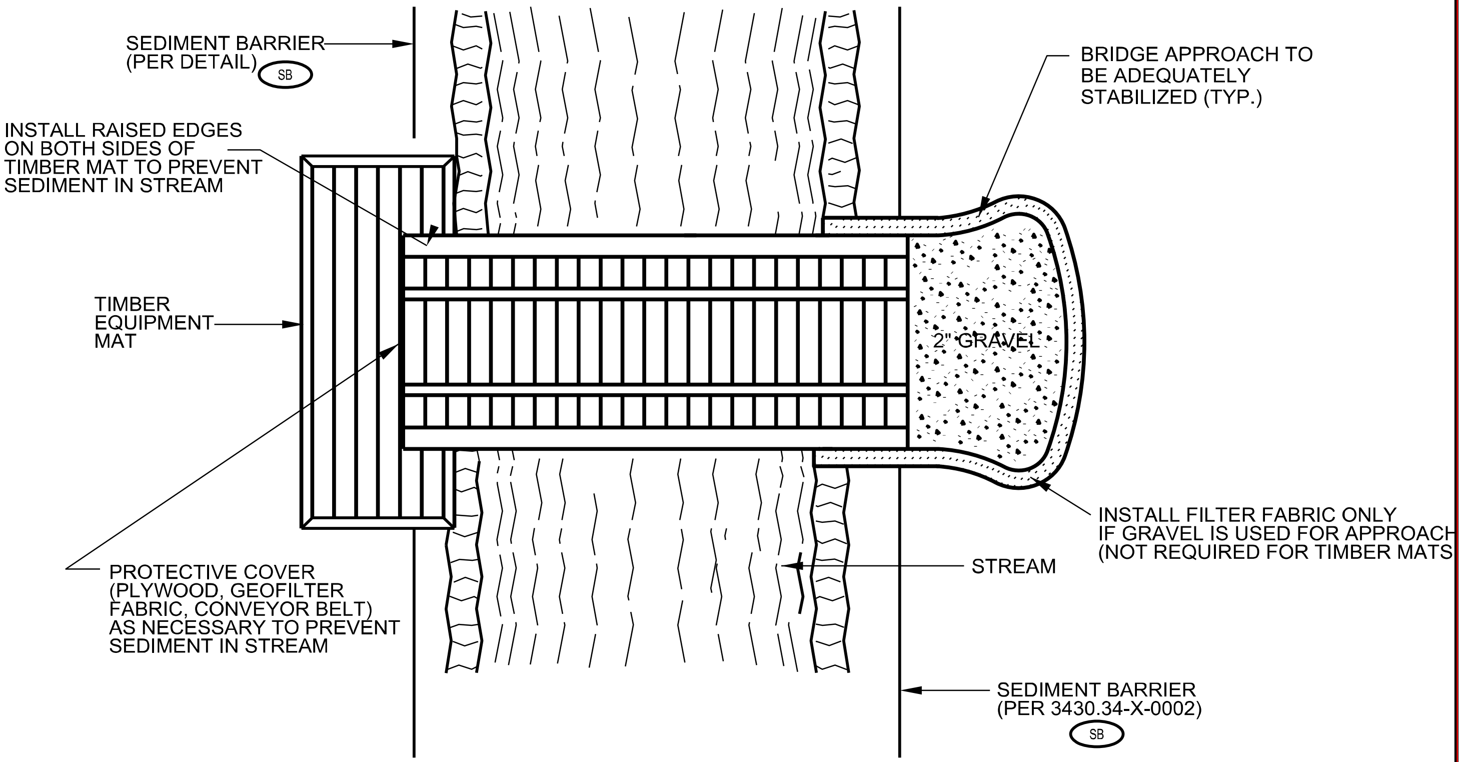
REVISIONS

NO.	DATE	BY	DESCRIPTION	W.O. NO.	CHK.	APP.
1	JUNE-2007	KLL	PREFILING 3rd DRAFT			
2	SEPTEMBER-2007	KLL	ISSUED FOR FERC FILING			

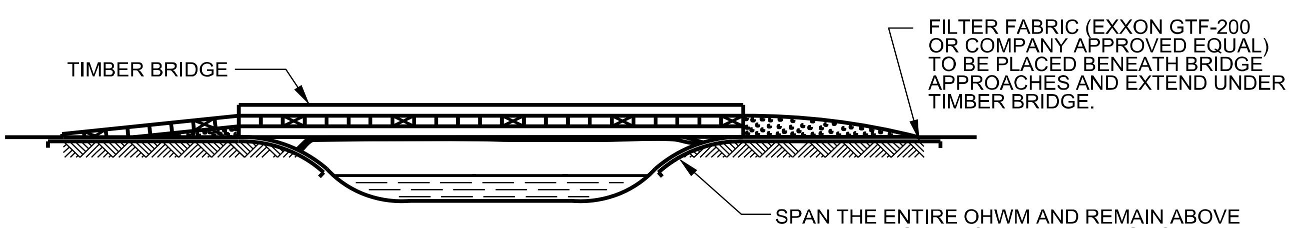
PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP
EAST FORK OF COQUILLE RIVER - OPEN CUT
MILE POST 29.89
SEC. 10, T-28-S, R-11-W
COOS COUNTY, OREGON

Pacific Connector GAS PIPELINE

DRAWN BY: KLL / JST	DATE: 5-29-2008	ISSUED FOR BID:	SCALE: 1" = 100'
CHECKED BY:	DATE:	ISSUED FOR CONSTRUCTION:	
APPROVED BY:	DATE:	DRAWING NUMBER: 3430.9-053	SHEET
WO:		6/9/2008 %DATE% Q:\Oregon_gas\Mapping\Waterbodies\3430_9-053.dgn	OF



PLAN



PROFILE

MINIMUM PERFORMANCE/DESIGN STANDARDS:

1. TIMBER BRIDGES SHALL BE ADEQUATELY ANCHORED AT ONE END.
2. BRIDGE APPROACHES SHALL BE EITHER COARSE AGGREGATE OR TIMBER EQUIPMENT MATS.
3. SEDIMENT AND DEBRIS SHALL NOT ENTER WATERBODY. PROVIDE RAISED EDGES ON BOTH BRIDGE EDGES AND PROTECTIVE COVER (PLYWOOD, GEOFILTER FABRIC, CONVEYOR BELT), AS NECESSARY, TO PREVENT SEDIMENT IN STREAM.
4. PERIODICALLY CHECK BRIDGE INSTALLATION AND REMOVE BUILD-UP OF SEDIMENT OR DEBRIS ON BRIDGE.
5. MATERIALS PLACED ALONG STREAM CHANNEL SHALL BE COMPLETELY REMOVED DURING FINAL CLEAN-UP. REMOVAL OF THIS STRUCTURE IS NOT CONTINGENT UPON ESTABLISHMENT OF PERMANENT VEGETATION.
6. THE TIMBER BRIDGE SHALL BE DESIGNED TO SPAND THE ENTIRE OHWM OF THE WATEBODIES AND REMAIN ABOVE THE WATER SURFACE ELEVATION AT ALL TIMES. ODFW RECOMMENDS 3-FT OF FREEBOARD FROM THE OHWM/ACTIVE CHANNEL TO THE BOTTOM OF THE BRIDGE.
7. CONTRACTOR MAY USE MANUFACTURED PORTABLE BRIDGES OR RAIL CAR BRIDGES AS SUBSTITUTES FOR THE MEASURES SHOWN, IF APPROVED BY COMPANY REPRESENTATIVE.
8. MID-STREAM BRIDGE SUPPORTS PIERS OR CULVERTS SHALL, SHALL BE USED TO PREVENT SETTLEMENT OF THE BRIDGE, IF NECESSARY. WHERE PIERS/CULVERTS ARE USED TO SUPPORT BRIDGES THEY SHALL NOT RESTRICT FLOW AND SHALL BE DESIGNED TO WITHSTAND AND PASS THE HIGHEST FLOW THAT WOULD OCCUR WHILE THE BRIDGE IS IN PLACE.
9. USE OF MID-STREAM BRIDGE SUPPORTS PIERS/CULVERTS WILL TRIGGER ODFW FISH PASSAGE PERMIT REQUIREMENTS AND APROVALS BEFORE INSTATALLATION.

DRAWING NO.	REFERENCE TITLE

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP

TYPICAL
TEMPORARY BRIDGE CROSSING
PB

Pacific Connector GAS PIPELINE SM

NO.	DATE	BY	REVISION DESCRIPTION	W.O. NO.	CHK.	APP.

DRAWN BY: KLL	DATE: 02-02-2001	ISSUED FOR BID:	SCALE: NOT TO SCALE
CHECKED BY:	DATE:	ISSUED FOR CONSTRUCTION:	
APPROVED BY:	DATE:	DRAWING NUMBER: 3430.34-X-0010 %TIME% %PATH%	SHEET 2 OF 2

Appendix 5
Fish Salvage Plan

Pacific Connector GAS PIPELINE

Pacific Connector Gas Pipeline, LP

Fish Salvage Plan

Pacific Connector Gas Pipeline Project

February 2019

1.0 INTRODUCTION

This fish salvage plan has been developed to minimize adverse effects to Endangered Species Act (ESA) listed salmonids (Southern Oregon/Northern California Coast coho salmon and Oregon Coast coho salmon), non-listed salmonids (Chinook, steelhead, cutthroat trout) and ESA-listed catostomids (Lost River sucker and shortnose sucker; Larson 2009) during construction of the Pacific Connector Gas Pipeline Project (Pipeline project) as well as other aquatic organisms. The plan has been developed to:

1. Exclude fish from instream construction sites;
2. Minimize risk of injury or death while capturing fish that might remain after exclusion efforts;
3. Minimize risk of injury or death due to handling captured fish; and
4. Release fish to non-impacted environments.

Portions of the plan relevant to salvaging ESA-listed salmonids were adapted from the protocol developed by Washington State Department of Transportation (WSDOT, 2008) which specifies procedures to 1) isolate the work area, 2) remove fish and dewatering the work area, 3) handle, hold and release fish, and 4) document fish that have been captured, handled, held and released and notify the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) when required.

2.0 PERMITS

The Oregon Department of Fish and Wildlife (ODFW) requires an Oregon Scientific Take Permit to take fish for scientific purposes, including rescue/salvage required for construction activities. (Required by ORS 497.298 and OAR 635-043, see http://www.dfw.state.or.us/fish/license_permits_apps/scientific_taking_permit.asp#oar).

In addition, an In Water Blasting Permit from the ODFW "is required for any use of explosives in the cause of removing any obstruction in any waters of this state, in constructing any foundations for dams, bridges or other structures, or in carrying on any trade or business" (Required by ORS 509.140, see http://licenseinfo.oregon.gov/?fuseaction=license_icon&link_item_id=14778).

For threatened or endangered species, permits will be required by NMFS and FWS for scientific research, enhancement of propagation or survival, and take that is incidental to an otherwise lawful activity.

3.0 INSTREAM CONSTRUCTION

Construction across waterbodies will occur within the ODFW recommended instream construction timing window, although the majority of bridges, where required, will be installed prior to and removed after the instream timing window. No work, including equipment crossing the stream to access the opposite bank when installing temporary bridges, would occur within the waterbody channel outside the ODFW-recommended construction window unless a waiver is obtained from ODFW. General timing of activities for each of the 8 construction spreads is discussed below. A more comprehensive description of potential impacts specific to each listed species has been included in the Applicant-Prepared Draft Biological Assessment (APDBA).

If water is present in the streambeds at the time of construction, Pacific Connector Gas Pipeline (PCGP) will utilize a dry-open cut crossing method (flume or dam and pump) to cross all minor and intermediate waterbodies consistent with the requirements of Section V.B.6 of the Federal Energy Regulatory Commission's (FERC) Wetland and Waterbody Procedures. Fluming and dam-and-pump procedures are described in Appendix BB to the POD. Both techniques require that the work space within a waterbody be isolated, usually by dams constructed of sand bags with interwoven plastic sheeting installed upstream and downstream from the site where the pipeline will be installed. Sand bag dams would be placed on the edges of the certificated construction right-of-way at the stream crossing site.

If blasting is required because the streambed is exposed bedrock, the dam-and-pump procedure will be utilized. Generally, the pipeline trench is not in the center of the instream construction right-of-way but offset to one side so that a temporary equipment crossing bridge can be placed on the opposite side of the right-of-way. The equipment bridge would be located across the stream within the area eventually to be isolated by the sand bag dams.

3.1 Fish Exclusion

Prior to any instream work and placement of the sand bags to be used for fluming or dam-and-pump procedures, as many fish as possible will be excluded from an area that includes the construction right-of-way. If blasting within the streambed or on stream banks is necessary during construction, the area of fish exclusion will likely be larger than the limits of the construction right-of-way across the waterbody. To minimize risk to listed and non-listed fish by blasting, they will be excluded from a distance where the overpressure change from the blast dissipates to 2.7 psi (Alaska Department of Fish and Game, 1991) a level for which no fish mortality would be expected (see Resource Report 3). Typical trench blasting scenarios use multiple 1 to 2-pound charges separated by an 8-milisecond delay to excavate the trench. With use of 1 to 2-pound charges in rock, the set back distance (at which 2.7 psi would occur) from the blast trench to the fish habitat is between 34 and 49 feet.

When using the dam-and-pump stream crossing methodology, the typical right-of-way distribution of an isolated streambed (dry open-cut) will be no less than 25-feet on one side of the pipe trench and 50+ feet on the opposite side of the pipe trench depending on whether it's a 75 or 95 foot width crossing. Therefore, an area within the waterbody crossing equivalent to the length of the blasting trench and approximately 25-feet wide, at most, would be exposed to instantaneous hydrostatic pressure changes above 2.7 psi. Thus, fish would be excluded within waterbodies from an additional 25 feet beyond both sides of the construction right-of-way.

One or more block nets will be installed upstream from the pipeline crossing, farther than 50 feet from the pipeline trench if blasting is required, and upstream from where the sand bag dam will be installed. The block net material is typically a 9.5 millimeter stretched mesh (WSDOT, 2008) that will prevent fish and other organisms from moving into the work area from upstream locations. Sites will be selected based on desirable attributes such as slower flows and without heavy vegetation, undercut banks, or deep pools so that the block net seals off the work area to the maximum extent possible. The block net(s) will be frequently inspected for sealing capacity and any accumulated leaf/debris will be removed as necessary for the proper function of the block nets. Block nets will be secured on both banks and within the stream channel to prevent failure (WSDOT, 2008).

Once the upstream block net is in place, one or more seining crews will proceed from that site to the downstream block net site. The objective of seining is not to capture fish but to maneuver them downstream and out of the construction zone. Small two-stick seines will be operated by at least 2 people although a third person may be required to move the seine over bottom debris and/or to seal the bottom of the net along the streambed. Similar to the block net, seines would be made of a 9.5 millimeter stretched mesh (WSDOT, 2008) that will prevent fish and other organisms from escaping.

In some situations where heavy instream and/or stream bank vegetation is present, or areas with undercut banks or deep pools, a haul seine or two-stick seine may not completely seal the water column from bank to bank or from water surface to streambed. In those situations, compressed air will be used to generate underwater bubbles, either from a perforated hose, wand or nozzle, that will drive fish away from vegetation debris, out from undercut banks or from deep pools in advance of the seining crew. Whether one or more air compressors are required to generate bubbles through more than one hose will depend on site conditions and the distances over which the bubble generator must operate. The use of bubble scare tactics will be site-dependent and may require one or more people in addition to the seining crew(s) to dislodge fish from difficult instream situations, to increase the efficiency of the seine, and to exclude as many fish as possible from the construction area.

Once the seining crew(s) reaches the downstream block net site, the downstream block net will be installed behind (upstream from) the seining crew(s). Similar precautions to ensure an adequate seal as those employed at the upstream site will be utilized. The downstream block net will also be monitored for accumulated litter and debris that will be removed as necessary while the block net is in use. These actions to exclude fish from the construction right-of-way and from areas where they could be affected by blasting will reduce or eliminate the risk of death or injury to fish from construction operations.

When construction has been completed, and the flume pipe or dam-and-pump diversion is removed, the upstream and downstream block nets will remain in place as the sand bag dams are removed. Generally, the downstream dam is the first to be removed. Retention of the block nets will limit fish from entering the construction zone as water flows over the site and when turbidity is most likely. Turbidity and sedimentation impacts associated with dry open cut methods are associated with 1) installation and removal of the upstream and downstream dams, 2) water leaking through the upstream dam and collecting sediments as it flows across the work area and continues through the downstream dam, 3) movement of instream rocks and boulders to allow proper alignment and installation of the flume and dams, and 4) when streamflow is returned to the construction work area after the crossing is complete and the dams and flume are removed (Reid et al., 2004). Both block nets will be removed when turbidity at the construction site has dissipated.

3.2 Dewatering and Fish Removal

Once the upstream and downstream block nets are in place, construction crews will begin building sand bag and plastic sheeting dams on the edges of the construction right-of-way to completely isolate the construction zone. When the dams are functional with flume pipes or dam-and-pump diversion installed and working, water contained between the dams will be pumped out and discharged into dewatering structures (see Appendix BB and I to the POD for fluming and dam-and-pump crossing details). All water intakes, whether for dewatering or for dam-and-pump diversion, will be screened according to NMFS standards to prevent entrainment of aquatic species. The screens will also prevent aquatic life from entering the intake hose if a block net should fail. Screens shall be placed approximately 2 to 4 feet from the end of the intake hose to assure fish are not pinned upon the screen (WSDOT, 2008).

Dewatering will be slow enough to allow for additional removal of fish if any remain after the fish exclusion procedures described above have been completed. During dewatering, the construction site will be monitored to prevent stranding of organisms.

PCGP will retain qualified fish removal and handling personnel to conduct the fish removal operations. These personnel will be on site when dewatering is occurring until the site is dewatered and the absence of stranded fish in the work area is confirmed by the EI and trench construction begins. Agency personnel will be allowed to observe the fish removal activities, but active participation will be limited to contractor personnel. PCGP will contract with either ODFW or a qualified consultant to capture the fish. Personnel that would handle and/or remove fish on federal lands would be approved by the Forest Service or the Bureau of Land Management or the Bureau of Reclamation (Reclamation) or be done directly by agency personnel if approved by ODFW. When crossing Reclamation facilities, fish salvage will be performed in coordination with Reclamation and the Klamath Falls U.S. Fish and Wildlife Service office. Additional fish removal from within the isolated construction site may include additional seining with two-stick seines, using dip nets, or removing fish and other organisms by hand. Additional fish removal will also be conducted in the remaining water column between the block nets and sand bag dams only if blasting is required to construct the pipeline through bedrock. Even though electrofishing can result in injury to fish, the risk of injury due to blasting in those water columns is likely to be greater and warrant electrofishing. Electrofishing will be used only when other methods have been determined to be ineffective (WSDOT, 2008), and if its use is approved by NMFS. At other (non-blasting) work areas, if other methods are ineffective, electrofishing will be utilized if its use is approved by NMFS.

The following have been incorporated or adapted from procedures and conditions developed by WSDOT (2008) to minimize risks to ESA-listed species by electrofishing to remove fish from construction zones:

1. The USFWS and NMFS will be provided a schedule 10 working days prior to the initiation of construction, whether or not electrofishing is actually utilized at a specific location.

2. Electrofishing shall only be conducted when a biologist with at least 100 hours of electrofishing experience is on site to conduct or direct all activities associated with capture attempts. Appropriate experience includes knowledge about electrofishing including the interrelated effects of voltage, pulse width and pulse rate on fish species and associated risk of injury/mortality, knowledge and abilities to recognize symptoms associated with galvanotaxis, narcosis, and tetany, and their respective relationships to injury/mortality rates.

3. The following table provides guidance for electrofishing in water where the potential to encounter ESA-listed juvenile fish exists. Only direct current (DC) or pulsed DC current will be used. Visual observation of the size classes of fish in the work area is helpful to avoid injury to larger fish by the mistaken assumption that they are not present.

Parameter	Initial Setting	Conductivity (µS/cm)	Maximum Settings
Voltage	100 V	≤300	800 V
		>300	400 V
Pulse Width	500 µs		5 ms
Pulse Rate	15 Hz		60 Hz [1]

[1] In general, exceeding 40 Hz will injure more fish

Source: WSDOT, 2008 - adapted from NMFS Backpack Electrofishing Guidelines, June 2000, and WDFW Electrofishing Guidelines for Stream Typing, May 2001

4. Electrofishing within each waterbody will begin with low settings for pulse width and pulse rate. If fish present in the area being electrofished do not exhibit an appropriate response, the settings shall be gradually increased until the appropriate response is achieved (galvanotaxis). The lowest effective setting for pulse width, pulse rate and voltage will be used to minimize personnel safety concerns and help minimize injury/mortality rates to listed fish species.
5. If blasting is required and electrofishing is necessary to remove fish from the water column between the sand bag dam and block net (whether upstream or downstream from the blasting site), an individual will be stationed at the downstream dam or block net continuously during electrofishing sessions to recover stunned fish in the event they are washed downstream and pinned against the structure or net.
6. The electrofishing operator will avoid allowing fish to come into contact with the anode. The zone of potential fish injury is 0.5 m from the anode. Netting shall never be attached to the anode. Techniques employed when using an unnetted anode keep fish farther from the anode and expose them to significantly less time in the zone of potential injury. Extra care shall be taken near in-water structures or undercut banks, in shallow waters or high-density fish areas. In these areas, fish are more likely to come into close contact with the anode because fish may be less visible and the voltage gradients may be abnormally intensified.
7. Voltage settings in shallow water sections shall be checked and readjusted by the operator, if necessary. When electrofishing areas near undercut banks or where structures may provide cover for fish, the anode will be used to draw the fish out by placing the activated anode near the area fish are likely present and slowly drawing the anode away. Fish experiencing galvanotaxis will be attracted to the anode and will swim away from the structure toward the anode so that they can be netted. This will not work on fish that experience narcosis or tetany. Therefore, fish response will be noted in adjacent areas prior to attempts made near structures. This should help avoid prolonged exposure of fish to the electrical field while in an immobilized state.
8. Electrofishing shall be performed in a manner that minimizes harm to fish. Once an appropriate fish response (galvanotaxis) is noted, the stream segment should be worked systematically, moving the anode continuously in a herringbone pattern through the water without electrofishing one area for an extended period of time. The number of passes will be kept to a minimum, will be dependent upon site-specific characteristics, and be at the discretion of the directing biologist. Adequate numbers of personnel shall be on-site to minimize the number of passes required for fish removal. Adequate staff to net, recover, and release fish as soon as possible shall be present. Fish shall be removed from the electrical field immediately. Fish shall not be held in the net while continuing to capture additional fish.

9. Condition of captured fish will be carefully observed and documented. Dark bands on the body and extended recovery times are signs of injury or handling stress. When such signs are noted, the settings for the electrofishing unit and/or manner in which the electrofishing session is proceeding will require adjustment and evaluation as to whether continued electrofishing is appropriate at the site.

10. Electrofishing will not occur when turbidity reduces visibility to less than 0.5 meter, when water conductivity exceeds 350 µS/cm, or when water temperature is above 18°C (64.4°F) or below 4°C (39.2°F).

Adult Pacific lamprey, and possibly ammocoetes, are expected to be captured during fish salvaging by seining. However, salvage techniques for salmonids may not be effective for salvaging ammocoetes which may remain in dewatered sediments. Electrofishing procedures to sample larval Pacific lampreys have been recommended (see Appendix A in FWS, 2010) but seining and use of dip-nets may also be effective once the workspace has been dewatered, depending on substrate conditions at the time of construction. A plan has been developed for salvaging Pacific lamprey ammocoetes and is provided in Attachment A.

3.3 Fish Handling, Holding and Release

The following has been adapted from procedures and conditions developed by WSDOT (2008) to minimize risks to ESA-listed species during their removal from construction zones and release:

1. Fish handling will be kept to the minimum necessary to remove fish from the work site.

2. Fish will not be sampled or anesthetized during removal activities as this protocol is intended to address fish removal not research. Fish species, number, age class estimate, and release location will be documented.

3. Individuals handling fish will ensure that their hands are free of sunscreen, lotion, or insect repellent and bare skin will be wetted to avoid drying out fish skin at points of contact and increasing potential for fungal or other skin lesions.

4. Fish or other aquatic life captured will immediately be put into dark colored containers filled with clean stream water. Fish removal personnel shall provide a healthy environment for fish with minimum holding periods and low fish densities in holding containers to avoid effects of overcrowding and providing aeration to keep the holding water oxygenated. Large fish shall be kept separate from smaller fish to avoid predation during containment. Water-to-water transfers will occur whenever possible.

5. ESA listed fish will not be transferred out of water to prevent added stress, unless necessary. Holding containers will be frequently monitored to assure that all specimens will be released unharmed. Shade areas and supplemental oxygen for fish holding shall be included in designing fish handling operations where conditions warrant.

6. Unless site conditions require alternative release locations, all fish captured by any means will be released upstream from the upstream block net. Release at an upstream site will ensure that the captured fish will be held for very short durations. If an ESA species is salvaged, it will be recorded and relocated without delay. Also, release

upstream will minimize potential effects to fish from turbidity generated when the sand bag dams are removed and water flows over the dry open-cut construction site.

7. Each released fish shall be capable of remaining upright and have the ability to actively swim upon release. ESA-listed or proposed fish will have priority over other species for release. Specimens will be transported in a timely manner to the site selected for release.

8. All dead ESA-listed fish will be preserved and delivered to the applicable regulatory agency (see documentation below) as required by permit conditions.

3.4 Documentation

1. All work area isolation, fish removal and fish release activity shall be thoroughly documented in a log book with the following information: project location, date, methods, personnel, instream temperature, visibility, electrofisher settings, and other comments.

2. Species, number of each species, age class estimate, and location of release will be recorded for all fish handled.

3. Information regarding injuries or mortalities to ESA-listed or proposed species will be documented and provided to NMFS or USFWS, depending on which agency has jurisdiction over that species, within a timeframe specified by each agency.

4.0 REFERENCES

Alaska Department of Fish and Game. 1991. Rationale for Blasting Standards (11 AAC 95) Developed to Prevent Explosive Injury to Fish. Alaska Department of Natural Resources Office of Habitat Management and Permitting. Online at: http://www.dnr.state.ak.us/habitat/explosives.htm

Larson, R. 2009. Fish Biologist, U.S. Fish and Wildlife Service, Klamath Falls, OR., personal communication with Edge Environmental, Inc. January.

Reid, S.M., F. Ade, and S. Metikosh. 2004. Sediment Entrainment During Pipeline Water Crossing Construction: Predictive Models and Crossing Method Comparison. Journal of Environmental Engineering and Science 3:81-88.

U.S. Fish and Wildlife Service. 2010. Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (*Entosphenus tridentatus*). Oregon Fish and Wildlife Office. Accessed online: http://www.fws.gov/oregonfwo/Species/Data/PacificLamprey/default.asp.

Washington State Department of Transportation. 2008. Chapter 14.0 In-Water Work. Pages 14.1 – 14.10 *in* Biological Assessment Preparation for Transportation Projects, Advanced Training Manual Version 10-08. Environmental Affairs Office, Washington State Department of Transportation, Olympia, WA.

Attachment A

Pacific Lamprey Ammocoete Salvaging Plan

ATTACHMENT A

Pacific Lamprey Ammocoete Salvage Plan

5.0 INTRODUCTION

Pacific lamprey (*Entosphenus tridentatus*) are found in coastal streams from California to Alaska. Pacific lamprey are a culturally important species, used by Native Americans for subsistence, ceremonial, and medicinal purposes (Columbia River Inter-Tribal Fish Commission 2011; FWS 2011). Pacific lamprey inhabit portions of the Coos, Coquille, South Umpqua, and Upper Rogue sub-basins, although they have probably been extirpated from streams above the Lost Creek Dam (William L. Jess Dam) on the Rogue River mainstem and Applegate Dam on the Applegate River, both within the Upper Rogue Sub-basin (ODFW 2005). Historical presence, only, has been documented in Upper Klamath sub-basin. If adult Pacific lamprey are present in streams crossed by the Pipeline in these sub-basins, they will be salvaged as well as other species at the time of construction as described in the *Fish Salvage Plan.*

Known presence of Pacific lamprey in waterbodies crossed by the Pipeline are included in Table M-1 in Appendix M to the Applicant-Prepared Draft Biological Assessment submitted to FERC in September 2018. Table A-1 below lists the waterbodies crossed by the Pipeline that are known or could support Pacific lamprey. Salvage of adult Pacific lamprey has been addressed in Section 3.2 of the *Fish Salvage Plan*, to which this Attachment A is appended.

Adult Pacific lamprey are parasitic during the portion of their life cycle within marine habitats but move up freshwater streams to spawn, generally between February and June. On the Oregon coast and in the Willamette Basin, Pacific lamprey have been observed spawning at the same time as winter steelhead, from February through May (Kostow 2002). Anadromous adults overwinter in freshwater, remaining for a year without feeding before spawning (FWS 2010). Pacific lamprey select spawning gravels, upstream from riffles and often near ammocoete habitat such as silty pools and banks (Kostow 2002). Spawning adults dig nests or “redds” in gravels and cobbles at the downstream ends of pools and slow water areas where water is flowing over gravel and cobble as well as low-gradient riffles (Natural Resources Conservation Service 2011).

Larval lamprey, or ammocoetes, live in fresh water where they are burrowing filter feeders. Lamprey undergoing metamorphism and spawning adults do not feed (Kostow 2002). Once they emerge from redds, larval lamprey drift downstream to slow water habitats such as backwaters, alcoves, sloughs or pocket pools where they burrow into mud, silt, or silty sand bottoms covered with organic detritus (Natural Resources Conservation Service 2011). Most downstream movement occurs at night (Kostow 2002). Although they are not strong swimmers, ammocoetes can make short upstream migrations (Moser et al. 2007); however, the extent of upstream movements is unknown (Columbia River Basin Lamprey Technical Workgroup 2004). Larval Pacific lamprey have been observed swimming against low velocity currents (0.1 m per second) for prolonged periods (>40 minutes) under laboratory conditions (Dawson et al. 2015). Ammocoetes of most species generally remain in natal streams for 3 to 7 years before transforming (metamorphosing/macrophthalmia) into adults in late September through October (FWS 2010; Dawson et al. 2015).

6.0 AMMOCOETE SALVAGE

2.1 Basic Assumptions

Based on the information included in Section 1, the following assumptions have been incorporated into the ammocoete salvage plan:

- ammocoetes are not expected in small, first order, headwater streams and probably not in second order streams, especially those that are intermittent and dry at the time of construction;
- ammocoetes are not expected at sites with bedrock substrates where suitable habitat is absent;
- ammocoetes would not be affected in waterbodies crossed by trenchless construction methods (HDD, direct pipe);
- ammocoetes are expected in suitable habitats of waterbodies where ODFW has documented occupancy that would be crossed in the Coos, Coquille, South Umpqua, and Upper Rogue sub-basins;
- ammocoetes are expected in suitable habitats at depositional sites (including alcoves, side channels, backwater areas, pools) and in low velocity stream and river margins that recruit fine sands and silts, downstream of spawning areas;
- ammocoetes are expected in suitable habitats of waterbodies crossed if adult Pacific lamprey are salvaged during implementation of the *Fish Salvage Plan*; and
- ammocoetes may occur for unknown distances upstream in suitable habitats of tributaries to waterbodies where ODFW has documented Pacific lamprey occupancy in the Coos, Coquille, South Umpqua, and Upper Rogue sub-basins. Tributaries that provide spawning and rearing habitats for coho salmon and/or steelhead are assumed to be suitable for occupancy by larval lamprey.

2.2 Ammocoete Salvage

1. Ammocoete salvage will be coordinated with salvage of other aquatic species (including adult lamprey), as described in the *Fish Salvage Plan*, to which this Attachment A is appended.
2. Prior to any instream work, biologist(s) employed to salvage fish would evaluate each Pipeline crossing site within the specified geographic range of Pacific lamprey for likelihood of presence. Potential risks to larval lamprey in waterbodies crossed by the Pipeline are included in Table A-1.
3. Salvaging will be conducted at waterbody crossings where Pacific lamprey are known to occur and where there is potential habitat for ammocoetes, as described above. Salvaging would also be conducted at waterbody crossings if adult Pacific lamprey are salvaged during implementation of the *Fish Salvage Plan*.
4. Ammocoete salvage will increase the total time that stream flow would be diverted and fish movement would be blocked. Therefore, adequate preparation with adequate numbers of knowledgeable personnel will be allotted to minimize the time spent for ammocoete salvage.

5. To the extent feasible, salvage will be conducted within 15 feet on either side of the centerline for a total salvage width of approximately 30 feet centered on the pipeline.

   The 30-foot salvage width will accommodate the entire excavated trench line and an additional 7.5 feet beyond the trench line, which is estimated to be a total of 15 feet wide for the 36-inch pipe, based on a top of pipe minimum burial depth of 5-feet. Suitable habitat beyond this distance from the pipeline trench would not be expected to become desiccated while the pipeline is installed because groundwater/hyporheic conditions are not expected to be affected at this distance from the excavated trench line due to the short duration of construction.

6. Because of risks of electofishing to ESA-listed salmonids (discussed in Section 3.2 of the *Fish Salvage Plan*), salvage of ammocoetes above the trench line will occur after salmonids have been salvaged within the construction right-of-way, which has been isolated by block nets and dam structures placed upstream and downstream and most of the workspace has been dewatered (see Section 3.2 in the *Fish Salvage Plan*) to depths of approximately 6 inches.

7. Use of a backpack or shore-based electrofisher will follow the two-stage method described by Moser et al. (2007) and FWS (2010).

   A 90–125 V direct current with a 10–25% duty cycle is applied at a slow rate of 3 pulses/second to induce ammocoetes to emerge from the sediment. A pattern of three slow pulses followed by a skipped pulse (3:1 pulse pattern) also helps to encourage emergence. Immediately after the ammocoetes emerge, a fast pulse setting of 30 pulses/second is used to immobilize them. Extended exposure to electrofishing can result in electronarcosis of buried ammocoetes and failure to emerge.

8. Emerging ammocoetes will be captured by seines and/or dipnets. The number of passes over potential habitat will be kept to a minimum, will be dependent upon site-specific characteristics, and will be at the discretion of the directing biologist. Adequate numbers of personnel will be on-site to minimize the number of passes required for maximum ammocoete removal.

9. Handling and release of captured ammocoetes will follow procedures in Section 3.3 in the *Fish Salvage Plan*.

7.0 DOCUMENTATION

Documentation of ammocoete salvage will follow requirements outlined in Section 3.4 in the *Fish Salvage Plan*.

8.0 REFERENCES

Columbia River Basin Lamprey Technical Workgroup. 2004. Passage Considerations for Pacific Lamprey. J. Stone Coordinator. U.S. Fish and Wildlife Service. Available online: http://cfw.nwcouncil.org/Committees/LTWG/meetings/2004_1005/Lamprey%20Passage%20Considerations%20October%205%202004.pdf

Columbia River Inter-Tribal Fish Commission. 2011. Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. Final Decision Document. Nez Perce, Umatilla, Yakama Warm Springs. Accessed online: http://fishery.critfc.org/FiSci/tdn/lamprey/lamprey_plan.pdf.

Dawson, H.A., B.R. Quintella, P.R. Aleida, A.J. Treble, and J.C, Jolley. 2015. The Ecology of Larval and Metamorphosing Lampreys. Chapter 3. Pages 75-137 *in* M.F. Docker (editor). Lampreys: Biology, Conservation and Control. Fish and Fisheries Series 27, Springer Science.

Kostow, K. 2002. Oregon Lampreys: Natural History Status and Analysis of Management Issues. Oregon Department of Fish and Wildlife, Salem, OR.

Moser, M.L., J.M. Butzerin, and D.B. Dey. 2007. Capture and Collection of Lampreys: the State of the Science. Reviews in Fish Biology and Fisheries 17(1):45-56.

Natural Resources Conservation Service. 2011. Pacific Lamprey and NRCS: Conservation, Management and Guidelines for Instream and Riparian Activities. Biology Technical Note No. 51. USDA-NRCS, Portland, OR.

Oregon Department of Fish and Wildlife. 2005. Oregon Native Fish Status Report. Fish Division, Oregon Department of Fish and Wildlife, Salem, Oregon.

Oregon Department of Fish and Wildlife. 2008. Oregon Guidelines for Timing of In-Water Work to Protect Fish and Wildlife Resources. Oregon Department of Fish and Wildlife, Salem, Oregon.

Oregon Department of Fish and Wildlife. 2017. Fish Habitat Distribution Data. GIS Shapefiles. Available online: https://nrimp.dfw.state.or.us/nrimp/default.aspx?p=259.

U.S. Fish and Wildlfie Service. 2010. Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (*Entosphenus tridentatus*). Oregon Fish and Wildlife Office. Accessed online: http://www.fws.gov / oregonfwo / Species / Data / PacificLamprey / default.asp.

U.S. Fish and Wildlife Service. 2011. Pacific Lamprey (*Entosphenus tridentatus*) Assessment and Template for Conservation Measures. U.S. Fish and Wildlife Service, Region 1. Portland, OR.

Table A-1
Waterbodies Crossed by the Proposed Pipeline from which Larval Pacific Lamprey Could Be Salvaged

Watershed and Waterbody Crossed	Approximate Pipeline Milepost (MP)	Landowner	Waterbody Type	Pacific Lamprey Presence [1]	Proposed Crossing Method	Risk to Larval Lamprey	Salvage Proposed	Fishery Construction Window [2]
Coos Sub-basin (HUC 17100304), Coos Bay-Frontal Pacific Ocean (HUC 1710030403) Fifth field Watershed								
Estuary Drain (Alt Wet NH (West))	0.00	State	Estuarine	Assumed	HDD Pullback	None – no disturbance to substrate	No	Oct 1 to Feb 15
Coos Bay (NE-26) WB-T02-001	0.28 to 1.00	State	Estuarine	Present	HDD	None – no disturbance to substrate	No	Oct 1 to Feb 15
Coos Bay (NE-26) WB-T02-002 W-T02-001D	1.46 to 3.02	State	Estuarine	Present	HDD	None – no disturbance to substrate	No	Oct 1 to Feb 15
Kentuck Slough (EE-SS-9004)	3.02 to 6.39R	Private	Perennial	Present	HDD Pullback	None – no disturbance to substrate	No	Jul 1 to Sep 15
Trib. to Coos Bay (EE-6)	6.39R	Private	Perennial	Assumed	Dry Open-Cut	Risk - if suitable habitat is within 15 feet of the pipeline centerline	To be determined on-site	Jul 1 to Sep 15
Coos River (BSP-119)	11.13R	Private	Estuarine	Present	HDD	None – no disturbance to substrate	No	Oct 1 to Feb 15
Vogel Creek (SS-100-005)	11.55BR	Private	Perennial	Unlikely	Dry Open-Cut	Unlikely – crossing is 1,250 m upstream from confluence with Coos River	To be determined on-site	Jul 1 to Sep 15
Coquille Sub-basin (HUC 17100305), North Fork Coquille River (HUC 1710030504) Fifth field Watershed								
Steinnon Creek (BR-S-63)	24.32BR	BLM – Coos Bay District	Perennial	Present	Dry Open-Cut	Risk - if suitable habitat is within 15 feet of the pipeline centerline	To be determined on-site	Jul 1 to Sep 15
N. Fork Coquille River (BSP-207)	23.06	Private	Perennial	Present	Dry Open-Cut	Risk - if suitable habitat is within 15 feet of the pipeline centerline	To be determined on-site	Jul 1 to Sep 15
Middle Creek (BSP-133)	27.04	BLM – Coos Bay District	Perennial	Present	Dry Open-Cut	Risk - if suitable habitat is within 15 feet of the pipeline centerline	To be determined on-site	Jul 1 to Sep 15
Coquille Sub-basin (HUC 17100305), East Fork Coquille River (HUC 1710030503) Fifth field Watershed								
E. Fork Coquille River (BSP-71)	29.85	Private	Perennial	Present	Dry Open-Cut	Risk- if suitable habitat is within 15 feet of the pipeline centerline	To be determined on-site	Jul 1 to Sep 15
Coquille Sub-basin (HUC 17100305), Middle Fork Coquille River (HUC 1710030501) Fifth field Watershed								
None								
South Umpqua (HUC 17100302) Sub-basin, Olalla Creek-Lookingglass Creek (HUC 1710030212) Fifth field Watershed								
Olalla Creek (BSP-155)	58.78	Private	Perennial	Present	Dry Open-Cut	Risk - if suitable habitat is within 15 feet of the pipeline centerline	To be determined on-site	Jul 1 to Sep 15

Watershed and Waterbody Crossed	Approximate Pipeline Milepost (MP)	Landowner	Waterbody Type	Pacific Lamprey Presence [1]	Proposed Crossing Method	Risk to Larval Lamprey	Salvage Proposed	Fishery Construction Window [2]
McNabb Creek (NSP-13)	60.48	Private	Perennial	Unlikely	Dry Open-Cut	Unlikely – crossing is 1,425 m upstream from confluence with Olalla Creek	To be determined on-site	Jul 1 to Sep 15
South Umpqua (HUC 17100302) Sub-basin, Clark Branch-South Umpqua River (HUC 1710030211) Fifth field Watershed								
Kent Creek (BSP-240)	63.97	Private	Perennial	Unlikely	Dry Open-Cut	Unlikely – crossing is 3,900 m upstream from confluence with S. Fork Umpqua R.	To be determined on-site	Jul 1 to Sep 15
Rice Creek (S2-04; BSP-227)	65.76	Private	Perennial	Unlikely	Dry Open-Cut (bedrock substrate)	Unlikely – crossing is 920 m upstream from confluence with S. Fork Umpqua R.	To be determined on-site	Jul 1 to Sep 15
Willis Creek (BSP-168)	66.95	Private	Perennial	Unlikely	Dry Open-Cut (bedrock substrate)	Unlikely – crossing is 1,200 m upstream from confluence with S. Fork Umpqua R.	To be determined on-site	Jul 1 to Sep 15
South Umpqua River (BSP-26)	71.34	Private	Perennial	Present	Direct Pipe	None – no disturbance to substrate	No	Jul 1 to Aug 31
South Umpqua (HUC 17100302) Sub-basin, Myrtle Creek (HUC 1710030210) Fifth field Watershed								
None								
South Umpqua (HUC 17100302) Sub-basin, Days Creek-South Umpqua River (HUC 1710030205) Fifth field Watershed								
Saint John Creek (ASP-303)	92.62	Private	Perennial	Unlikely	Dry Open-Cut	Unlikely – crossing is 3,300 m upstream from confluence with South Umpqua R.	To be determined on-site	Jul 1 to Sep 15
South Umpqua River (ASP-196)	94.73	Private	Perennial	Present	Diverted Open-Cut	Risk - if suitable habitat is within 15 feet of the pipeline centerline	To be determined on-site	Jul 1 to Aug 31
South Umpqua (HUC 17100302) Sub-basin, Upper Cow Creek (HUC 1710030206) Fifth field Watershed								
None								
Upper Rogue (HUC 17100307) Sub-basin, Trail Creek (HUC 1710030706) Fifth field Watershed								
Trib. to Trail Creek (ASI-206)	121.57	Private	Intermittent	Unlikely	Dry Open-Cut	Unlikely – crossing is 2,000 m upstream from confluence with Rogue River	To be determined on-site	Jun 15 to Sep 15
Upper Rogue (HUC 17100307) Sub-basin, Shady Cove-Rogue River (HUC 1710030707) Fifth field Watershed								
Rogue River (ASP-235)	122.65	Private	Perennial	Present	HDD	None – no disturbance to substrate	No	Jun 15 to Sep 15
Upper Rogue (HUC 17100307) Sub-basin, Big Butte Creek (HUC 1710030704) Fifth field Watershed								
None								
Upper Rogue (HUC 17100307) Sub-basin, Little Butte Creek (HUC 1710030708) Fifth field Watershed								
None								
Notes: [1] ODFW 2017 [2] ODFW 2008								

Appendix 6
Risk Assessment

Stream Crossing Risk Analysis
Stream Crossing Risk Analysis Addendum

Stream Crossing Risk Analysis

Pacific Connector Gas Pipeline
Coos, Douglas, Jackson and Klamath Counties, Oregon

for
Pacific Connector Gas Pipeline, LP

August 29, 2017

GeoEngineers
Earth Science + Technology

Stream Crossing Risk Analysis

Pacific Connector Gas Pipeline
Coos, Douglas, Jackson and Klamath Counties, Oregon

for
Pacific Connector Gas Pipeline, LP

August 29, 2017

GeoEngineers

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Stream Crossing Risk Analysis

Pacific Connector Gas Pipeline
Coos, Douglas, Jackson, and Klamath Counties, Oregon

File No. 22708-001-00

August 29, 2017

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INTRODUCTION

This report describes the riverine resources and potential risks associated with stream crossings along the Pacific Connector Gas Pipeline alignment that is proposed for construction by Pacific Connector Gas Pipeline, LP (PCGP). The PCGP route extends from a new liquefied natural gas (LNG) terminal in Coos Bay, Oregon, to the California border near Malin, Oregon (Figure 1). The natural gas pipeline will have a diameter of 36 inches and a total length of about 229 miles. A wide variety of terrain and geologic conditions exist along the planned pipeline alignment. Route planning to date has attempted to avoid as many stream crossings and other geologic hazard areas to the extent possible.

For the purposes of hazards associated with stream crossings in this report, a distinction is made between the hazards associated with a stream or river behavior expected to occur over the life of the project, and the risk associated with that hazard. In the following discussions, statements of risk apply to the potential for exposure of the pipeline resulting from stream and river channel erosion and/or movement. It is recognized that the consequences of a pipeline exposure may include rupture and involve fire and/or explosion. However, the consequences of exposure are location-specific and are not considered in the following evaluations of risk to the pipeline.

This Stream Crossing Risk Analysis is provided by PCGP in response to information requested as part of a previous filing in a March 2, 2010 letter from the Oregon Department of Environmental Quality (DEQ) addressed to Jordon Cove Energy, LP, Oregon International Port of Coos Bay, and Pacific Connector Gas Pipeline, LP. In that letter, DEQ states:

"*Fluvial processes need to be understood to determine risk and contingency actions in choosing crossing locations, choosing crossing methods and future monitoring and response*"

and that:

"*DEQ supports risk assessment for stream crossings based on fluvial geomorphic analyses as recommended by the US Fish and Wildlife Service (USFWS) comments with Appendix describing the federal evaluation approach. Please apply this methodology to assess risk of potential impairment due to fluvial processes on all stream crossings*."

A risk assessment was completed by PCGP according to the protocol identified by DEQ. PCGP confirmed the approach through progress meetings with DEQ, U.S. Army Corps of Engineers (Corps) and USFWS representatives. Pipeline design and construction measures that are commensurate with the results of the risk assessment have been developed and are described in this report.

SCOPE

The purpose of the Stream Crossing Risk Analysis is to:

- Identify the dominant fluvial processes present at each of the stream crossings along the PCGP route.
- Determine the potential response of the stream channel in the vicinity of the stream crossing to pipeline construction and operation.
- Identify high-level riparian and aquatic habitat characteristics of each stream crossing, for purposes of determining the crossing's overall risk rating.

- Estimate the degree to which aggregate habitat characteristics could be affected by pipeline installation.
- Assign a risk level to each stream crossing for the channel stability and habitat quality measures.
- Identify design guidance, contingency measures, and monitoring protocol specific to crossings within each risk level.

The following specific scope of services has been completed during preparation of this Stream Crossing Risk Analysis:

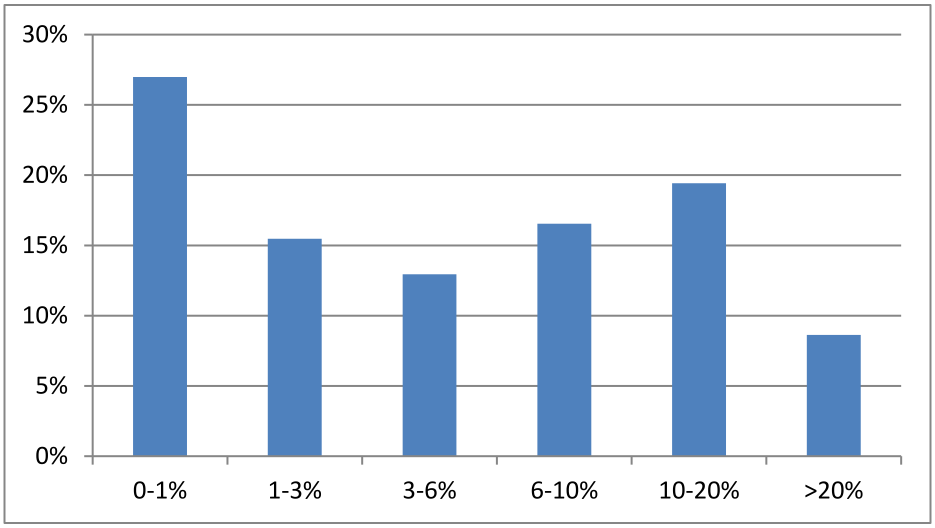
1. Review of the DEQ data requests and work plan development.
2. Compile all existing data from previous PCGP studies pertaining to stream crossings
3. Identify data gaps and collect published data and GIS data layers from public agencies or from consultants.
4. Develop a comprehensive Geographic Information Systems (GIS) database to support all analyses requested by DEQ, including the Stream Crossing Risk Analysis and Water Quality Studies.
5. Conduct a focused, on-the-ground site reconnaissance of stream crossings spanning geology, ecoregion, aspect, and width classes where access was available.
6. Update the database with field data.
7. Complete the Risk Analysis according to the federal guidance and USFWS protocol.

PROJECT BACKGROUND

The project alignment extends 229 miles through southwestern Oregon and crosses four physiographic provinces. The pipeline route begins in Coos Bay within the Coast Range physiographic province, an area underlain by estuarine and alluvial deposits in lowland areas and sedimentary rocks in the uplands. The alignment then passes eastward through the Klamath Mountains physiographic province, which consists of several complex geologic terrains composed of metamorphosed and fractured volcanic and marine sedimentary rocks. East of the Klamath Mountains, the pipeline route enters the Cascade Range physiographic province and crosses the Western Cascades, a range of dormant volcanoes, and their more recent counterpart the High Cascades, a chain of geologically active volcanoes with high, andesitic peaks. The easternmost section of the alignment is within the Basin and Range physiographic province, an area characterized by ridges and valleys that are separated by faulting (Burns, 1998; GeoEngineers, 2017a). The distribution of stream gradients crossed by the alignment (Figure 2) reflects this physiography.

PCGP proposes to cross 330 waterbodies listed in Table A2-2 of Resource Report (RR) 2 of Pacific Connector Certificate application (2017). Ditches or canals are included in Table A2-2 of RR2 and are not considered as having the potential for natural channel processes; these were identified on aerial photographs and topographic maps as described below and carried into the initial risk evaluation. Several of the waterbodies identified in Table A2-2 consist of stock ponds, colluvial hollows without established stream channel beds or banks, or ditches and canals that, upon field inspection and review of existing information, are artificially maintained and do not function with normative fluvial geomorphic processes. Other waterbodies were located in the construction right of way but would not be trenched for pipeline installation across their channel course. Because the risk analysis is specifically geared toward characterizing and assessing the risk associated with pipeline installation on fluvial processes, it is not applicable to these waterbodies. Removing these cases from the analysis, a total of 173 crossings were evaluated using the USFWS risk matrix. Management approaches for irrigation canals and ditches in the Bureau of Reclamation Klamath Project are described in PCGP (2017).

FIGURE 2. DISTRIBUTION OF CHANNEL GRADIENTS FOR STREAMS CROSSED BY THE PCGP PROJECT



Proposed site construction and restoration techniques and approaches for the PCGP project have been outlined and their impacts assessed to date in a number of environmental documents, specifically:

- RR1 or RR2 of the Pacific Connector Certificate Application (2017), including the following appendices:
  - Appendix B.1 "Erosion Control and Revegetation Plan" (ECRP); RR1
  - Appendix F.2 "Groundwater Monitoring and Mitigation Plan"; RR2
  - Appendix E.2 "Water Crossing Plans and Figures"
  - Appendices G.2, H.2, and I.2 of RR2 related to horizontal directional drilling methods.
- RR3 of the Pacific Connector Certificate Application (2017)

Impact analyses contained in these documents were based, in turn, on a number of specialty investigations. Of particular importance to this risk investigation are two additional reports:

- Geologic Hazards and Mineral Resources Report (including the Phase II Scour Assessment, RR6; GeoEngineers, 2017b).
- Wetland Delineation Report (ICF Jones & Stokes, 2009). This report provides an inventory of stream crossings in the proposed alignment and presents the mapped Ordinary High-Water Marks (OHWM) for waters of the state.

The use of these documents is described in the Methods section of this report.

Maintaining the stability of stream channels and their associated instream and riparian/floodplain habitat structure in association with in-water disturbance is a key component to maintaining the beneficial uses of those streams. PCGP submitted a Joint Permit Application (JPA) to the Corps and Oregon Department of State Lands (DSL) for permission to remove and fill materials from wetlands and waters of the state under Section 404 of the Clean Water Act (PCGP, 2017). As part of previous filings of the JPA, in regards to the Clean Water Act Section 401 water quality certification of the JPA, the DEQ requested on March 2, 2010 that PCGP evaluate stream crossings along its route according to the Pipeline Screening Risk Matrix. This matrix was developed by the USFWS and presented in its December 23, 2009 comments on the JPA.

After project permits have been obtained, PCGP will be able to plan for acquiring easements needed for construction. Following this step, a pre-construction survey will occur to document site conditions. This survey will be performed by a team of professionals qualified to assess terrestrial and aquatic habitat and the geotechnical and geomorphic conditions germane to pipeline construction across stream channels and ditches. Once this survey is completed, project construction will move forward as described in these permit documents.

This report documents the results of a comprehensive data compilation and risk analysis of this previously collected and evaluated information together with newly developed information on waterbody crossings by PCGP. The pipeline risk analysis framework was developed in late 2009 and first presented to PCGP as a response to a previous certificate application in December 23, 2009 by USFWS. The risk analysis is part of a broader evaluation of potential water quality impacts requested by DEQ specifically with regard to temperature, hyporheic exchange, turbidity, nutrients, and metals.

CONSTRUCTION AND SITE RESTORATION METHODS

Construction of the pipeline at the majority of those crossings will involve open trenching, primarily dry open cut, which will remove and replace bed and bank materials from the stream. The pipeline will also be installed using trenchless methods (conventional bore or horizontal directional drilling, representing no instream surface disturbance) at 6 locations. Details of typical stream crossing construction are described in Appendices C.2, D.2, and E.2 in RR2 and site restoration is described in Appendix B.1 in RR1 (PCGP, 2017). Key components of the design and proposed construction methods that were considered during this risk analysis are as follows:

- The PCGP alignment was carefully selected to avoid geologic hazards (e.g., landslides, debris flow hazard zones) and to minimize impacts to stream crossings.

  Nineteen crossings will be accomplished using trenchless methods and one will be spanned. Those crossings that are not expected to disturb the streambed and streambank surfaces are not included in the risk analysis.

- Mitigation measures are planned for streams that were previously identified as being at high risk for channel migration and scour, as described in the RR6 Phase II Channel Migration and Scour Analysis (GeoEngineers, 2017b). As described in Appendices C.2, D.2 and E.2 of RR2 (PCGP, 2017), "The final design will include additional depth requirements and the distance away from the stream that additional pipe depth will be needed. The Phase II Channel Migration and Scour Analysis addressed the need for hydrologic controls or bank armoring that may be necessary to ensure that the project disturbance does not cause lateral migration, head cutting, scour, or debris loading of streams."

- Once all easements are in place and construction is scheduled, PCGP will perform a survey of aquatic habitat to document immediate pre-project conditions for purposes of finalizing construction and site restoration methods for each crossing.
- A site-specific review of waterbody crossings relative to the findings and conclusions of this risk analysis will be conducted prior to construction as outlined in this report.
- The PCGP disturbance width is limited by FERC guidelines to 75 feet through waterbodies, where feasible, based on site-specific conditions and engineering constraints. The disturbance width is limited to 95 feet outside of designated waterbodies.
- The excavation cross section for installation of a 36-inch pipe is expected to be 4 to 6 feet wide at the bottom, 6 to 12 feet wide at the top, and 6 to 12 feet deep absent difficult topographic conditions.
- Site restoration will replace materials to the pre-project grades as the default condition. Steep slopes may be addressed by being laid back to more gentle configurations or reconstructed with structural fill as described in the ECRP narrative. As described in Appendices C.2, D.2, and E.2 of RR2 the Pacific Connector Certificate Application, "After the pipe has been installed, the trench will be backfilled with the native material that was excavated from the trench. In all fish-bearing streams, the upper 1 foot of the trench will be backfilled with clean gravel or native cobbles. The backfill material will match the natural streambed material size, gradation and composition as closely as possible. The stream bed profile will be restored to pre-existing contours and grade conditions. To restore the streambanks, PCGP will explore options such as tree revetments, stream barbs/flow deflectors, toe-rock and vegetation riprap before using hard bank protection. Streambanks will be returned to their preconstruction contours or shaped to a stable angle (3:1). Erosion control fiber fabric or matting will be installed on slopes adjacent to streams. The use of rip-rap is not anticipated, but if used would be limited to the areas where flow conditions preclude effective vegetation stabilization techniques. On some banks, depending on site-specific conditions, fiber rolls may also be installed to stabilize bank toes. The streambanks will be seeded and woody riparian vegetation planted for stabilization."
- Site revegetation, as described in Appendices C.2, D.2, and E.2 of RR2 of the Pacific Connector Certificate Application, will use weed-free native plants and seeds that are adapted to the local moisture regime to achieve maximum allowable restoration to high-functioning riparian habitat. Specific prescriptions outlined in this document include:

    a. "The riparian strip would be maintained to allow an herbaceous cover 10 feet in width centered over the pipeline to facilitate corrosion and leak surveys. Trees that are within 15 feet of the pipeline and are 15 feet in height would be selectively removed from the corridor. The remaining area of the construction right-of-way could be replanted with trees that would provide greater height and stream shading over time."

    b. "On a site-specific basis, and in consultation with individual landowners, riparian areas (of both perennial and intermittent waterbodies) within PCGP's permanent easement will be restored and enhanced using plantings of native shrubs and trees to within 25 feet of the streambanks, depending on existing land use and vegetation conditions."

    c. "Riparian revegetation species will incorporate fast growing native trees and shrubs (cottonwood trees and willows) placed closest to the bank top to provide canopy recovery as quickly as possible to shade and overhang the waterbodies. Plantings will conform to FERC's Wetland and Waterbody Procedures (part VI.D.1) which recommend that trees exceeding 15 feet tall grow no closer than

15 feet to the pipeline. The riparian strip will generally be replanted with willow cuttings to provide a quick cover for shading and streambank stability. Other appropriate species would also be installed such as dogwood and other similar species."

d. "On federal lands, PCGP has committed to extending the riparian strip plantings along all streams (perennial or intermittent) within federally-designated Riparian Reserves to 100 feet from the OHWM (subject to the same 5-foot (shrubs) and 15-foot (trees) restrictions on either side of the centerline). The extended riparian planting area within Riparian Reserves will occur to 100 feet or to the limit of the existing riparian vegetation where it does not extend to 100 feet."

e. "PCGP would install large woody debris in the stream where required by federal or state permits to provide shade and additional habitat. Large woody debris would be installed at the time of restoration dependent on the site-specific conditions at each specific stream crossing. These site-specific conditions include available space within the working corridor that is not occupied by the temporary crossing bridge or flume pipes and efforts to minimize disturbing existing stable banks."

- Environmental Inspection: PCGP will conform to all of the FERC-recommended project mitigation measures as Environmental Conditions). Included in these conditions are requirements that the Environmental Inspector must be suitably trained to address issues of construction in environmentally sensitive areas. The Environmental Inspector must also be empowered to evaluate methods used by the construction contractor(s) and order corrective actions to ensure compliance with all environmental conditions outlined to date or required by subsequent permits or agency-issued opinions.

RISK ANALYSIS BACKGROUND

The pipeline risk analysis framework, shown in Figure 3 and articulated by USFWS in their December 23, 2009 comments on a previous certificate application is designed to respond to two specific questions initially posed with respect to Federal trust resources:

- What impact will the project have on the short-term and long-term stability of the stream channel at the location of pipeline construction as well as upstream and downstream of the site?
- What impact will the proposed project have on the ecological functions and values of the streams and riparian areas being crossed by pipelines, particularly with respect to hydrogeomorphic and ecological connectivity? Evaluation of the expected ecological structure at stream crossings along the pipeline route forms the basis of this analysis. This evaluation can form the basis for documenting important site conditions that would need to be rebuilt as part of post-construction site restoration or mitigated elsewhere.

Each of these two questions is evaluated individually on the X and Y axes of the risk matrix, respectively, to determine whether a specific crossing presents a high, low, or moderate risk from construction using industry standard or company-specific typical methods and techniques that provide the *minimum* compliance with U.S. Department of Transportation (DOT) and the Federal Energy Regulatory Commission (FERC).

The first question is addressed by the "Stream and Site Potential" X-axis. This axis is designed to identify those streams where the combination of channel characteristics could result in short or long-term exposure of the pipeline or related instability if "typical" pipeline construction techniques are used during initial site inventory. The risk of channel instability based on the attributes on the X-axis is based on the conceptual model of stream response first articulated by Schumm (1977). This conceptual model is expanded to include the relationship between channel morphology and gradient developed by Montgomery and Buffington (1998). The model was further supplemented by the experience of the interagency RiverRAT team in assessing stability of rivers in the western United States (Skidmore, et al. 2010),[1] and revised to address pipeline-specific analyses by USFWS. Detailed rationale for the selection and relative ranking of stream attributes along the X-axis is presented in Appendix A of the December 23, 2009 USFWS comments on the previous JPA. The attributes for scoring each crossing, as outlined by USFWS, are summarized below. There are four attributes on which this X-axis is scored as follows:

- Channel Slope or Stream Type: higher gradient slopes—often associated with bedrock or coarse colluvial material in the streambed or banks—represent relatively low risk, while low gradient channels that are prone to depositional instability, lateral migration, or avulsion (as on an alluvial fan) are associated with high risk. Incised channels are also associated with high relative risk.
- Riparian Corridor: wide or unconfined riparian corridors represent relatively low risk and confined or infrastructure-constrained (e.g., with roads, levees) riparian corridors representing high risk.
- Bank Characteristics: bedrock represents a low-risk bank. Risk increases with more erodible banks, but erodibility is left open to consider the interactions of bank soil grain size, bank stratigraphy and consolidation/cementation, bank angle, and bank vegetation.
- Bed Materials: this attribute is directly related to the ease of erosion and arranged in risk order from low (bedrock) to high (sand). Risk order for granular materials is based on erosion thresholds rather than strictly grain size. Due to cohesion, a clay or silt bedded stream is less erodible than a sand-bedded stream.

The second question is addressed by the “Project Impact Potential” Y-axis and is designed to estimate the amount and quality of aquatic and riparian habitat that would be disturbed by construction of the pipeline, again using typical construction approaches, and thereby estimate the “risk” to habitat integrity by pipeline construction. The four attributes on which this “Y” axis is scored are:

- Artificial Bed/Bank Stabilization: a low risk designation is given to those locations where existing bed or bank hardening is removed, allowing greater expression of normative geomorphic processes. The high-risk designation is given to those locations where rigid (i.e., non-deformable) bed or bank stabilization must be used to stabilize the channel to prevent post-construction instability as evaluated by the “X” axis of the Risk Matrix. Non-deformable stabilization includes any structures that are designed to maintain the location or grade of the channel margin in the face of extreme flood events.
- Construction Methods/Duration: based on the intensity of surface disturbance, low risk is allocated to trenchless techniques, while high risk is associated with locations requiring blasting or other means of invasive rock fracturing. Typical pipeline construction techniques score on the low- to moderate- part of this axis.
- Channel Disturbance Width: this attribute is based on the assumption that variations in channel geometry, such pools and riffles, is an indication of high quality aquatic habitat. Because these

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[1] The November 2010 revision to RiverRAT added an evaluation of dominant hydrologic regime to the Pipeline Risk Matrix developed by USFWS. However, this evaluation of the PCGP project was also well underway when that modification was published. For this reason, the contribution of dominant hydrologic regime to channel stability risk was not assessed in this current study.

morphologic variations typically occur on longitudinal dimensions proportional to channel width, fixed width construction activities that disrupt a narrower channel could potentially disturb more distinct aquatic habitat units than construction activities that disrupt a wider channel. Therefore, headwater streams will score high on this attribute.

- Floodplain Disturbance Width: this attribute assumes that perpendicular crossings of the stream will be associated with reduced loss of riparian and floodplain habitat because a relatively small proportion of the floodplain is disturbed in the down-valley direction, while alignments that parallel rivers are considered to more readily alter patterns of down-valley transport. This attribute carries less significance with respect to habitat loss in areas where the floodplain is already modified by existing land use.

Actual scoring and consideration of the scoring and weighting of these attributes is left to professional judgment; no specific guidance is provided by USFWS. The approach to measure and score these attributes is presented below.

METHODS

DEQ's request for PCGP to perform this risk analysis is based, in large part, on the comments made by the USFWS in their December 23, 2009 letter commenting on the Public Notice for the Corps' Section 404 permit of the previous project application. The intent of the risk analysis is to require applicants such as PCGP to focus resources on those waterbody pipeline crossings that present the greatest risk of impacts to beneficial uses through degradation of water quality resulting from construction impacts or presence and maintenance of the pipeline over the life of the project. In their letter to PCGP of March 2, 2010, DEQ supports use of the risk matrix analytical framework recommended by USFWS. DEQs regulatory authority under the Clean Water Act and Oregon Administrative Rule is focused on maintenance of beneficial uses through enforcement of water quality standards, including anti-degradation.[2] DEQ's specific focus for this project has been on temperature, turbidity/sedimentation, dissolved oxygen, and nutrients. Instream construction, hydraulic disconnection, and unstable channels following construction could potentially degrade water quality; the impact is likely to be small on the scale of a single water body crossing. At issue is also whether these impacts are substantial at a larger watershed scale.

The Risk Matrix is a screening tool, to be used in project planning and design to avoid, reduce and mitigate for impacts in combination with the added information that will be developed as the project approaches final design and construction. This risk analysis followed three phases:

- Phase I: Compilation of existing information obtained in prior studies for the PCGP project and identification of data gaps.
- Phase II: Field investigation to observe sites directly and obtain additional information on site characteristics to inform the risk analysis and related water quality investigations.

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[2] DEQ's statutory authority and approach to the Clean Water Act 401 certification process with respect to topics of review and coordination with other state and federal agencies in the is outlined here: http://www.deq.state.or.us/wq/sec401cert/faqs.htm#q6.

- Phase III: Estimation of key parameters that were not directly observed, followed by scoring for the eight attributes in the risk matrix defined above based directly on or inferred from all available data.

The full dataset on which this risk analysis is based in contained in a GIS database and is available for review.

Phase I Data Compilation and GIS Analysis

Much of the GIS data compiled for this effort was available from prior work on the PCGP Channel Migration and Scour Analysis (GeoEngineers, 2017b) or existed as part of the larger PCGP geodatabase maintained by Edge Environmental, Inc. (Edge). We understand that the waterbody layer in the geodatabase provided by Edge was compiled from data sources including the National Hydrography Dataset, Jones and Stokes Field Surveys (2009), Ecology and Environment (September 2017), PCGP Updated Wetland Delineation Report (2016), and consultations with various federal agencies. GeoEngineers acquired and processed the LiDAR topographic data and compiled geologic mapping, and soils data.

GeoEngineers compiled a geodatabase of specific parameters necessary to complete the stream crossing risk analysis. Table 1 below provides a list of the parameters along with the sources used to populate those fields.

TABLE 1. PARAMETERS FOR WATERBODY RISK ANALYSIS

Variable	Notes/Sources
Drainage Area	Measured from USGS digital elevation model (DEM)
Sixth Field HUC	Oregon Water Resources Department (OWRD) GIS analysis (GEO, 2010)
Fifth Field HUC	OWRD GIS analysis (GEO, 2010)
Fourth Field HUC	OWRD GIS analysis (GEO, 2010)
Stream type (Reach)	
Bedrock	Wetland Delineation (ICF Jones & Stokes, 2009), RR6 Phase I or Phase II Scour Analysis (GeoEngineers, 2017b), aerial photographic interpretation
Colluvial	Ditto
Alluvial	Ditto, geologic maps
Stream slope (Reach)	Measured from light detection and ranging (LiDAR) coverage or U.S. Geological Survey (USGS) DEM and aerial photographs
Channel dimensions (Site)	
Width - bankfull/ OHWM	Wetland Delineation (ICF Jones & Stokes, 2009), Channel Migration and Scour Analysis (GeoEngineers, 2017b), aerial photographic interpretation
Bankfull depth	Wetland Delineation (limited), field observation
Active channel depth	Wetland Delineation (limited), field observation
Cross-sectional area	Wetland Delineation (limited), field observation
Bed materials (Site)	Wetland Delineation (limited), field observation

Variable	Notes/Sources
Bank materials (Site)	Wetland Delineation (limited), field observation, inferred from soils
Streambank erosion (Reach)	Aerial photos for larger streams. Obtain from landowner stream surveys if available.
Grade controls (Reach)	Field observation
Valley width (Reach)	Measured from LiDAR or USGS DEM
Floodplain Width	Measured from LiDAR or USGS DEM
Riparian Corridor Width	Measured from aerials
Canopy class	Measured from aerials
Density (by canopy layer)	Measured from LiDAR first return-bare earth + aerials
Channel sinuosity (Reach)	Measured from LiDAR or USGS DEM
Soils	Natural Resources and Conservation Service soil data mart (NRCS, 2010; http://soildatamart.nrcs.usda.gov)

To facilitate queries of the GIS database, a polygon was constructed for each stream crossing extending across the width of the right of way and beyond the channel banks to the outer margin of clear riparian vegetation or 100 feet beyond the streambank, whichever was less. This allowed queries accurate of soils, geology, and vegetation databases. A channel centerline was also scribed for a 500-foot distance and the elevation at each end of the centerline was determined to allow measurement of channel gradient. Drainage areas upstream of each stream crossing were delineated and calculated for natural watersheds. Drainage basin areas were not calculated for canals and irrigation ditches, particularly in those areas where topographic resolution was poor (e.g., the Klamath Basin).

At the end of this exercise, data gaps were reviewed to select target stream channels for field investigation. The purpose of the field reconnaissance was to collect information on stream channel characteristics that could facilitate this risk analysis as well as the other related water quality evaluations requested by DEQ. The primary data gaps related to the risk analysis were associated with bed and bank material types.

Phase II Field Reconnaissance

Once data gaps were identified for the risk analysis and the associated water quality evaluations, a list of 96 target stream crossings was developed to address the data gaps needed to complete the risk evaluation and related water quality evaluations. These target crossings were selected to be representative of each ecoregions and represent the range of widths/gradients and aspects of the stream crossings in each ecoregion traversed by this project. The list of target crossings was approximately twice as large as needed to obtain a suitable subset of sites providing the desired variation in site settings knowing that landowner permission could not be obtained so long after initial fieldwork for the project in the absence of easements. This list was screened by PCGP land agents for potential access during the week of August 23, 2010. Access limitations reduced the list nearly by half. Fieldwork was accomplished by three field teams of two each deployed across the alignment (Figure 1) to collect site data at identified locations. Two teams split sites in the Coos-Coquille, Umpqua, and Rogue River drainages at the crossing of I-5, with one team working primarily northwest and another working southeast of this location. The third team performed a reconnaissance of these segments of the line, following the alignment as closely as possible on publicly accessible roads (i.e., county roads, highways, and major forest roads) before evaluating sties in the Klamath Basin. Each team had at least one member with geomorphic expertise. Each team was directed to get as close to the location of the pipeline crossing as allowed given limitations of site access.

Field observations related to the risk analysis included channel dimensions (width, depth, gradient), bed and bank material and erosional status, and presence or absence of evidence for incision, aggradation, or avulsion. Within the Klamath Basin, most of the data collection was focused on evaluation of other water quality parameters rather than the risk analysis.

Phase III Risk Evaluation

Following fieldwork, data were entered into the GIS database for analysis. Where direct observation of bed and bank materials had not been accomplished with any of the prior field efforts, estimates of these material properties were made by additional reviews of existing data and the application of current geomorphic approaches to understanding watershed and stream morphology (e.g., Thorne et al., 1997, as described to and concurred with by Janine Castro, personal communication). Inferences regarding bed and bank materials and artificial stabilization were made on the basis of field data collected at sites with similar physiography, watershed position, geology, soils, and drainage basin areas by an experienced geomorphologist using the best available data.

To estimate bank material properties, floodplain soil profile information (NRCS, 2010) was reviewed. It was assumed that the texture of the base of the soil profile (particularly for bedrock channels) represented the controlling erosional properties of the bank. Vegetation characteristics of streambanks were evaluated from aerial photographs and from sites with equivalent physiographic and ecoregional characteristics.

For those areas where bed material was not known, this attribute was inferred from the following sources in this order:

- Evaluation of the amount of coarse material (gravel, rock) in the base of the soil profile of the adjacent floodplain. Equivalent soil data were not available on USFS lands.
- Extrapolation from other streams in the same ecoregion, geologic terrain, and slope class (as defined by the risk matrix).
- Interpretation from channel planform shown on aerial photographs through observations of channel turbidity (indicative of sandy or muddy bed material in mid-summer).

Information regarding existing artificial bed and bank stabilization was obtained from field observations (primarily during 2010) and as noted in the Wetland Delineation Report (ICF Jones & Stokes, 2009). This is likely not a comprehensive observation of all of the previously stabilized locations, so this parameter may require updating during the pre-construction survey. Artificial stabilization was not assumed at any other locations. Locations where riprap was observed or is likely (based on adjacent infrastructure) were assumed to have the riprap replaced following pipeline installation. Locations where banks are highly incised were assumed to receive unspecified deformable stabilization as part of pipeline installation.

Bankfull or ordinary high-water width, necessary to estimate risk for the channel disturbance attribute, was not available for a small subset of stream crossing locations. Width classes (0-10, 10-40, and >40 feet) were estimated from field observations in either the Wetland Delineation Report, or the Phase II scour analysis in RR6 (GeoEngineers, 2017b). The mid-point of each width class was used as the site estimate for channel width. Because the channel disturbance attribute is sensitive to stream width at closer to an order of magnitude scale, this was determined to provide a sufficiently robust estimate for use in evaluating the risk associated with this attribute. Exact measurements of bankfull and low-flow wetted width will be made during the pre-construction survey.

Each channel or site attribute was ranked against the risk matrix using the criteria and scoring scheme protocol outlined in Table 2 below. When scoring sites that had not been observed directly, prior indications of risk from the Phase I and Phase II risk analysis were considered by selecting a higher point value than other indicators would suggest for the site attribute. After each attribute was scored, the totals for each attribute on the two axes were added. No weighting was performed. Each axis was then ranked high, medium, or low using these breaks:

- High: Axis scores 15 - 20
- Moderate: Axis scores 11-14
- Low: Axis scores 0 – 10

The results of the risk ranking for each evaluated stream using this scoring is presented in Table A-1 of Appendix A. The relatively high break for the "low" risk conditions allows each attribute to have up to a moderate risk. This is considered to represent a low risk in aggregate at this stage of project development; however, as described in the Project Background section above, substantial consideration has already been put into reducing construction and post-construction channel stability issues and impacts for the PCGP alignment with respect to the stream and site potential axis of the risk matrix. Construction methods explicitly consider steep slopes and other physiographic conditions along the project alignment. Site-suitable revegetation and site-restoration schemes have been developed to minimize aquatic and riparian habitat inputs. Therefore, the "typical" construction approach developed for the PCGP project carries relatively less risk to watercourses along the alignment than construction approaches for which the risk analysis was originally developed.

RESULTS AND DISCUSSION

The ultimate purpose of the risk matrix is two-fold. For new projects, the matrix is designed to highlight important site attributes of stream channels to characterize during project studies. For new and existing projects, the risk matrix is designed to segregate streams into different management prescriptions. These actions should address crossing design, the application of types of best management practices, and post-construction monitoring requirements. The distribution of channel crossings in each of the 9 risk categories based on the risk ranking and category breaks presented above is shown in Table 3 below. Once each stream crossing was assigned a point value, several crossings in each 5th field HUC were reviewed to verify whether the score accurately represented observed or estimated conditions.

TABLE 2. POINT VALUES FOR SITE ATTRIBUTES USED IN THE RISK MATRIX

Attribute	Point Value 5	Point Value 4	Point Value 3	Point Value 2	Point Value 1
Stream and Site Response Potential "X" Axis					
Landscape Sensitivity / Stream Type	Gradient <1% *OR* Channel incised >3 feet OR Channel incision = Yes for FERC major or intermediate class channels OR Scour, avulsion, or lateral migration high risk Channel Migration and Scour Analysis (GeoEngineers, 2017b)	Gradient 1-3% OR Channel incised ≤ 3 feet OR Channel incision = Yes for FERC minor class channels	Gradient 3-6% AND Channel is alluvial	Gradient 6 to 10%	Gradient > 10% AND Channel is colluvial (assumes that flow is low and that sufficient wood and rock structure is present to dissipate stream power
Riparian Corridor (Indicated by Woody Vegetation)	Laterally continuous and wide (at least ~ ½ site potential tree height)	Semi-continuous and wide	Moderately continuous and moderately wide	Discontinuous and narrow (minimal woody vegetation)	No riparian corridor (herbaceous vegetation only) OR Constrained by infrastructure (levees, roads)
Bank Characteristics	Highly erodible OR Soil is sandy or sandy loam OR Erosion visible on aerial photographs	Moderately erodible OR Soil cohesive (loam, silt loam)	Erosion resistant. OR Soil is clay, clay loam or contains some gravel rock, stone, cobble	Highly erosion resistant. OR Soil contains clay or boulders OR Soil basal texture is weathered bedrock	Bedrock OR Soil basal texture is unweathered bedrock

Attribute	Point Value 5	Point Value 4	Point Value 3	Point Value 2	Point Value 1
Bed Characteristic	Sand	Silt OR Sandy Gravel OR "mud"	Clay OR Gravel	Cobble OR Cobble/Boulder OR Some bedrock on channel margins	Bedrock OR Boulder
Project Impact Potential "Y" Axis					
Artificial Bed/Bank Stabilization	Non-deformable stabilization of bed or banks required due to immediately adjacent major infrastructure	Deformable stabilization of bed or banks required, including structural fill or bioengineered bank stabilization. Assumed to be the case for incised streams ≥ 2 feet OR bank scores =4,5	Existing stabilization replaced in kind	No stabilization or existing stabilization not disturbed	Artificial bed or bank stabilization to be removed permanently
Construction Methods/ Duration	Rock fracturing OR Multiple construction seasons at a single site	Deep trench, i.e., potential for more than standard cover to address scour risk OR Channel incised ≥ 2 feet OR Channel slope >20%	Moderate trench, i.e., standard cover AND Channel somewhat incised (up to 2 feet)	Shallow trench, i.e., standard 5-foot cover AND Channel not incised AND Side slopes not steep (indicated by channel slope < 20%)	Trenchless installation using HDD or conventional bore
Channel Disturbance	>20 times channel width	9-20 times channel width	5-8 times channel width	3- 5 times channel width	1-2 times channel width

Attribute	Point Value 5	Point Value 4	Point Value 3	Point Value 2	Point Value 1
Floodplain Disturbance	Line parallels stream	Floodplain <50 feet wide OR Line crosses at <45° angle	Floodplain 50 - 100 feet wide AND Line crosses approximately perpendicular	Floodplain > 100 feet wide	No floodplain

TABLE 3. FREQUENCY DISTRIBUTION OF STREAM CROSSINGS IN THE RISK MATRIX

		Stream and Site Response Potential			
	Axis Categories	**Low**	**Moderate**	**High**	**Total**
Project Impact Potential	***High***	0	1	0	**1**
	Moderate	45	61	6	**112**
	Low	29	29	2	**60**
	Total	**74**	**91**	**8**	**173**

To implement the results of the risk analysis, stream crossings are grouped into five management categories, each with specific construction, site restoration, and monitoring approaches based on their respective risk. Proposed construction and site restoration approaches for each category are shown in Figure 3.

Construction and Site Restoration Approaches

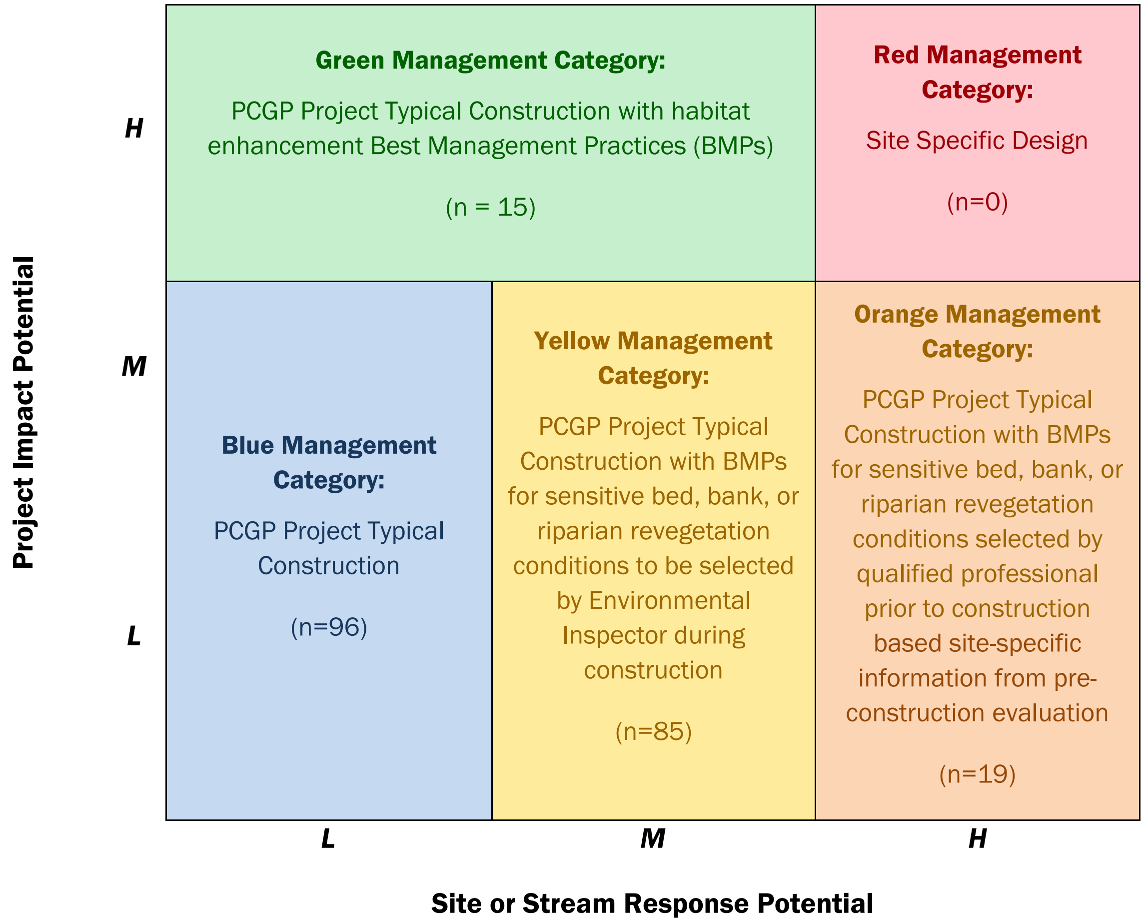
Proposed construction and site restoration methods outlined by PCGP include numerous measures to reduce the likelihood of stream channel instability and long-term habitat loss. These measures are summarized previously in this report and also in greater detail in RR1 of the Pacific Connector Certificate Application (2017).

Much of the land traversed by the PCGP pipeline alignment constitutes a working landscape, primarily devoted to agriculture, industrial and federal timberlands, and utility and transportation corridors. Habitats in these areas can be (and often are) degraded, such that additional disturbance would have negligible impacts on current conditions. PCGP has developed an alignment meant to reduce floodplain and channel disturbance, and developed robust "Project Typical" construction measures to minimize in-stream impacts. These measures include:

- Route selection to minimize the number of crossings, and to allow crossings to be perpendicular to channels wherever possible;
- Trenchless crossings of larger rivers where subsurface conditions allow, resulting in no disturbance to streambed and streambanks.
- Use of dry open-cut trench methods of crossing streams wherever possible, and making use of dry season dewatered conditions in intermittent and ephemeral stream crossings.
- Narrowed disturbance corridor: 75 feet within the channel and wherever possible in adjacent riparian zones.

For these reasons, sites with low and moderate project impact potential are grouped together for the purposes of developing crossing specific construction approaches during the detailed pipeline design phase that will occur following the pre-construction survey. Details of the information to be gathered during the pre-construction survey is presented in a later section.

FIGURE 4. CONSTRUCTION AND SITE RESTORATION APPROACHES FOR CHANNELS FOLLOWING THE RISK MATRIX EVALUATION



Blue Management Category

Waterbody crossings in this category have low or moderate scores for all 8 risk factors. Construction and site restoration will follow the methods and typical drawings shown in the ECRP (Appendix B.1 of the RR1 of the Pacific Connector Certificate Application). Post construction site restoration will use BMPs such as seeding, planting, and hydromulch or erosion control blankets to minimize surface erosion while new vegetation becomes established. Typical site revegetation and backfill will be used to address habitat issues at these sites. The BMPs common to all waterbody crossings regardless of risk level are presented in Table 4.

TABLE 4. PCGP PROPOSED BMPS FOR USE AT WATERBODY CROSSINGS IN ALL MANAGEMENT CATEGORIES

Sensitive Crossing Component	BMPs (BMP Source)
Streambed	Dry ditch crossings (5) Backfill with native material (3,4) Backfill to match existing streambed gradation, composition as much as possible (4) Profile restored to existing profile and grade (4) Stratified backfill for fish-bearing streams (1)
Streambanks	Typical erosion and sediment control BMPs including erosion control blankets, silt fence, etc. Narrowed construction disturbance (75 feet) corridor where feasible (2,3,4) Narrowed permanent management corridor (2,3,4) Revegetation with native plant materials (3,4,6)
Riparian Vegetation	Revegetation with native trees to within 15 feet of the pipeline parallel to the alignment (1,3,5,6) Revegetation with native woody riparian shrubs and trees for willing landowners (3) Widened riparian corridor (Federal lands, willing landowners) (3,6) Use of fast growing native tree species to accelerate shading (3)
Aquatic Habitat	Stratified backfill for fish-bearing streams (1,2,4,6) Placement of large wood where appropriate (2,4,6) De-watering and re-watering plan where necessary Fish salvage and handling plan where necessary (reference?) Hazardous materials handling plan if necessary

Note: BMP Sources:

1 FERC Guidelines
2 FEIS, RR2 Appendix M.2; JPA, Appendix C Project Description
3 RR2 Appendix B.1; ECRP
4 RR2 Appendices C.2, D.2, E.2
5 RR2 Appendices C.2, D.2
6 JPA Appendix H, Compensatory Mitigation Plan

Yellow and Orange Management Categories

Sites in the yellow management category represent moderate risk to stream channel stability based on this risk analysis scoring. This scoring typically requires at least one high-risk channel attribute and the remaining attributes to be at least moderate. These channels occur at all points in the watershed.

More robust BMPs, particularly to manage for potential impacts to streambanks and streambeds, to be used in addition to those included in the "Project Typical" set of BMPs are described in Table 5. Specific BMPs would be selected by the Environmental Inspector or suitably trained professionals prior to construction based on results of the pre-construction survey.

TABLE 5. PCGP ADDITIONAL PROPOSED BMPS FOR USE AT WATERBODY CROSSINGS IN THE YELLOW AND ORANGE MANAGEMENT CATEGORIES

Sensitive Crossing Component	BMPs (BMP Source)
Streambed	Stratified backfill for high gradient streams (5) Trenchless crossing (1, 4)
Streambanks	Structural fill placement (2) Bank graded/terraced to 3:1 (2,3) Geotextile reinforced slope (5) Fiber rolls (3) Stream barbs/flow deflectors (5) Toe rock placement (3) Riprap placement (3) Biotechnical "vegetation" riprap (3) Tree revetments (3)

Note: BMP Sources:

[1] FEIS, RR2 Appendix M.2; JPA Appendix C Project Description

[2] RR1 Appendix B.1 ECRP

[3] RR2 Appendices C.2, D.2, E.2

[4] RR2 Appendices G.2, H.2, and I.2

[5] This document.

Sites in the orange management category represent the highest potential risk for short and long- term channel stability. This scoring typically requires more than one high-risk (score of 4 or 5) channel attribute and the remaining attributes to be at least moderate. Not surprisingly, several of the channels that ranked in this category will be crossed by HDD or direct pipe trenchless construction methods because of their relatively high risk of channel instability: Coos River, South Umpqua River #1, Rogue River and the Klamath River.

Channel conditions that have placed streams in the yellow or orange management categories include:

- Channel incision: Incised channels represent the greatest risk observed on the PCGP alignment because they are likely to result in continued bank erosion as channel banks evolve into a more stable configuration. For those incised channels that are not already eroded down to bedrock, additional scour is also possible depending on whether downstream grade control is present in proximity to the crossing site. Channel banks would require the incorporation of deformable stabilization during site restoration.
- Channel slope: Streams at lower and moderate slopes are more prone to channel migration, while streams on moderate slopes are prone to channel scour. Channel migration and scour risk were assessed previously for the named waterbodies (GeoEngineers, 2017b) and are accounted for in location of the pipe overbend and burial depths. Streams with very high channel slopes (>20%) require selective placement of coarse materials available from the pipeline trench to provide additional grade control.

- Riparian condition: More robust woody vegetation in the riparian zone typically reduces avulsion risk and aids in reducing erosion of stream banks. Revegetation to maintain the continuity of the existing riparian zone is appropriate for these streams.
- Channel bed and bank materials: Erodible materials in the bed or bank present a greater short-term risk of scour or lateral migration than do non-erodible materials. Erodible banks are more likely to require the addition of deformable bank or bank toe stabilization. Channel scour is addressed by selection of the pipe burial depth and by the selective placement of available coarse materials in the backfill.

Green Management Category

Streams in the green field, for sites with high habitat impact potential, will use typical site construction methods. The PCGP project has incorporated a number of considerations to reduce impacts to aquatic and riparian habitat that are part of the "project typical" methods described in Table 4. In addition to these BMPs, the following measures have been incorporated into the project to reduce impacts to aquatic and riparian habitat:

- Routing avoidance of waterbody crossings;
- Route avoidance of riparian areas where the pipeline more closely parallels stream channels;
- Trenchless and dry-cut crossing techniques wherever possible;
- Minimized disturbance corridor of 75 feet in riparian areas wherever possible:
- Compensatory mitigation for riparian reserve impacts on lands governed by the Northwest Forest Plan, and route avoidance of riparian zones.

Channels placed in this field typically are those that disturb a greater proportion of the existing floodplain or – in narrower streams – potentially disturb more varied aquatic habitat. During site restoration, however, particular effort will be made for opportunistic habitat enhancement BMPs as detailed from observations obtained during the pre-construction survey. These enhancements could include riparian planting to improve existing habitat conditions in the floodplain, placement of large wood or rock to improve in-stream habitat, or modification of existing riprap to improve habitat (e.g., launchable riprap or riprap with included root wads). Where these channels require the addition of deformable bank stabilization, maximum use would be made of BMPs that promote bank revegetation with woody materials. In addition to the "Project Typical" BMPs, PCGP would propose additional BMPs for use at crossings in this management category, as shown in Table 6.

In addition to the BMPs presented in Tables 4 and 5, BMPs to address specific components of waterbody crossings at sensitive crossing locations (i.e., with high project impact potential and moderate or high site or stream response potential) are summarized in Table 6. Specific BMPs would be selected by the Environmental Inspector suitably trained professionals prior to construction.

TABLE 6. PCGP ADDITIONAL PROPOSED BMPS FOR USE AT WATERBODY CROSSINGS IN THE GREEN MANAGEMENT CATEGORY

Sensitive Crossing Component	BMPs (BMP Source)
Riparian Vegetation	Invasive species control during plant establishment period
Aquatic Habitat	Streambed to match existing gradation and distribution of physical habitat features Rootwad enhancement of bank stabilization

Note: BMP Source: This document.

Red Management Category

No channels were found to score in the red management category. This field would require site specific design and specifications such as that which is required by FERC (2003) for major waterbodies (>100-foot crossing widths) prior to construction. The Pacific Connector Certificate Application (2017) contains detailed information on the HDD crossings (Coos River, Rogue River, and Klamath River), while Appendix G contains site-specific crossing design for Catching Slough, the North and East Forks of the Coquille River, and both crossings of the South Umpqua River. Additional site-specific drawings will be produced prior to construction for the remaining major waterbodies. Following the pre-construction survey, should more detailed information result in the re-classification of a site into this field (for example, due to the necessity of adding non-deformable bank stabilization), a site-specific design would be developed and incorporated into project construction plans if a permit approval is received for the change in the placement of fill.

Pre-Construction Survey

The purpose of the pre-construction surveys is to confirm current existing conditions for all sites and inventory site conditions to ensure site reclamation is specific to existing conditions at stream crossings. Preconstruction surveys have been completed at 53 sites and are described in the Risk Analysis Addendum (GeoEngineers, 2017c). At sites where conditions have changed significantly from those which are described by ICF Jones and Stokes (2009) or GeoEngineers (this study), the pre-construction survey will evaluate whether the management category for that site should be modified. Channel information to be collected during the pre-construction survey at the high-risk habitat or high-risk stream channel sites (green or orange management categories) includes channel configuration/morphology; size and distribution of instream structure that affects the in-channel distribution of hydraulic energy (e.g., logs and large rock), substrate grain size and thickness of the active channel substrate, and bank geometry and material configuration. Appropriate permitting entities will be notified of changes in management approach and the rationale for such changes, with respect to habitat conditions, the pre-construction survey documents the type and frequency of individual aquatic habitat units; and specific information on current riparian vegetation.

Specific observations and measurements that are made during the pre-construction survey to adequately reclaim the site to pre-project conditions and habitat types are to include:

- Representative cross sections identifying existing channel geometry, including low flow, high flow channels, and floodplain areas within disturbed reach.
- Profile of the channel through the disturbed area identifying habitat units such as pools, riffles, steps, in-stream wood, etc.

- Bed and bank material, including estimates of particle size distribution.
- Riparian vegetation types, distribution, and density.
- Large wood loading.

Monitoring Approaches

Long term monitoring of the stream crossings along the pipeline route will be completed by PCGP to ensure channel erosion or migration does not destabilize or expose the pipeline. Full details on the monitoring plan are provided in (need report reference here). The monitoring will consist of:

- Quarterly site visits for 2 years post construction to monitor, among other things, re-vegetation success and evidence of channel migration, erosion, head-cutting, or incision that could influence stream or pipeline stability.
- Annual reporting is required in Years 1, 2, 3, 5, 7, and 10 following construction to outline observations of stream crossings and any remedial action taken to restore site conditions.
- Aerial photos are taken annually for the life of the pipeline and reviewed for major landscape changes such as channel migration and excessive erosion. Potential problem areas are subsequently visited by PCGP operators.

CONCLUSIONS

The PCGP project traverses four major river basins and three major physiographic provinces and mountain ranges. The alignment has been evaluated in detail and selected to minimize impacts to sensitive waterbody crossings. Nevertheless, 173 waterbodies—streams and ditches with elements to natural geomorphic processes—will be crossed by the current alignment. An analysis of the risk to both channel stability and habitat impact has been performed to further guide management actions prior to and during construction and in post-construction monitoring activities, as requested by DEQ. Site attributes that formed the basis for this risk analysis were compiled or developed from:

- Prior field efforts associated with environmental permitting that has occurred to date.
- Analysis of topographic information and aerial photographs.
- Field investigation to gather additional data at a subset of sites, distributed across the major ecoregions and channel watershed positions.
- Estimation of site attributes based on observations at sites similarly situated with respect to watershed position, watershed and channel slope, geology, soils, and plant community structure.

Nearly half of the stream crossings evaluated scored at low risk for both habitat impact and stream/site potential, allowing “project typical” construction methods. No crossings scored as being at high risk for both of these conditions; less than 10 percent scored as having high potential for habitat impacts. Fewer than 10 percent of the crossings scored as high risk on the stream and site potential axis, requiring pre-construction selection of appropriate BMP types. Even before this exercise, issues of channel stability risk were addressed by the PCGP project: several of these channels will be crossed using trenchless techniques as a means of substantially reducing the risk of channel instability, for instance. The remaining crossings scored as moderate risk on the stream/site potential axis, requiring that BPMs beyond those typically employed be selected during construction to increase the stability of the channel bed or banks or improve riparian conditions.

PCGP will be performing a detailed pre-construction survey once full easements to the alignment have been acquired, and will collect information at that time to refine this risk analysis and support selection of site-suitable BMPs at the more complex crossings. At all sites, the survey will confirm existing conditions. At the high channel risk sites ("orange"), existing conditions will be confirmed. Additional channel dimension measurements or observations may be obtained if needed for selection of appropriate BMPs. At the high habitat risk sites ("green"), additional observations regarding instream or riparian habitat conditions may be obtained as needed to guide selection site restoration materials or strategies.

Long term monitoring of the pipeline will be conducted by PCGP according to the plans presented in the Project Certificate Application. All stream crossings, regardless of risk category, will be monitored eight times in the two years following construction. Any signs of channel instability that could adversely affect habitat or the pipeline crossing will be identified and remedial action taken according to the plans presented in the Pacific Connector Certificate Application and additional requirements set forth in project permits.

REFERENCES

Burns, S.F., 1998. Geologic and Physiographic Provinces of Oregon, in Environmental, Groundwater and Engineering Geology – Applications in Oregon, S.F. Burns, editor, p 3-14, Starr Publishing Co., Belmont, California.

Castro, J. M., 2010. Conversation regarding risk matrix application to Pacific Connector project with Pacific Connector team and Michele Hanson, USACE. USFWS Oregon State Office, Portland, Oregon.

Edge Environmental, 2017. Pacific Connector Geographic Information System Project Repository, Edge Environmental, Inc., Lakewood, Colorado.

Federal Energy Regulatory Commission, 2003. Wetland and Waterbody Construction and Mitigation Procedures, http://www.ferc.gov/industries/gas/enviro/wetland.pdf.

GeoEngineers, Inc., 2017a, Geologic Hazards and Mineral Resources Report, Pacific Connector Gas Pipeline Project, Coos Bay to Malin, Oregon. File No. 22708-001-00. Prepared for Pacific Connector Gas Pipeline, LP, GeoEngineers, Inc, Portland, Oregon, August 21, 2017.

GeoEngineers, Inc., 2017b, Channel Migration and Scour Analysis, Pacific Connector Gas Pipeline Project, Coos Bay to Malin, Oregon. File No. 22708-001-00. Prepared for Pacific Connector Gas Pipeline, LP, GeoEngineers, Inc, Portland, Oregon, August 28, 2017.

GeoEngineers, Inc., 2017c, Stream Crossing Risk Analysis Addendum, Pacific Connector Gas Pipeline Project, Coos Bay to Malin, Oregon. File No. 22708-001-00. Prepared for Pacific Connector Gas Pipeline, LP, GeoEngineers, Inc, Portland, Oregon, August 28, 2017.

ICF Jones & Stokes, 2009. Proposed Pipeline Alignment Wetland Delineation Report, Pacific Gas Pipeline Project. ICF J&S 06250.06, Prepared for Pacific Connector Gas Pipeline, LP, ICF Jones & Stokes, Portland, Oregon.

Montgomery, D.R., and J.M. Buffington, 1988. Channel Processes, Classification, and Response, in *River Ecology and Management*, R. Naiman and R. Bilby, eds., Springer-Verlag, New York, NY, pp. 13-42.

NRCS, 2010. Soil data mart, http://soildatamart.nrcs.usda.gov. Accessed variously May – June 2010. Natural Resources Soil Conservation Service.

Oregon GeoSpatial Enterprise Office, 2010. Oregon Spatial Data Library. http://spatialdata.oregonexplorer.info/GPT9/catalog/main/home.page. Accessed variously May – September 2010.

Oregon Water Resources Department (OWRD), 2010. GIS analysis.

Pacific Connector Gas Pipeline, LP, Certificate Application, 2017, Joint Permit Application Form, submitted to the U.S. Army Corps of Engineers (Portland District) and the Oregon Department of State Lands. Prepared for Pacific Connector by Edge Environmental, Lakewood, Colorado.

Skidmore, P. B., Thorne, C.R., Cluer, B., Pess, G.R., Castro, J., T., Beechie, J., and Shea, C.C., 2010. Science base and tools for evaluating stream engineering, management, and restoration proposals. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC.

Schumm, S.A., 1977. *The Fluvial System*, John Wiley & Sons, New York, 338 pp.

Thorne, C.R., Hey, R.D., and Newson, M.D., 1997. Applied *Fluvial Geomorphology for River Engineering and Management*. John Wiley and Sons, Chichester, UK, 376 pp.

U.S. Bureau of Land Management, 2007. Hydraulic Considerations for Pipelines Crossing Stream Channels, Technical Note 423.

U.S. Forest Service, 1979. Soil Resource Inventory - Fremont National Forest. Fremont-Winema National Forests, Klamath Falls, Oregon. (GIS format developed 2009).

U.S. Forest Service, 1992. Soil Resource Inventory: Umpqua National Forest, Roseburg, Oregon. (GIS format developed 2009).

FIGURES

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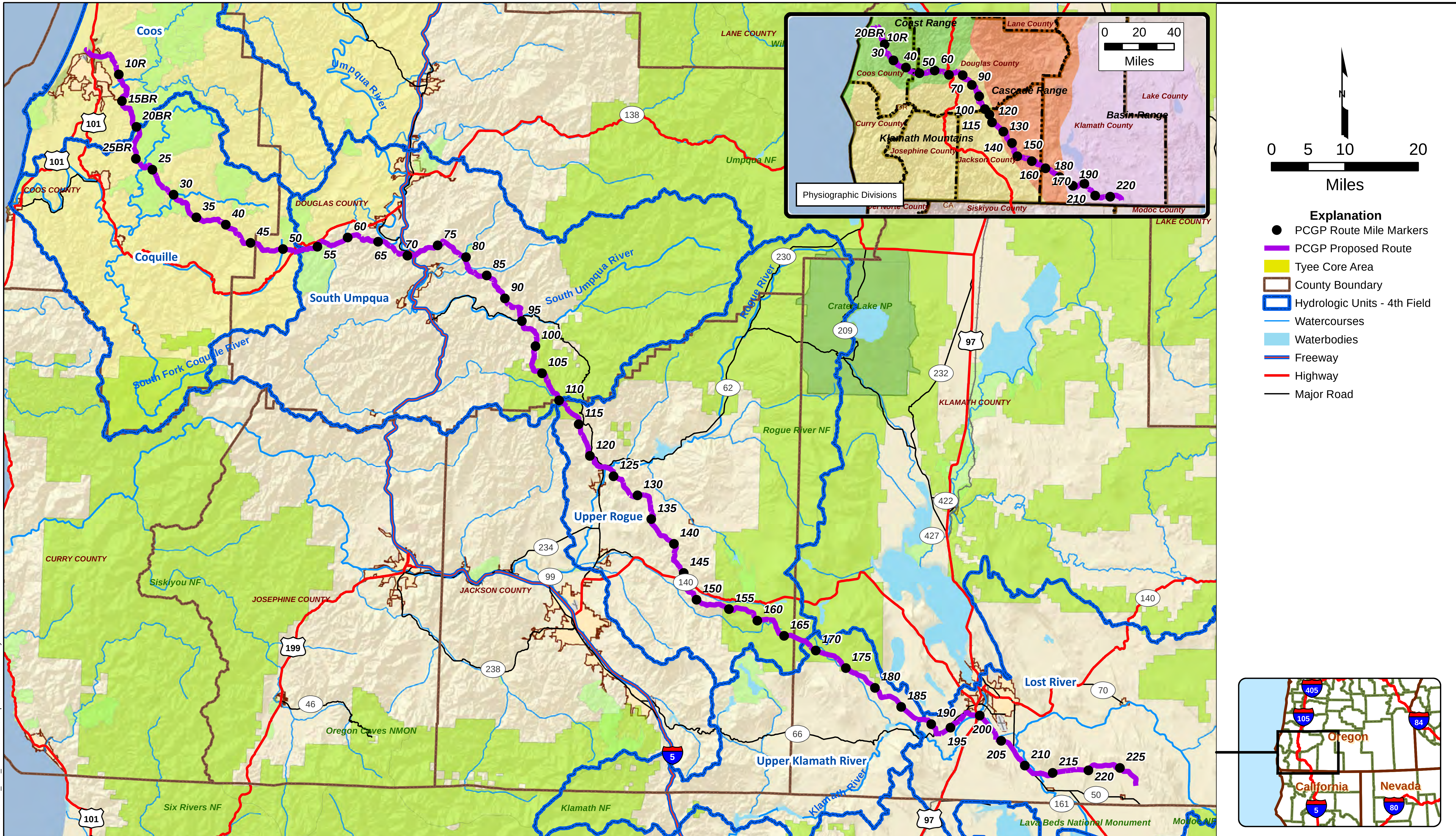

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. GeoEngineers, Inc. cannot guarantee the accuracy and content of this map.
3. It is unlawful to copy or reproduce all or any part of this document whether for personal use or resale, without permission.

Data Sources are detailed in attached document.

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PROPOSED ALIGNMENT SITE MAP

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP

FIGURE 1

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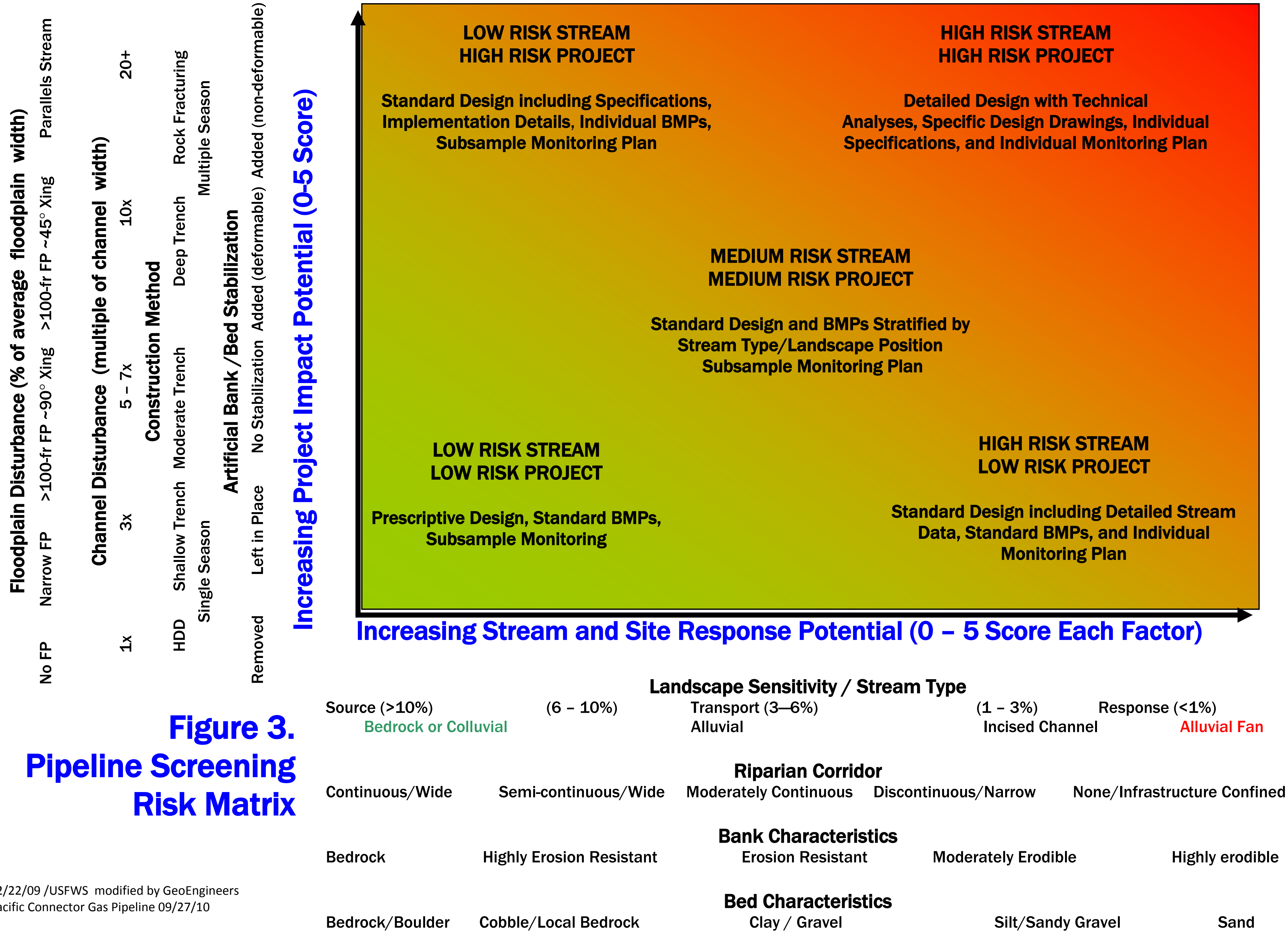

Figure 3.
Pipeline Screening Risk Matrix

12/22/09 /USFWS modified by GeoEngineers
Pacific Connector Gas Pipeline 09/27/10

APPENDICES

Appendix A
PCGP Stream Crossing Risk Analysis Rankings

Table A-1

Stream Crossing Risk Analysis

Pacific Connector Gas Pipeline

Coos, Douglas, Jackson and Klamath Counties, Oregon

2017 MP	Waterbody	Waterbody ID	Landscape Stream Type Score	Riparian Score	Bank Score	Bed Score	X-Axis Score	X-Axis Rating	Floodplain Disturbance Score	Channel Disturbance Score	Construction Score	Stabilization Score	Y-Axis Score	Y-Axis Rating
6.39R	Trib. to Coos Bay	S1-01 (EE-6)	3	2	3	5	13	M	3	3	2	4	12	M
8.27R	Willanch Slough	S1-04 (EE-7 (MOD))	3	4	3	3	13	M	1	4	1	2	8	L
8.48R	Trib. to Willanch Slough	GDX-30	4	2	2	2	10	L	3	4	2	3	12	M
10.21R	Trib. to Cooston Channel (Echo Creek)	SS-100-002	4	2	3	3	12	M	3	3	2	2	10	L
11.55BR	Vogel Creek	SS-100-005 (BR-S-02)	5	1	2	3	11	M	3	3	3	2	11	M
15.11BR	Stock Slough	BR-S-36	3	2	3	4	12	M	2	3	3	4	12	M
15.32BR	Stock Slough	EE-SS-9068	3	2	3	4	12	M	2	3	3	4	12	M
20.20BR	Steinnon Creek	SS-500-003 (BR-S-63)	3	5	3	3	14	M	3	3	3	3	12	M
23.06	North Fork Coquille River	BSP-207	5	3	3	1	12	M	3	1	4	4	12	M
24.32	Steinnon Creek	BR-S-63	4	3	3	3	13	M	3	3	3	3	12	M
25.18	Trib. to Middle Creek	EE-SS-9073	1	4	3	2	10	L	1	4	4	3	12	M
27.01	Trib. to Middle Creek	BSI-137	1	1	3	3	8	L	1	4	2	2	9	L
27.03	Trib. to Middle Creek	BSI-135	1	1	5	3	10	L	1	5	2	4	12	M
27.04	Middle Creek	BSP-133	5	1	4	2	12	M	3	1	4	4	12	M
28.86	Trib. To E. Fork Coquille	BSP-77	3	2	3	1	9	L	1	3	3	3	10	L
29.30	Trib. To E. Fork Coquille	BSP-74	4	4	2	1	11	M	1	4	3	3	11	M
29.47	Trib. To E. Fork Coquille	BSI-76	4	4	2	1	11	M	1	4	3	3	11	M
29.85	East Fork Coquille River	BSP-71	5	2	3	1	11	M	1	4	4	3	12	M
30.22	Trib. to E. Fork Coquille	SS-003-007A	4	3	3	2	12	M	3	2	3	3	11	M
30.29	Trib. to E. Fork Coquille	SS-003-007B	4	3	3	2	12	M	3	1	2	3	9	L
31.64	Trib. to E. Fork Coquille	BSI-70	1	3	3	2	9	L	1	4	4	4	13	M
32.40	Elk Creek	BSP-57	5	4	3	1	13	M	1	4	3	3	11	M
32.44	Trib. To Elk Creek	BSP-55	1	3	3	1	8	L	1	3	3	3	10	L
32.56	Trib. To Elk Creek	SS-100-030	1	3	3	3	10	L	1	3	3	3	10	L
32.63	Trib. To Elk Creek	SS-100-031	5	5	3	3	16	*H*	1	3	4	5	13	M
33.00	Trib. To Elk Creek	BSP-49	3	1	3	3	10	L	1	4	3	3	11	M
33.02	Trib. To Elk Creek	BSP-50	4	1	3	1	9	L	3	5	2	3	13	M
34.46	South Fork Elk Creek	CSP-5	4	1	3	2	10	L	1	4	2	3	10	L
35.51	Trib. To S. Fork Elk Creek	BSI-251	1	1	3	2	7	L	1	4	2	3	10	L
35.87	Trib. To Big Creek	BLM-35.87/CSP-2	1	4	3	2	10	L	1	4	4	3	12	M
36.48	Trib. To Big Creek	BLM 36.48	1	2	3	3	9	L	1	5	2	3	11	M
36.54	Trib. To Big Creek	GSI-25/BSI-253	1	2	3	3	9	L	1	5	2	3	11	M
36.85	Trib. To Big Creek	BLM 36.85	1	1	3	3	8	L	1	5	3	3	12	M
36.92	Trib. To Big Creek	BSI-252	1	1	3	3	8	L	1	5	3	3	12	M
37.32	Trib. to Big Creek	ESI-19	4	4	3	1	12	M	1	3	2	3	9	L
37.35	Trib. to Big Creek	ESP-20	5	4	2	3	14	M	1	4	3	3	11	M
44.21	Upper Rock Creek	BSP-41	5	1	3	3	12	M	3	3	2	2	10	L
46.56	Trib. to Trib. to Upper Rock Creek	S3-07(BW-38)	5	2	3	3	13	M	4	3	2	3	12	M
48.27	Deep Creek	BSP-257(MOD)	5	3	2	3	13	M	3	1	2	4	10	L
50.28	Middle Fork Coquille River	BSP-30	5	4	3	3	15	*H*	3	4	3	3	13	M
50.45	Trib. to Middle Fork Coquille	GDX-36 (BS-66/67)	4	2	2	2	10	L	3	3	2	3	11	M
50.71	Belieu Creek	GSI-37 (BSP-61)	4	1	2	4	11	M	1	4	2	3	10	L
51.02	Trib. to Middle Fork Coquille	S1-07 (GSI-38)	2	3	2	3	10	L	3	2	2	3	10	L
51.71	Unnamed Creek	SS-222-006	2	1	3	3	9	L	1	3	2	2	8	L
55.90	Trib. to Shields Creek	BSI-202	4	4	3	3	14	M	3	3	4	4	14	M

2017 MP	Waterbody	Waterbody ID	Landscape Stream Type Score	Riparian Score	Bank Score	Bed Score	X-Axis Score	X-Axis Rating	Floodplain Disturbance Score	Channel Disturbance Score	Construction Score	Stabilization Score	Y-Axis Score	Y-Axis Rating
55.94	Trib. to Shields Creek	BSI-203	4	4	2	1	11	M	1	3	2	3	9	L
56.28	Trib. to Shields Creek	DA-13	4	1	2	3	10	L	2	5	2	2	11	M
56.34	Trib. to Shields Creek	DA-14	4	1	2	3	10	L	2	5	2	2	11	M
57.11	Trib. to Olalla Creek	BSI-140	4	2	2	3	11	M	3	4	2	3	12	M
57.31	Trib. to Olalla Creek	BSI-138	4	2	2	3	11	M	3	4	4	4	15	M
57.84	Trib. to Olalla Creek	EE-12 (BSI-147)	4	3	3	2	12	M	3	5	4	4	16	*H*
58.20	Trib. to Olalla Creek	BSI-151	4	2	5	3	14	M	3	3	2	4	12	M
58.55	Trib. to Olalla Creek	BSP-159	3	4	4	1	12	M	5	1	4	4	14	M
58.78	Olalla Creek	BSP-155	5	2	3	2	12	M	1	4	4	3	12	M
59.29	Trib. to Olalla Creek	BSI-132	4	2	4	2	12	M	3	3	4	4	14	M
59.65	Trib. to Olalla Creek	BSI-129	4	1	5	2	12	M	1	4	2	4	11	M
60.13	Trib. to McNabb Creek	NSP-14	1	3	2	2	8	L	3	3	2	3	11	M
60.48	McNabb Creek	NSP-13	4	2	4	2	12	M	1	3	4	4	12	M
63.97	Kent Creek	BSP-240	4	3	5	2	14	M	3	1	4	4	12	M
65.76	Rice Creek	S2-04 BSP-227 (MOD)	5	3	4	2	14	M	3	1	4	4	12	M
66.87	Trib. to Willis Creek	BSI-230	1	4	3	1	9	L	1	4	2	3	10	L
66.95	Willis Creek	BSP-168	5	4	4	2	15	*H*	3	3	2	4	12	M
67.00	Trib. to Willis Creek	BSI-169	1	4	4	1	10	L	3	1	4	4	12	M
69.29	Trib. to South Umpqua River	SS-004-004 (SS-100-012)	5	2	3	3	13	M	2	2	4	4	12	M
69.35	Trib. to South Umpqua River	SS-004-005 (SS-100-013)	5	1	3	3	12	M	2	2	4	4	12	M
71.35	Trib. to South Umpqua River	SS-005-008 (SS-100-016)	2	1	3	3	9	L	1	4	4	4	13	M
71.51	Trib. to South Umpqua River	SS-005-008 (SS-100-016)	1	1	3	3	8	L	1	4	4	4	13	M
73.04	Trib. to South Umpqua River	SS-005-009 (SS-100-019)	1	5	2	2	10	L	1	4	4	2	11	M
73.51	Trib. to South Umpqua River	SS-005-013 (SS-100-020)	1	2	3	3	9	L	1	3	2	3	9	L
73.56	Trib. to South Umpqua River	SS-005-011 & 012 (SS-100-021)	1	2	3	3	9	L	2	3	2	3	10	L
73.73	Unnamed Creek	SS-005-010	2	2	3	3	10	L	2	4	2	3	11	M
75.33	Rock Creek	EE-SS-9032	1	4	3	3	11	M	2	3	3	3	11	M
75.34	Trib. to Rock Creek	EE-SS-9033	1	3	3	3	10	L	2	4	3	3	12	M
76.38	Bilger Creek	BSP-1	5	5	2	3	15	*H*	1	5	2	3	11	M
77.71	Little Lick Creek	BSP-6	3	1	3	2	9	L	3	1	4	4	12	M
77.93	Trib. to Little Lick Creek	BSI-8	2	1	3	4	10	L	1	3	3	3	10	L
78.02	Trib. to Little Lick Creek	BSI-10	3	4	3	3	13	M	3	4	2	2	11	M
79.12	North Myrtle Creek	NSP-37	5	3	4	1	13	M	3	1	2	4	10	L
79.15	Trib. to North Myrtle Creek	NSP-38	4	3	2	1	10	L	1	4	2	3	10	L
81.19	South Myrtle Creek	BSP-172	5	1	2	2	10	L	3	4	4	4	15	M
81.38	Trib. to S. Myrtle Creek	BSP-259	5	2	3	2	12	M	3	2	2	4	11	M
81.93	Trib. to S. Myrtle Creek	EE-SS-9074	1	5	3	3	12	M	1	4	4	4	13	M
84.17	Wood Creek	BSP-226	4	2	3	3	12	M	3	1	3	3	10	L
85.69	Trib. to Wood Creek	EE-SS-9041	3	5	3	2	13	M	1	4	4	4	13	M
85.71	Trib. to Wood Creek	EE-SS-9042	3	5	3	2	13	M	1	4	4	4	13	M
86.07	Trib. to Wood Creek	EE-SS-9044	1	5	3	2	11	M	1	4	3	3	11	M
88.20	Trib. to Fate Creek	BSI-236	4	4	3	3	14	M	1	4	2	2	9	L
88.48	Fate Creek	BSP-232	4	1	2	2	9	L	3	2	4	4	13	M
88.60	Days Creek	BSP-233	4	3	4	1	12	M	3	1	3	4	11	M
92.62	Saint John Creek	ASP-303	4	3	2	2	11	M	1	3	2	3	9	L
94.73	South Umpqua River	ASP-196	5	1	2	1	9	L	1	4	4	3	12	M
94.85	Trib. to South Umpqua River	ASI-193 (ASI-191)	1	1	4	4	10	L	1	4	2	4	11	M
95.03	Trib. to South Umpqua River	ASI-193 (ASI-191)	4	2	4	3	13	M	1	4	4	4	13	M
98.46	Trib. to South Umpqua River	ASI-190	1	1	4	1	7	L	1	4	4	4	13	M
109.33	Trib. to East Fork Cow Creek	GSI-16 (FS-HF-F)	1	1	4	4	10	L	1	3	2	4	10	L
109.17	Trib to East Cow Creek (wetland)	GW-14 (FS-HF-C)	1	1	4	5	11	M	3	3	3	4	13	M

2017 MP	Waterbody	Waterbody ID	Landscape Stream Type Score	Riparian Score	Bank Score	Bed Score	X-Axis Score	X-Axis Rating	Floodplain Disturbance Score	Channel Disturbance Score	Construction Score	Stabilization Score	Y-Axis Score	Y-Axis Rating
109.47	East Fork Cow Creek	GSP-19 (ASP-297/FS-HF-G)	4	1	3	3	11	M	1	3	4	4	12	M
109.69	East Fork Cow Creek	GSP-22 (ASP-297/FS-HF-M)	1	4	3	2	10	L	1	4	4	4	13	M
109.69	Trib. to East Fork Cow Creek	FS-HF-J	1	4	3	2	10	L	1	4	4	4	13	M
109.78	Trib. to East Fork Cow Creek	FS-HF-K	4	3	5	2	14	M	3	1	4	4	12	M
110.96	Trib. to East Fork Cow Creek	FS-HF-N (ESI-68)	4	4	2	4	14	M	1	5	2	3	11	M
118.80	Trib. to W. Fork Trail Creek	SS-100-032	1	3	3	3	10	L	1	4	3	3	11	M
118.89	West Fork Trail Creek	ASP-202	5	2	3	1	11	M	3	1	3	3	10	L
119.84	Trib. to Trail Creek	S1-06 (DA-16 (MOD))	1	3	2	3	9	L	3	2	2	3	10	L
120.45	Canyon Creek	NSP-11	4	3	3	1	11	M	3	3	2	3	11	M
120.90	Trib. to Trail Creek	ASI-205	3	2	3	2	10	L	1	4	4	4	13	M
121.57	Trib. to Trail Creek	ASI-206	4	4	3	2	13	M	1	1	1	2	5	L
125.91	Trib. to Indian Creek	ASI-223	1	4	1	2	8	L	1	4	2	3	10	L
125.98	Trib. to Indian Creek	ASI-222	1	4	2	3	10	L	1	4	2	3	10	L
126.53	Trib. to Indian Creek	RS-4	1	3	2	2	8	L	1	3	2	3	9	L
126.56	Trib. to Indian Creek	ASI-221	1	4	2	2	9	L	1	4	2	3	10	L
128.49	Deer Creek	ASP-307	4	1	3	3	11	M	4	3	2	2	11	M
128.61	Indian Creek	AW-278	4	3	2	2	11	M	1	5	2	3	11	M
128.68	Trib. to Indian Creek	ASP-310	4	5	1	1	11	M	1	4	2	2	9	L
130.86	Trib. to Neil Creek	ASI-246	4	5	3	1	13	M	4	4	2	2	12	M
132.12	Neil Creek	ASP-252	5	1	2	1	9	L	1	3	2	3	9	L
132.77	Quartz Creek	S5-02 (AW-264)	4	3	2	1	10	L	1	3	3	3	10	L
137.48	Whiskey Creek	ASI-207	3	2	1	2	8	L	1	5	3	3	12	M
138.26	Trib. to Lick Creek	ASI-208	1	2	2	4	9	L	1	4	3	3	11	M
138.44	Trib. to Lick Creek	SS-GM-10	3	2	3	3	11	M	3	2	3	3	11	M
138.50	Trib. to Lick Creek	ASI-210	1	4	2	2	9	L	1	3	3	3	10	L
138.55	Trib. to Lick Creek	SS-GM-11	3	3	3	3	12	M	3	3	3	3	12	M
138.74	Trib. to Lick Creek	SS-GM-13	3	3	3	3	12	M	3	3	3	3	12	M
139.07	Trib. to Lick Creek	SS-GM-14	3	4	2	3	12	M	1	3	3	3	10	L
139.21	Trib. to Lick Creek	SS-GM-15	4	4	2	2	12	M	1	3	3	3	10	L
139.28	Trib. to Lick Creek	SS-GM-16	4	4	2	2	12	M	1	3	3	3	10	L
139.42	Trib. to Lick Creek	ASI-217	2	2	2	3	9	L	1	4	3	3	11	M
139.59	Trib. to Lick Creek	ASI-226	2	2	1	2	7	L	1	5	3	3	12	M
139.63	Trib. to Lick Creek	ASI-227	2	2	1	2	7	L	1	5	3	3	12	M
139.68	Trib. to Lick Creek	ASI-228	2	2	2	2	8	L	1	1	2	2	6	L
139.72	Trib. to Lick Creek	ASI-229	2	4	2	2	10	L	1	5	2	2	10	L
140.27	Lick Creek	ASI-233	4	4	3	3	14	M	3	2	3	3	11	M
141.48	Trib. to Salt Creek	ASI-188	1	3	2	1	7	L	3	1	3	3	10	L
141.95	Trib. to Salt Creek	ESI-30	2	2	2	2	8	L	1	4	3	3	11	M
142.57	Salt Creek	ESP-34	4	1	2	2	9	L	3	3	3	3	12	M
143.12	Trib. to Salt Creek	ESI-37	2	2	2	2	8	L	1	5	3	3	12	M
143.51	Trib. to Long Branch Creek	ESI-38	2	2	3	3	10	L	1	5	3	3	12	M
143.74	Trib. to Long Branch Creek	ESI-39	2	2	3	3	10	L	1	3	3	3	10	L
143.77	Trib. to Long Branch Creek	ESI-40	2	2	2	4	10	L	1	3	3	3	10	L
144.11	Long Branch Creek	ESI-38	3	3	3	3	12	M	3	3	3	4	13	M
144.70	Trib. to S. Fork Long Branch Creek	GSP-5 (ESP-48)	4	3	2	3	12	M	1	3	3	3	10	L
145.27	South Fork Long Branch Creek	GSI-6 (ESP-59)	3	2	3	2	10	L	3	1	3	3	10	L
145.54	Trib. to S. Fork Long Branch Creek	ESI-61	4	2	2	2	10	L	1	3	3	3	10	L
145.69	North Fork Little Butte Creek	ESP-66	4	2	2	3	11	M	1	3	3	3	10	L
146.05	Trib. to N. Fork Little Butte	ESI-56	2	2	2	2	8	L	1	4	3	3	11	M
146.38	Trib. to N. Fork Little Butte	ESI-55	2	1	3	2	8	L	3	3	2	3	11	M
162.45	South Fork Little Butte Creek	ASP-165	5	2	3	2	12	M	3	4	2	4	13	M

2017 MP	Waterbody	Waterbody ID	Landscape Stream Type Score	Riparian Score	Bank Score	Bed Score	X-Axis Score	X-Axis Rating	Floodplain Disturbance Score	Channel Disturbance Score	Construction Score	Stabilization Score	Y-Axis Score	Y-Axis Rating
166.21	Daley Creek	ESI-76 (ESI-84)	3	4	2	2	11	M	4	4	2	1	11	M
171.07	Spencer Creek	WW-001-013 (EW-85)	3	1	4	4	12	M	1	3	3	4	11	M
173.74	Trib. to Spencer Creek	ESI-106a	4	2	4	4	14	M	1	5	2	4	12	M
176.54	Trib. to Spencer Creek	ESI-69	1	5	4	4	14	M	3	3	3	4	13	M
176.56	Trib. to Spencer Creek	GSI-10	1	5	4	4	14	M	3	3	3	4	13	M
177.76	Clover Creek	SS-502-EW103	3	4	4	2	13	M	1	4	2	4	11	M
177.76	Clover Creek	GSI-11	3	4	4	2	13	M	1	4	2	4	11	M
186.61	Trib. to Klamath River	ESI-97	3	4	3	2	12	M	1	1	1	2	5	L
186.65	Trib. to Klamath River	ESI-99	5	1	3	3	12	M	1	4	2	2	9	L
186.74	Trib. to Klamath River	ESI-100	3	5	3	4	15	*H*	3	4	3	4	14	M
188.90	Trib. to Klamath River	SS-001-001 (SS-100-025)	2	4	1	2	9	L	3	2	3	4	12	M
205.97	Wetland Ditch	ADX-112	5	1	4	4	14	M	2	2	3	4	11	M
207.60	Drainage Ditch; Irrigation 5-A Drain	ADX-118	3	4	4	5	16	*H*	1	1	4	4	10	L
207.99	Drainage Ditch; Irrigation 5-A Drain	ADX-119	3	4	3	4	14	M	3	2	2	3	10	L
208.18	Drainage Ditch; Irrigation 5-A Drain	ADX-123	3	4	3	4	14	M	3	1	4	4	12	M
210.26	River)	SS-003-001 (ADX 143)	5	1	3	4	13	M	2	3	2	2	9	L
210.85	River)	ADX-260	5	1	3	4	13	M	2	2	4	4	12	M
212.07	Lost River	SS-003-005 (NSP-1)	5	4	3	5	17	*H*	1	4	4	3	12	M
216.10	Unnamed Creek	ASI-51	3	4	3	2	12	M	3	1	2	3	9	L
216.11	Unnamed Creek	ASI-52	2	5	3	2	12	M	3	2	2	3	10	L
216.30	Unnamed Creek	ASI-50	2	4	3	3	12	M	3	1	2	3	9	L
216.44	Unnamed Creek	ASI-49	3	4	3	4	14	M	3	1	2	3	9	L
218.09	Trib. to D Canal	ASI-136	5	2	2	4	13	M	3	2	2	3	10	L
218.46	Trib. to D Canal	ASI-137	5	5	2	4	16	*H*	3	2	2	3	10	L
219.69	Trib. to D Canal	ASI-291	3	1	3	3	10	L	4	4	2	2	12	M
225.96	Trib. to V Canal	ASI-140	2	1	3	3	9	L	4	3	3	3	13	M

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Stream Crossing Risk Analysis Addendum

Pacific Connector Gas Pipeline
Coos, Douglas, Jackson and
Klamath Counties, Oregon

for

Pacific Connector Gas Pipeline, LP

April 6, 2018

GeoEngineers
Earth Science + Technology

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Stream Crossing Risk Analysis Addendum

Pacific Connector Gas Pipeline
Coos, Douglas, Jackson, and Klamath Counties, Oregon

File No. 22708-001-00

April 6, 2018

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INTRODUCTION

This report serves as an addendum to the 2017 Pacific Connector Gas Pipeline Stream Crossing Risk Analysis (GeoEngineers, 2017a) prepared for Pacific Connector Gas Pipeline, LP (PCGP), and presents the findings from preconstruction surveys of moderate and high-risk stream crossings. The preconstruction surveys were identified as a requirement in the Risk Analysis in order to: (1) "ground truth" the preliminary risk rankings, (2) revise the management categories as appropriate based on-site observations, and (3) develop site-specific best management practices (BMPs) and restoration plans for Yellow and Orange management category stream crossings, respectively. The Risk Analysis and Addendum provide information on stream channel characteristics to assist PCGP in identifying stream crossings that require atypical approaches to waterbody crossing and site restoration but does not make recommendations for pipeline alignment modifications or pipeline construction techniques.

The proposed PCGP pipeline route extends from the proposed Jordan Cove liquefied natural gas (LNG) terminal in Coos Bay, Oregon, to the California border near Malin, Oregon (Figure 1). The natural gas pipeline will be 36-inch-diameter and approximately 229 miles long. PCGP proposes to cross 330 waterbodies listed in Table A.2-2 of Resource Report 2 of the Pacific Connector Certificate application (PCGP, 2017). A number of the waterbodies identified in Resource Report 2 consisted of stock ponds, wetland swales without established stream channel beds or banks, or ditches and canals that, upon field inspection and review of existing information, are artificially maintained and do not function with normative fluvial geomorphic processes. Other waterbodies were located in the construction right-of-way but would not be trenched for pipeline installation across their channel course. Because the risk analysis is specifically geared toward characterizing and assessing the risk associated with pipeline installation on fluvial processes, it is not applicable to these waterbodies. In addition, horizontal directional drilling and direct pipe trenchless methods are proposed for six crossings from Table A.2-2 of Resource Report 2 eliminating the need to assess risk at these locations. Removing these cases from the analysis, a total of 173 crossings were evaluated in the 2017 Risk Analysis using the United States Fish and Wildlife Services (USFWS) risk matrix. Management approaches for irrigation canals and ditches in the Bureau of Reclamation Klamath Project are described in PCGP (2017).

This addendum to the Stream Crossing Risk Analysis is provided by PCGP in fulfillment of information requested from the Oregon Department of Environmental Quality (ODEQ) in a March 2, 2010 letter. In that letter, ODEQ states:

> "*Fluvial processes need to be understood to determine risk and contingency actions in choosing crossing locations, choosing crossing methods and future monitoring and response*".

This addendum to the Stream Crossing Risk Analysis provides information related to waterbody crossings and site restoration requested through recommendations of the Federal Energy Regulatory Commission (FERC) Draft Environmental Impact Statement (DEIS), issued November 2014 and specifically addresses the following requirements made by FERC in their DEIS:

"23. *Pacific Connector shall file with the Secretary individual stream crossing designs for stream crossings that:*

   a. *support or are assumed to support federally listed fish species and are rated by the FWS matrix evaluation methods as having either a high stream response potential and moderate project impact potential, or a moderate stream response potential and high project impact potential; or*

b. *are of special concern to the BLM and Forest Service for stream crossing construction effects.*

*The designs shall be based on site-specific information for each of these crossings including stream characteristics, bank conditions, and riparian habitat. (*EIS section 4.6.2.3*)*

24. *Pacific Connector shall file with the Secretary a stream crossing monitoring plan to be implemented during operation of the pipeline. The plan shall include the rationale for scheduling the timing of stream monitoring, monitoring locations, and the specific criteria Pacific Connector would use to determine whether stream stability and bank conditions are being maintained, as well as remediation actions what would occur should crossing not meet the criteria. The plan shall include documentation of Pacific Connector's consultation with the appropriate agencies in developing the plan." (*EIS section 4.6.2.3*)*

PCGP is submitting a Joint Permit Application (JPA) to the Corps and Oregon Department of State Lands (ODSL) for permission to dredge and fill materials from wetlands and waters of the state under Section 404 of the CWA (PCGP, 2017). As part of the CWA Section 401 water quality certification of the JPA, the ODEQ requested on March 2, 2010 that PCGP evaluate stream crossings along their route according to the Pipeline Screening Risk Matrix. The matrix was developed by the USFWS and was presented in their December 23, 2009 comments on the JPA. The matrix was presented as Figure 3 in the Stream Crossing Risk Analysis and is presented below:

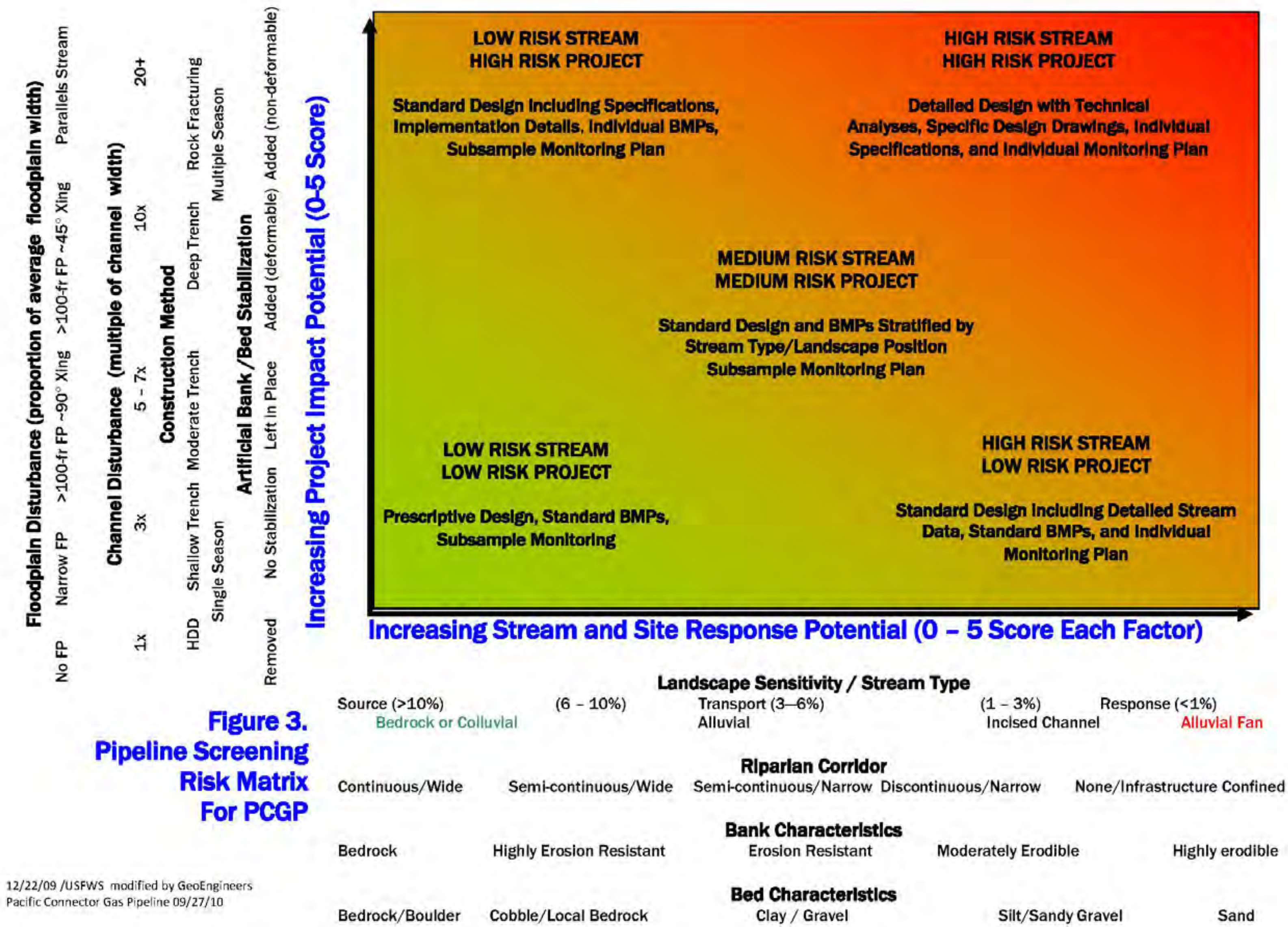


Figure 3.
Pipeline Screening Risk Matrix For PCGP

RISK ANALYSIS BACKGROUND

The Stream Crossing Risk Analysis is part of a broader evaluation of potential water quality, stream channel stability, and riparian impacts resulting from pipeline construction and maintenance. The studies requested by ODEQ also included a thermal impacts analysis, hyporheic exchange impacts analysis, and a study on the impacts to turbidity, nutrients, and metals along the streams crossed by the PCGP route.

ODEQ's request for PCGP to perform the original Risk Analysis was based, in large part, on comments made by the USFWS in their December 23, 2009 letter in response to the Public Notice for the Army Corps of Engineers' (Corps) Section 404 permit application. The intent of the Risk Analysis is to require applicants such as PCGP to focus resources on those waterbody pipeline crossings that present the greatest risk of impacts to beneficial uses through construction impacts or maintenance of the pipeline over the life of the project. ODEQ's regulatory authority under the Clean Water Act (CWA) and Oregon Administrative Rule is provided to maintain beneficial uses through enforcement of water quality standards. ODEQ's specific focus for the PCGP project has been on temperature, turbidity/sedimentation, dissolved oxygen, and nutrients. Instream construction, hydraulic disconnection, and unstable channels following pipeline construction could potentially degrade water quality and aquatic habitat resources.

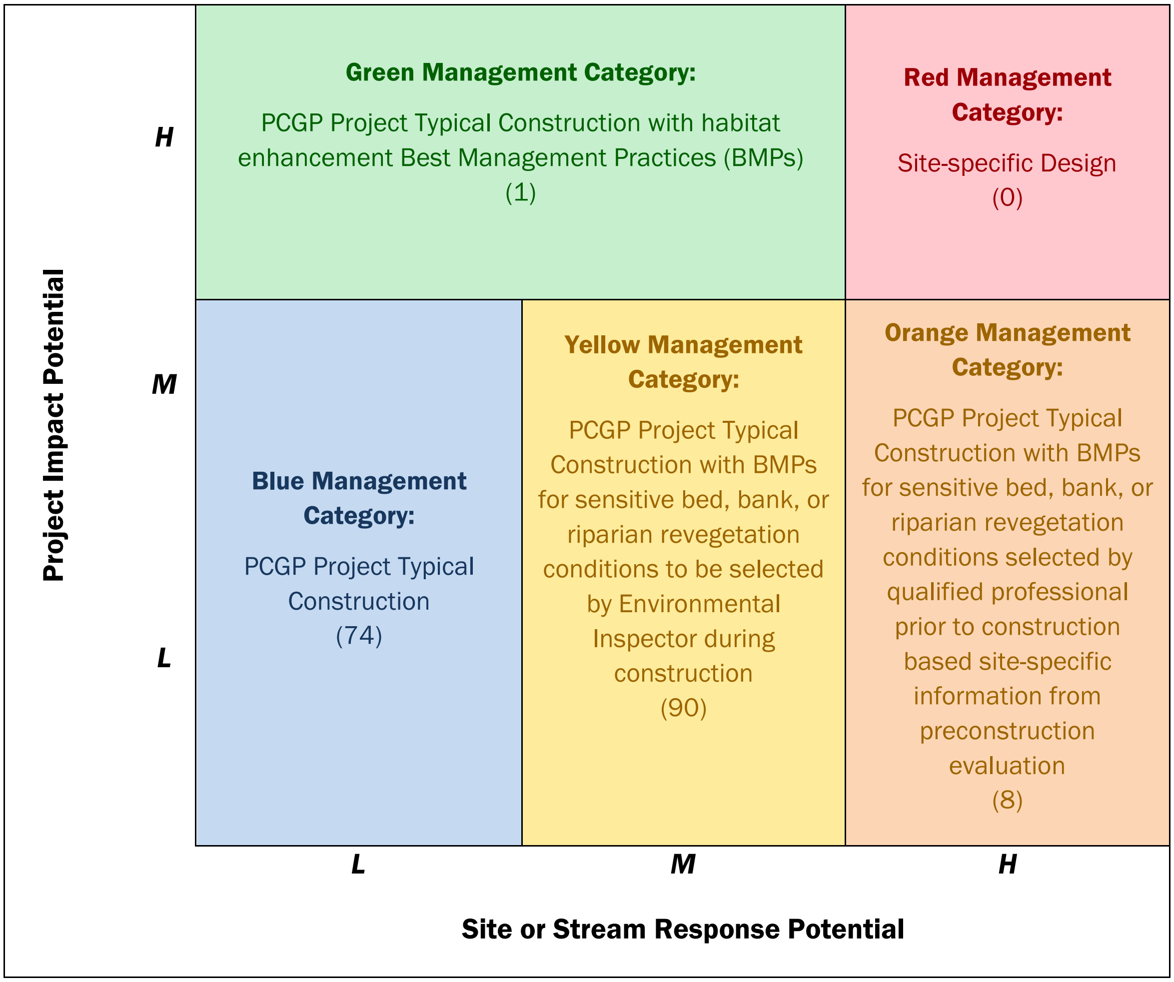
GeoEngineers, Inc. (GeoEngineers) completed the following scope of services as part of the 2017 Stream Crossing Risk Analysis:

1. Identified the absence or presence of fluvial processes at each of the stream crossings along the PCGP route;
2. Estimated the potential response of the stream channel in the vicinity of the stream crossing to channel disturbance from pipeline construction and operation;
3. Identified high-level riparian and aquatic habitat characteristics at each stream crossing, for purposes of determining the crossing's overall risk rating;
4. Estimated the degree to which aggregate habitat characteristics could be affected by pipeline installation;
5. Assigned a risk level to each stream crossing based on the channel stability and habitat quality measures;
6. Identified general design guidance, contingency measures, and monitoring protocol specific to crossings within each risk level; and
7. Identified next steps for additional data collection, including those completed as part of this addendum.

The Stream Crossing Risk Analysis matrix distinguishes between the hazards associated with stream or river behavior expected to occur over the life of the project, and the risk associated with that hazard. The assessment of risk was applied based on the potential for exposure of the pipeline resulting from stream and river channel erosion and/or movement, not the consequences of potential exposure. Following a desktop study and preliminary field investigation, crossings were evaluated according to the Risk Matrix and categorized as one of the nine possible risk categories (for example, ML = Moderate along the X axis, Low along the Y axis). Stream crossings were grouped into management categories with designated construction and/or site restoration approaches ranging from site-specific design to typical construction methods.

A graphic showing the management category classifications from Figure 4 of the 2017 Stream Crossing Risk Analysis is presented below:

MANAGEMENT CATEGORY CLASSIFICATIONS



2017 Risk Analysis Management Categories

A total of 173 waterbody crossings were considered to have fluvial characteristics and were, therefore, evaluated using the USFWS Pipeline Screening Matrix. In the original Risk Analysis, the 173 sites were classified and grouped into the following management categories: 74 Blue, 90 Yellow, 8 Orange, 1 Green and 0 Red. A total of 98 sites were classified within the Yellow or Orange management categories; equating to moderate and high risk for pipeline exposure due to potential stream instability as a result of pipeline construction.

PURPOSE AND SCOPE OF THE ADDENDUM

The purpose of this Addendum is to present results of additional work that was completed according to the terms outlined in the Risk Analysis. Specifically, PCGP agreed to conduct field investigations at Orange and Yellow sites in order to confirm or revise the risk assignments made during the desktop study.

The scope of work completed to achieve the purpose of the Addendum to the Stream Crossing Risk Analysis included:

- Review previous methods and risk management assignments;
- Complete a field assessment of all accessible Orange and Yellow sites;
- Identify physical characteristics that could affect the response of the stream channel in the vicinity of the stream crossing to pipeline construction and operation; and
- Evaluate the risk assignments for moderate and high hazard crossings:
  - Revise risk and identify a new management category for each site as appropriate using updated information;
  - Identified BMPs that can be implemented to maintain stream stability at Yellow sites to be implemented during construction; and
  - Identified unique site attributes and develop site-specific designs for Orange sites.

This analysis applies to all stream crossings that have been evaluated to display fluvial characteristics, including those known or assumed to support federally listed fish species. The Risk Analysis also addresses streams that are of special concern to the Bureau of Land Management (BLM) and US Forest Service.

METHODS

Review Stream Crossing Risk Analysis and Field Planning

Table A-1 in the 2017 Stream Crossing Risk Analysis had 98 sites in the Yellow and Orange management categories. Preconstruction survey was planned for the following stream crossings:

1. All 98 Orange and Yellow sites (Orange given the highest priority).
2. Four Blue sites and one Green site that were added at the request of Edge Environmental based on their prior site observations of potentially geomorphically unstable sites.
3. Three Blue sites that were added by GeoEngineers to validate lower risk ranking stream crossings and to increase the sample size of preconstruction survey sites.

A total of 106 sites were identified for preconstruction survey based on the criteria above. Table A-1 (Appendix A) summarizes all the sites subject to preconstruction survey planning and their respective pre- and post-survey management categories.

GeoEngineers provided the list of crossings to PCGP Lands Division (Lands) to acquire the necessary access agreements. Access agreements were subsequently acquired for a portion of the sites. For a small group of sites, the observations of nearby or adjacent streams were considered to be representative of the stream crossings that were on the preconstruction survey list. Forty-eight of the stream crossings sites were physically observed between May and August 2014. Access to the remaining sites has not been granted by the property owners as of the date of this report.

Preconstruction Surveys

Preconstruction surveys were performed at the selected crossings described above to observe current site conditions, ground-truth data from the desktop study, and to provide a basis for developing site-specific approaches for restoration planning. Fieldwork was completed during two time periods, in May and August 2014. Each field team consisted of a geomorphologist and/or a hydrologist/hydraulic engineer qualified to assess the conditions germane to pipeline construction across stream channels. The final determination of the management category for five sites was based on data collected from adjacent or nearby streams with similar geomorphic characteristics and supplemented with additional desktop data. These sites are identified in Table A-1.

Data collected during the preconstruction surveys were selected to specifically identify physical characteristics of stream channel stability as defined by the X-axis of the USFWS Pipeline Screening Risk Matrix presented in the Introduction section above, which addresses "Stream and Site Potential". The X-axis of the Risk Matrix was designed to identify those streams where the combination of channel characteristics could result in short- or long-term exposure of the pipeline or related instability if "typical" pipeline construction techniques are used. Channel characteristics that affect stream stability include: channel slope or stream type, width of the riparian corridor, bank materials characteristics, and bed material distribution.

Stream channel data collected during the preconstruction survey include channel configuration/morphology; size and distribution of instream structure(s) that affects the in-channel distribution of hydraulic energy (e.g., logs and large rock), substrate grain size, and bank geometry/material composition. Habitat conditions were evaluated during the preconstruction surveys for consideration of additional BMPs beyond the typical that may be required for site restoration. Site conditions were documented in a field data collection worksheet developed by GeoEngineers specifically for the PCGP project. The form was developed to ensure that the necessary input parameters for the Risk Matrix were collected consistently and uniformly at each observed crossing location. Exhibit A-2 in Appendix A provides the field forms from the 2014 preconstruction surveys.

Specific observations and measurements made during the preconstruction surveys include:

- Representative cross sections identifying existing channel geometry, including low flow, high flow channels, and floodplain areas within the proposed crossing corridor.
- Profile of the channel through the area to be disturbed identifying habitat units such as pools, riffles, steps, in-stream wood, etc.
- Bed and bank composition and cohesive properties.
- Vertical or lateral scour features.
- Large wood loading.

Cross sections and/or profiles were field measured at sites where field designations confirmed an Orange risk ranking, suggesting high potential for instability and the need for site-specific design.

Risk Assessment and Updated Management Category Assignment

The risk rankings at 48 crossing sites were revised as necessary based on results of the 2014 preconstruction surveys. In general, revisions to the assessed risk were a result of changes from the assumed to the actual observed physical parameters input along the X-axis of the Risk Matrix. Exhibit A-2 presents the field forms with updated risk rankings. One exception to this was at a single crossing within the green management category (MP 57.84) where updates to variables along the Y axis led to a change from the green to blue management category.

Sites were then reclassified to either the Blue, Yellow or Orange management categories; no sites were reclassified to Red or Green management categories resulting from the preconstruction survey. Changes to risk designation and reclassification of a site into a new management category and the rationale for such changes are documented in the results section of this Addendum, Appendix A, and Appendix B.

Additionally, management category assignments were determined for several crossings that were not physically observed but at which nearby streams with similar geology, valley, and channel characteristics could be observed. For each of these five stream crossings, management categories were made based not only on field observation of nearby streams, but also through additional aerial photo and/or LiDAR interpretation. Sites meeting these criteria are identified as such with a footnote in Table A-1.

Review and Incorporation of Site-Specific Recommendations from BLM and USFS

The PCGP pipeline route crosses Bureau of Land Management (BLM) and United States Forest Service (USFS) jurisdictions. These agencies have provided an evaluation of select, perennial waterbodies to identify resource values and recommendations for restoration planning (North State Resources, 2014). BMPs for construction and site-specific recommendations for restoration of these select crossings are presented in a similar manner as this Addendum. Site-specific BMPs and recommendations are provided for the following perennial streams on their lands:

- MP 24.07 Middle Creek
- MP 37.35 Tributary to Big Creek
- MP 48.27 Deep Creek
- MP 109.17 Tributary to East Fork Cow Creek
- MP 109.47 East Fork Cow Creek
- MP 109.69 Tributary to East Fork Cow Creek
- MP 109.78 Tributary to East Fork Cow Creek
- MP 162.45 South Fork Little Butte Creek

GeoEngineers reviewed the recommendations presented by the USFS and BLM and have incorporated those recommendations into the site-specific BMPs or the site-specific restoration plans, depending on the management category of the particular stream crossing.

Development of Site-Specific BMPs

Construction of the PCGP pipeline through the stream crossings evaluated as part of this study will typically be completed via dry, open cut trench, which will remove and replace bed and bank materials from the stream. Details of typical stream crossing construction and site restoration methods are described in Appendix F "Affected Water Resources" of Resource Report 2 (PCGP, 2017). Sites within the Blue management category require typical stream crossing construction methods. Sites within the Yellow and Orange management categories require site-specific measures to maintain channel stability or replace disturbed habitat. Typical BMPs were developed for use at Yellow management category sites, while site-specific restoration plans were prepared for the Orange management category sites.

Typical BMPs were developed to provide PCGP and their contractors with a suite of "typical" channel restoration methods that can be implemented as needed at Yellow (or other) management category site locations. The BMPs are designed to be applied to a variety of channel sizes, planforms, slopes, and instream features that are representative of suggested restoration techniques that are appropriate for the stream crossings traversed by the PCGP pipeline route. Site-specific BMPs can be selected by PCGP or their representatives during stream crossing restoration to address easily identified instabilities related to bed and/or bank instabilities. The BMPs can be applied to restore the site in a manner that allows for long-term stream stability and protection of the pipeline from potential exposure.

The typical BMPs were developed for sites in the Yellow management category to address risks posed by bed and bank instability or degradation to existing high quality aquatic habitat. These site-specific BMPs were developed based on field observation of natural analog structures and widely accepted techniques for bank restoration, bed restoration, and aquatic habitat restoration techniques. Site-specific BMPs are classified into two categories to address potential stream stability issues. Table 1 below shows the various BMPs developed for PCGP:

TABLE 1. BEST MANAGEMENT PRACTICES OPTIONS

Bed Restoration BMPs	Bank Restoration BMPs
Mini Jam*	Meander Jam*
Single Channel Cross Log*	Coir Wrap Wall
Mid Channel Key Logs*	Parallel Log Benches
Boulder Cascade*	Toe Protection Log
Boulder Pocket Water*	Turning Wad*
Cobble Check Dam	Sweeper*
Longitudinal Log*	

* BMPs that also function as habitat enhancement features.

Bed restoration BMPs are designed to restore the streambed to preconstruction character by providing stability to the streambed and by minimizing vertical incision, therefore reducing the potential of pipeline exposure in the future. These BMPs generally function by providing erosion resistant hard points along the channel bed that help retain the existing channel profile. Bed restoration BMPs have been developed for a variety of stream types, based on channel slope, substrate, and instream wood content.

Bank restoration BMPs are designed to restore the streambanks to their preconstruction character in areas with erodible banks, by providing roughness and/or stability to existing unstable bank slopes or stream systems with a high potential for lateral instability. These BMPs function to impede lateral erosion within the vicinity of the pipeline crossing. Similar to the bed restoration BMPs, the bank restoration BMPs are designed for application in the wide variety of stream systems present along the PCGP route.

The BMPs were designed to also maintain or enhance the aquatic habitat present in the stream. As such, the BMPs function with a dual purpose in that they can be used to replace naturally occurring large wood or other habitat elements that must be disturbed during construction. These structures will often act to create complexity in the channel by scouring pools and sorting gravels as well as providing refugia for juvenile fish. These dual-purpose structures are marked with an asterisk in Table 1.

Drawings of the typical BMPs are presented in Appendix B. Each BMP was developed to address particular bed or bank instabilities and habitat mitigation elements. Each drawing identifies the appropriate types of conditions at which the BMP may be applied and construction details to assist the contractor in project implementation. The BMP sheets presented in Appendix B display a plan view and details depicting recommended locations for the BMP with respect to the channel geometry and profile. Table B-1 provides an overview of the Yellow management category sites visited during the preconstruction surveys and the recommended BMPs at each site to complete site restoration.

The actual extent and selection of a BMP will depend on conditions identified in the field at the time of construction. Only areas that are disturbed through trenching or grading will require site restoration; areas within the construction right-of-way, but adjacent to disturbed zones, will not be restored. Prior to pipeline construction and stream crossing restoration, PCGP will complete a training for the Environmental Inspectors (EIs) and the contractors responsible for stream crossing restoration to communicate the various types of BMPs to be utilized on the Yellow management category crossings. The training will identity the appropriate applications for each BMP, materials, and construction techniques. Ultimately, site-specific BMPs will be selected in the field in coordination with the EI.

Development of Site-Specific Crossing Restoration Plans

Site-specific restoration plans were developed for crossings that were assessed to be within the Orange management category based on the findings of the preconstruction surveys. The need for site-specific designs is due to more complex geomorphic or hydraulic features that increase risk of channel response to the pipeline, or unique high value habitat features. Site-specific designs were developed using results of the preconstruction surveys, including geomorphic/hydraulic/habitat observations, topographic cross sections, and profiles collected using a hand level and stadia rod.

The site-specific restoration plans utilize similar BMPs as defined for the Yellow management category crossings. The distinction for the Orange management category sites is that specific BMPs are identified to be applied in specific areas to meet clear objectives for stream channel stability or habitat restoration. Crossings where site-specific restoration plans were developed include:

- MP 27.04, Middle Creek
- MP 32.40, Elk Creek
- MP 37.35. Tributary to Big Creek

- MP 44.21, Upper Rock Creek
- MP 109.47, East Fork Cow Creek
- MP 118.89, West Fork Trail Creek
- MP 162.45, South Fork Little Butte Creek

A written description of site-specific features and restoration priorities, and design drawings are presented for each crossing in Appendix C. Each restoration plan typically includes the following sheets: (1) existing conditions plan view, (2) proposed conditions plan view, and (3) proposed sections and details. Descriptive narratives of each Orange site are provided to describe the existing conditions, unique site attributes, and the restoration priorities that are addressed by the site-specific design. Discussions also address the site concerns and restoration actions taken to address concerns at the BLM and USFS sites (North State Resources, 2015). The site-specific restoration plans utilize many of the site-specific BMPs for both consistency and ease of implementation.

The actual extent and installation of site-specific restoration plans will depend on conditions identified in the field at the time of construction. Only areas that are disturbed through trenching or grading will require site restoration; areas within the construction right-of-way, but adjacent to disturbed zones, will not be restored. Site-specific plans will be adjusted in the field in consultation with the EI or other authorized PCGP representative.

SUMMARY OF RESULTS

Preconstruction surveys were completed at a total of 48 sites in 2014. Five of those sites were evaluated using a combination of observation of nearby channels and additional aerial photo/LiDAR analysis. A summary of the management category changes of the 48 sites resulting from the 2014 preconstruction surveys are presented in Table 2.

TABLE 2. SUMMARY OF MANAGEMENT CATEGORY CHANGES RESULTING FROM 2014 FIELD SURVEYS

Management Category	Number of Sites per Category Prior to 2014 Preconstruction Surveys	Number of Sites per Category Following 2014 Preconstruction Surveys
Green	1	0
Blue	5	25
Yellow	38	16
Orange	4	7

The changes resulted in a breakdown of the 173 Risk Analysis sites into management categories as depicted in the following graphic. This breakdown is provisional as there are 58 sites that still require preconstruction assessments.

MANAGEMENT CATEGORY CLASSIFICATIONS AFTER 2014 PRECONSTRUCTION SURVEYS

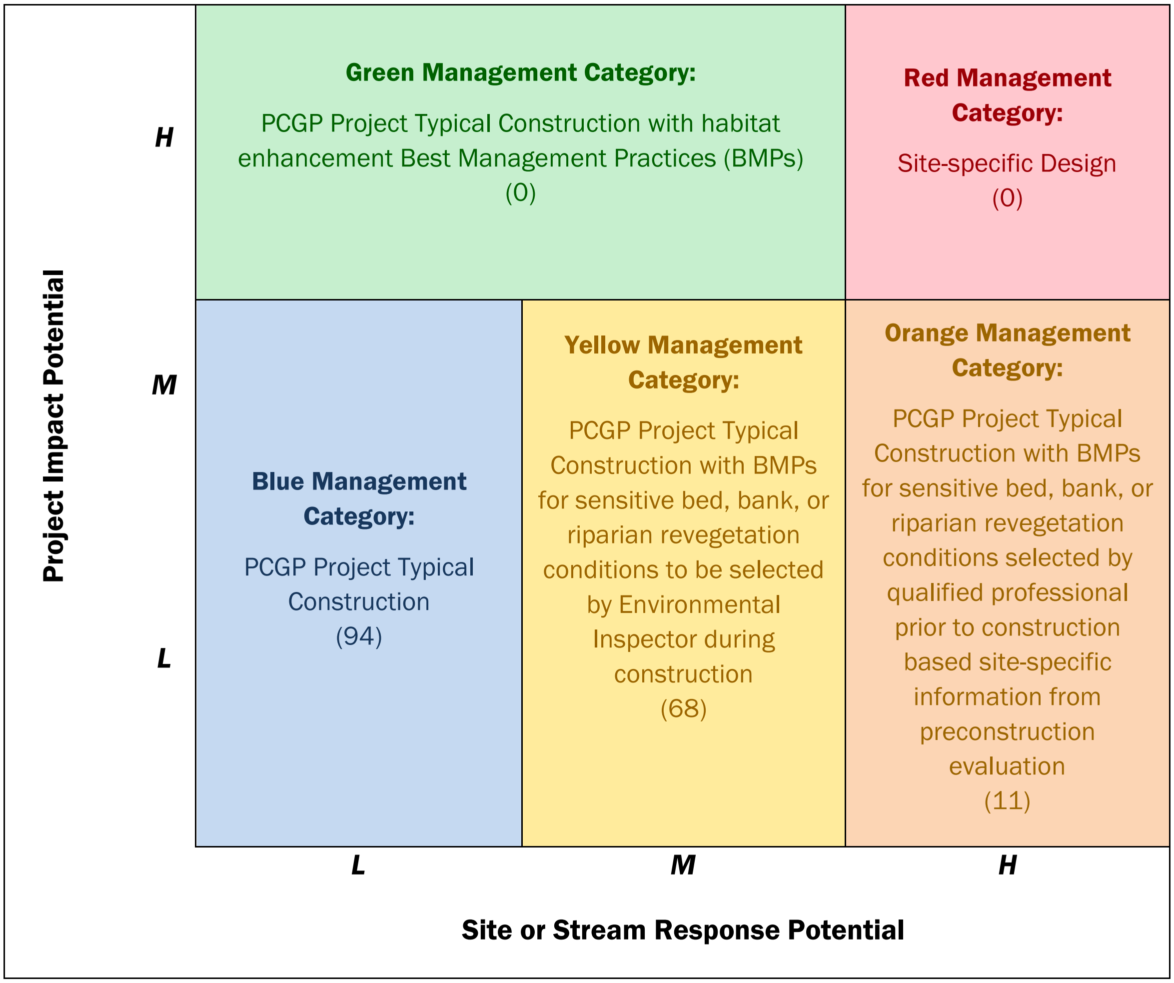


Table A-1 in Appendix A provides a complete and current inventory of the management categories for the 106 stream crossings along the PCGP route that require preconstruction surveys. Sites that have not been observed (58) retain their original management category from the 2017 Risk Analysis. These sites will be subject to preconstruction survey prior to construction following approval of land owner access agreements.

Typical BMPs were developed to provide PCGP and their contractors with a suite of “typical” channel restoration methods that can be implemented as needed at Yellow (or other) management category site locations. Table B-1 provides an overview of the 16 Yellow management category sites evaluated during the 2014 preconstruction surveys. Examples of recommended BMPs for site restoration are identified in Table B-1.

Site-specific restoration plans were developed for seven Orange management category sites based on geomorphic and habitat observations made during the preconstruction surveys. Appendix C presents the site summaries and plans for the seven Orange management category sites.

MONITORING PLAN

Long term monitoring of the stream crossings is required by FERC as outlined in Section 4.6 of the DEIS (FERC, 2014). The general parameters of the monitoring plan described here supersede those previously presented in the 2017 Risk Analysis and DEIS, as related to stream channel monitoring. As requested by FERC in the DEIS, this plan was developed following consultation with a representative from US Fish and Wildlife Service and National Marine Fisheries Service (Castro, 2015).

Monitoring of stream crossings along the pipeline route will be completed by PCGP to ensure long term success of the restoration, maintenance of fish passage, and to identify channel erosion, scour or migration that could destabilize the site or expose the pipeline. The monitoring plan will be customized to address the risks of each stream crossing as identified in the Risk Analysis, and to be identified in subsequent preconstruction surveys. The methods for the monitoring plan will consist of standard methods completed by PCGP for pipeline integrity as well as specialized monitoring approaches for stream crossings.

Monitoring will consist of:

- Annual visits to all stream crossings, regardless of risk level, as part of PCGP's monitoring of pipeline integrity. These visits will be completed by PCGP staff and will note any obvious signs of channel erosion, pipeline exposure, or major shifts in restoration elements. Potential problem areas are subsequently visited by PCGP and a geoprofessional.
- Aerial reconnaissance will be completed annually for the life of the pipeline and stream crossings will be reviewed for major landscape changes such as channel migration and excessive erosion. Potential problem areas are subsequently visited by PCGP and a geoprofessional.
- Quarterly site visits to all sites in the Orange management category for 2 years post construction to monitor revegetation success, structural stability of the restoration elements, any changes to fish passage potential resulting from the project, evidence of channel migration, erosion, head-cutting, or other stream channel movement that could influence stream or pipeline stability. Field measurements will be taken to monitor adjustments to the channel profile and cross-sectional area.
- Annual site visits to 15 percent of all sites in the Blue management category and 100 percent of all sites in the Yellow management category for 2 years post construction to monitor revegetation success, structural stability of the restoration elements, any changes to fish passage potential resulting from the project, evidence of channel migration, erosion, head-cutting, or other stream channel movement that could influence stream or pipeline stability. Field measurements will be taken to monitor adjustments to the channel profile and cross-sectional area.
- Annual site visits to 50 percent of the sites in the Yellow and 100 percent of sites in the Orange management category by a geo-professional in Years 3, 5, 7, and 10 to monitor revegetation success, structural stability of the restoration elements, any changes to fish passage potential resulting from the project, evidence of channel migration, erosion, head-cutting, or other stream channel movement that could influence stream or pipeline stability. Field measurements will be taken to monitor adjustments to the channel profile and cross-sectional area.
- Observations will be made during all site visits on the effects of cattle/elk browsing on restoration success, and of impacts associated with recreational use.
- Revegetation planning along the right-of-way is detailed in the PCGP Erosion Control and Revegetation Plan (ECRP). The ECRP describes monitoring and performance standards for revegetation.

- Records shall be maintained annually to document any significant hydrologic events (flow or rainfall) that occur in between site visits. This shall be done to better understand the site response to moderate or large flood events. As gauging stations are extremely limited over the majority of the crossings along the pipeline route, rainfall records will be used to identify the potential flooding that may occur in between scheduled monitoring events. These climatic events will be considered during annual monitoring when evaluating site response.

  Unscheduled site visits may be completed at stream crossings on BLM and USFS jurisdiction following localized rainfall events exceeding a 25-year rainfall intensity to monitor revegetation success, structural stability of the restoration elements, any changes to fish passage potential resulting from the project, evidence of channel migration, erosion, head-cutting, or other stream channel movement that could influence stream or pipeline stability. Field measurements will be taken to monitor adjustments to the channel profile and cross-sectional area.

- Annual reporting in Years 1, 2, 3, 5, 7, and 10 following construction will be provided to outline observations of stream crossings and any remedial action taken to restore site conditions.

- Monitoring frequency and locations may be modified in response to demonstrating site restoration success in the Annual Monitoring reports.

REFERENCES

Castro, 2015. Personal communication between GeoEngineers and Janine Castro. February 11, 2015.

Federal Energy Regulatory Commission, 2003. Wetland and Waterbody Construction and Mitigation Procedures, http://www.ferc.gov/industries/gas/enviro/wetland.pdf.

Federal Energy Regulatory Commission, 2014. Draft Environmental Impact Statement. Jordan Cove Energy and Pacific Connector Gas Pipeline Project. FERC/EIS 0256D. November 2014.

GeoEngineers, Inc., 2017a, Stream Crossing Risk Analysis, Pacific Connector Gas Pipeline Project, Coos Bay to Malin, Oregon. File No. 16724-001-08. Prepared for Pacific Connector Gas Pipeline, LP, GeoEngineers, Inc., Portland, Oregon, August 2017.

GeoEngineers, Inc., 2017b, Geologic Hazards and Mineral Resources Report, Pacific Connector Gas Pipeline Project, Coos Bay to Malin, Oregon. File No. 16724-001-08. Prepared for Pacific Connector Gas Pipeline, LP, GeoEngineers, Inc., Portland, Oregon, August 21, 2017.

GeoEngineers, Inc., 2017c, Channel Migration and Scour Analysis, Pacific Connector Gas Pipeline Project, Coos Bay to Malin, Oregon. File No. 16724-001-08. Prepared for Pacific Connector Gas Pipeline, LP, GeoEngineers, Inc., Portland, Oregon, August 28, 2017.

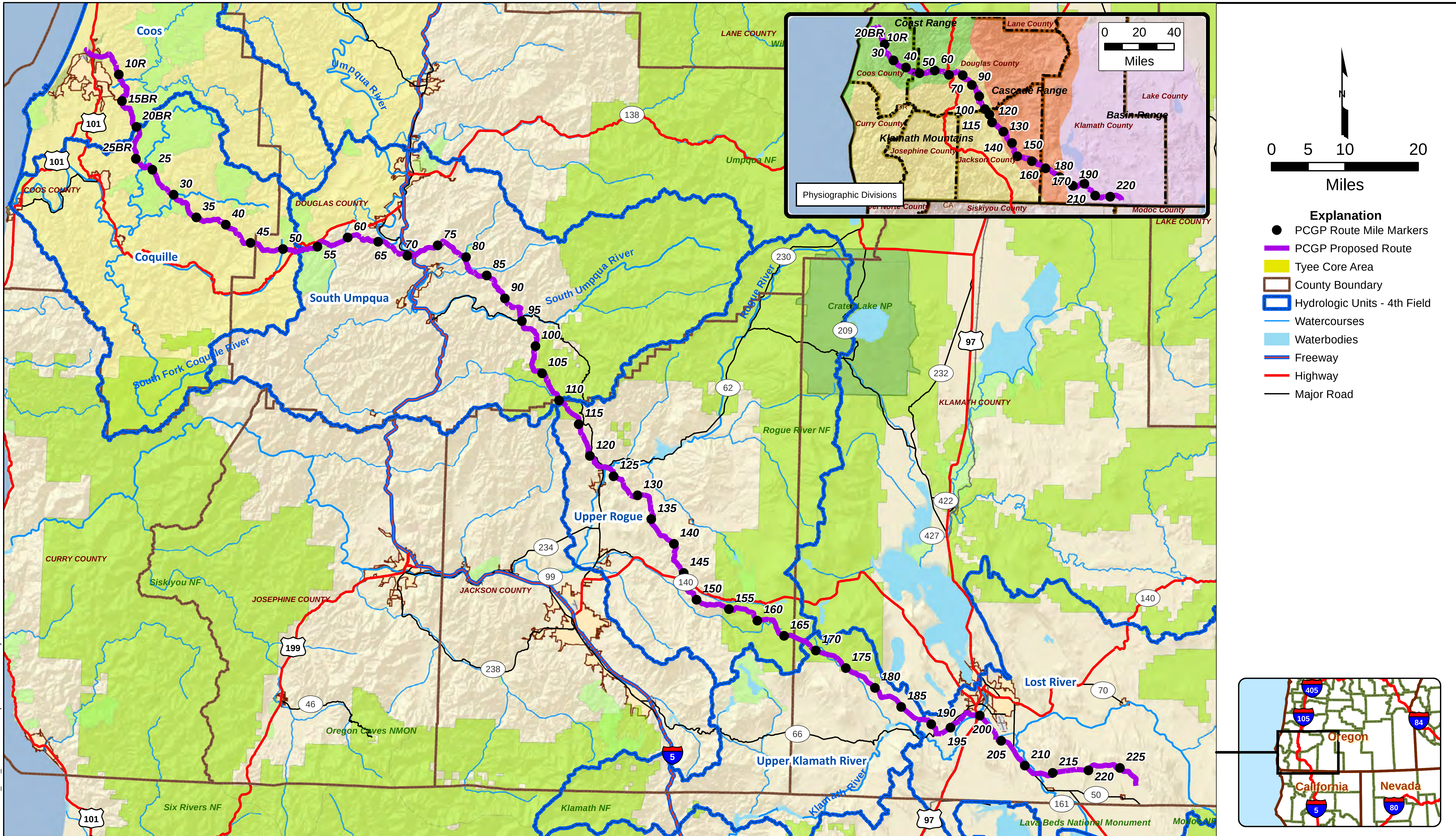
GeoEngineers, Inc. 2017d, Stream Crossing Hyporheic Analysis, Pacific Connector Gas Pipeline Project, Coos Bay to Malin, Oregon. File No. 16724-001-06. Prepared for Pacific Connector Gas Pipeline, LP, GeoEngineers, Inc. Portland, Oregon, August 2017.

North State Resources, Inc. 2014, Site-Specific Stream Crossing Prescriptions Perennial Streams on BLM and National Forest System Lands, Pacific Connector Gas Pipeline Project. File No. 29128-2-14. Prepared for USDI Bureau of Land Management/USDA Forest Service, North State Resources, Inc. Redding, California, December 2014.

Pacific Connector Gas Pipeline, LP, Certificate Application, 2017, Joint Permit Application Form, submitted to the U.S. Army Corps of Engineers (Portland District) and the Oregon Department of State Lands. Prepared for Pacific Connector by Edge Environmental, Lakewood, Colorado.

FIGURES

GeoEngineers



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Data Sources are detailed in attached document.

GEOENGINEERS

PROPOSED ALIGNMENT SITE MAP

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP

FIGURE 1

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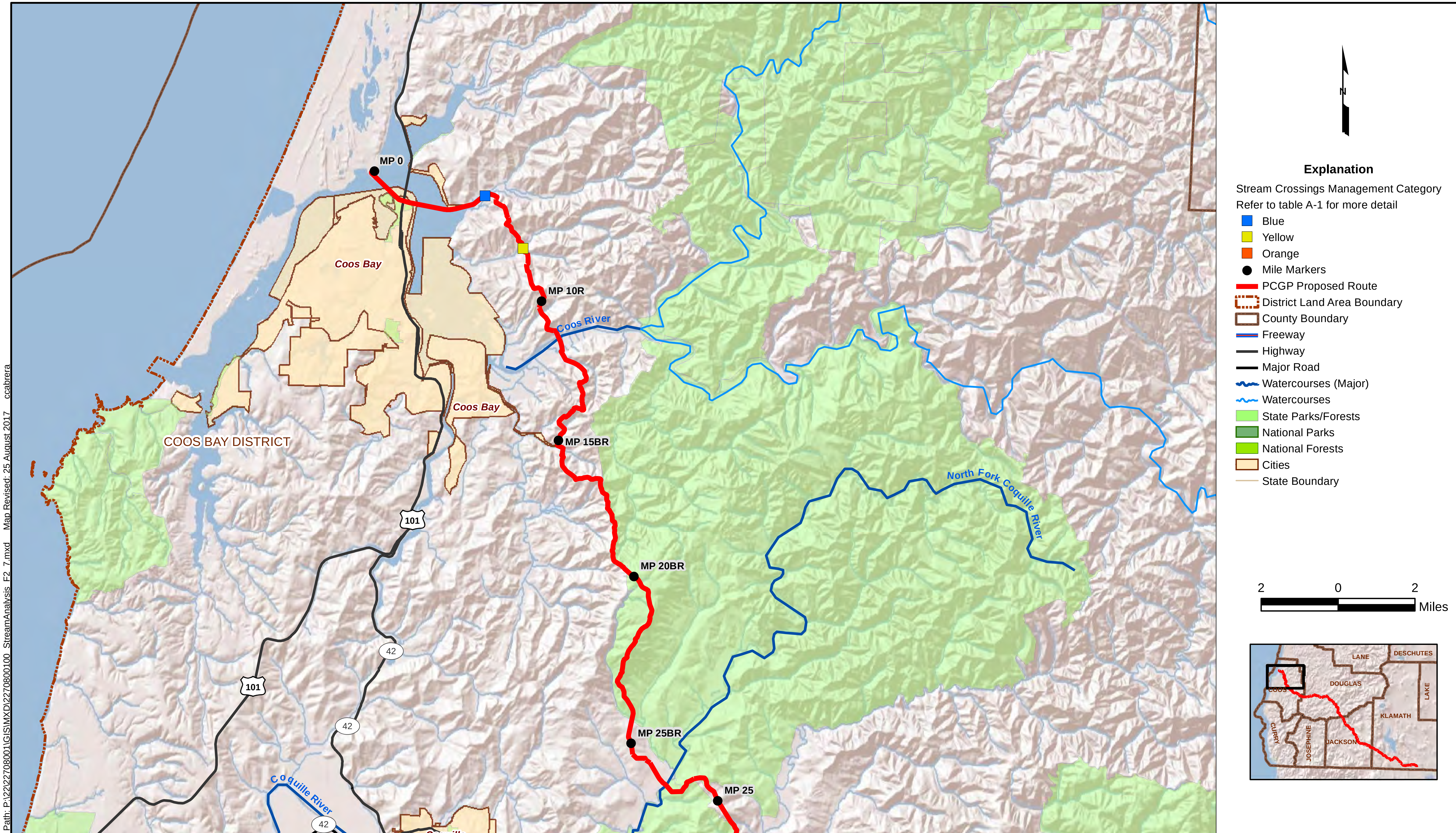

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GEOENGINEERS

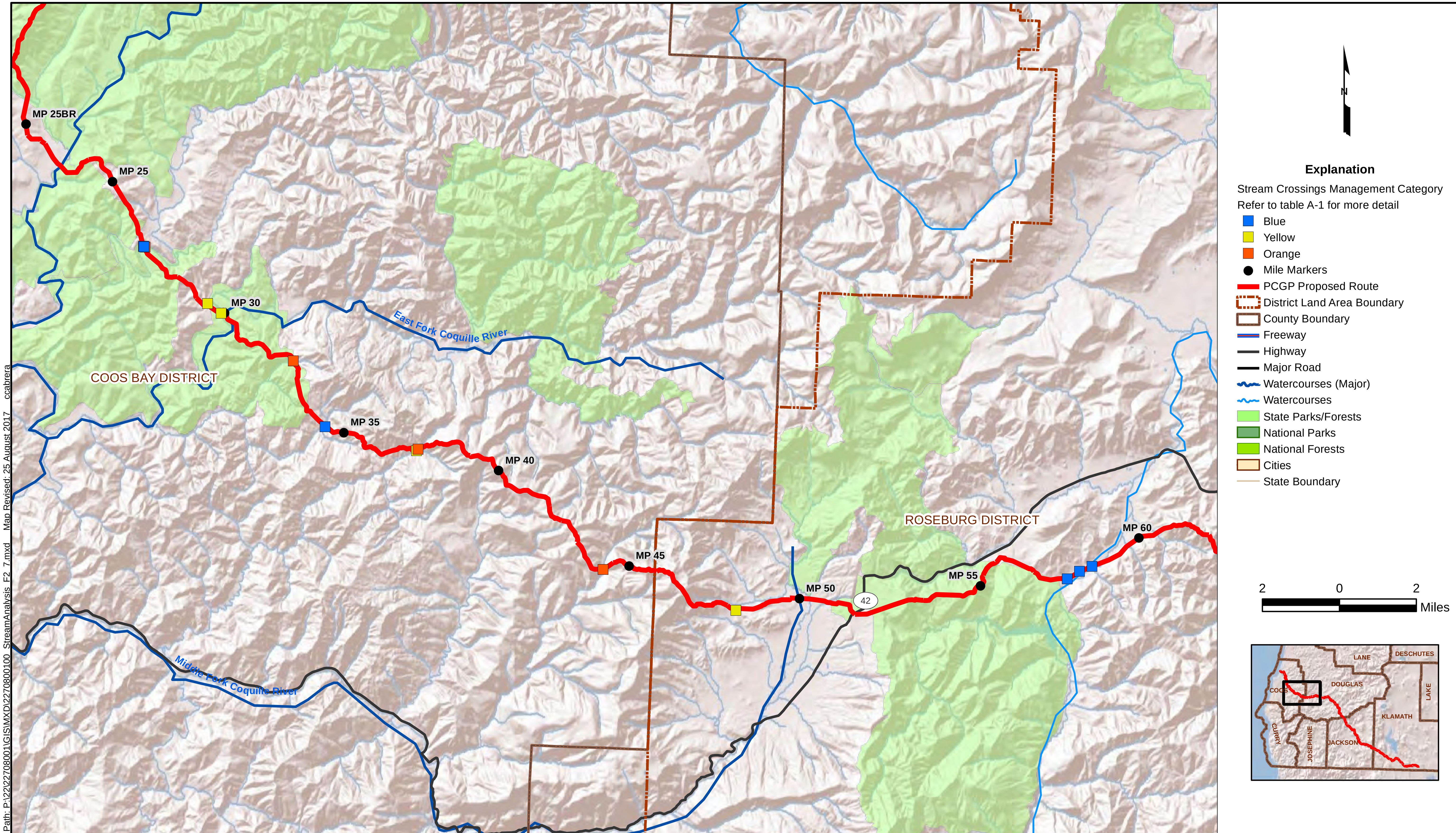
REVISED STREAM CROSSING MANAGEMENT CATEGORIES

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP
MP 0 TO 25

FIGURE 2a

SHEET

1 of 7



Path: P:\22\22708001\GIS\MXD\2270800100_StreamAnalysis_F2_7.mxd Map Revised: 25 August 2017 ccabrera

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GEOENGINEERS

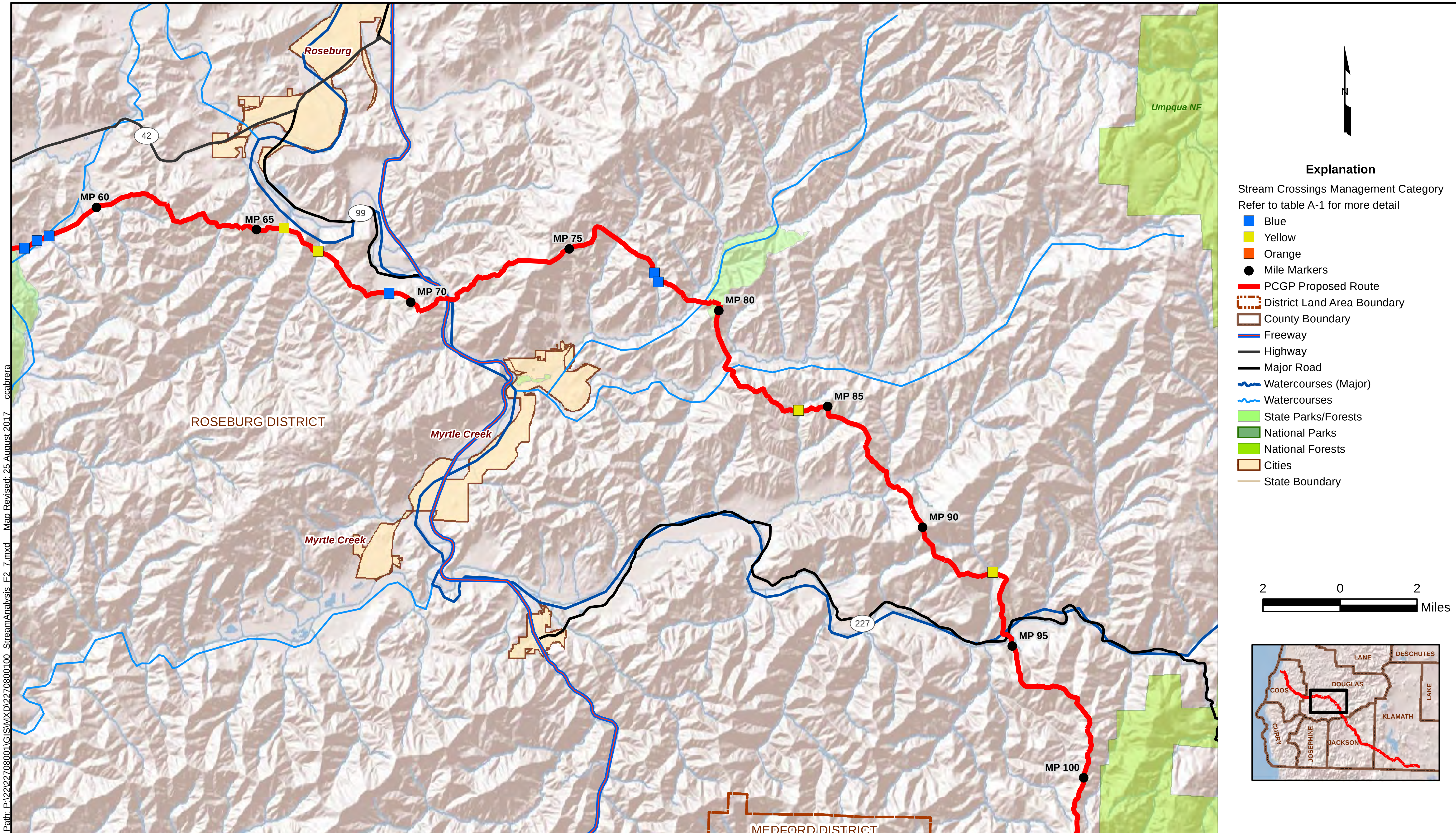
REVISED STREAM CROSSING MANAGEMENT CATEGORIES

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP
MP 25 TO 60

FIGURE 2b

SHEET

2 of 7



Path: P:\22\2270800\GIS\MXD\2270800100_StreamAnalysis_F2_7.mxd Map Revised: 25 August 2017 ccabrera

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GEOENGINEERS

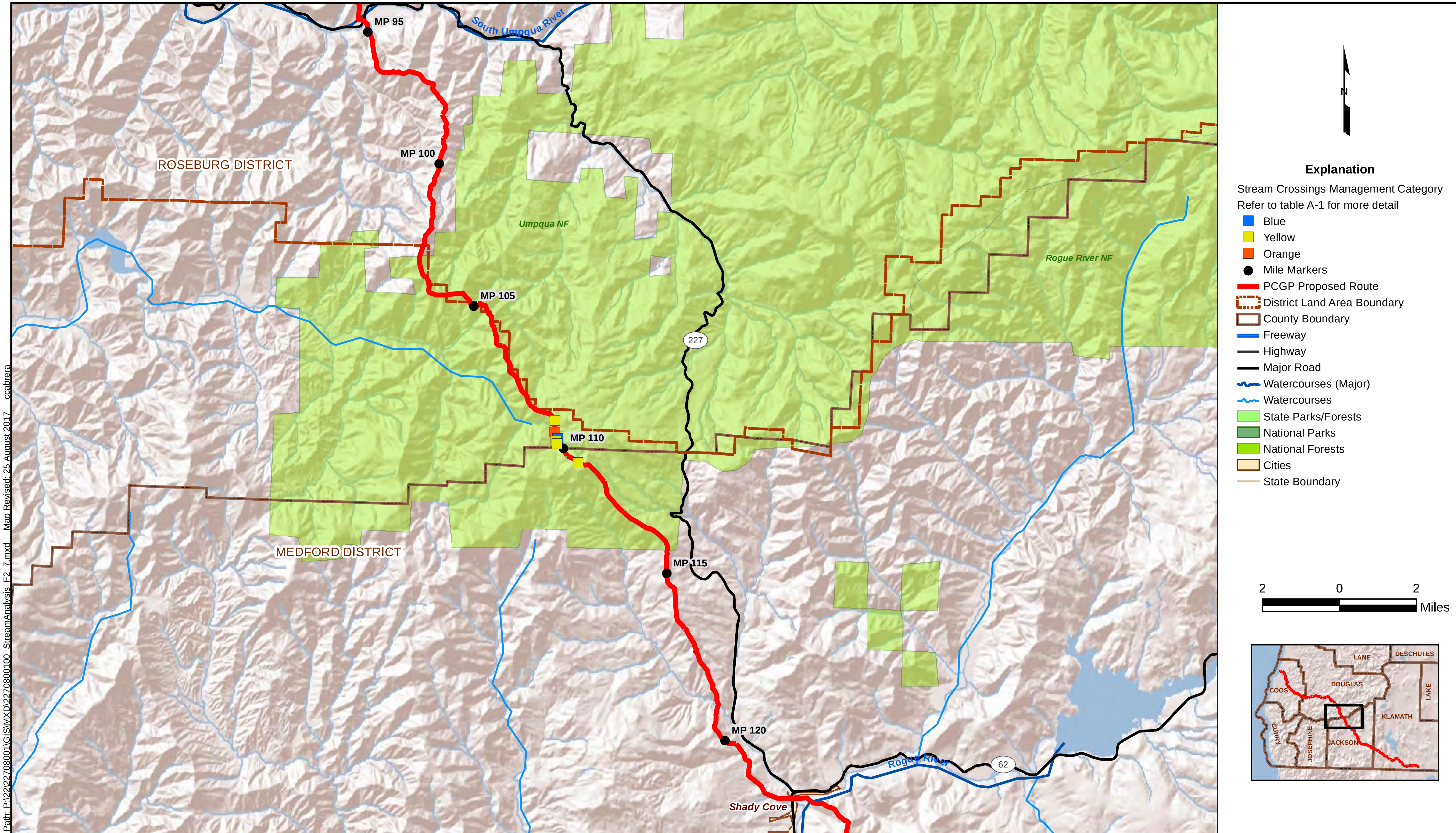
REVISED STREAM CROSSING MANAGEMENT CATEGORIES

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP
MP 60 TO 100

FIGURE 2c

SHEET

3 of 7



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GeoEngineers

REVISED STREAM CROSSING MANAGEMENT CATEGORIES

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP
MP 100 TO 120

FIGURE 2d

SHEET

4 of 7

Path: P:\22\2270800\GIS\MXD\2270800100_StreamAnalysis_F2_7.mxd Map Revised: 25 August 2017 ccabrera

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GeoEngineers

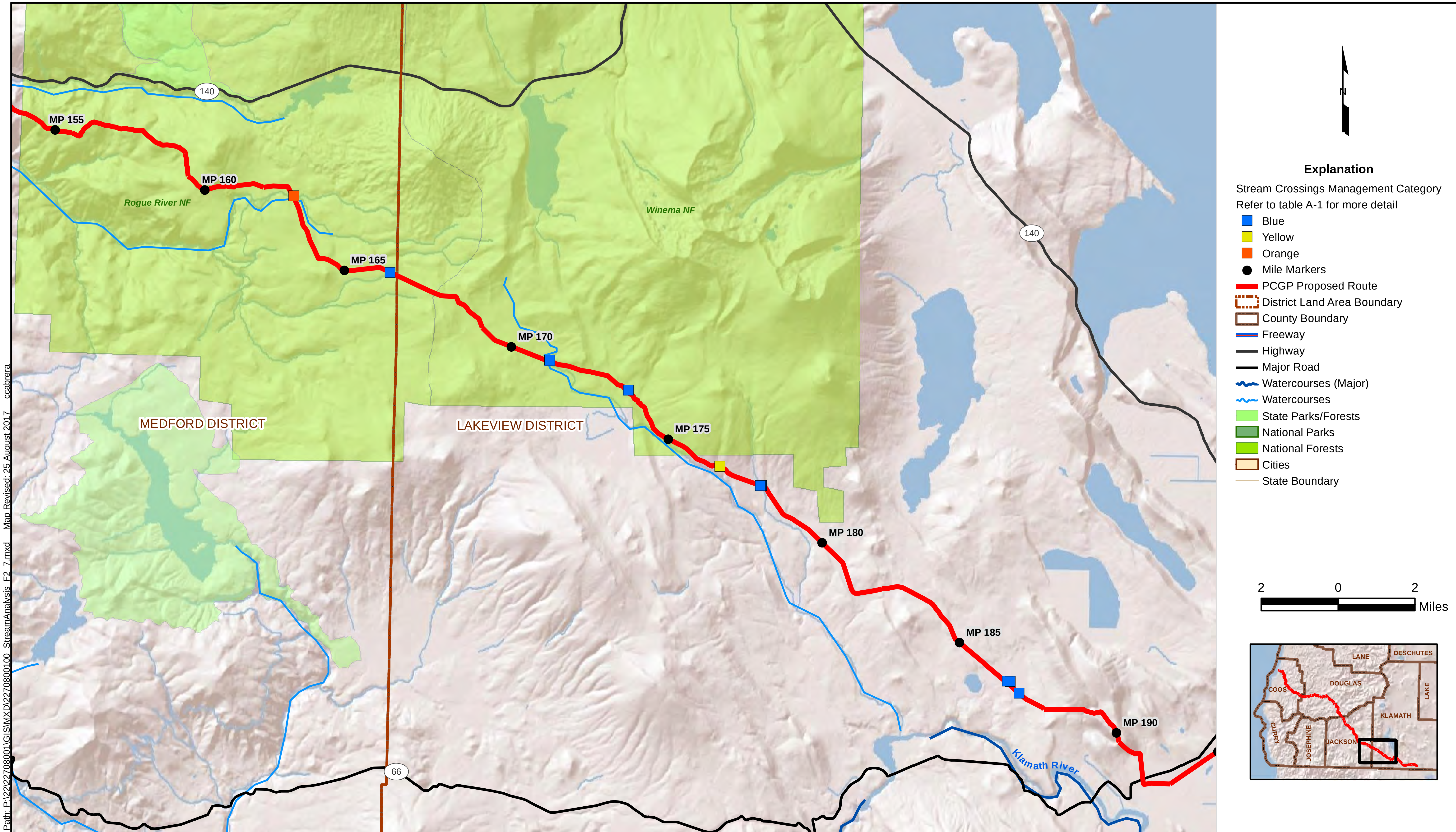
REVISED STREAM CROSSING MANAGEMENT CATEGORIES

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP
MP 120 TO 155

FIGURE 2e

SHEET

5 of 7



Path: P:\22\22708001\GIS\MXD\2270800100 StreamAnalysis F2 7.mxd Map Revised: 25 August 2017 ccabrera

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GEOENGINEERS

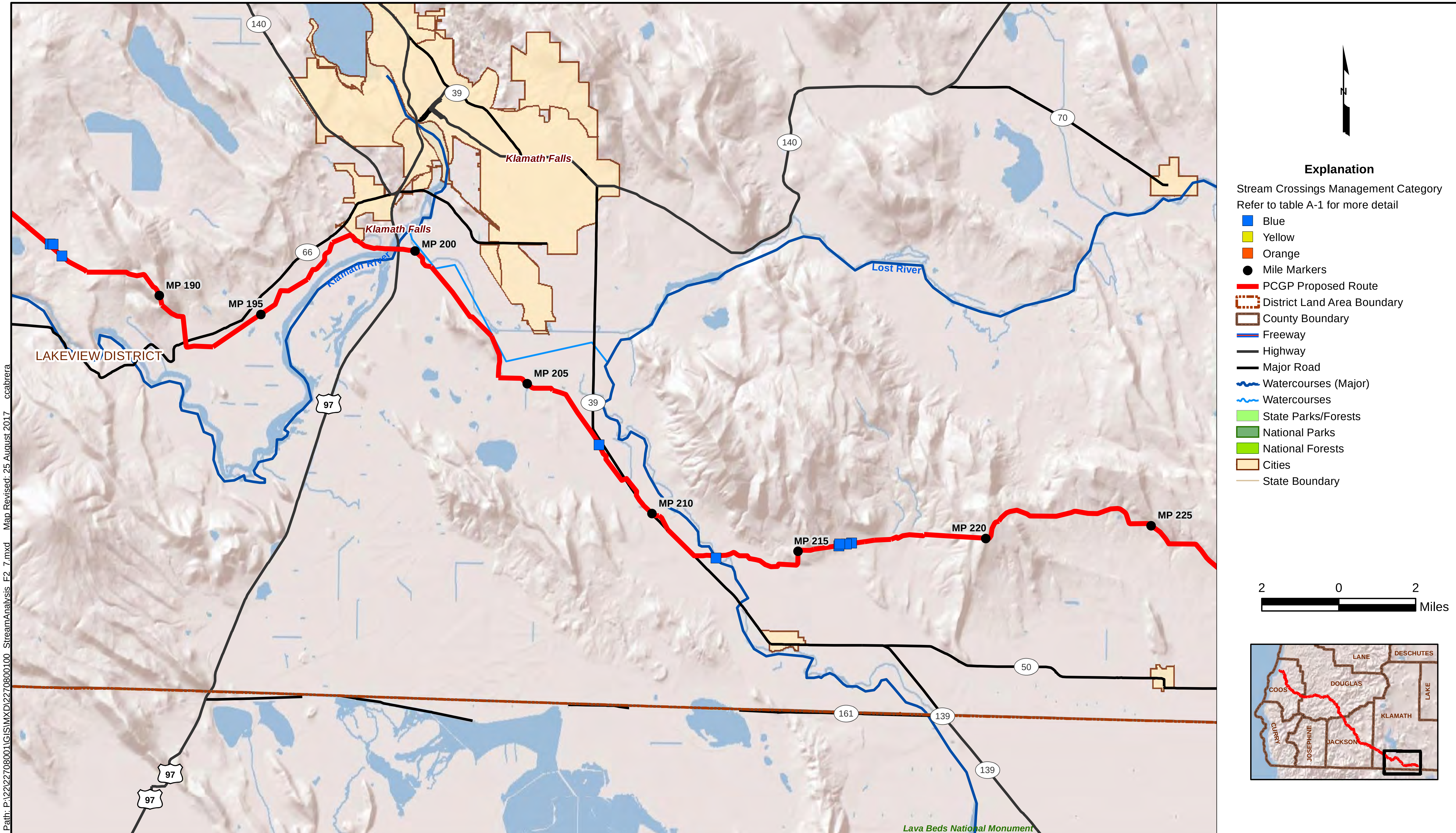
REVISED STREAM CROSSING MANAGEMENT CATEGORIES

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP
MP 155 TO 190

FIGURE 2f

SHEET

6 of 7



Path: P:\22\2270800\GIS\MXD\2270800100_StreamAnalysis_F2_7.mxd Map Revised: 25 August 2017 ccabrera

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GeoEngineers

REVISED STREAM CROSSING MANAGEMENT CATEGORIES

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE, LP
MP 190 TO 225

FIGURE 2g

SHEET

7 of 7

APPENDICES

APPENDIX A
Revised Risk Analysis Rankings and Management Categories

Table A-1

Site Specific Rankings and Management Categories

Pacific Connector Gas Pipeline

Multiple Locations, Oregon

Route Milepost	Waterbody Name	Waterbody ID	2017 Desktop Risk Management Category	Sites Evaluated by GeoEngineers in 2014	No Access Provided 2014	Post Survey Management Category	Justification for Change in Management Category
6.39R	Trib. to Coos Bay	S1-01 (EE-6)	Y	X		B	Tide gate controlled. Low flow and gradient will likely not cause erosion.
8.27R	Willanch Slough	S1-04 (EE-7 (MOD))	Y	X		Y	
10.21R	Trib. to Cooston Channel (Echo Creek)	SS-100-002	Y				
11.55BR	Vogel Creek	SS-100-005 (BR-S-02)	Y				
15.11BR	Stock Slough	BR-S-36	Y				
15.32BR	Stock Slough	EE-SS-9068	Y				
20.20BR	Steinnon Creek	SS-500-003 (BR-S-63)	Y				
23.06	North Fork Coquille River	BSP-207	Y		X		
24.32	Steinnon Creek	BR-S-63	Y				
27.04	Middle Creek	BSP-133	Y	X		O	Observations of 12-15 ft high erodible banks upgrades risk.
29.30	Trib. To E. Fork Coquille	BSP-74	Y				
29.47	Trib. To E. Fork Coquille	BSI-76	Y	X		Y	
29.85	East Fork Coquille River	BSP-71	Y	X		Y	
30.22	Trib. to E. Fork Coquille	SS-003-007A	Y				
30.29	Trib. to E. Fork Coquille	SS-003-007B	Y				
32.40	Elk Creek	BSP-57	Y	X		O	Incised stream with steep valley walls is a concern for bed and bank erosion. Complex pool-riffle morphology should be retained.
32.63	Trib. To Elk Creek	SS-100-031	O				
34.46	South Fork Elk Creek	CSP-5	B	X*		B	Channel is line with cobble and no bank erosion or significant bed scour associated with boulders or wood indicates stability.
37.32	Trib. to Big Creek	ESI-19	Y	X		Y	Active incision was observed at this site.
37.35	Trib. to Big Creek	ESP-20	Y	X		O	Channel is incised with steep erodible banks. High quality habitat should be retained.
44.21	Upper Rock Creek	BSP-41	Y	X		O	Potential for channel migration and downcutting was identified
46.56	Trib. to Trib. to Upper Rock Creek	S3-07(BW-38)	Y				
48.27	Deep Creek	BSP-257(MOD)	Y	X		Y	
50.28	Middle Fork Coquille River	BSP-30	O		X		
50.71	Belieu Creek	GSI-37 (BSP-61)	Y		X		
55.90	Trib. to Shields Creek	BSI-202	Y		X		
55.94	Trib. to Shields Creek	BSI-203	Y		X		
57.11	Trib. to Olalla Creek	BSI-140	Y		X		
57.31	Trib. to Olalla Creek	BSI-138	Y		X		
57.84	Trib. to Olalla Creek	EE-12 (BSI-147)	G	X*		B[b]	Based on proximity and similar characteristics at MP 58.20.
58.20	Trib. to Olalla Creek	BSI-151	Y	X		B	This is a low energy stream with little stream power to cause erosion.
58.55	Trib. to Olalla Creek	BSP-159	Y	X		B[b]	Based on proximity and similar characteristics at MP 58.20.
58.78	Olalla Creek	BSP-155	Y		X		
59.29	Trib. to Olalla Creek	BSI-132	Y		X		
59.65	Trib. to Olalla Creek	BSI-129	Y		X		
60.48	McNabb Creek	NSP-13	Y		X		
63.97	Kent Creek	BSP-240	Y		X		
65.76	Rice Creek	BSP-227	Y	X		Y	
66.95	Willis Creek	BSP-168	O	X		Y	Designation determined from observations downstream of site. Low discharge downgrades risk.
69.29	Trib. to South Umpqua River	SS-004-004 (SS-100-012)	Y				
69.35	Trib. to South Umpqua River	SS-004-005 (SS-100-013)	Y	X		B	A gravel-cobble bed with vegetation indicates vertical stability. Minor bank erosion is observed but typical methods should suffice.
75.33	Rock Creek	EE-SS-9032	Y				
76.38	Bilger Creek	BSP-1	O		X		
77.71	Little Lick	BSP-6	B	X[a]		B	
78.02	Trib. to Little Lick Creek	BSI-10	Y	X		B	No defined Stream Channel was identified in the vicinity of the crossing.

Route Milepost	Waterbody Name	Waterbody ID	2017 Desktop Risk Management Category	Sites Evaluated by GeoEngineers in 2014	No Access Provided 2014	Post Survey Management Category	Justification for Change in Management Category
79.12	North Myrtle Creek	NSP-37	Y		X		
81.19	South Myrtle Creek	BSP-172	B		X[a]		
81.38	Trib. to S. Myrtle Creek	BSP-259	Y		X		
81.93	Trib. to S. Myrtle Creek	EE-SS-9074	Y				
84.17	Wood Creek	BSP-226	Y	X		Y	
85.69	Trib. to Wood Creek	EE-SS-9041	Y				
85.71	Trib. to Wood Creek	EE-SS-9042	Y				
86.07	Trib. to Wood Creek	EE-SS-9044	Y				
88.20	Trib. to Fate Creek	BSI-236	Y		X		
88.48	Fate Creek	BSP-232	B		X[a]		
88.60	Days Creek	BSP-233	Y		X		
92.62	Saint John Creek	ASP-303	Y	X		Y	
95.03	Trib. to South Umpqua River	ASI-193 (ASI-191)	Y				
109.17	Trib to East Cow Creek (wetland)	GW-14 (FS-HF-C)	Y	X*		Y	
109.47	East Fork Cow Creek	GSP-19 (ASP-297/FS-HF-G)	Y	X		O	Large boulder cascade just downstream of crossing should not be disturbed to prevent headcutting.
109.69	East Fork Cow Creek	GSP-22 (ASP-297/FS-HF-M)	B	X*		B	
109.69	East Fork Cow Creek	FS-HF-J	B	X*		Y	A large Log jam near crossing raises risk designation as it should not be disturbed and gradient should be maintained.
109.78	Trib. to East Fork Cow Creek	FS-HF-K	Y	X		Y	
110.96	Trib. to East Fork Cow Creek	FS-HF-N (ESI068)	Y	X		Y	
118.89	West Fork Trail Creek	ASP-202	Y	X	X[a]	O[b]	Observations downstream of the crossing indicate a complex bedrock channel with quality fish habitat that should be retained.
120.45	Canyon Creek	NSP-11	Y				
121.57	Trib. to Trail Creek	ASI-206	Y		X		
128.49	Deer Creek	ASP-307	Y				
128.61	Indian Creek	AW-278	Y		X		
128.68	Trib. to Indian Creek	ASP-310	Y		X		
130.86	Trib. to Neil Creek	ASI-246	Y	X		B	This creek had no evidence of bank erosion or vertical scour in the vicinity of the crossing indicating low risk.
132.12	Neil Creek	ASP-252	B	X*		B	
138.44	Trib. to Lick Creek	SS-GM-10	Y				
138.55	Trib. to Lick Creek	SS-GM-11	Y				
138.74	Trib. to Lick Creek	SS-GM-13	Y				
139.07	Trib. to Lick Creek	SS-GM-14	Y		X		
139.20	Trib. to Lick Creek	SS-GM-15	Y				
139.28	Trib. to Lick Creek	SS-GM-16	Y				
140.27	Lick Creek	ASI-233	Y	X		Y	
144.41	Long Branch Creek	ESI-38	Y				
144.70	Trib. to S. Fork Long Branch	GSP-5 (ESP-48)	Y		X		
145.69	North Fork Little Butte Creek	ESP-66	Y		X		
162.45	South Fork Little Butte Creek	ASP-165	Y	X		O	Several high flow channels present a risk for avulsion at this site. High quality habitat should be retained.
166.21	Daley Creek	ESI-76 (ESI-84)	Y	X		B	No defined Stream Channel was identified in the vicinity of the crossing.
171.07	Spencer Creek	WW-001-013 (EW-85)	Y	X		B	No defined Stream Channel was identified in the vicinity of the crossing.
173.74	Trib. to Spencer Creek	ESI-106a	Y	X		B	No defined Stream Channel was identified in the vicinity of the crossing.
176.54	Trib. to Spencer Creek	ESI-69	Y	X		Y	
176.56	Trib. to Spencer Creek	GSI-10	Y	X		Y	
177.76	Clover Creek	SS-502-EW-103(MOD)	Y	X		B	No defined Stream Channel was identified in the vicinity of the crossing.
177.76	Clover Creek	GSI-11	Y	X		B	No defined Stream Channel was identified in the vicinity of the crossing.
186.61	Trib. to Klamath River	ESI-97	Y	X		B	Very low gradient ephemeral stream in flat meadow not likely to cause significant erosion.
186.65	Trib. to Klamath River	ESI-99	Y	X		B	Very low gradient ephemeral stream in flat meadow not likely to cause significant erosion.
186.74	Trib. to Klamath River	ESI-100	O	X		B	Very low gradient ephemeral stream in flat meadow not likely to cause significant erosion.
205.97	Wetland Ditch	ADX-112	Y				
207.60	Drainage Ditch; Irrigation 5-A Drain	ADX-118	O	X		B	Low gradient with no evidence of erosion or scour downgrades risk.
207.99	Drainage Ditch; Irrigation 5-A Drain	ADX-119	Y		X		

Route Milepost	Waterbody Name	Waterbody ID	2017 Desktop Risk Management Category	Sites Evaluated by GeoEngineers in 2014	No Access Provided 2014	Post Survey Management Category	Justification for Change in Management Category
208.18	Drainage Ditch; Irrigation 5-A Drain	ADX-123	Y		X		
210.26	Irrigation Ditch; No. 5 Drain (Trib. to Lost River)	SS-003-001 (ADX-143)	Y				
210.85	Irrigation Ditch; 5-H Drain (Trib. to Lost River)	ADX-260	Y				
212.07	Lost River	SS-003-005 (NSP-1)	O	X		B	No bank erosion, historical migration or vertical scour.
216.10	Unnamed Creek	ASI-51	Y	X		B	No defined Stream Channel was identified in the vicinity of the crossing.
216.11	Unnamed Creek	ASI-52	Y	X		B	Stream is an ephemeral swale with no defined banks which downgrades risk.
216.30	Unnamed Creek	ASI-50	Y	X		B[b]	Based on crossing at MP 216.11
216.44	Unnamed Creek	ASI-49	Y	X		B[b]	Based on crossing at MP 216.11
218.09	Trib. to D Canal	ASI-136	Y		X		
218.46	Trib. to D Canal	ASI-137	O		X		

Notes:

* Site visited to verify rankings of a greater subset of crossings that include the lower risk crossings or visited based on professional judgement indicating potential fluvial processes at the site

[a] Site visited at the request of Edge Environmental

[b] Site management category assigned based on an up or downstream location, or a nearby crossing in a similar geomorphic settings.

Blue shading = Pacific Connector Project Typical Construction

Green shading = Pacific Connector Project Typical Construction with Habitat Enhancement BMPs

Yellow shading = Pacific Connector Project Typical Construction with BMPs for sensitive bed, bank, or riparian revegetation conditions to be selected by Environmental Inspector during construction

Orange shading = Pacific Connector Project Typical Construction with BMPs for sensitive bed, bank or riparian vegetation conditions selected by qualified professional prior to construction based on site-specific information from pre-construction evaluation

EXHIBIT A-2
Preconstruction Survey Field Forms and Risk Rankings

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Trib to Coos Bay
Crossing Milepost: 6.39R S1-01(EE-6)
Original Risk Designation: yellow
Final Risk Designation: blue

Staff Present: JMA, MLT
Date and Time: 8/25/14; 7PM
Units: SU
Estimated Q: V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight
M&B classification:
Bed composition: gravel Dom gravel Subdom silt D50
Bedrock (Y / N): no
Structures / obstructions: no
Bank composition: silt
Channel width: 8' Avg Chan. Depth: 2' Max Chan. Depth: 3'
Valley Width (est): ~500 Gradient: <1%
Floodplain character: pasture/agriculture

Channel Process

Bank erosion: Y / N Describe: no

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: no

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
Ditched, tidal gate, low flow from upland areas. Cattle grazing up to fence line at ditch.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	4	**5**	
Riparian Corridor	1	2	3	4	**5**	none, farmed/cattle
Bank Characteristics	1	2	3	**4**	5	vertical banks 3-4'
Bed Characteristics	1	2	**3**	4	5	

New risk ranking and criteria for decision

Blue: low slope=low velocities. Gradient held by downstream tidal gate. Current banks holding with minor erosion.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Willanch Slough	Staff Present:	JMA, MLT
Crossing Milepost:	8.27R S1-04 (EE-7 (MOD))	Date and Time:	8/26/14; 9:30AM
Original Risk Designation	yellow	Units:	SU
Final Risk Designation	yellow	Estimated Q:	V 0.5

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: slightly sinuous

M&B classification: glide riffle, riffle composed of small gravel

Bed composition: sand and gravel Dom sm grvl Subdom sand D50 sm grvl

Bedrock (Y / N): no

Structures / obstructions: no

Bank composition: silty sand

Channel width: 12' Avg Chan. Depth: ____ Max Chan. Depth: ____

Valley Width (est): ____ Gradient: ____

Floodplain character: silty sand

Channel Process

Bank erosion: Y / N Describe: some bank erosion/high near vertical banks, some undercut banks

Scour: Y / N Describe: potential for bank erosion, no large pools observed

Bed armored / embedded: Y / N Describe: no armor, bed material small so likely easily moved

Migration/Avulsion: Y / N Describe: none

Deposition: Y / N Describe: bars only

Function

Cause and effect relationships:

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	**4**	5	
Riparian Corridor	1	2	3	**4**	5	
Bank Characteristics	1	2	3	**4**	5	
Bed Characteristics	1	2	3	**4**	5	

New risk ranking and criteria for decision

BMP - Bank stabilization, toe protection, revegetation

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Middle Creek	Staff Present:	JMA
Crossing Milepost:	27.04 BSP-133	Date and Time:	May 2o, 2014
Original Risk Designation	Orange	Units:	SU
Final Risk Designation	Orange	Estimated Q:	10 V 2 fps

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight, incised

M&B classification:

Bed composition: sand/gravel Dom Subdom D50

Bedrock (Y / N): none seen, but indications of bedrock upstream and downstream

Structures / obstructions: ~mid-channel sand bars

Bank composition: alluvial

Channel width: 60' Avg Chan. Depth: Max Chan. Depth:

Valley Width (est): 120' Gradient:

Floodplain character: alluvia, forested

Channel Process

Bank erosion: Y / N Describe: Yes, lower and upper bank subject to sloughing and expansion

Scour: Y / N Describe: minor scour along pools at toe

Bed armored / embedded: Y / N Describe: no

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no

Function

Cause and effect relationships:

12-15 ft high vertical banks create a confined channel with a semi-resistant bed. Stream power erodes sandy bannks and leads to sloughing and bank erosion.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	**3**	4	5	
Riparian Corridor	1	2	**3**	4	5	
Bank Characteristics	1	2	3	4	**5**	
Bed Characteristics	1	2	3	**4**	5	

New risk ranking and criteria for decision

Issues: steep, vertical alluvial banks. Toe protection and bank grading, slope stabilization.

Orange

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	East Fork Coquille	Staff Present:	JAM, MLT
Crossing Milepost:	29.85 BSP-71	Date and Time:	8/26/14; 3:30PM
Original Risk Designation		Units:	SU
Final Risk Designation	yellow	Estimated Q:	V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: meandering

M&B classification:

Bed composition: BR, cobbles, sand Dom BR Subdom cobble D50

Bedrock (Y / N): yes; channel spanning - clay that acts like bedrock, highly resistant

Structures / obstructions: no

Bank composition: sandy silt

Channel width: 100' Avg Chan. Depth: 4' Max Chan. Depth: 30'

Valley Width (est): >1000' Gradient: low

Floodplain character: agricultural

Channel Process

Bank erosion: Y / N Describe: very little

Scour: Y / N Describe: scour halted by compact clay that acts like bedrock, gray

Bed armored / embedded: Y / N Describe: dense clay

Migration/Avulsion: Y / N Describe: minor potential as is but significant vegetation hinders

Deposition: Y / N Describe: minor--some lateral bars with vegetation mostly grasses

Function

Cause and effect relationships:

Scoured to clay acting like bedrock. Little to no wood except for downed trees in place from side/bank slopes.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	**4**	5	
Riparian Corridor	1	2	**3**	4	5	
Bank Characteristics	1	2	**3**	4	5	
Bed Characteristics	**1**	2	3	4	5	

New risk ranking and criteria for decision

Yellow due to steep slopes to be disturbed. Potential for erosion after disturbance rises.

Site specific BMP - bank stabilization.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Elk Creek
Crossing Milepost: 32.4 BSP-57
Original Risk Designation: yellow
Final Risk Designation: orange

Staff Present: JAM, MLT
Date and Time: 8/26/14; 5:30PM
Units: SU
Estimated Q: 2 V n/a

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: meandering
M&B classification: cascade pool
Bed composition: cobble boulder Dom m-l cobble Subdom sm cobble D50
Bedrock (Y / N): no
Structures / obstructions: some large wood, single and piles
Bank composition: sandy silt
Channel width: 8' Avg Chan. Depth: 2' Max Chan. Depth: 4'
Valley Width (est): 100' at top Gradient: steep >=3%
Floodplain character: forested

Channel Process

Bank erosion: Y / N Describe: undercut banks

Scour: Y / N Describe: scour around wood

Bed armored / embedded: Y / N Describe: boulder and large cobble

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
Large rock is armoring bed. Trees and thick brush line slopes and banks.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	**4**	5	
Riparian Corridor	**1**	2	3	4	5	
Bank Characteristics	1	2	**3**	**4**	5	
Bed Characteristics	1	**2**	3	4	5	

New risk ranking and criteria for decision

Orange: Re-use stream bed materal to maintain channel integrity and place to recreate cascade/pool morphology.
Toe protection suggested at banks. Complex pool riffle morphology.

Orange

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: South Fork Elk Creek
Crossing Milepost: 34.46 CSP-5
Original Risk Designation: Blue
Final Risk Designation: Blue

Staff Present: JMA
Date and Time: May 21 2014 12 pm
Units: SU
Estimated Q: 5 cfs V 1 fps

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight
M&B classification: glide/riffle
Bed composition: cobb dom/sand sub Dom md gravel Subdom sm cobble D50 large cobble - 15"
Bedrock (Y / N): no
Structures / obstructions: rock ledges / wood
Bank composition: gravel / sand
Channel width: 15' Avg Chan. Depth: 8' Max Chan. Depth: 18'
Valley Width (est): 15 x 4 = 60' Gradient: 1-3%
Floodplain character: alluvial cobbles; straightly cobble lined stream, low floodplain, low entrenchment, lined with alders and maples

Channel Process

Bank erosion: Y / N Describe: no, stable channel planform through pipeline

Scour: Y / N Describe: no, scour associated with boulders/wood

Bed armored / embedded: Y / N Describe: yes, slightly armored with coarser material

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no, crossing is near downstream end of a transport zone

Function

Cause and effect relationships:
Little incision noted.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	4	5	
Riparian Corridor	1	2	3	4	5	
Bank Characteristics	1	2	3	4	5	
Bed Characteristics	1	2	3	4	5	

New risk ranking and criteria for decision

Stable bed and banks

Blue

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Trib to Trib of Big Creek	Staff Present:	JMA
Crossing Milepost:	37.32 ESI-19	Date and Time:	March 20 2014 10 ai
Original Risk Designation	Yellow	Units:	SU
Final Risk Designation	Yellow	Estimated Q:	0 V 0

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: steep straight gully

M&B classification: colluvia; channel

Bed composition: sand Dom sand Subdom silt D50

Bedrock (Y / N): N

Structures / obstructions: Roots

Bank composition: Sand

Channel width: 3 ft Avg Chan. Depth: 3 ft Max Chan. Depth: 3 ft

Valley Width (est): 60 ft Gradient: >3%

Floodplain character: forested

Channel Process

Bank erosion: Y / N Describe: yes, slightly

Scour: Y / N Describe: yes

Bed armored / embedded: Y / N Describe: No

Migration/Avulsion: Y / N Describe: No

Deposition: Y / N Describe: No

Function

Cause and effect relationships:

Steep, incising gully along the alignment. Valley scale downcutting to continue and could risk exposure of the pipeline if grade control is not provided. Recommend large rock or large trees placed downstream of the pipeline and keyed into the banks

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	**4**	5	
Riparian Corridor	1	**2**	3	4	5	
Bank Characteristics	1	2	3	4	**5**	
Bed Characteristics	1	2	3	4	**5**	

New risk ranking and criteria for decision

Site Specific BMP required

Yellow

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Big Creek
Crossing Milepost: 37.35 ESP-20
Original Risk Designation: 4 yellow
Final Risk Designation: 5 orange

Staff Present: AL, JS, JA, MT
Date and Time: 8/25/2014
Units: US
Estimated Q: 2 cfs V 0.25 fps

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: slightly sinuous
M&B classification: step pool
Bed composition: cobble Dom boulder Subdom cobble/grvl D50
Bedrock (Y / N): very ;large boulders lining bed and banks
Structures / obstructions: boulders
Bank composition: silt, silting clay
Channel width: 5.0' Avg Chan. Depth: 1 ft Max Chan. Depth: 4 ft
Valley Width (est): ~30' Gradient: 5%
Floodplain character: N/A

Channel Process

Bank erosion: Y / N Describe: yes, undercut

Scour: Y / N Describe: yes

Bed armored / embedded: Y / N Describe: yes, armored with boulders

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: deposition upstream of wood and rock obstructions

Function

Cause and effect relationships:
Boulders controlling bed grade and froming pools. Logs along banks maintain stability at toe.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	**3**	4	5	transport reach
Riparian Corridor	**1**	2	3	4	5	
Bank Characteristics	1	2	3	**4**	5	
Bed Characteristics	1	**2**	3	4	5	

New risk ranking and criteria for decision

5: Site specific plan needed to re-create unique site attributes

Orange

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Rock Creek	Staff Present:	APL, JS
Crossing Milepost:	44.21 BSP-41	Date and Time:	8/26/2014
Original Risk Designation	4 yellow	Units:	SU
Final Risk Designation	5 orange	Estimated Q:	10 cfs V 1fps

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: slightly sinuous

M&B classification: pool riffle without riffles at crossing

Bed composition: Dom sand Subdom fine gravel D50 sand

Bedrock (Y / N): no

Structures / obstructions: log groins protruding from banks into channel; rootwads

Bank composition: sand

Channel width: 20' Avg Chan. Depth: 3' Max Chan. Depth: 5

Valley Width (est): 30' Gradient: <1%

Floodplain character: over bank channels and sand deposits on right bank upstream from crossing

Channel Process

Bank erosion: Y / N Describe: no

Scour: Y / N Describe: yes associated with pools and wood accumlation

Bed armored / embedded: Y / N Describe: probe to 1.5': soft sand with fine gravel; cobble bars downstream

Migration/Avulsion: Y / N Describe: lateral migration at meander bend; low alluvial terraces

Deposition: Y / N Describe: yes, bars composed of sand at crossing

Function

Cause and effect relationships:

Shallow stream gradient. Bed aggradation along reach; very sandy with bars compressing towards meander bends.
Wood splitting flows and causing scours.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	4	**5**	
Riparian Corridor	**1**	2	3	4	5	
Bank Characteristics	1	2	3	4	**5**	
Bed Characteristics	1	2	3	4	**5**	

New risk ranking and criteria for decision

5: Dyamic reach with loads of sediment accumulating on bars. Lateral bend migration and evidence of high flow channels along inside of bend (opposite lateral migration on apex).

Orange

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Deep Creek	Staff Present:	JAM, MLT
Crossing Milepost:	48.27 BSP-257(MOD)	Date and Time:	8/27/14; 10AM
Original Risk Designation	yellow	Units:	SU
Final Risk Designation	yellow	Estimated Q:	0 V 0

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: slightly sinuous

M&B classification: step pool/glide

Bed composition: gravel   Dom lg gravel   Subdom sm gravel   D50 good component of sand interstitial

Bedrock (Y / N): no

Structures / obstructions: some wood

Bank composition: compacted sandy silt

Channel width: 6'   Avg Chan. Depth: 1'   Max Chan. Depth: 2-3'

Valley Width (est): 100'   Gradient: 2-2.5%

Floodplain character: well vegetated: willows, firs, vine maple and understory extends 50' either side

Channel Process

Bank erosion: Y / N Describe: no significant bank erosion

Scour: Y / N Describe: scour/pools associated with wood in channel

Bed armored / embedded: Y / N Describe: no

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: behind logs and small wood

Function

Cause and effect relationships:

Wood is factor in controlling gradient. Some pools associated with wood. No rootwads--mainly small wood.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	**4**	5	
Riparian Corridor	1	**2**	3	4	5	thick
Bank Characteristics	1	2	**3**	4	5	
Bed Characteristics	1	2	3	**4**	5	

New risk ranking and criteria for decision

Yellow: BMP - small wood to be used to hold gradient. Re-use native gravels to backfill.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Trib to Olalla
Crossing Milepost: 58.2 BSI-151
Original Risk Designation: yellow
Final Risk Designation: blue

Staff Present: JMA, AL, JS, MLT
Date and Time: 8/25/14; 11AM
Units: SU
Estimated Q: V 0

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight
M&B classification: ditch
Bed composition: silt and gravel Dom ______ Subdom ______ D50 >1"
Bedrock (Y / N): no
Structures / obstructions: culvert at DS end of row
Bank composition: silt
Channel width: ~3' Avg Chan. Depth: 1' Max Chan. Depth: 2'
Valley Width (est): >1000' Gradient: really low
Floodplain character:

Channel Process

Bank erosion: Y / N Describe: no

Scour: Y / N Describe: some entrenchment at lower end

Bed armored / embedded: Y / N Describe: no

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
Low drainage area - low flow. Low flow in low slope/gradient with a DS grade control (culvert) = no incision and little bank erosion.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	4	**5**	
Riparian Corridor	1	2	3	**4**	5	
Bank Characteristics	1	2	**3**	4	5	
Bed Characteristics	1	**2**	3	4	5	

New risk ranking and criteria for decision

Blue - low slope, minor flow
BMP - maintain culvert or single grade control at lower end (downstream).

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Willis Creek
Crossing Milepost: 66.95 BSP-168
Original Risk Designation: orange
Final Risk Designation: yellow

Staff Present: JAM, MLT
Date and Time: 8/27/14; 1PM
Units: SU
Estimated Q: V 0

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: sinuous
M&B classification: pool/glide - riffle
Bed composition: Dom sm cobble Subdom lg gravel D50
Bedrock (Y / N): yes, in locations
Structures / obstructions: no
Bank composition: silt reworked due to agriculture and cattle grazing. 8' high
Channel width: 30' Avg Chan. Depth: 3' Max Chan. Depth: 8'
Valley Width (est): 150' Gradient: low
Floodplain character: grassy - few mature trees - grazed

Channel Process

Bank erosion: Y / N Describe: some evidence - scallops filled in with rip-rap

Scour: Y / N Describe: some pools

Bed armored / embedded: Y / N Describe: in some locations

Migration/Avulsion: Y / N Describe: potential

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
Mature trees line channel banks - aid in stabilization. Rip-rap placed in scallops along banks. Bedrock holds gradient.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	4	**5**	
Riparian Corridor	1	2	3	**4**	5	
Bank Characteristics	1	2	**3**	4	5	
Bed Characteristics	1	2	**3**	4	5	

New risk ranking and criteria for decision

Bank slopes: lay back and tie in to minimize potential erosion or add toe protection and raise to low vertical bank then lay back slope above.
Bed: re-use or replace with same size material - for gradient control.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Trib to South Umpquah
Crossing Milepost: 69.35 SS-004-005 (SS-100-013)
Original Risk Designation: N/A added by Edge
Final Risk Designation: blue

Staff Present: JAM; MLT
Date and Time: 8/27/14; 2PM
Units:
Estimated Q: V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: sinuous slightly
M&B classification: incised ditch
Bed composition: sand, cobble, gravel Dom sand Subdom gravel D50 0.25
Bedrock (Y / N): no
Structures / obstructions: no
Bank composition: small size alluvial fan seds. Gravel
Channel width: 6' Avg Chan. Depth: 2' Max Chan. Depth: 4'
Valley Width (est): 1000' Gradient: 1. >1%
Floodplain character: agriculture

Channel Process

Bank erosion: Y / N Describe: sloughing and erosion forming cut bank (vertical) in areas

Scour: Y / N Describe: no; vertical scour

Bed armored / embedded: Y / N Describe: no armoring but cobbles line bed

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
Potential widening occurring at seemingly slow rate.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	**4**	5	
Riparian Corridor	1	2	3	**4**	5	
Bank Characteristics	1	2	**3**	4	5	
Bed Characteristics	1	**2**	3	4	5	

New risk ranking and criteria for decision

Laying back slopes and revegetation - typical construction techniques

Blue

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Little Lick Creek	Staff Present:	AL, JS
Crossing Milepost:	77.71 BSP-6	Date and Time:	8/27/2014
Original Risk Designation	yellow	Units:	SU
Final Risk Designation	3 blue	Estimated Q:	n/a V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight

M&B classification: plane bed

Bed composition: gravel/cobble Dom fine gravel Subdom cobble D50 1.5"

Bedrock (Y / N): no

Structures / obstructions: large cobbles, keypiece vls ~ soft (3'dbh x 15'L) parallel on bank toe

Bank composition: stiff silt

Channel width: 2.5/4 (BFW) Avg Chan. Depth: 1' Max Chan. Depth: 1'

Valley Width (est): 35' Gradient: 1.5'

Floodplain character: n/a - V-shape/entrenched

Channel Process

Bank erosion: Y / N Describe: yes; left bank influenced by road parallel

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: yes; armored with gravel and small 3" cobble

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no; only in local areas trapped by cobbles.

Function

Cause and effect relationships:

Scour from high flows and wet season brings deposition. Bed probed to 0-0.5". Banks probed to 1" - 0.5' (stiff). Incision upstream of crossing ~50ft.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	**2**	3	4	5	
Riparian Corridor	1	2	3	**4**	5	
Bank Characteristics	1	2	3	**4**	5	
Bed Characteristics	1	**2**	3	4	5	

New risk ranking and criteria for decision

3: No flow, long-term intermittent. Only need to regrade slopes to 2:1, which are already on left bank. Bed well-structured. Replace bed with cobbles and gravel (native material).

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Trib to Little Lick Creek
Crossing Milepost: 78.02 BSI-10
Original Risk Designation: yellow
Final Risk Designation: 3 blue

Staff Present: AL, JS
Date and Time: 8/27/2014
Units: SU
Estimated Q: n/a V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight
M&B classification: colluvial
Bed composition: grass/silt Dom silt Subdom silt D50
Bedrock (Y / N): no
Structures / obstructions: no
Bank composition: silt
Channel width: 2' Avg Chan. Depth: 0.5' Max Chan. Depth: 0.5'
Valley Width (est): 7500' Gradient: 1'
Floodplain character: wide, flat field

Channel Process

Bank erosion: Y / N Describe: no

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: no

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
Ephemeral stream. May have scarf deposition upstream. Pockets of stream scour (1.5-3' linear) - but no continuous alluvial features. Pockets include gravels.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	4	**5**	
Riparian Corridor	1	2	3	4	**5**	
Bank Characteristics	1	**2**	3	4	5	
Bed Characteristics	1	2	3	**4**	5	

New risk ranking and criteria for decision

3: No risk; ephemeral stream lacks a channel. General construction BMPs will be adequate.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Wood Creek	Staff Present:	APL, JS
Crossing Milepost:	84.17 BSP-226	Date and Time:	8/27/14; 12:30PM
Original Risk Designation	4 yellow	Units:	SU
Final Risk Designation	4 yellow	Estimated Q:	~0.2 cts V 0.6 tips

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight

M&B classification: pool - riffle

Bed composition: sand/gravel/cobble Dom ______ Subdom ______ D50 ______

Bedrock (Y / N): no

Structures / obstructions: LWD spanning channel creating pool-riffle sequence

Bank composition: sand, some vertical cut banks <1.5'

Channel width: 5' Avg Chan. Depth: 0.8' Max Chan. Depth: ______

Valley Width (est): BFW = 7' Gradient: 2%

Floodplain character: disconnected from historic floodplain

Channel Process

Bank erosion: Y / N Describe: Yes; minor in localized locations

Scour: Y / N Describe: Yes; associated with in-channel LWD

Bed armored / embedded: Y / N Describe:

Migration/Avulsion: Y / N Describe: 2" depth of refusal in riffles, 1.0' in sandy pools

Deposition: Y / N Describe: Yes; lateral sand bars

Function

Cause and effect relationships:

Channel spinning LWD creating pool-riffle sequence. Sand dominant in pools, gravel/cobble dominant in riffles.

Risk Analysis Scoring (refer to risk matrix)

	1	2	3	4	5	Comments
Landscape Sensitivity/Stream Type	1	2	3	**4**	5	
Riparian Corridor	**1**	2	3	4	5	
Bank Characteristics	1	2	3	**4**	5	
Bed Characteristics	1	**2**	3	4	5	

New risk ranking and criteria for decision

4 - Install channel spinning logs to recreate pool riffle sequence. Use native materials or salvaged timber.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: St. John Creek
Crossing Milepost: 92.62 ASP-303
Original Risk Designation: 4 yellow
Final Risk Designation: 4 yellow

Staff Present: AL, JS
Date and Time: 8/27/2014
Units: SU
Estimated Q: 0.2 V 0.4 ft/s

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: slightly sinuous
M&B classification: pool - riffle
Bed composition: cobble/gravel/bed Dom cobble Subdom gravel D50 2
Bedrock (Y / N): yes; bedorck sills intruding at crossing, contours u/s
Structures / obstructions: bedrock and boulders
Bank composition: silt
Channel width: 14' Avg Chan. Depth: 0.5' Max Chan. Depth: 1'
Valley Width (est): 150' Gradient: 2
Floodplain character: confined to channel floor, paleo terrace (floodplain) extends to hill slopes 150ft (right side)

Channel Process

Bank erosion: Y / N Describe: yes; localized adjacent to bedrock for 20'

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: yes; cobble/bedrock/boulder

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: yes; cobble bars being deposited from compression by bedrock

Function

Cause and effect relationships:
Bedrock and boulders maintaining grade control. LWD pieces wedged perpendicular and parallel into bank toes.
Bedrock and boulders forming plunge pools.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	**4**	5	
Riparian Corridor	1	2	**3**	4	5	
Bank Characteristics	1	2	3	**4**	5	
Bed Characteristics	1	**2**	3	4	5	

New risk ranking and criteria for decision

4: No high risk due to well-maintained bed grade control. No risk of avulsion due to bank and bed structure.
*Fish present.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Trib to E Fork Cow Creek
Crossing Milepost: 109.17 GW-14 (FS-HF-C)
Original Risk Designation: yellow
Final Risk Designation: yellow

Staff Present: JAM, MLT
Date and Time: 8/27/2014; 4PM
Units: SU
Estimated Q: V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight
M&B classification: channel eminating from wetland
Bed composition: mud organics Dom ____ Subdom ____ D50 ____
Bedrock (Y / N): no
Structures / obstructions: no
Bank composition: forest duff & soils
Channel width: 2' Avg Chan. Depth: 0.5' Max Chan. Depth: 1'
Valley Width (est): ____ Gradient: 73%
Floodplain character: forest floor

Channel Process

Bank erosion: Y / N Describe: no

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: no

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
Wetland at top slope near road prior to steepening & channelizing.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	**2**	3	4	5	
Riparian Corridor	1	2	**3**	4	5	
Bank Characteristics	1	**2**	3	4	5	
Bed Characteristics	1	**2**	3	4	5	

New risk ranking and criteria for decision

Yellow based on steep gradient. Hold gradient with large wood. Maintain wetland / rebuild if possible.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: East Fork Cow Creek
Crossing Milepost: 109.47 GSP-19 (ASP-297/FS-HF-G)
Original Risk Designation: yellow
Final Risk Designation: orange

Staff Present: JAM, MLT
Date and Time: 8/27/2014; 4PM
Units: SU
Estimated Q: 0.1 V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight
M&B classification: cascade downstream riffle/pool @ crossing and upstream
Bed composition: boulder, cobble, sand Dom cobble Subdom sand D50
Bedrock (Y / N): no, but large boulders hold gradient
Structures / obstructions: boulders and large wood
Bank composition: silt
Channel width: Avg Chan. Depth: 2' Max Chan. Depth: 5'
Valley Width (est): Gradient: at crossing 1%
Floodplain character: forested downstream closer to 5-10%

Channel Process

Bank erosion: Y / N Describe: no

Scour: Y / N Describe: some adjacent boulder constrictions

Bed armored / embedded: Y / N Describe: yes, boulders act to armor

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: behind channel spanning

Function

Cause and effect relationships:
Large boulders ~ 2-3' and large 3' diameter logs control gradient and line banks, hindering/impeding erosion and incision.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	**3**	4	5	
Riparian Corridor	1	**2**	3	4	5	
Bank Characteristics	1	2	**3**	4	5	
Bed Characteristics	1	**2**	3	4	5	

New risk ranking and criteria for decision

Use large wood to line toe of channel or place boulders at toe. Slope banks from top of logs or boulders.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Trib to E Fork Cow Creek	Staff Present:	JMA
Crossing Milepost:	109.69 FS-HF-J	Date and Time:	May
Original Risk Designation		Units:	SU
Final Risk Designation	4	Estimated Q:	<2 cfs V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: steep, cascade

M&B classification:

Bed composition: boulders, LWD Dom Subdom D50

Bedrock (Y / N):

Structures / obstructions: massive log jam maintaining grade upstream of centerline

Bank composition: cobble/gravel

Channel width: 8' Avg Chan. Depth: n/a Max Chan. Depth: 4'

Valley Width (est): 15' Gradient: >3%

Floodplain character: forested

Channel Process

Bank erosion: Y / N Describe: yes; minor bank erosion around loss and upper banks

Scour: Y / N Describe: minor scour associated with LWD

Bed armored / embedded: Y / N Describe: yes; armored with large cobble/boulders

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no

Function

Cause and effect relationships:

Massive log jam upstream of crossing is holding a lot of sediment upstream. Boulder/gravel channel through crossing.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	**2** (highlighted)	3	4	5	
Riparian Corridor	1	2	**3** (highlighted)	4	5	
Bank Characteristics	1	2	3	**4** (highlighted)	5	
Bed Characteristics	1	**2** (highlighted)	3	4	5	

New risk ranking and criteria for decision

Crossing: Minimize disturbance to large log jam upstream. Renewal of LWD could result in severe channel adjustments and debris torrents. Restoration priorities: Habitat not a major consideration. Fish passage limited by waterfall. Vertical stability primary concern. Minimize disturbance to log jam, support if necessary.

Yellow ranking due to presence of sensitive log jam upstream.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Trib to E Fork Cow Creek
Crossing Milepost: 109.78 FS-HF-K
Original Risk Designation: yellow
Final Risk Designation: yellow

Staff Present: JAM, MLT
Date and Time: 8/27/14; 4PM
Units: SU
Estimated Q: V 0

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: sinuous
M&B classification: step pool/glide
Bed composition: boulders>sand Dom cobble Subdom sand D50 2.5 in
Bedrock (Y / N): no but very large boulders
Structures / obstructions: boulders and large wood
Bank composition: sand/gravel
Channel width: 6' Avg Chan. Depth: 2' Max Chan. Depth: 4'
Valley Width (est): 30' Gradient: 4%
Floodplain character:

Channel Process

Bank erosion: Y / N Describe: yes; high cut bank on outside bend of turn

Scour: Y / N Describe: yes, around wood and boulders

Bed armored / embedded: Y / N Describe: No

Migration/Avulsion: Y / N Describe: potential within valley

Deposition: Y / N Describe: yes, associated with wood

Function

Cause and effect relationships:
Boulders and cobbles hold gradient along with large wood in channel.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	**4**	5	
Riparian Corridor	1	**2**	3	4	5	
Bank Characteristics	1	2	3	**4**	5	
Bed Characteristics	1	2	**3**	4	5	

New risk ranking and criteria for decision

Maintain gradient, re-use boulders, re-construct sinuosity/maintain alignment.
Line toe of banks with large wood, parallel to bank, no RW needed
Bury pipeline same as stream depth out to within 5' of valley edge.

Yellow ranking for Site Specific BMP's for bank restoration and bed restoration

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: W Fork Trail Creek
Crossing Milepost: 118.89 ASP-202
Original Risk Designation Orange
Final Risk Designation Orange

Staff Present: JMA
Date and Time: May 21, 2014, 2 pm
Units: SU
Estimated Q: V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: multi thread bedrock bed channel
M&B classification: cascade
Bed composition: boulder/cobble Dom ______ Subdom ______ D50 ______
Bedrock (Y / N): yes; bedrock outcrops central channel location perched over floodplain
Structures / obstructions: bedrock steers channel
Bank composition: alluvial banks
Channel width: varies Avg Chan. Depth: 1.5' Max Chan. Depth: 3.5'
Valley Width (est): 75' Gradient: <1%
Floodplain character: low floodplain beyond braided zone

Channel Process

Bank erosion: Y / N Describe: no; channel maintains corridor over bedrock

Scour: Y / N Describe: yes; minor (>less than 3') around bedrock or boulders

Bed armored / embedded: Y / N Describe: armored; bed material immobile in many locations

Migration/Avulsion: Y / N Describe: no avulsion; migration associated with braided planform

Deposition: Y / N Describe: no; little in-channel deposits

Function

Cause and effect relationships:
Perched channel atop bedrock maintains high quality emrgent wetland habitat and offf channel areas.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	**2**	3	4	5	
Riparian Corridor	1	2	**3**	4	5	
Bank Characteristics	1	2	**3**	4	5	
Bed Characteristics	**1**	2	3	4	5	

New risk ranking and criteria for decision

Restoration: multi-thread channel to be restored using bedrock, large blasted rock,imported material. Riparian wetland function relies on perched water atop impervious bed.

Final ranking as Orange only to restore the site in a particular manner to maintain unique site attributes and hydrologic regime

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Trib to Neil Creek
Crossing Milepost: 130.86 ASI-246
Original Risk Designation: 4 yellow
Final Risk Designation: 3 blue

Staff Present: AL, JS
Date and Time: 8/27/2014
Units: US
Estimated Q: n/a (dry) V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: sinuous
M&B classification: c-stream (Rosgen), meandering short-term intermittent
Bed composition: silt Dom silt Subdom D50 silt
Bedrock (Y / N): no
Structures / obstructions: no
Bank composition: silt
Channel width: 2.2/3.3 (BFW) Avg Chan. Depth: 0.9 Max Chan. Depth: 1 (BFD)
Valley Width (est): 7500 Gradient: <1%
Floodplain character:

Channel Process

Bank erosion: Y / N Describe: no

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: no

Migration/Avulsion: Y / N Describe: no; not enough discharge

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
Very low energy stream system. Short-term intermittent channel dissiplates energy from its sinuosity, so no downcutting or avulsion risk.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	4	**5**	
Riparian Corridor	**1**	2	3	4	5	
Bank Characteristics	1	**2**	3	4	5	
Bed Characteristics	1	2	3	**4**	5	

New risk ranking and criteria for decision

3: Not enough sediment or discharge to cause risk of stream impairment during and post- construction. Standard construction BMPs will be adequate.

Final rank of Blue

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Neil Creek	Staff Present:	JMA
Crossing Milepost:	132.12 ASP-252	Date and Time:	3/20/2014 17:00
Original Risk Designation	Blue	Units:	SU
Final Risk Designation	Blue	Estimated Q:	<4 cfs V <1 fps

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight, ditched

M&B classification: plane bed

Bed composition: sand/gravel Dom ______ Subdom ______ D50 ______

Bedrock (Y / N): no

Structures / obstructions: willow rootmasses

Bank composition: alluvial

Channel width: 5' Avg Chan. Depth: 5" Max Chan. Depth: 10"

Valley Width (est): 30' Gradient: 0-1%

Floodplain character: pasture, some woody shrubs, heavily grazed

Channel Process

Bank erosion: Y / N Describe: yes; minor sloughing in areas devoid of vegetation

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: yes, embedded; fine material filled in around larger substrate, very little erosive power

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no

Function

Cause and effect relationships:

re-grade banks similar to existing, tie in up/down stream backfill native.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	**4**	5	
Riparian Corridor	1	2	3	**4**	5	
Bank Characteristics	1	2	3	**4**	5	
Bed Characteristics	1	2	**3**	4	5	

New risk ranking and criteria for decision

Site ranked blue due to low gradient, ditch conditions. Site is in the middle of a pasture, which is the primary reason for erodible banks and degraded habitat

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Lick Creek
Crossing Milepost: 140.27 ASI-233
Original Risk Designation: 4 yellow
Final Risk Designation: 4 yellow

Staff Present: JS, AL
Date and Time: 8/28/14; 10:30AM
Units: SU
Estimated Q: V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: meandering, entrenched channel
M&B classification:
Bed composition: cobble/boulder Dom cobble Subdom boulder D50 3"
Bedrock (Y / N): no
Structures / obstructions: large wood and boulders in channel
Bank composition: resistant silt
Channel width: 8' Avg Chan. Depth: 1' Max Chan. Depth:
Valley Width (est): BFW = 11' Gradient: 5%
Floodplain character: left: disconnected; right: valley slope, no floodplain

Channel Process

Bank erosion: Y / N Describe: yes; undercut banks along right bank 3-4' cut slope

Scour: Y / N Describe: no; localized scour associated w/ boulders and LWD, bed resistant to scour

Bed armored / embedded: Y / N Describe: yes; cobble armored bed

Migration/Avulsion: Y / N Describe: yes; potential migration along right bank, undercut bank, pistol butt conifers

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
Lateral migration along right bank due to bed resistance to scour in flow events. Bank is more easily aroded than bed.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	**3**	4	5	
Riparian Corridor	**1**	2	3	4	5	
Bank Characteristics	1	2	3	**4**	5	
Bed Characteristics	1	**2**	3	4	5	

New risk ranking and criteria for decision

4: Need bank protection along right bank to prevent continued migration. Install turning rootwads along 6' high cut bank at outside of meander. Install sweeper logs along 3' high cut bank to roughen bank, stabilize bank, and replace existing in-channel wood.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	S Fork Little Butte Creek	Staff Present:	AL, JS
Crossing Milepost:	162.45 ASP-165	Date and Time:	8/28/2014
Original Risk Designation	5 orange	Units:	SU
Final Risk Designation	5 orange	Estimated Q:	12 cf/s V 10 ft/s

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: sinuous

M&B classification: plane bed

Bed composition: gravel, sand, cobble Dom cobble/gvl Subdom cbl/gvl/bldr D50 3"

Bedrock (Y / N): very large boulders (3-6') anchored along banks and bed

Structures / obstructions: boulders and rootwads

Bank composition: silt (probes to 1-2')

Channel width: 12' Avg Chan. Depth: 1.9' Max Chan. Depth: 2.4 (BFD)

Valley Width (est): 40' Gradient:

Floodplain character: shallow gradient channel, can jump to alluvial terrace (0.5-1' above BFD)

Channel Process

Bank erosion: Y / N Describe: no, local bank scour adjacent to boulders, mostly well-vegetated

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: yes, no depth to refusal in cobble/gravel/boulder

Migration/Avulsion: Y / N Describe: yes, low elevation difference between BFD and terrace, combined with boulder could cause avulsion

Deposition: Y / N Describe: no

Function

Cause and effect relationships:

Boulders lining banks will armor channel, but could cause avulsions where no boulders exist, splitting flows at boulder towards terraces. Wood accumulations also cause widening. Boulder and cobble armoring restrict knickport development.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	4	**5**	
Riparian Corridor	**1**	2	3	4	5	
Bank Characteristics	1	2	3	4	**5**	
Bed Characteristics	**1**	2	3	4	5	

New risk ranking and criteria for decision

5: Very high avulsion risk upstream and downstream of crossing. Low gradient increases likelihood of avulsion.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Daily Creek	Staff Present:	JS, AL
Crossing Milepost:	166.21 ESI-76 (ESI-84)	Date and Time:	8/27/14 6:00PM
Original Risk Designation	4 yellow	Units:	SU
Final Risk Designation	3 blue	Estimated Q:	V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: braided where present
M&B classification: ephemeral headwater stream
Bed composition: gravel/cobble Dom gravel Subdom cobble D50
Bedrock (Y / N): no
Structures / obstructions: no
Bank composition: no banks, channel lacks defines structure
Channel width: <1' Avg Chan. Depth: Max Chan. Depth:
Valley Width (est): 50' Gradient:
Floodplain character: broad, flat area lacking defined channel

Channel Process

Bank erosion: Y / N Describe: no

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: yes

Migration/Avulsion: Y / N Describe: yes, stream lacks defined channels and is located in wide flood plain area

Deposition: Y / N Describe: yes, localized deposition associated with large rocks and wood

Function

Cause and effect relationships:
Small ephemeral stream with limited defined channel. Low risk due to ability for flows during storm events to spread across wide flood plain area and dissipate energy.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	**3**	4	5	
Riparian Corridor	**1**	2	3	4	5	
Bank Characteristics	1	2	**3**	4	5	
Bed Characteristics	1	2	**3**	4	5	

New risk ranking and criteria for decision

3: No defined stream channel, localized areas of substrate. Evidence of flow in winter. Low risk to crossing from seasonal flows. Ground surface resistant to any downcutting.

Blue

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Trib to Spencer Creek	Staff Present:	JAM, MLT
Crossing Milepost:	173.74 ESI-106a	Date and Time:	8/28/14; 10AM
Original Risk Designation	yellow	Units:	SU
Final Risk Designation	blue	Estimated Q:	V 0

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: sinuous

M&B classification:

Bed composition: sand, gravel, cobble Dom sand Subdom sm-m grave D50

Bedrock (Y / N): no

Structures / obstructions: no

Bank composition: forest floor duff

Channel width: 3-8' Avg Chan. Depth: <1' Max Chan. Depth: 1'

Valley Width (est): Gradient: <1%

Floodplain character: forest floor duff

Channel Process

Bank erosion: Y / N Describe: no

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: no

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no

Function

Cause and effect relationships:

Channel is undefined. Flow spreads across forest floor. Channel is covered with needles and organic debris ~40'.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	**2**	3	4	5	
Riparian Corridor	1	2	3	**4**	5	
Bank Characteristics	**1**	2	3	4	5	
Bed Characteristics	1	2	**3**	4	5	

New risk ranking and criteria for decision

Blue: Channel is a swale, flow likley insignificant.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Trib to Spencer Creek	Staff Present:	JAM, MLT
Crossing Milepost:	176.54 and 176.56 ESI-69	Date and Time:	8/28/14; 10:30AM
Original Risk Designation	yellow GSI-10	Units:	SU
Final Risk Designation	yellow	Estimated Q:	V 0

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: slightly sinuous

M&B classification: step/glide alluvial fan environment

Bed composition: silt, gravel Dom Subdom D50

Bedrock (Y / N): no

Structures / obstructions: no

Bank composition: forest floor silt duff

Channel width: 5' top, 3' bottom Avg Chan. Depth: 1' Max Chan. Depth: 3'

Valley Width (est): Gradient: 1-3%

Floodplain character: forest floor silt and duff

Channel Process

Bank erosion: Y / N Describe:

Scour: Y / N Describe: no pools

Bed armored / embedded: Y / N Describe: small boulders control gradient

Migration/Avulsion: Y / N Describe: there is potential for avulsion

Deposition: Y / N Describe: not significantly

Function

Cause and effect relationships:

Alluvial fan environment--avulsion potential.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	**4**	5	
Riparian Corridor	**1**	2	3	4	5	
Bank Characteristics	1	2	3	**4**	5	
Bed Characteristics	1	2	3	**4**	5	

New risk ranking and criteria for decision

Make sure to bury pipeline same depth across both channels. Control gradient with boulders.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Clover Creek	Staff Present:	JAM, MLT
Crossing Milepost:	177.76 SS-502-EW-103(MOD)	Date and Time:	8/28/14; 10:45AM
Original Risk Designation	yellow	Units:	SU
Final Risk Designation	green	Estimated Q:	V 0

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform:
M&B classification:
Bed composition: Dom Subdom D50
Bedrock (Y / N):
Structures / obstructions:
Bank composition:
Channel width: Avg Chan. Depth: Max Chan. Depth:
Valley Width (est): Gradient:
Floodplain character:

Channel Process

Bank erosion: Y / N Describe:

Scour: Y / N Describe:

Bed armored / embedded: Y / N Describe:

Migration/Avulsion: Y / N Describe:

Deposition: Y / N Describe:

Function

Cause and effect relationships:

No defined channel--could not locate. Any flow likely spreads out over 30-50' of aspen and pine and thick understory.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	**2**	3	4	5	
Riparian Corridor	1	2	3	**4**	5	thick understory
Bank Characteristics	1	2	**3**	4	5	shrubs
Bed Characteristics	1	2	**3**	4	5	

New risk ranking and criteria for decision

Green: Unable to identify single channel. Any flow likely spread out. Riparian may play key role in "restoration"--
thick understory of shrubs.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Trib to Klamath River	Staff Present:	JAM, MLT
Crossing Milepost:	186.61 - 186.65 ESI-97 ESI-99	Date and Time:	8/28/14; 12 noon
Original Risk Designation	yellow	Units:	SU
Final Risk Designation	blue	Estimated Q:	V 0

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: sinuous
M&B classification: meadow stream
Bed composition: silt Dom ____ Subdom ____ D50 ____
Bedrock (Y / N): no
Structures / obstructions: no
Bank composition: silt/meadow
Channel width: 3' Avg Chan. Depth: 1' Max Chan. Depth: 2'
Valley Width (est): 1000' Gradient: ____
Floodplain character: ____

Channel Process

Bank erosion: Y / N Describe: minor

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: no

Migration/Avulsion: Y / N Describe: minor potential but at very slow rate, insignificant

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
Two low gradient "meadow" channels empty into a watering hole with a culvert under road as an outlet. Low drainage area + low volume + flat slope = little power.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	4	**5**	
Riparian Corridor	1	2	3	4	**5**	pasture/agricultural
Bank Characteristics	1	2	**3**	4	5	silt
Bed Characteristics	1	2	**3**	4	5	silt

New risk ranking and criteria for decision

Blue: Insignificant flow to scour vertically. Potential bank erosion due to grazing cattle but migration unlikely.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Trib to Klamath River
Crossing Milepost: 186.74 ESI-100
Original Risk Designation: orange
Final Risk Designation: blue

Staff Present: JAM, MLT
Date and Time: 8/28/14; 12 noon
Units: SU
Estimated Q: V 0

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight
M&B classification: "meadow"
Bed composition: silt Dom ___ Subdom ___ D50 ___
Bedrock (Y / N): no
Structures / obstructions: no
Bank composition: silt/meadow
Channel width: 3' Avg Chan. Depth: 1' Max Chan. Depth: 2'
Valley Width (est): >1000' Gradient: ___
Floodplain character: meadow, dry grass

Channel Process

Bank erosion: Y / N Describe: minor

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: no

Migration/Avulsion: Y / N Describe: no significant potential

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
See 186.61 and 186.64

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	3	4	**5**	
Riparian Corridor	1	2	3	4	**5**	
Bank Characteristics	1	2	**3**	4	5	
Bed Characteristics	1	2	**3**	4	5	

New risk ranking and criteria for decision

Blue: Insignificant flow for vertical scour and culvert at DS controls grade. Bank erosion observed but migration unlikely.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name: Ditch
Crossing Milepost: 207.6 ADX-118
Original Risk Designation: 5 orange
Final Risk Designation: 3 blue

Staff Present: JS, AL
Date and Time: 8/28/14; 5:00PM
Units: SU
Estimated Q: V

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform: straight
M&B classification: irrigation canal
Bed composition: silt Dom ____ Subdom ____ D50 ____
Bedrock (Y / N): no
Structures / obstructions: no
Bank composition: grass-lined channel
Channel width: ~15' Avg Chan. Depth: ____ Max Chan. Depth: ____
Valley Width (est): >500' Gradient: ____
Floodplain character: adjacent farm fields

Channel Process

Bank erosion: Y / N Describe: no

Scour: Y / N Describe: no

Bed armored / embedded: Y / N Describe: no

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no

Function

Cause and effect relationships:
Irrigation canal with levees on both banks.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	2	**3**	4	5	
Riparian Corridor	1	2	3	**4**	5	
Bank Characteristics	1	2	**3**	4	5	
Bed Characteristics	1	2	**3**	4	5	

New risk ranking and criteria for decision

3: Irrigation canal. ~20' tall right bank. Low risk, construction BMPs adequate.

Sketch representative channel plan-view and cross-section on back of page.

PCGP Stream Risk Analysis Field Assessment

Crossing Name:	Unnamed Creek	Staff Present:	JAM, MLT
Crossing Miepost:	216.10 through 216.44 ASI-51	Date and Time:	8/28/14; 2PM
Original Risk Designation	yellow ASI-52	Units:	SU
Final Risk Designation	blue ASI-50	Estimated Q:	V 0
	ASI-49		

For moderate risk (yellow/4) sites list site specific BMP's on back
For high risk (orange/5) sites, measure representative transect and profile + identify site specific restoration concepts

Channel Form

Channel planform:

M&B classification: swale with some small steps but fairly continuous

Bed composition: silt Dom Subdom D50

Bedrock (Y / N): no outcrops but could be basalt not far below (or broken bedrock)

Structures / obstructions: no

Bank composition: silt

Channel width: 6' Avg Chan. Depth: 1' Max Chan. Depth: 1.5'

Valley Width (est): 200' Gradient: 5%

Floodplain character: rocky, sage and juniper

Channel Process

Bank erosion: Y / N Describe: no real banks

Scour: Y / N Describe: no scour observed

Bed armored / embedded: Y / N Describe: may have large cobbles below silt bottom

Migration/Avulsion: Y / N Describe: no

Deposition: Y / N Describe: no significant

Function

Cause and effect relationships:

Ephemeral streams.

Risk Analysis Scoring (refer to risk matrix)

						Comments
Landscape Sensitivity/Stream Type	1	**2**	3	4	5	
Riparian Corridor	**1**	2	3	4	5	
Bank Characteristics	1	**2**	3	4	5	
Bed Characteristics	1	**2**	3	4	5	

New risk ranking and criteria for decision

Sketch representative channel plan-view and cross-section on back of page.

APPENDIX B

Site-Specific Best Management Practices (BMPs) Typical Detail Sheets for Yellow Management Category Crossings

Table B-1

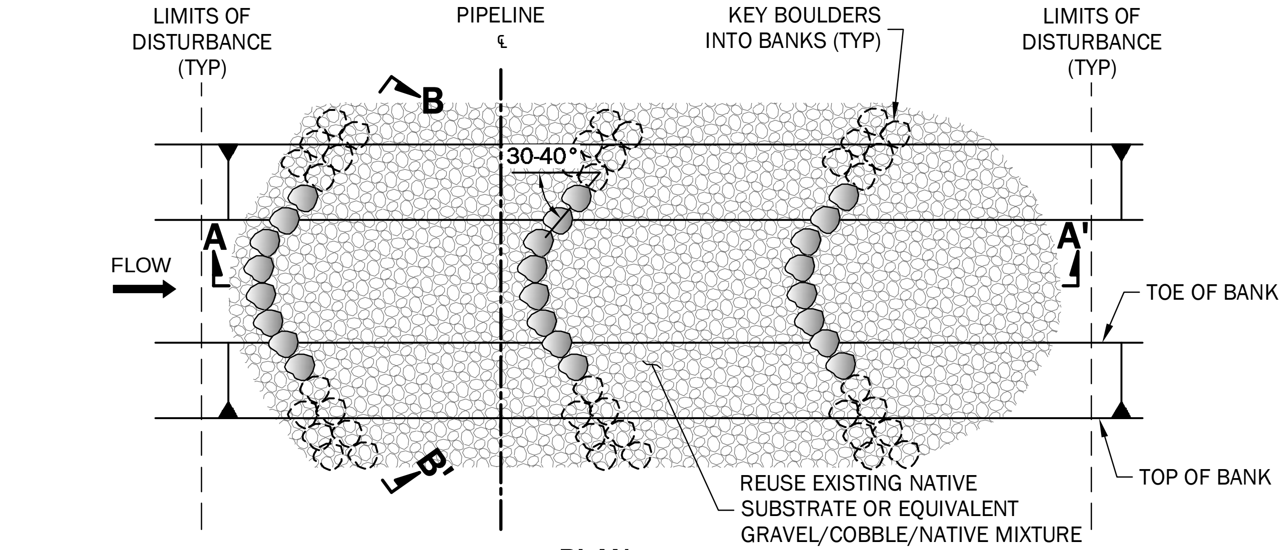
Yellow Management Category Stream Crossings: Example Site Specific Best Management Practices

Pacific Connector Gas Pipeline

Multiple Locations, Oregon

	Bed Control						Bank Protection							
Location	**Boulder Cascade**	**Boulder Pocket Water**	**Cobble Check Dam**	**Mid-channel Key Logs**	**Mini Log Jam**	**Cross Channel Logs**	**Vegetated, Encapsulated Soil Lifts**	**Longitudinal Toe Log**	**Meander Jam**	**Parallel Log Benches**	**Sweeper**	**Toe Protection Log with Coir Mat**	**Turning Wad**	**Logs With/Without Rootwads**
8.27R Willanch Slough S1-04 (EE-7 (MOD))				x	x	x	x					x	x	with
29.47 Trib to E. Fork Coquille BSI-76						x	x					x		without
29.85 East Fork Coquille River BSP-71							x	x		x		x		without
37.32 Trib to Trib to Big Creek ESI-19				x										without
48.27 Deep Creek BSP-257(MOD)				x		x								without
65.76 Rice Creek BSP-227							x		x				x	with
66.95 Willis Creek BSP-168				x		x						x		without
84.17 Wood Creek BSP-226				x		x								with
92.62 Saint John Creek ASP-303		x									x			with
109.17 Trib to East Fork Cow Creek FS-HF-C (GW-14)						x								without
109.69 Trib to East Fork Cow Creek FS-HF-J	x	x				x	x	x						without
109.78 Trib to East Fork Cow Creek FS-HF-K	x	x			x	x		x			x		x	without
110.96 Trib to East Fork Cow Creek FS-HF-N (ESI068)		x			x	x					x		x	without
140.27 Lick Creek ASI-233									x		x			with
176.54 Trib to Spencer Creek ESI-69		x												NA
176.56 Trib to Spencer Creek GS-10		x												NA

EXHIBIT B-2
Bed Restoration BMPs



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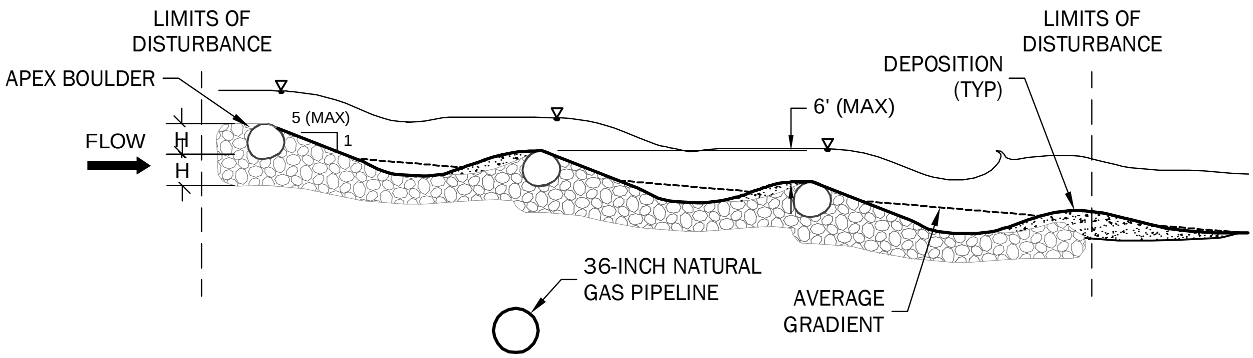


SECTION A-A'
NOT TO SCALE

Purpose and Application:

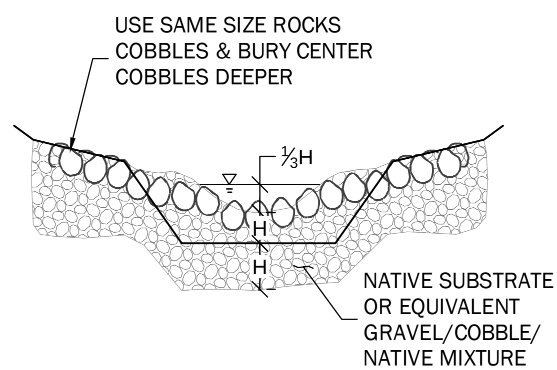
- Functions as bed control in steep, coarse substrate, high energy stream systems.
- Can be used in steep to moderate gradient channel with boulder and/or cobble dominant substrate.
- Enhances fish habitat by creating pool-riffle sequences and cascades.
- Provides bed control and flow direction for full range of flows.

Construction Notes:

- Generally large, stream-wide structure with center coincident with channel centerline or thalweg.
- Key largest Boulders into bank so they do not overtop or become "out-flanked" during flood flows.
- Use same size boulders & bury center boulders deeper.
- "Upstream Vee" configuration directs water to center of channel. Plant dense vegetation along banks.
- Reinforce channel bed with footer boulders and cobbles to prevent scour at/below boulders.
- Reuse existing native bed substrate or equivalent gravel/cobble/native mixture.

General Notes:

- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.



SECTION B-B'
NOT TO SCALE

Boulder Cascade
Site Specific BMPs - Moderate Risk Stream Crossings

Pacific Connector Gas Pipeline
Oregon

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Exhibit B-2.1

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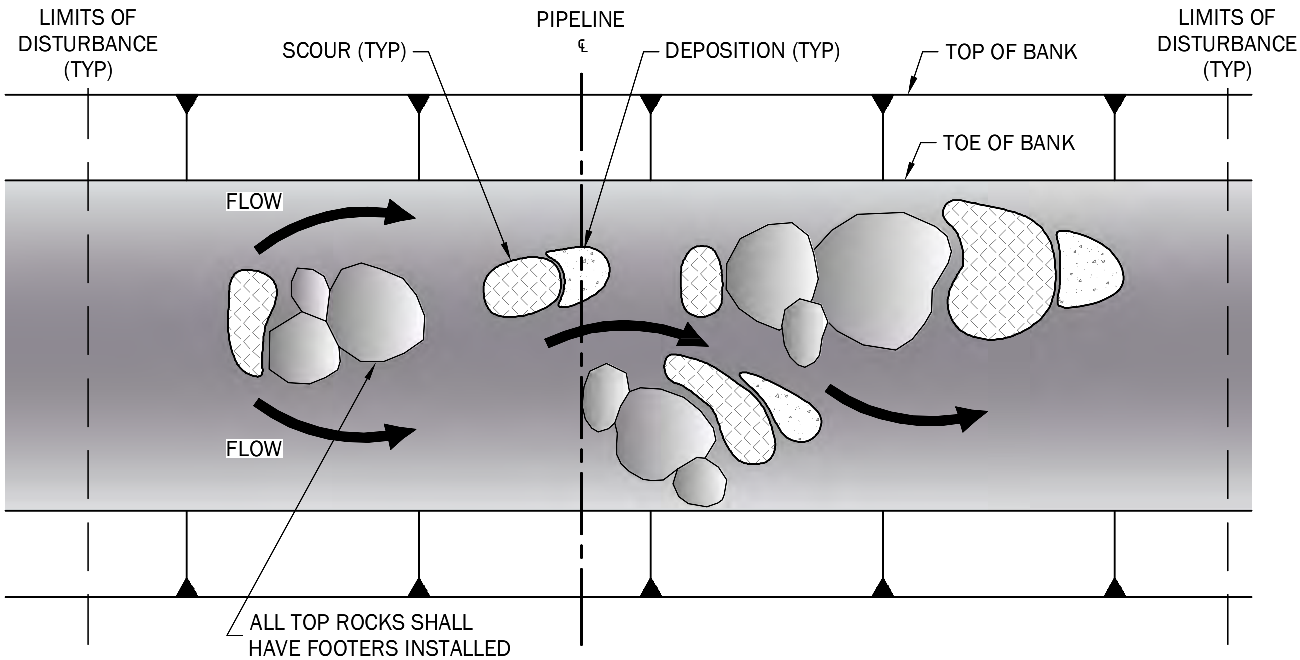

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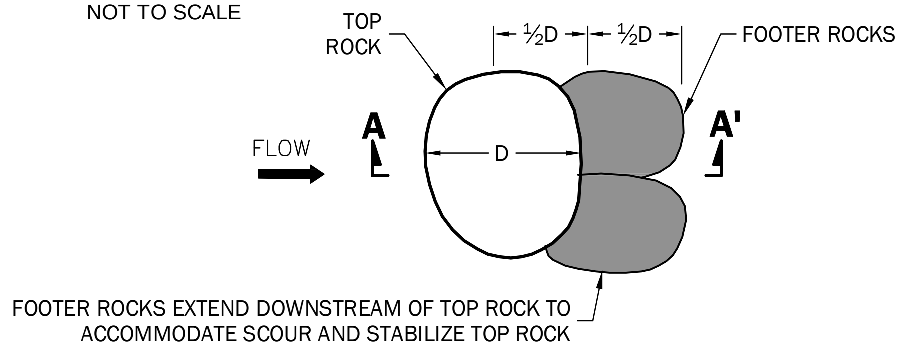
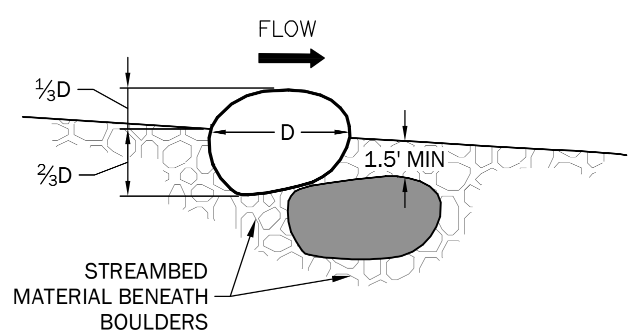


BOULDER REINFORCEMENT DETAIL
NOT TO SCALE



SECTION A-A'
NOT TO SCALE

Purpose and Application:
- Bed control in low to high gradient streams with existing boulder substrate
- Develops meandering flow path and retains stream gradient.
- Encourage scour pool formation and deposition of gravel.
- Provide low velocity zones for salmonid rearing and migration

Construction Notes:
- Place in straight to moderately meandering reaches.
- All boulders shall be rounded and a minimum of 1-foot diameter. Size shall equal native boulders.
- Where feasible, use existing boulders salvaged during pipeline installation.
- All top boulders to be supported by footer rocks as shown in detail. Footer rocks shall be of similar size as top rocks.
- Remaining backfill shall be vertically integrated to mimic naturally occurring substrate.

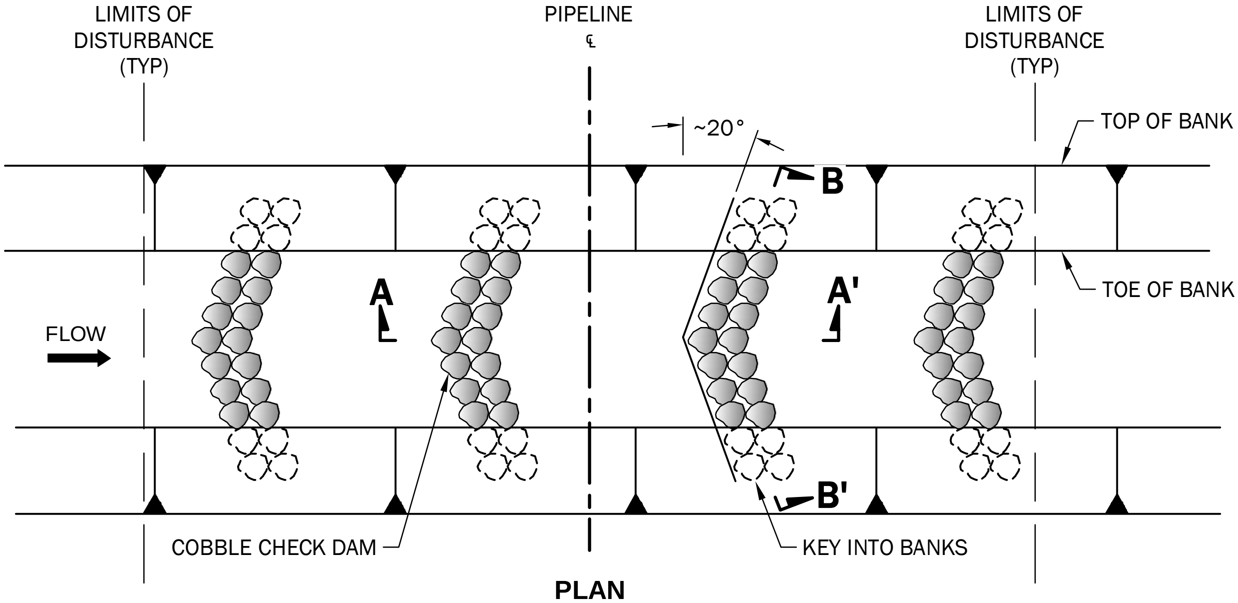
General Notes:
- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

Boulder Pocket Water
Site Specific BMPs - Moderate Risk Stream Crossings

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit B-2.2



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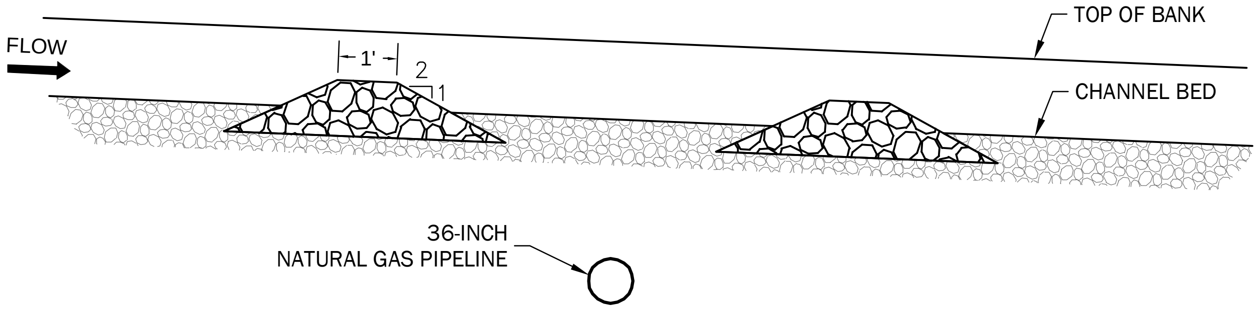

SECTION A-A'
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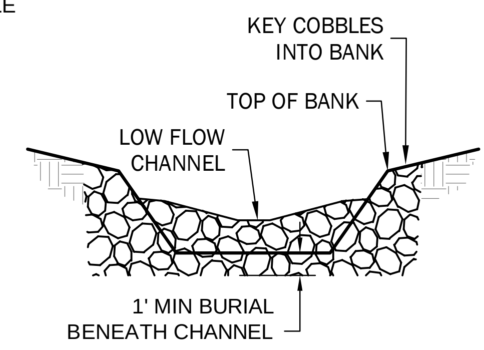


SECTION B-B'
NOT TO SCALE

Purpose and Application:
- Functions as bed control in low to moderate slope, fine substrate streams.
- Minimizes channel incision by providing grade control in erosive stream beds.

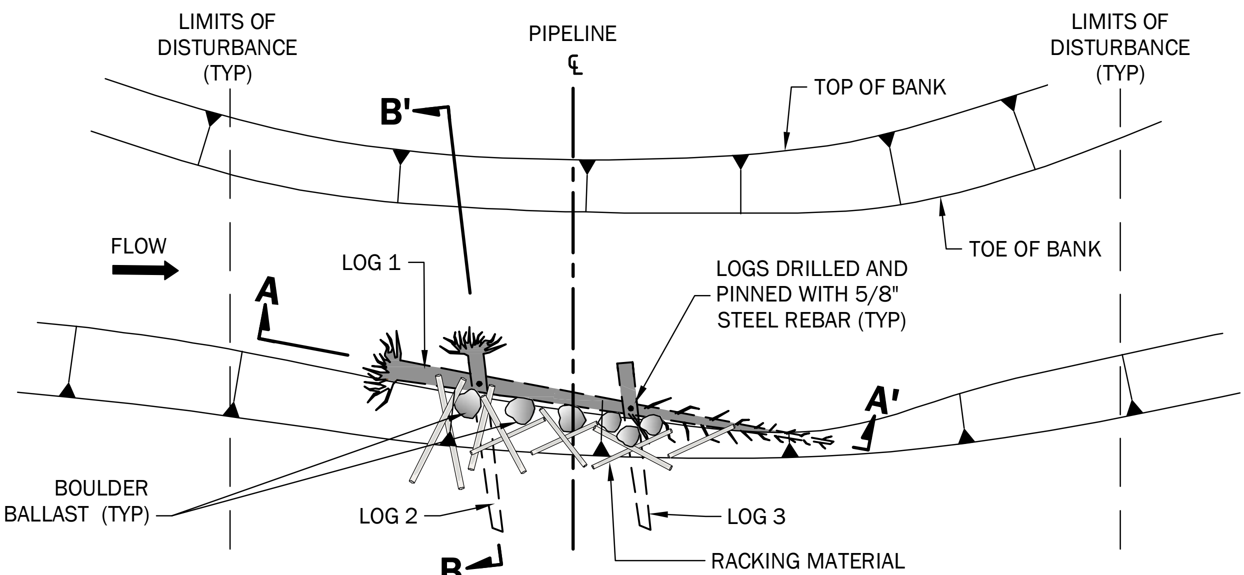
Construction Notes:
- Cobble check dams are keyed into banks with low spot in center of channel for lower flows.
- Orient check dams at ~20° from perpendicular to flow.
- “Upstream Vee” configuration directs water to center of channel. Plant dense vegetation along banks.
- Cobbles shall be sized larger than the natural D_{100} to ensure that check dams remain stationary in all flow events.
- Dimensions shown on cobble check dams are a minimum and may be enlarged as is appropriate for stream system.

General Notes:
- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

Cobble Check Dam
Site Specific BMPs - Moderate Risk Stream Crossings

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS | **Exhibit B-2.3**



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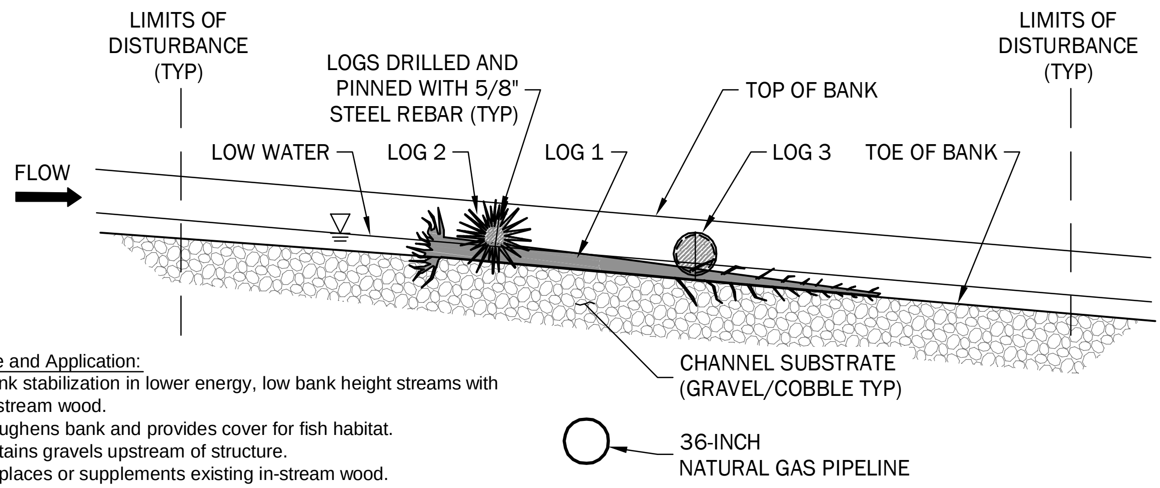

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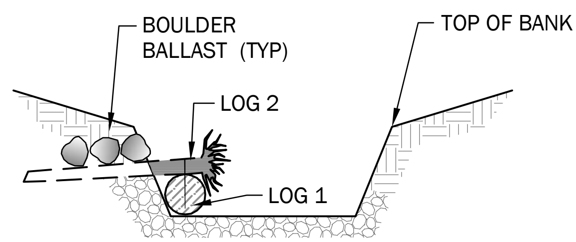

SECTION B - B'
NOT TO SCALE

Purpose and Application:
- Bank stabilization in lower energy, low bank height streams with in-stream wood.
- Roughens bank and provides cover for fish habitat.
- Retains gravels upstream of structure.
- Replaces or supplements existing in-stream wood.

Construction Notes:
- Place in straight reaches and along outside of bends with low banks.
- Place root wad on stream bed adjacent to bank.
- Trees with branches or multiple trunks preferred. Minimum tree diameter at breast height shall be 18-inch.
- Log 1 shall be placed first with downstream end buried into bank. Logs 2 and 3 shall be set on top of Log 1. Logs 2 and 3 shall be pinned to Log 1.
- Secure key members by drilling and pinning with 5/8-inch steel rebar. Racking material shall be placed between key members and the bank.
- Racking material shall consist of 6" minimum diameter 5- to 15-foot long pieces of woody debris.
- Ballast shall be installed over Logs 2 and 3 buried into bank. Ballast shall consist of a minimum of 8, 2-foot diameter boulders or equivalent.

General Notes:
- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

Longitudinal Toe Log
Site Specific BMPs - Moderate Risk Stream Crossings

Pacific Connector Gas Pipeline
Oregon

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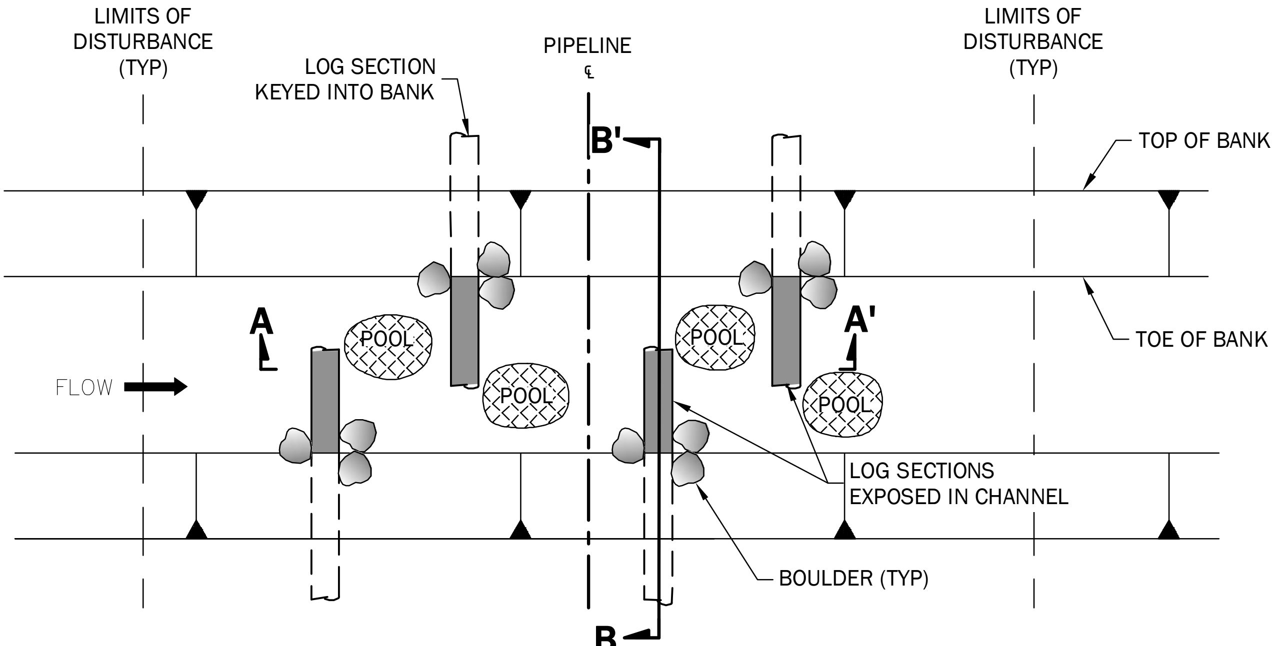
Exhibit B-2.4



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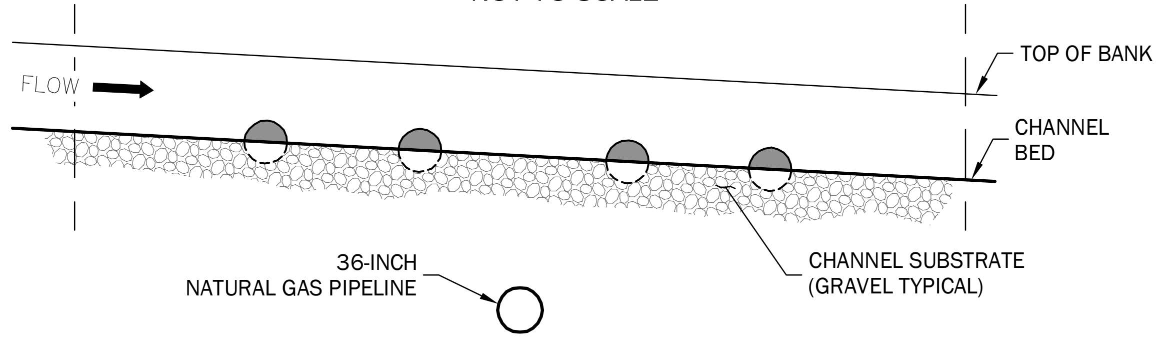

SECTION A-A'
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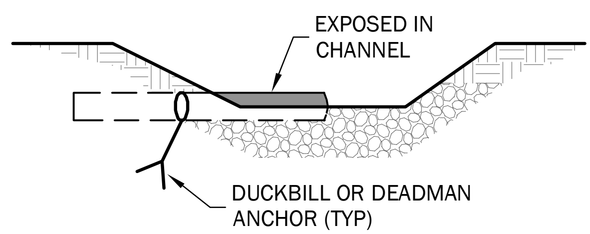

SECTION B-B'
NOT TO SCALE

Purpose and Application:

- Bed control in low to medium gradient streams with in-stream wood.
- Promotes meandering channel plan form and pool-riffle channel sequence.
- Retains gravels upstream of logs.
- Replaces or supplements existing in-stream wood.

Construction Notes:

- Place in straight or moderately meandering reaches.
- Use onsite wood material where feasible.
- Embed log ends within bank and anchor with duckbill or deadman anchor.
- Do not place rootwads within stream channel, rootwads may be buried in banks.
- Place boulders downstream to keep logs perpendicular to bank.
- Logs shall be minimum of 18-inches in diameter and extend ½ - ⅔ of the way across the channel.
- Bury logs ~½ of diameter into channel bed.
- Log spacing to vary based on slope of channel. Lower slope will require longer spacing.

General Notes:

- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

Mid-channel Key Logs
Site Specific BMPs - Moderate Risk Stream Crossings

Pacific Connector Gas Pipeline
Oregon

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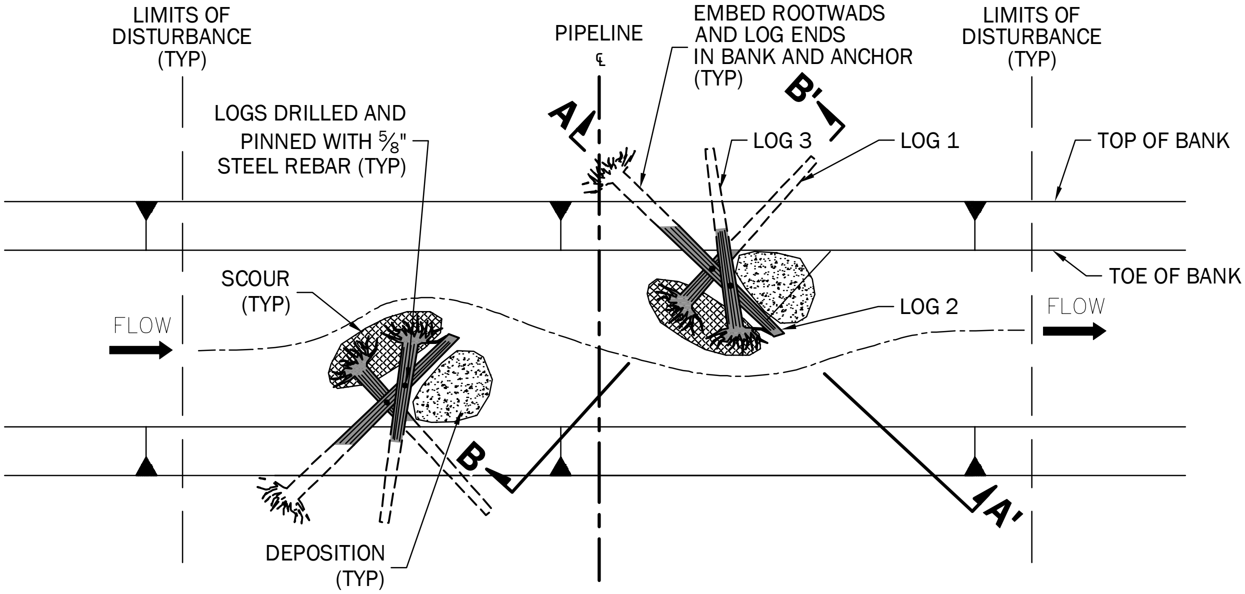
Exhibit B-2.5



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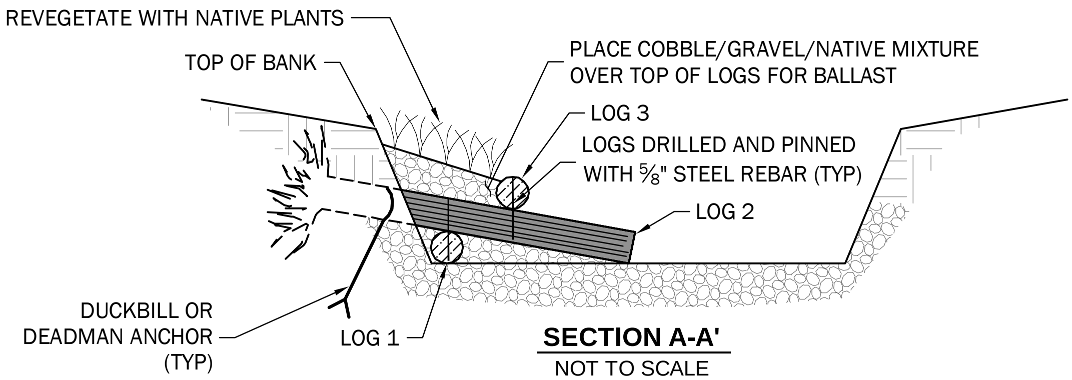

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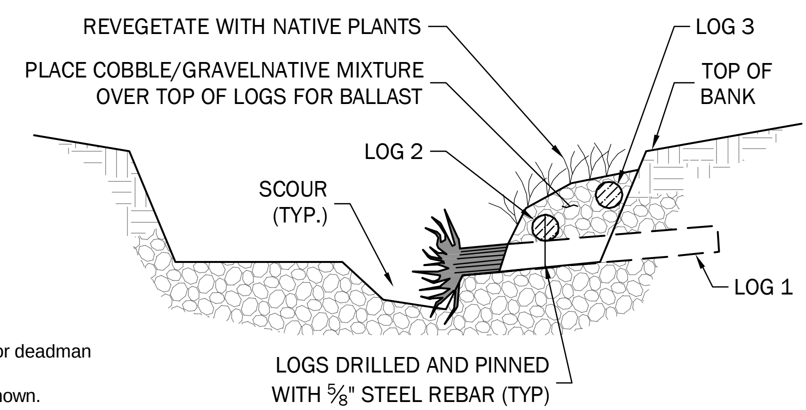

SECTION B-B'
NOT TO SCALE

Purpose and Application:
- Functions as bed control bank stabilization in larger streams with existing in-stream wood.
- Multiple structures can be used on opposite banks to develop meandering channel platform.
- Enhances fish habitat by creating scour pools a and providing in-stream woody cover
- Provides bank stabilization and flow direction for full range of flows.

Construction Notes:
- Use 18-inch minimum diameter logs with rootwads.
- Slope logs downward toward center of channel.
- Place logs in following order: Log 1, Log 2, Log 3.
- Key rootwads into bank and anchor Log 2 with duckbill or deadman anchor.
- Drill and pin logs together with 5/8-inch steel rebar as shown.
- Cover logs along bank with streambed mixture for ballast.
- Plant top of structure with native riparian vegetation

General Notes:
- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

Mini Log Jam
Site Specific BMPs - Moderate Risk Stream Crossings

Pacific Connector Gas Pipeline
Oregon

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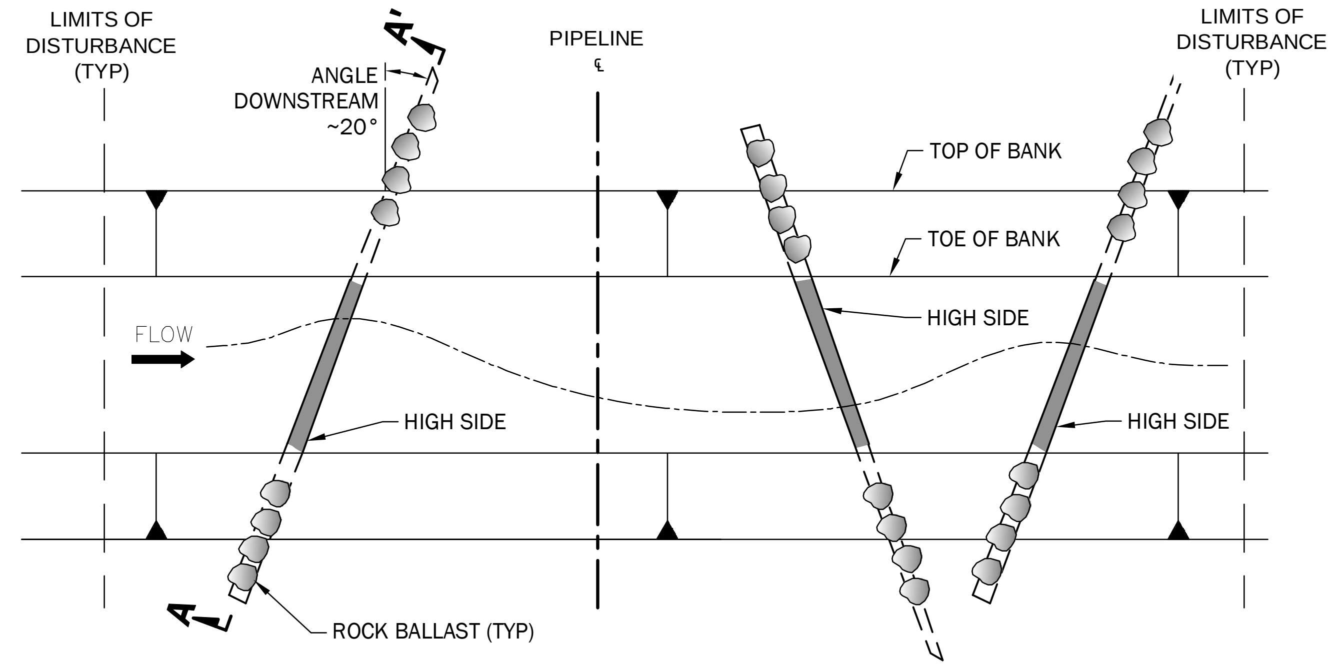
Exhibit B-2.6



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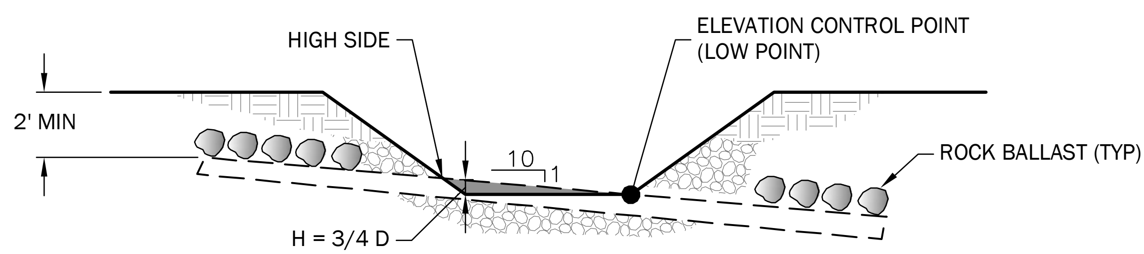


SECTION A-A'
NOT TO SCALE

Purpose and Application:

- Bed control in low gradient, straight channels with in-stream wood.
- Develops meandering flow path.
- Retains gravels upstream of structure.
- Replaces or supplements existing in-stream wood

Construction Notes:

- Place in straight to slightly sinuous reaches.
- Tip ends shall be keyed into banks.
- Angle logs ~20° downstream from perpendicular to flow path.
- Set log elevation so low side is at bed elevation and high side is at ¾ of log diameter above bed.
- Alternate logs so high side varies from bank to bank with each log.
- Pack upstream side of logs with substrate material.
- No rootwads on logs.
- Place rock ballast or boulders over log ends on each bank.

General Notes:

- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

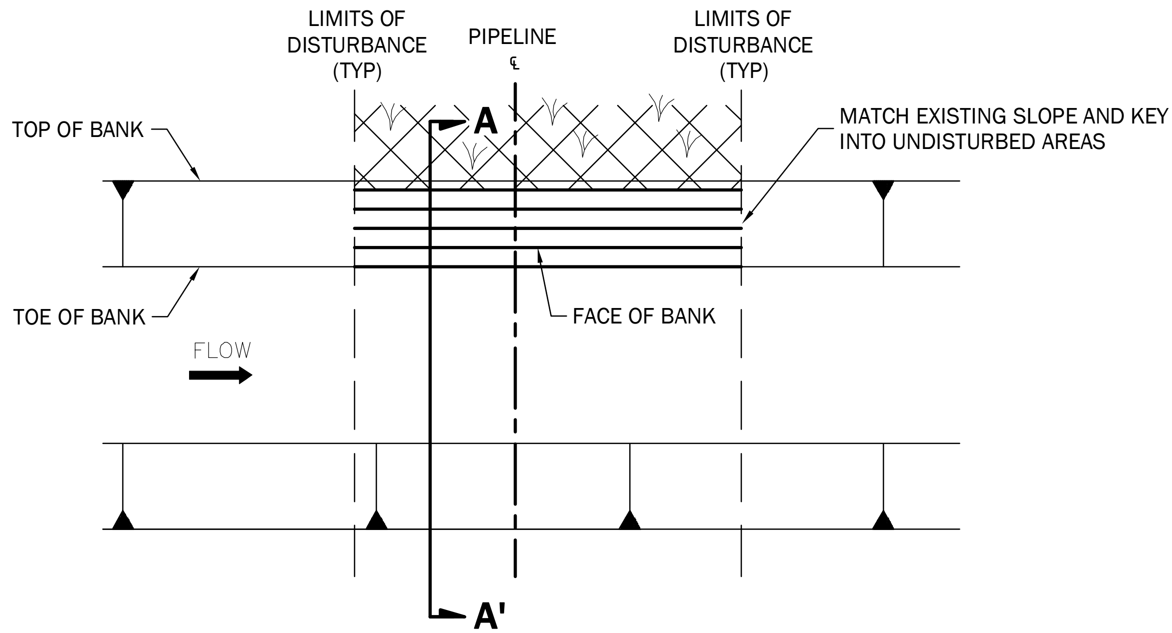
Cross Channel Logs
Site Specific BMPs - Moderate Risk Stream Crossings

Pacific Connector Gas Pipeline
Oregon

GeoEngineers

Exhibit B-2.7

EXHIBIT B-3
Bank Restoration BMPs



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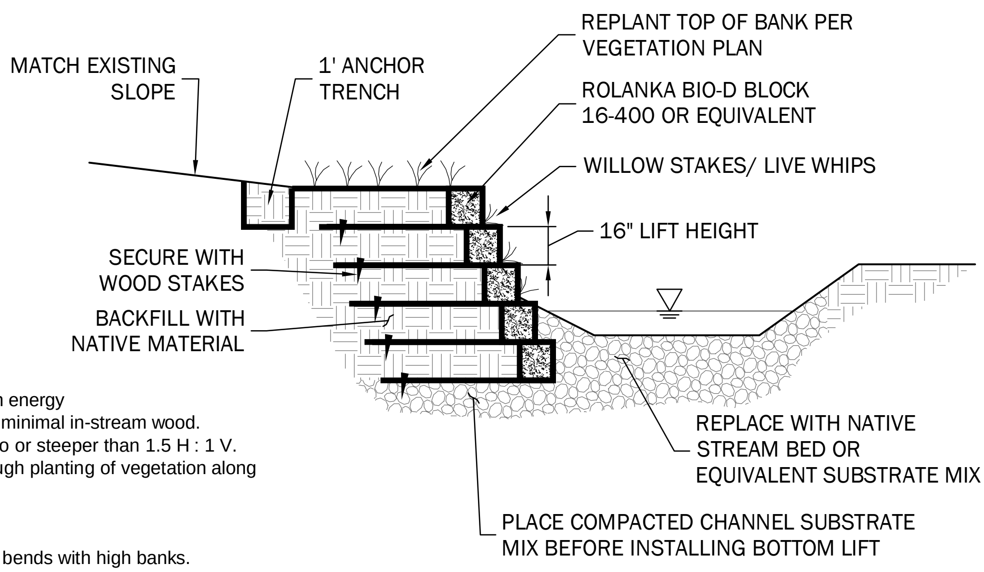

SECTION A-A'
NOT TO SCALE

Purpose and Application:

- Bank stabilization in medium to high energy streams, with high bank height and minimal in-stream wood.
- Stabilizes banks with slopes equal to or steeper than 1.5 H : 1 V.
- Provides edge habitat benefits through planting of vegetation along wall.

Construction Notes:

- Place in straight reaches and along bends with high banks.
- Place bottom lift atop compacted substrate mix.
- Match existing bank slope at upstream and downstream transition from coir wall wrap.
- Use Rolanka BioD Block 16-400 or equivalent product.
- Use sufficient number of lifts to match existing bank height upstream and downstream of coir wrap wall.
- Place live whips or willow stakes between lifts.
- Apply native seed mix on top of compacted soil prior to covering with coir fabric.

General Notes:

- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

Vegetated, Encapsulated Soil Lifts

Site Specific BMPs - Moderate Risk Stream Crossings

Pacific Connector Gas Pipeline
Oregon

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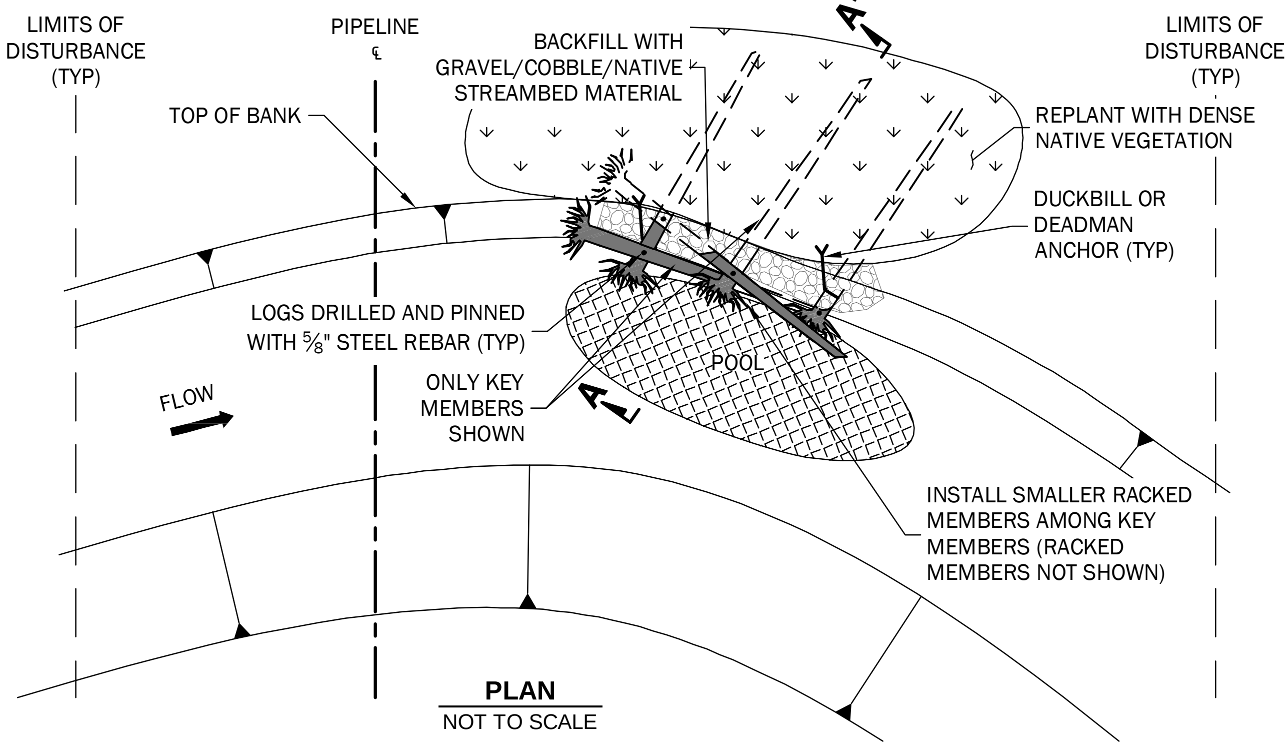
Exhibit B-3.1



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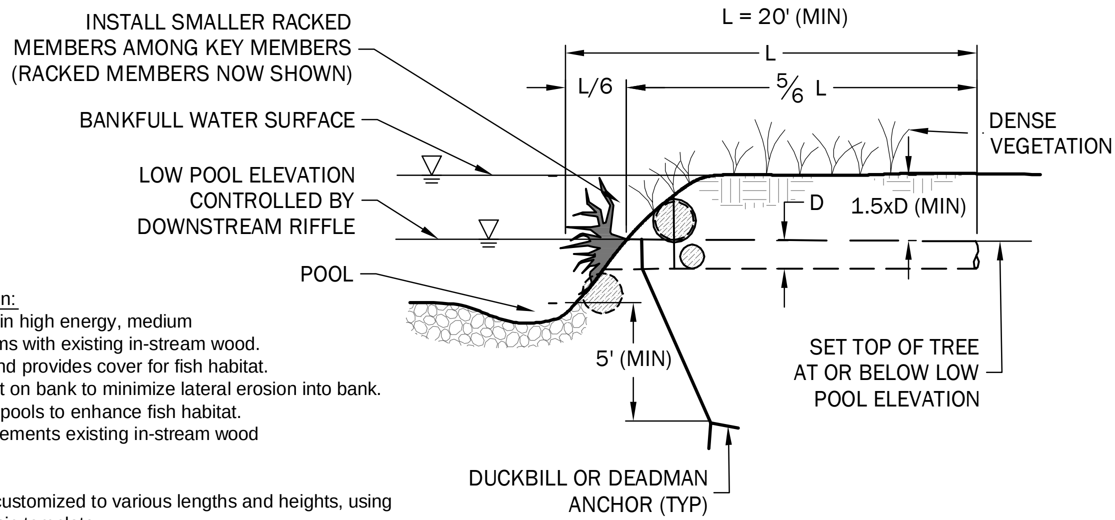


SECTION A-A'
NOT TO SCALE

Purpose and Application:
- Bank stabilization in high energy, medium bank height streams with existing in-stream wood.
- Roughens bank and provides cover for fish habitat.
- Provides hardpoint on bank to minimize lateral erosion into bank.
- Creates bankside pools to enhance fish habitat.
- Replaces or supplements existing in-stream wood

Construction Notes:
- Structure can be customized to various lengths and heights, using this detail as a basic template.
- Place along outsides of channel bends.
- Key members shall be 18-inch minimum diameter and 20-foot long logs with rootwads secured into banks with duckbill or deadman anchors.
- Racking material shall consist of 6-inch minimum diameter and 10-foot minimum length wood pieces wedged between key members.
- Backfill with stream substrate and plant dense native vegetation on top to bank.

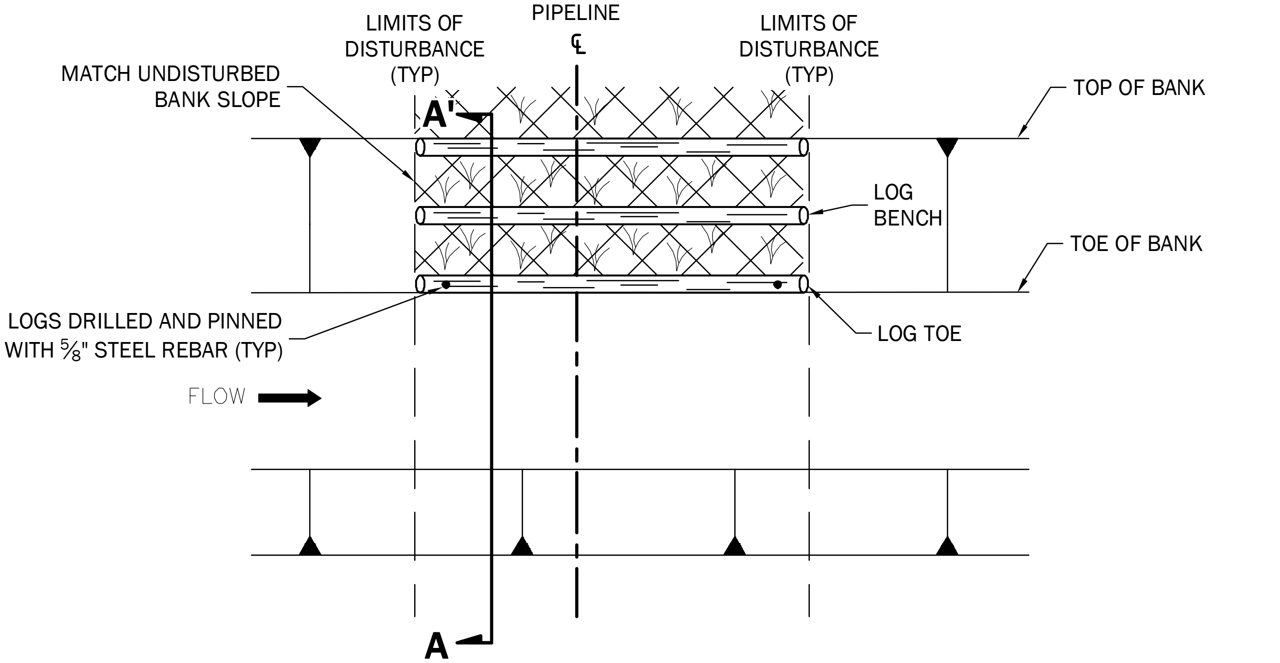
General Notes:
- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

Meander Jam
Site Specific BMPs - Moderate Risk Stream Crossings

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit B-3.2



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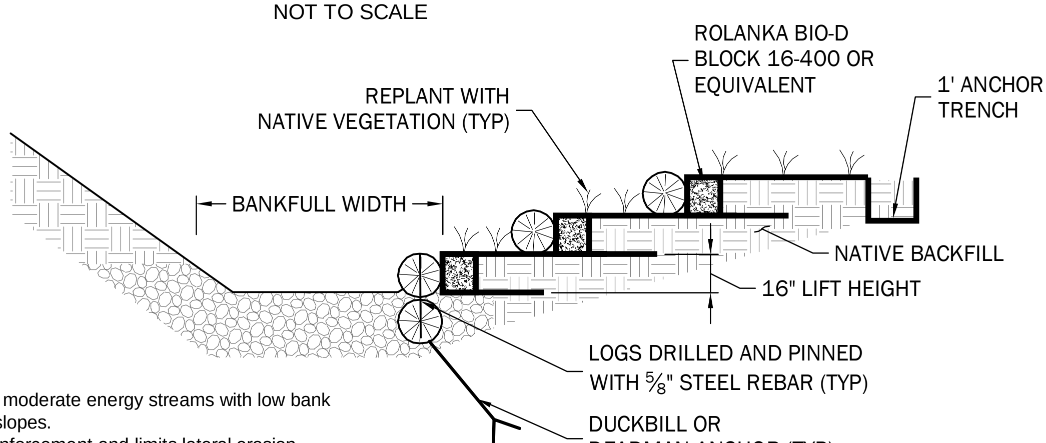


SECTION A-A'
NOT TO SCALE

Purpose and Application:
- Bank stabilization in low to moderate energy streams with low bank heights and gradual bank slopes.
- Toe logs provides bank reinforcement and limits lateral erosion.
- Varying slope geometries can be used with this application.
- Can be used to recreate floodplain terraces and gradual bank slope transitions.

Construction Notes:
- Place in straight reaches and along outside of bends with low banks.
- Bury bottom log completely in channel and drill and pin with ⅝-inch steel rebar upper log to toe log at upstream and downstream ends.
- Wrap coir mat behind toe log at bottom of slope.
- Bank slopes 2:1 maximum.
- Key top end of coir mat with 1-foot anchor trench.
- Toe protection log shall be minimum of 18-inch diameter.
- Parallel log benches may be extending to protect longer sections of unstable banks. Place end of upstream log flush with top of next log to ensure continuous bank protection.

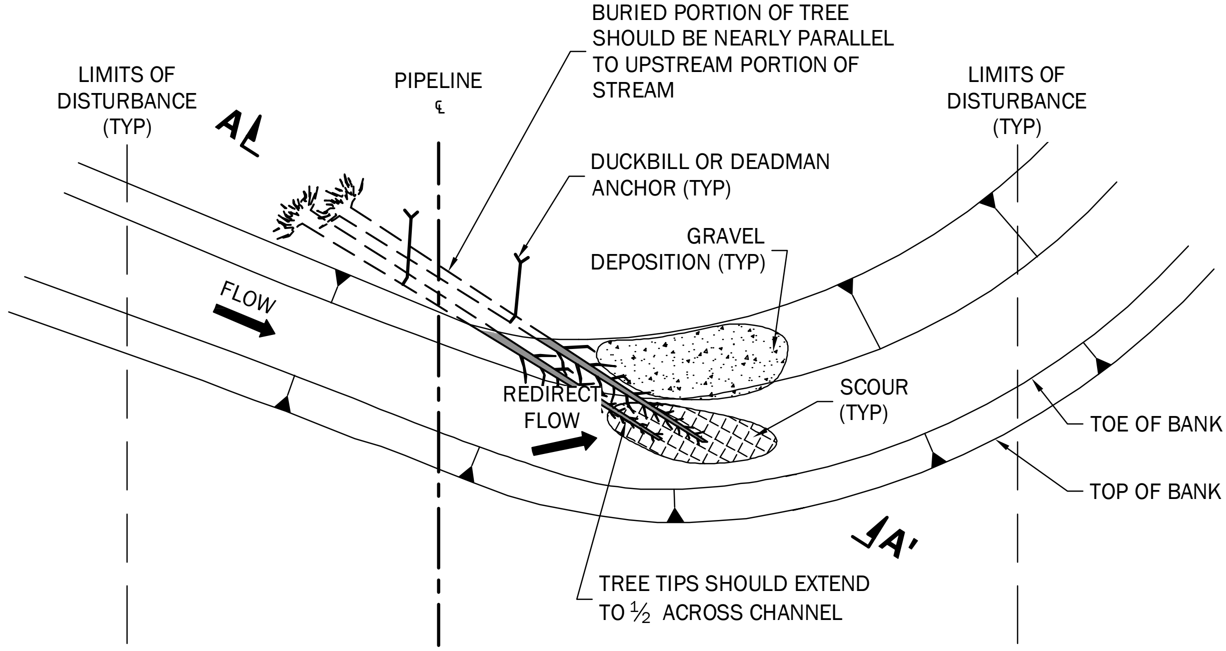
General Notes:
- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

Parallel Log Benches
Site Specific BMPs - Moderate Risk Stream Crossings

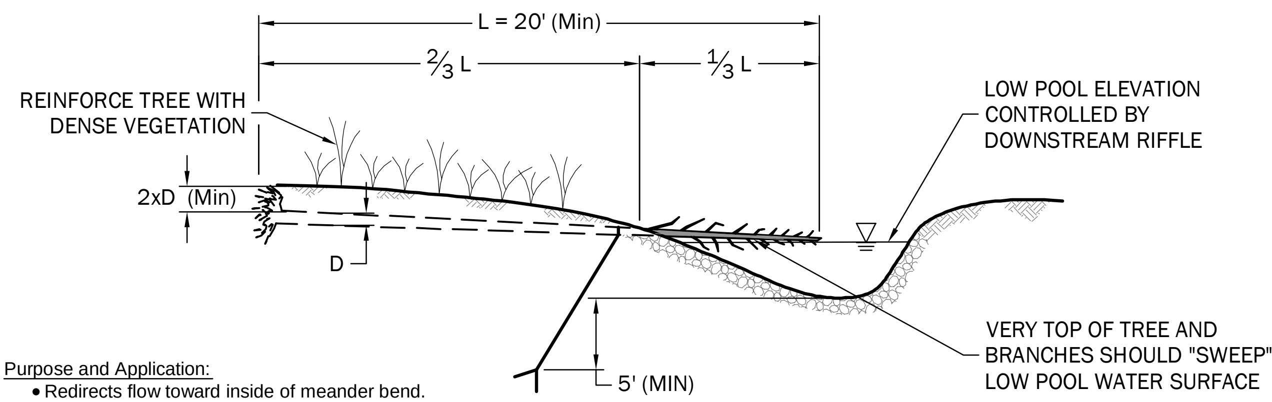
Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS | **Exhibit B-3.3**

P:\16\16724001_Pdx\10\CAD\BMPs\PARALLEL LOG BENCHES.dwg TAB:Toe Proection with Coir Mat Date Exported: 02/12/15



PLAN
NOT TO SCALE



SECTION A-A'
NOT TO SCALE

Purpose and Application:
- Redirects flow toward inside of meander bend.
- Encourages gravel deposition on bank.
- Encourages pool formation.
- Replaces or supplements existing in-stream wood.
- Provides covert for aquatic habitat/thermal refugia.

Construction Notes:
- Sweeper logs shall be freshly cut trees with intact branches.
- Logs shall be 8-inch minimum diameter and 15-foot minimum length.
- Place at upstream ends of bend at inside bank.
- Bury min ⅔ of log length and secure with duckbill or deadman anchors.
- Backfill with stream substrate and plant dense native vegetation on top to bank.

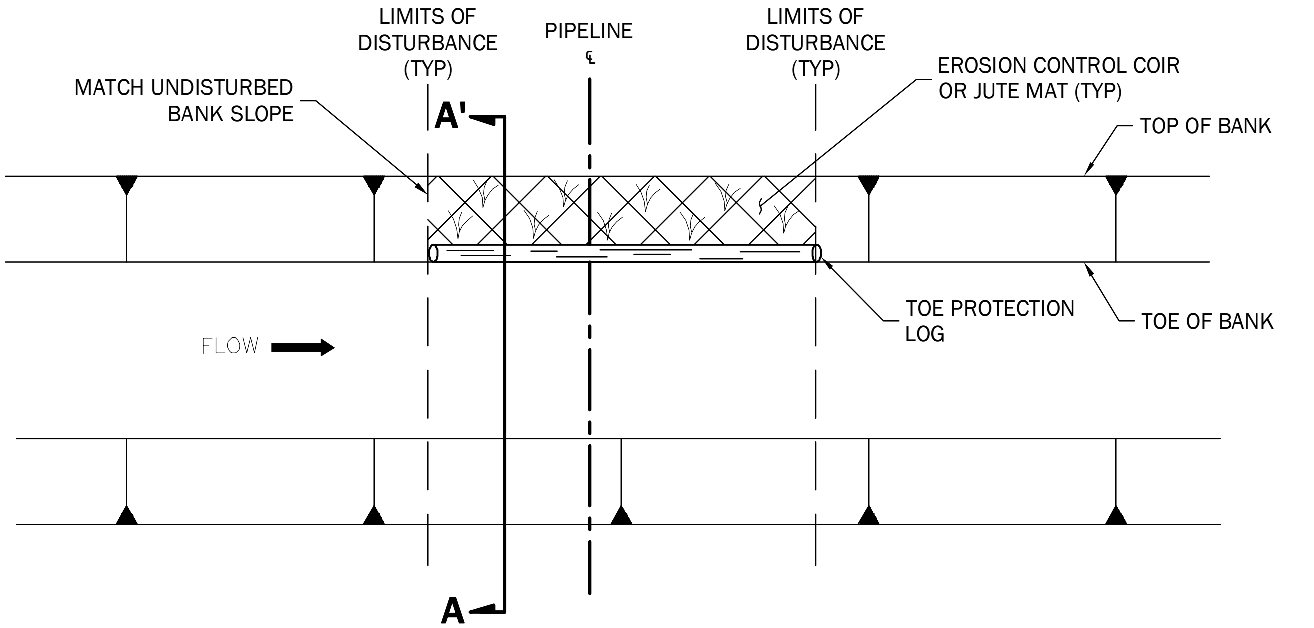
General Notes:
- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

Sweeper
Site Specific BMPs - Moderate Risk Stream Crossings

Pacific Connector Gas Pipeline
Oregon

GeoEngineers

Exhibit B-3.4



PLAN
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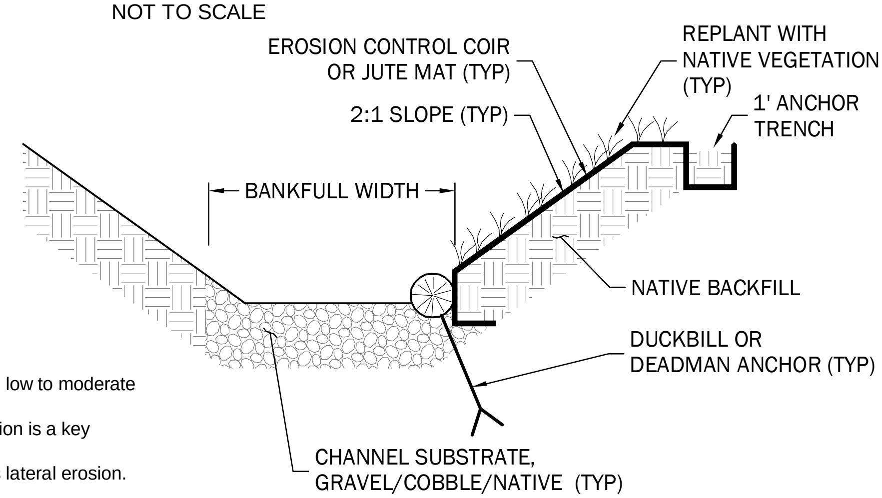


SECTION A-A'
NOT TO SCALE

Purpose and Application:
- Bank stabilization in lower energy streams with low to moderate bank heights and in-stream wood.
- For use in streams where overhanging vegetation is a key component of existing habitat quality.
- Toe log provides bank reinforcement and limits lateral erosion.
- Fabric and native vegetation stabilizes slope.

Construction Notes:
- Place in straight reaches and along outside of bends with low banks
- Place toe protection log at toe of unstable bank and embed ¼ - ⅓ of the diameter into the channel bed.
- Toe protection log can have rootwad in larger width streams.
- Wrap coir mat behind toe log at bottom of slope.
- Key top end of coir mat with 1-foot anchor trench.
- Toe protection log shall be minimum of 18-inches in diameter.
- In larger width streams rootwad may be included and shall be oriented on the upstream end of the coir mat.
- Multiple toe protection logs may be used to extend coir mat along longer sections of unstable banks. Place end of upstream log flush with top of next log to ensure continuous bank protection.

General Notes:
- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

Toe Protection Log with Coir Mat

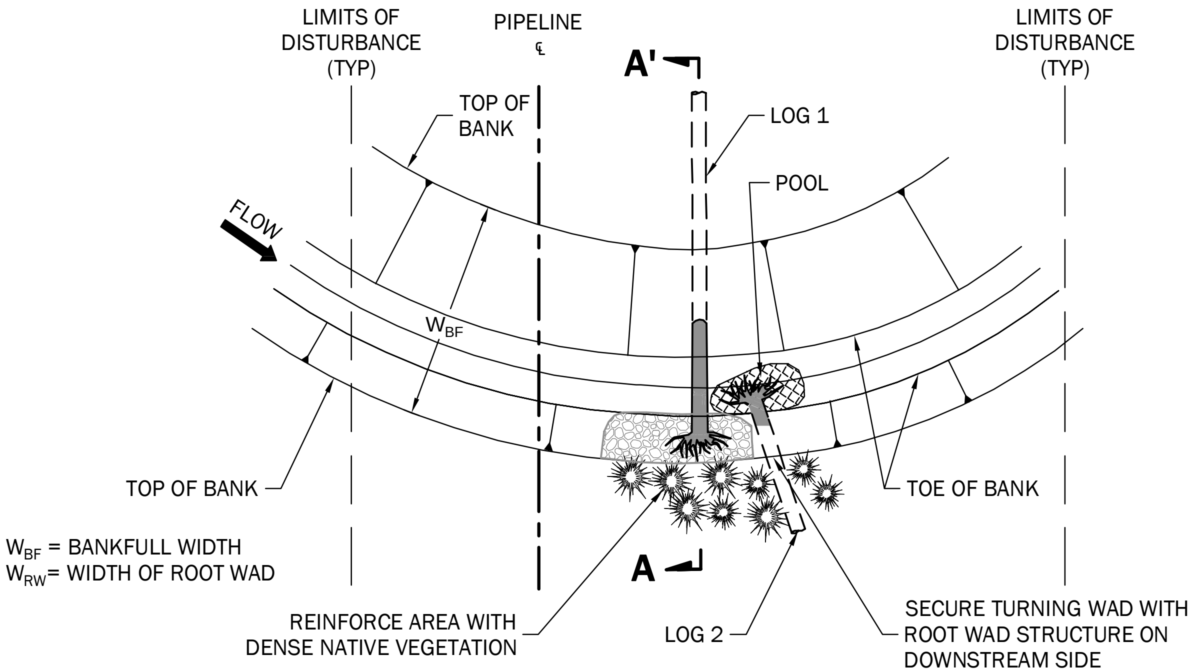
Site Specific BMPs - Moderate Risk Stream Crossings

Pacific Connector Gas Pipeline
Oregon

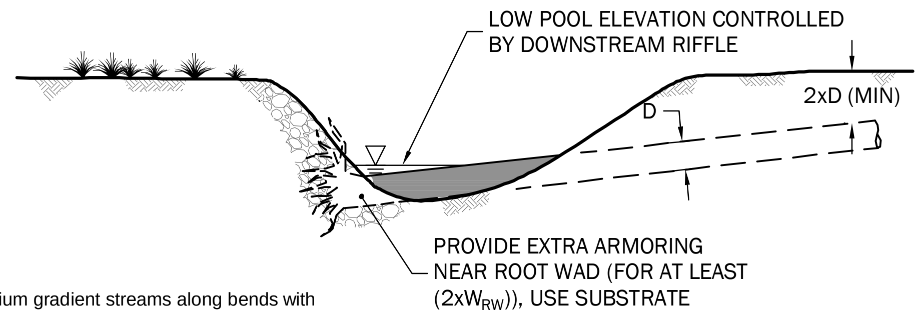
GeoEngineers

Exhibit B-3.5

P:\16\16724001_Pdx\10\CAD\BMPs\TOE PROTECTION LOG.dwg TAB:Toe Proection with Coir Mat Date Exported: 02/12/15



PLAN
NOT TO SCALE



SECTION A-A'
NOT TO SCALE

Purpose and Application:
- Bed control in low to medium gradient streams along bends with in-stream wood.
- Stabilizes existing channel bends.
- Retains gravels upstream of logs.
- Replaces or supplements existing in-stream wood.
- Creates pools with cover.

Construction Notes:
- Place turning wad at upstream end of bend.
- Place root wad of Log 1 into bank as shown for ballast.
- Place Root Wad of Log 2 into stream where pool will form downstream.
- Log 2 should not block more than 50% of channel cross sectional area (at base flow).
- Log 2 may be installed at, near or below low pool elevation.
- Place trees, branches, gravel and cobbles on upstream of tree to prevent water from flowing beneath log.

General Notes:
- The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
- The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.

Turning Wad **Site Specific BMPs - Moderate Risk Stream Crossings**	
Pacific Connector Gas Pipeline Oregon	
GeoEngineers	**Exhibit B-3.6**

Office: BAM P:\16\16724001_Pdx\10\CAD\BMPs\TURNING WAD.dwg TAB:Typical Turning Wad Detail jsmith Feb-12-15

APPENDIX C
Site-Specific Restoration Plans for Orange Management Category Crossings

EXHIBIT C-1

MP 27.04 Middle Creek

Site Summary

Exhibit C-1 presents results and site-specific design for restoration of Middle Creek. Middle Creek, located at MP 27.04, was initially ranked a moderate risk (Yellow management category) site. Upon completion of the preconstruction survey, the site was reclassified as a high risk (Orange management category) stream, due to the following characteristics:

- Over-steepened banks
- Highly erodible banks
- Actively scouring streambed
- Recent channel widening
- Potential for stream to retain large amounts of sediment

Site Photos

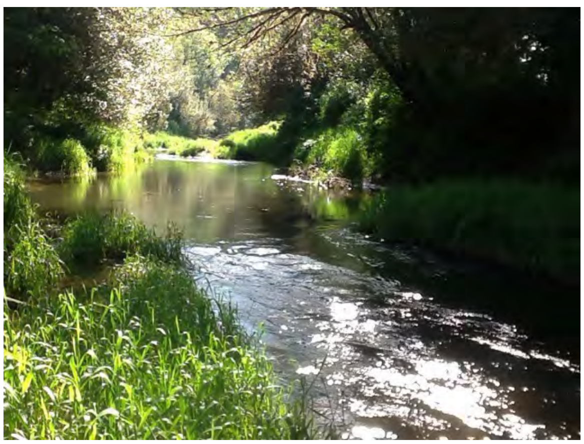


Photo 1. Looking upstream at crossing.

Photo 2. Looking at oversteepened bank. Note the sloughed material at the toe of the bank.

Photo 3. Large instream wood within a deep pool.

Photo 4. Seep/wetland feature located north of the Middle Creek pipeline crossing.

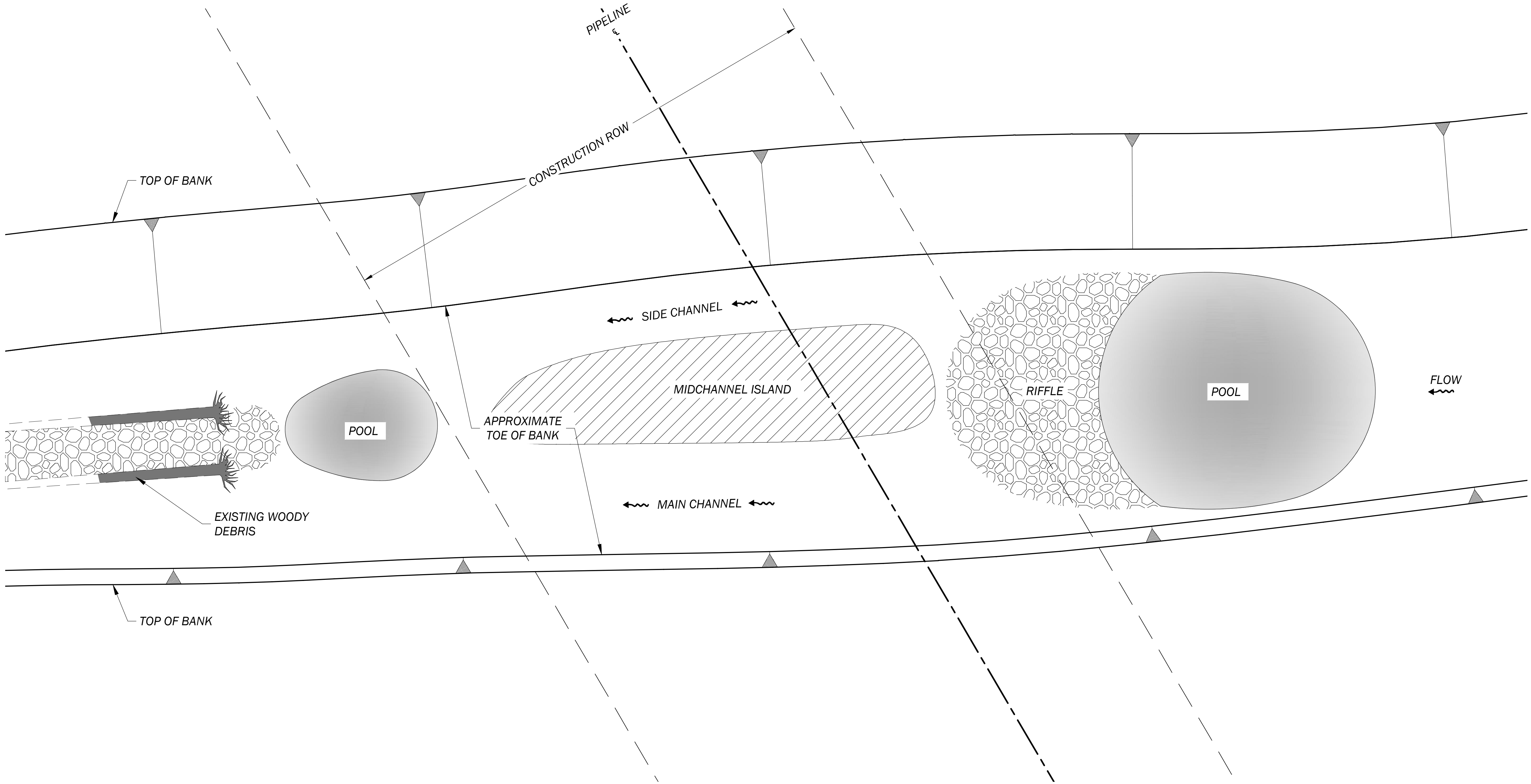
Key Restoration Actions

- Protect banks from erosion by installing vegetated, encapsulated soil lifts at 1:1 slope on left bank and 1.5:1 to 2:1 slope on right bank.
- Transition banks at top of soil lifts to existing bank slope at a 2:1 angle.
- Place light, loose riprap underneath the bottom of soil lifts to stabilize toe.
- Transition from vegetated, encapsulated soil lifts to existing bank slopes gradually and stabilize slopes with erosion control fabric and native vegetation.
- Protect against streambed incision by regrading channel bed using existing streambed or cobble/gravel native mixture.
- Vertically stratify backfill similar to material excavated from trench.

Additional Recommendations to Address BLM/FS Resource Concerns

Mitigation recommendations to address BLM concerns about pipeline construction impacts are listed below. The proposed site-specific design is consistent with these recommendations:

- Contouring or tapering banks upstream and downstream of the pipeline crossing.
- Use of erosion control fabric to stabilize banks and accelerate Revegetation.
- Liberally apply large woody debris (LWD) and coarse woody slash above high-water mark to prevent rill erosion or hillslope gullying.
- Revegetation of disturbed soils, adhering to planting plan presented in the BLM/FS report.
- Avoid armoring banks with logs or riprap at the crossing below the high-water mark as defined by the BLM.
- Install channel plugs in the adjacent wetland area to prevent pipeline trench from capturing and channeling groundwater.
- Use large wood and densely planted willow cuttings or other species to stabilize any part of the intermittent channel influenced by construction activities.
- Employ detention structures for water pumped out of the trench so that potential volumes can be effectively managed.
- Maintain hyporheic flows using stratified backfilling during construction.
- Anticipate a bankfull event during the construction and postconstruction period.

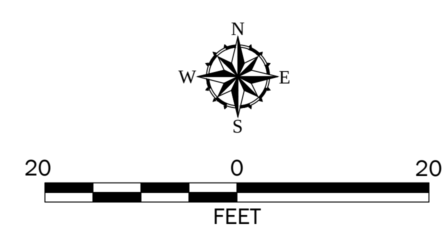


EXISTING CONDITIONS

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
3. The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Pipeline alignment provided by Williams Pipeline.



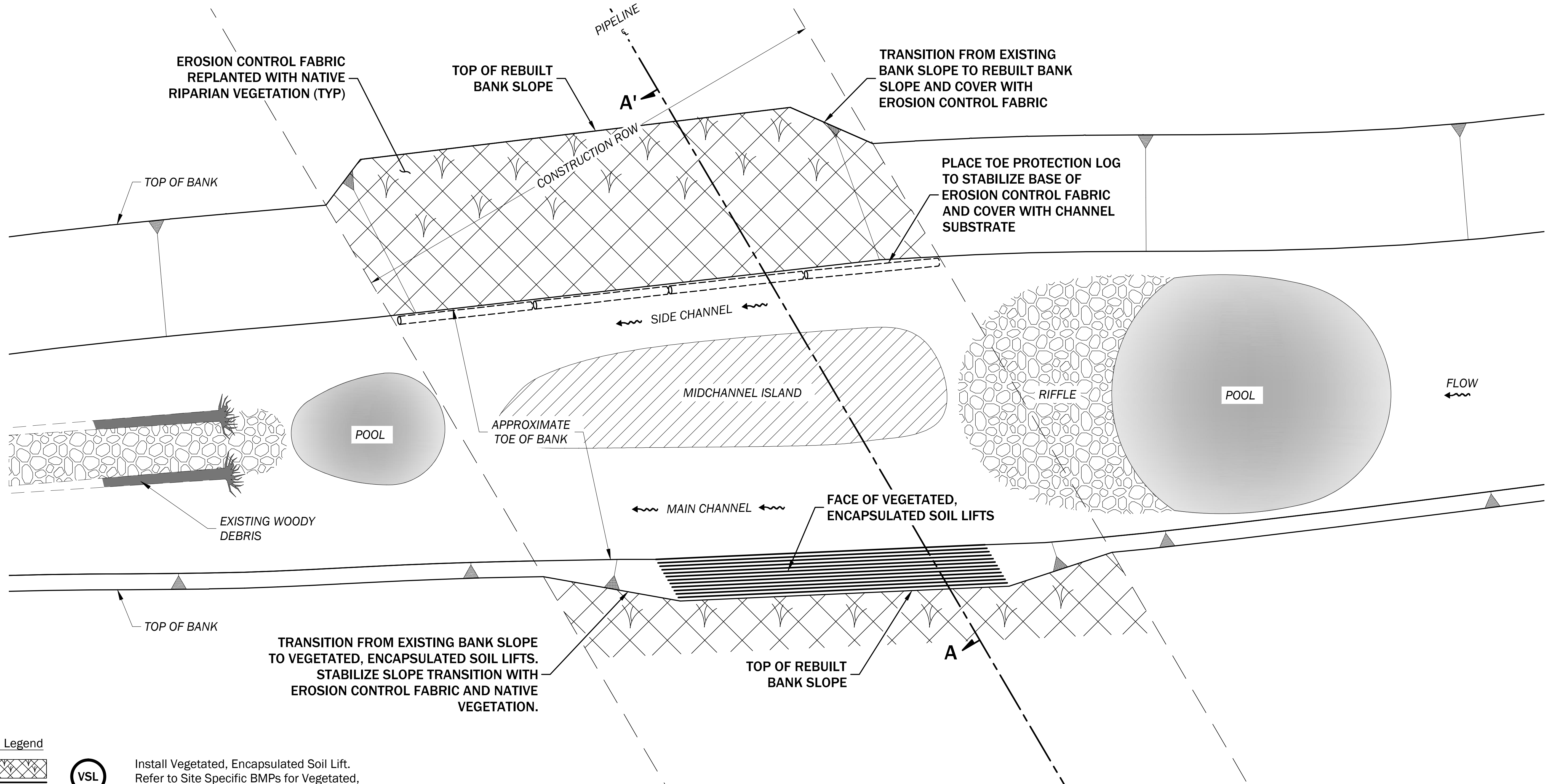
Existing Conditions Plan View
MP 27.04 Middle Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-1.1

OFFICE: BAM   P:\16\1672400_Pdx\10\CAD\High Risk Sites\MP 27.04 Middle Creek.dwg\TAB:11x17 EX COND modified by jsmith on Feb 12, 2015 - 13:21



Design Legend

VSL — Install Vegetated, Encapsulated Soil Lift. Refer to Site Specific BMPs for Vegetated, Encapsulated Soil Lift Detail

PROPOSED RESTORATION PLAN

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
3. The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.
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Data Source: Pipeline alignment provided by Williams Pipeline.

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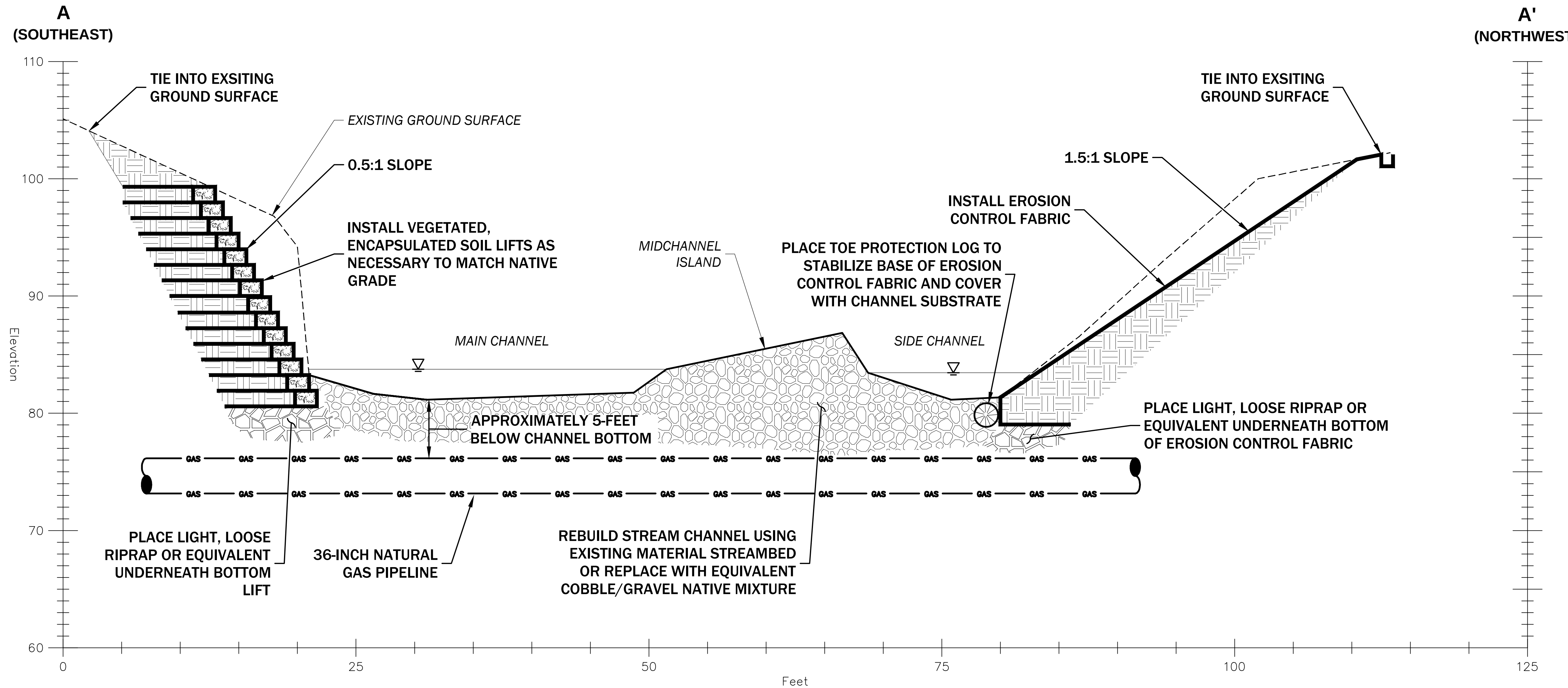
Site Specific Restoration Plan
MP 27.04 Middle Creek

Pacific Connector Gas Pipeline
Oregon

GeoEngineers

Exhibit C-1.2

OFFICE: BAM P:\16\1672400_Pdx\10\CAD\High Risk Sites\MP 27.04 Middle Creek.dwg\TAB:11x17 RESTORATION PLAN modified by jsmith on Feb 12, 2015 - 13:19



SECTION A-A'

(LOOKING DOWNSTREAM)

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
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Data Source: Section generated from field collected topographic data on project specific vertical datum.

HORIZONTAL SCALE: 1"= 10'
VERTICAL SCALE: 1"= 10'
VERTICAL EXAGGERATION: 1X

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FEET

Site Specific Restoration Section A-A'
MP 27.04 Middle Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-1.3

OFFICE: BAM P:\16\1672400_PDX\10\CAD\HIGH RISK SITES\MP 27.04 MIDDLE CREEK.DWG\TAB:11X17 PROFILE MODIFIED BY JSMITH ON FEB 12, 2015 - 13:45

EXHIBIT C-2

MP 32.40 Elk Creek

Site Summary

Exhibit C-2 presents results and a conceptual restoration plan for the crossing of Elk Creek. The Elk Creek crossing, located at MP 32.4, was initially ranked a moderate risk (yellow management category) site. Upon field review, the site was reclassified as a high-risk stream (Orange management category), due to the following characteristics:

- Undercutting stream banks.
- Active bank erosion.
- Complex bed substrate and habitat features.

Site Photos

Photo 1. Looking down hillslopes to stream channel.

Photo 2. Looking upstream at stream channel. Note the broad side slopes and undercutting (on right).

Key Restoration Actions

- Install boulders to maintain existing bed profile and cascade/pool morphology.
- Place toe protection logs with coir fabric to stabilize slopes adjacent to channel.
- Place logs with rootwads in channel and secure with large boulders to replicate existing habitat features.
- Vertically stratify backfill similar to material excavated from trench.

EXISTING CONDITIONS

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
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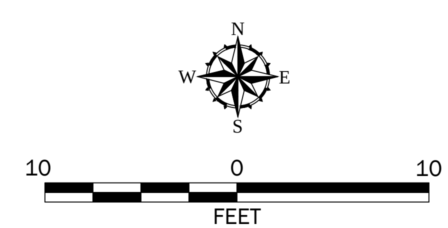
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Topographic contours and pipeline alignment provided by Williams Pipeline.



Existing Conditions Plan View
MP 32.4 Elk Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-2.1

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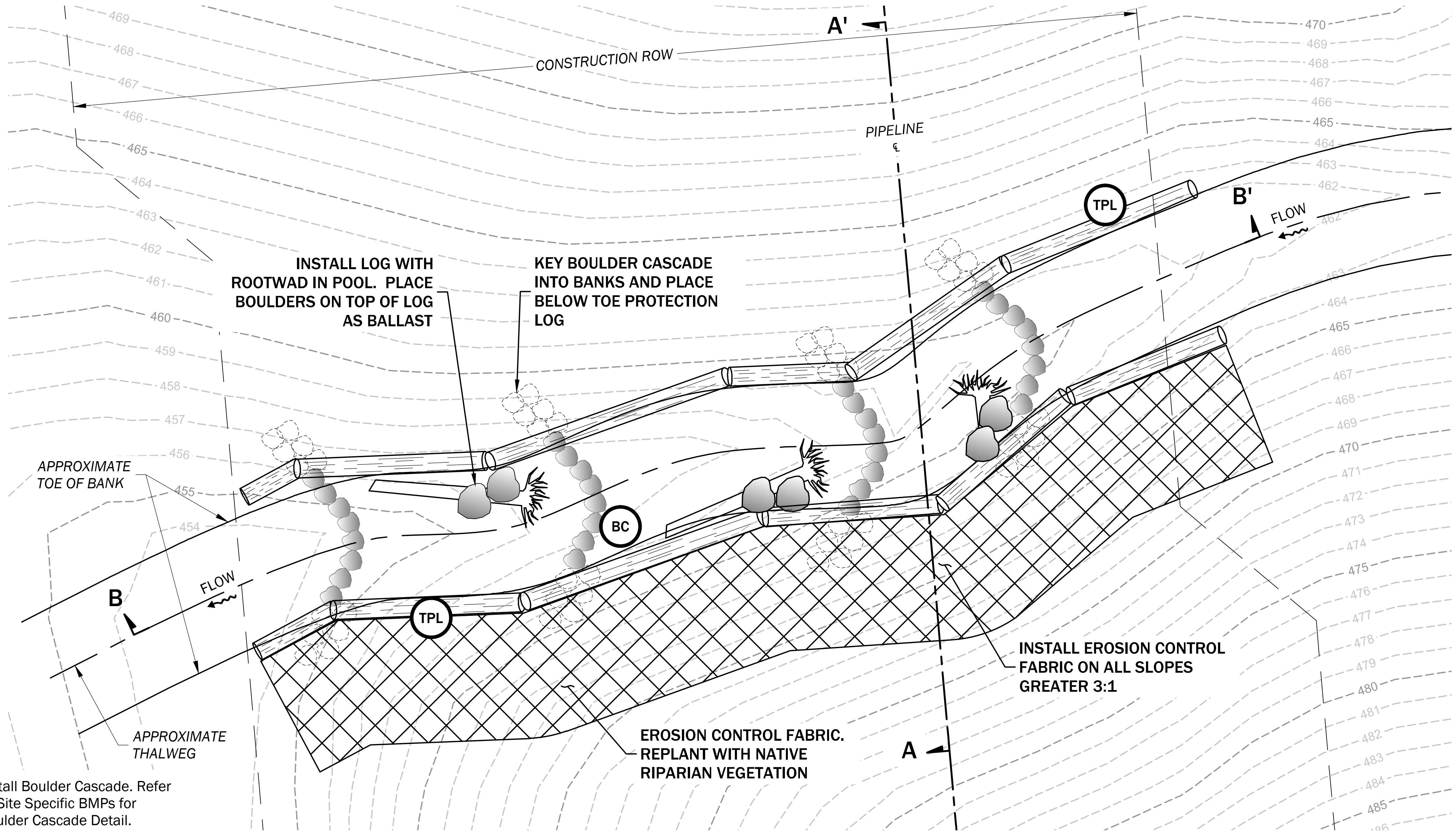
OFFICE: BAM



Design Legend

BC — Install Boulder Cascade. Refer to Site Specific BMPs for Boulder Cascade Detail.

TPL — Install Toe Protection Log. Refer to Site Specific BMPs for Toe Protection Log Detail.

Install log with rootwad facing upstream and place boulders as ballast.

PROPOSED RESTORATION PLAN

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
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Data Source: Topographic contours and pipeline alignment provided by Williams Pipeline.

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Site Specific Restoration Plan
MP 32.4 Elk Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-2.2

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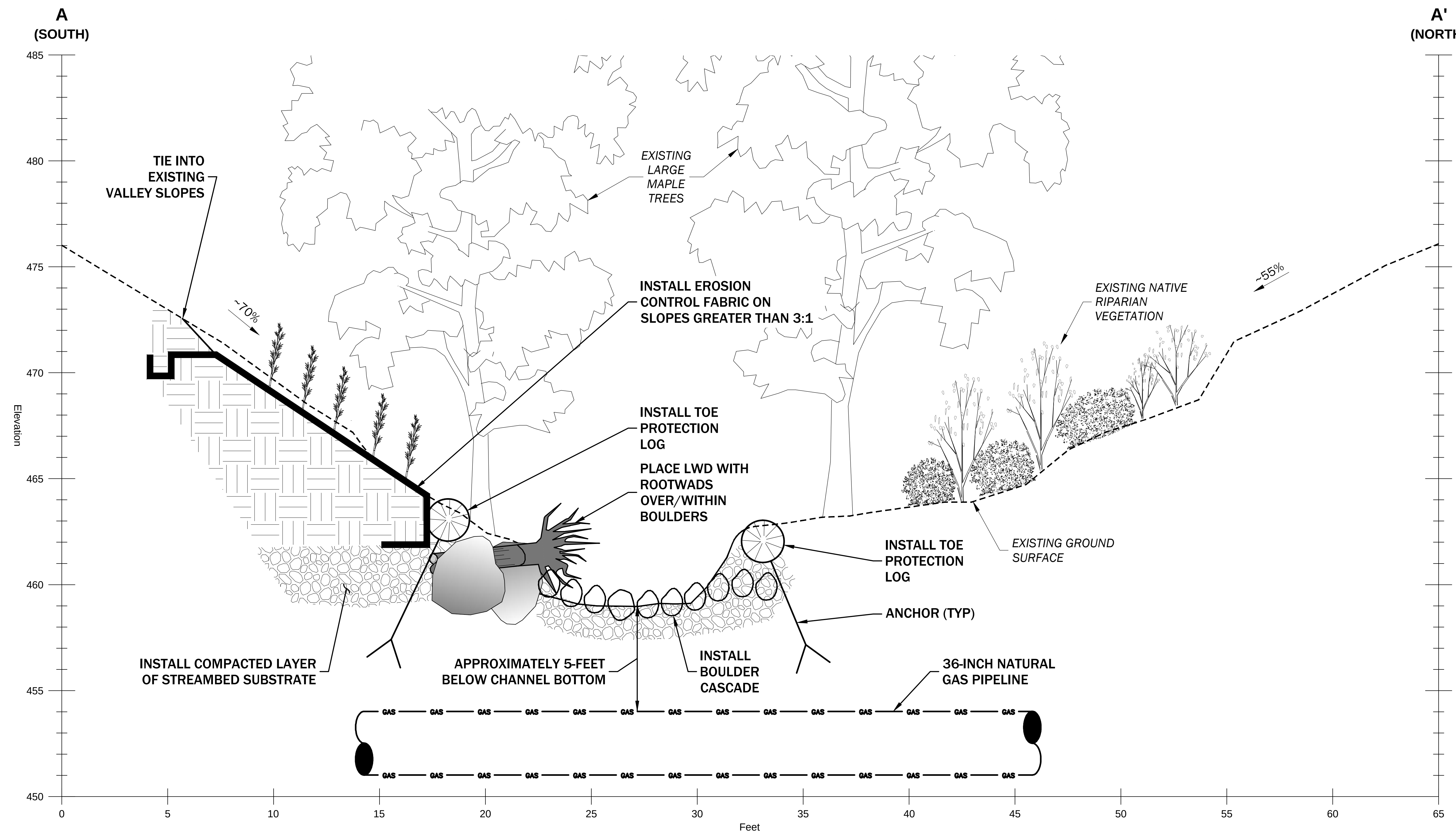

SECTION A-A'

(LOOKING DOWNSTREAM)

Notes:

1. The locations of all features shown are approximate.
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4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Section generated from topographic contours provided by Williams Pipeline and field collected measuresments by GeoEngineers.

HORIZONTAL SCALE: 1"= 5'
VERTICAL SCALE: 1"= 5'
VERTICAL EXAGGERATION: 1X

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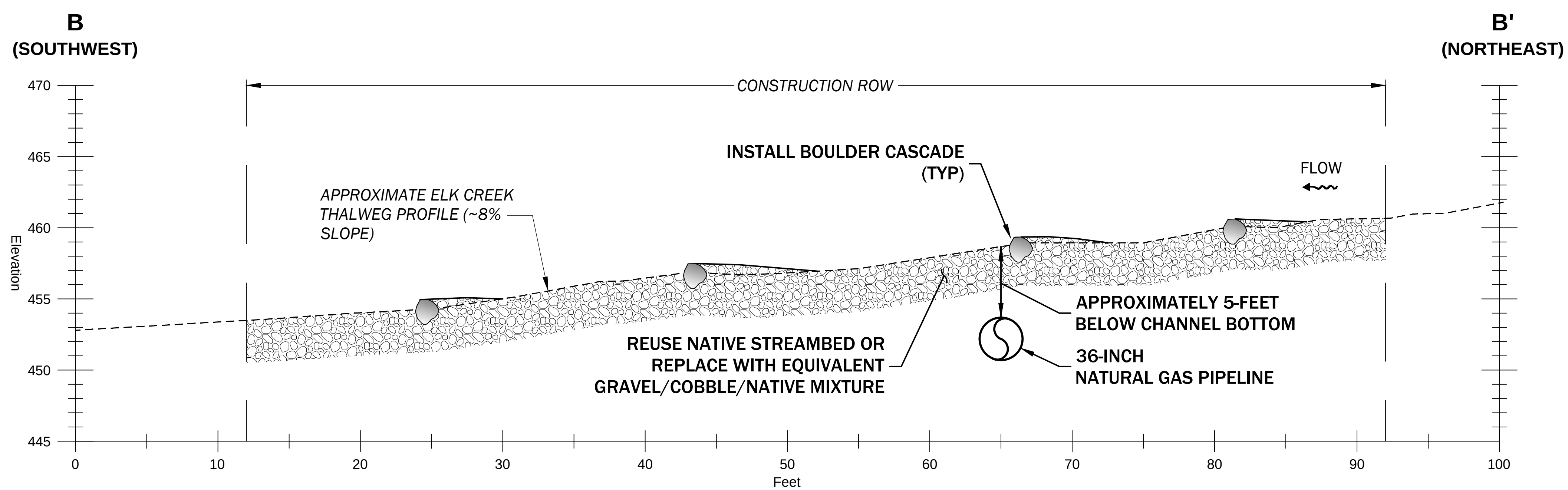
Site Specific Restoration Section A-A'
MP 32.4 Elk Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-2.3

OFFICE: BAM P:\16\1672400_Pdx\10\CAD\High Risk Sites\MP 32.4 Elk Creek.dwg\TAB:11x17 SECTION AA' modified by jsmith on Feb 12, 2015 - 13:54



SECTION B-B'

Notes:

1. The locations of all features shown are approximate.
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4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Section generated from topographic contours provided by Williams Pipeline.

HORIZONTAL SCALE: 1"= 10'
VERTICAL SCALE: 1"= 10'
VERTICAL EXAGGERATION: 1X

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FEET

Site Specific Restoration Section B-B'
MP 32.4 Elk Creek

Pacific Connector Gas Pipeline
Oregon

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Exhibit C-2.4

OFFICE: BAM P:\16\1672400I_PDX\10\CAD\HIGH RISK SITES\MP 32.4 ELK CREEK.DWG\TAB:11X17 SECTION BB' MODIFIED BY JSMITH ON FEB 12, 2015 - 13:56

EXHIBIT C-3
MP 37.35 Tributary to Big Creek

Site Summary

Exhibit C-3 presents results and a site-specific design for restoration of Tributary to Big Creek. Tributary to Big Creek, located at MP 37.35, was initially ranked a high risk (Orange management category) site. Upon field review, the site was confirmed a high-risk stream, due to the following characteristics:

- Steep banks,
- Incised channel,
- Highly erodible banks,
- Scour pool associated with woody debris and boulders,
- Deposition of fine to coarse bedload in the vicinity of the crossing,
- High quality habitat potential and riparian corridor, and
- Ratio of channel width to construction disturbance.

Site Photos

Photo 1. Looking upstream.

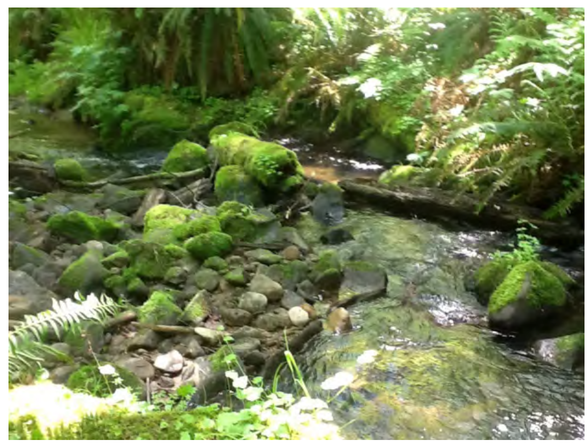


Photo 2. Looking downstream.

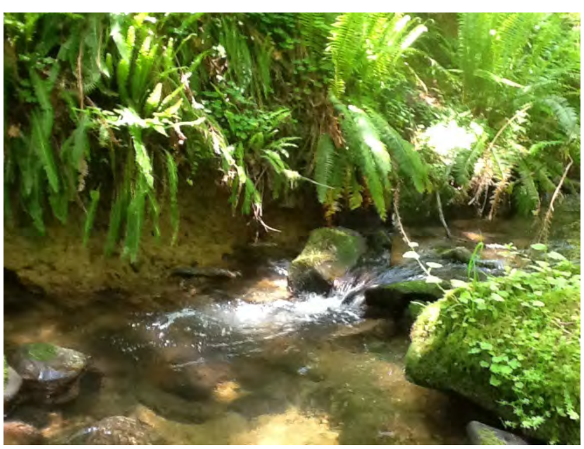


Photo 3. Steep banks, erodible toe.

Photo 4. Scour pools associated with wood boulders.

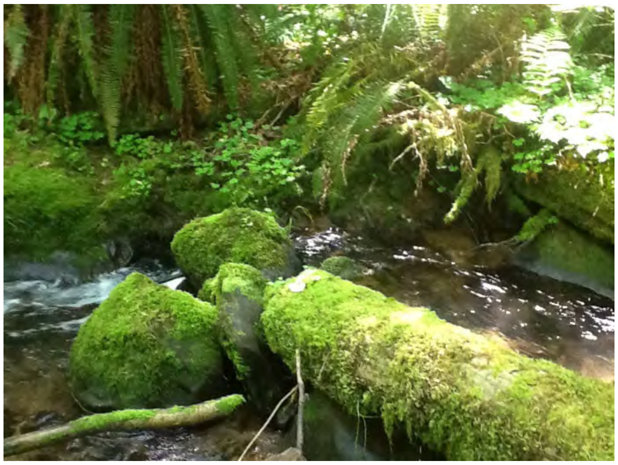


Photo 5. Toe of bank supported by large wood and boulders.

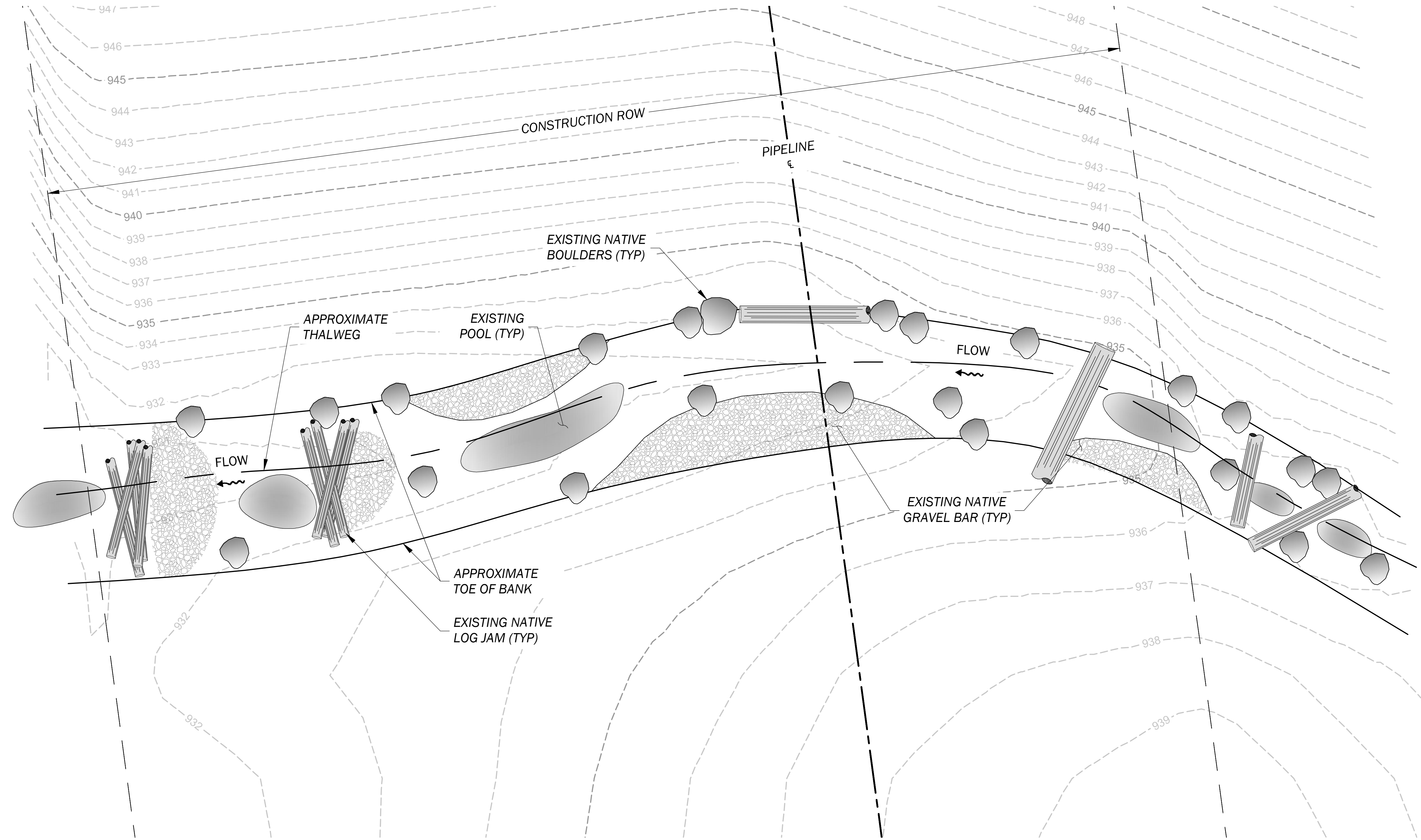
Key Restoration Actions

- Maintain habitat units through use of complex bed controls such as boulders and wood.
- Salvage on-site wood and boulders for restoration actions.
- Pre-excavate scour pool downstream of boulder of wood control similar in length and depth to existing.
- Vertically stratify backfill similar to material excavated from trench.
- High bank along west bank will require composite bank restoration, to include a boulder and wood toe, backfill placed to stable slope using soil encapsulated lifts vegetated with native riparian species.

Additional Recommendations to Address BLM/FS Resource Concerns

Mitigation recommendations to address BLM concerns about pipeline construction impacts are listed below. The proposed site-specific design is consistent with these recommendations:

- Install large wood with a rootwad attached at toe of bank ensure bank stability.
- Install BMPs to mitigate sediment transport downstream to Big Creek.
- Replace large boulders (less than 6-foot-diameter) in channel and along banks.
- Subsurface (hyporheic) flows within a landslide deposit will not be altered by PCGP trench backfill.
- Adhere to planting plan presented in the BLM/FS Resource Concern report.
- Plan on effective discharge (bankfull) events to occur during wintertime construction activities.



EXISTING CONDITIONS

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
3. The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Topographic contours and pipeline alignment provided by Williams Pipeline.

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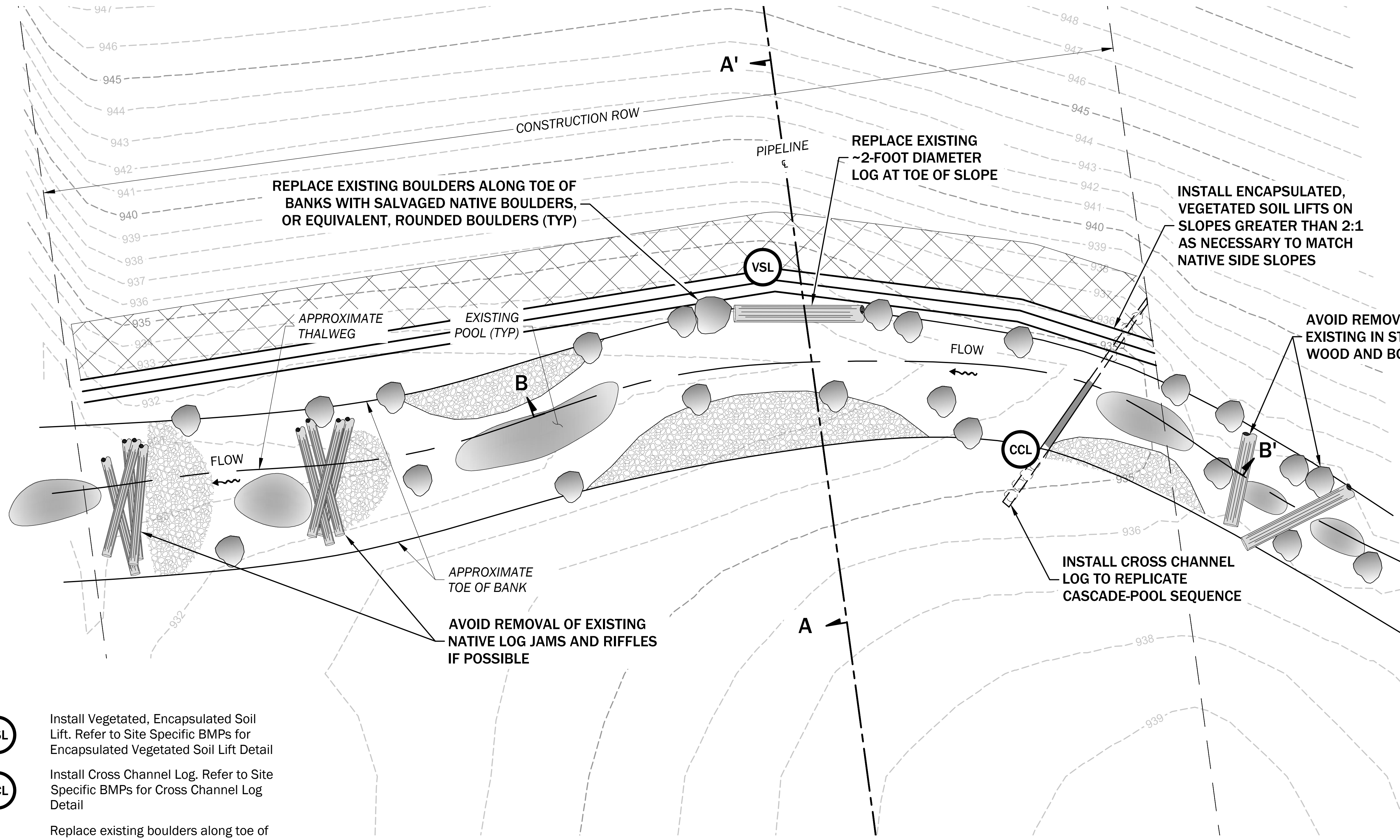
Existing Conditions Plan View
MP 37.35 Trib to Big Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

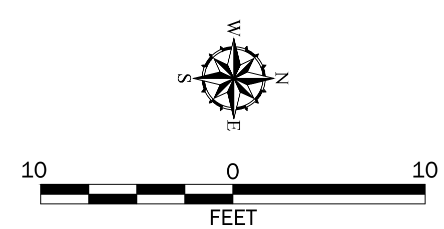
Exhibit C-3.1



Design Legend

(soil lift symbol)	VSL	Install Vegetated, Encapsulated Soil Lift. Refer to Site Specific BMPs for Encapsulated Vegetated Soil Lift Detail
(log symbol)	CCL	Install Cross Channel Log. Refer to Site Specific BMPs for Cross Channel Log Detail
(boulder symbol)		Replace existing boulders along toe of bank with salvaged native boulders or equivalent, rounded boulders

PROPOSED RESTORATION PLAN



Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
3. The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Topographic contours and pipeline alignment provided by Williams Pipeline.

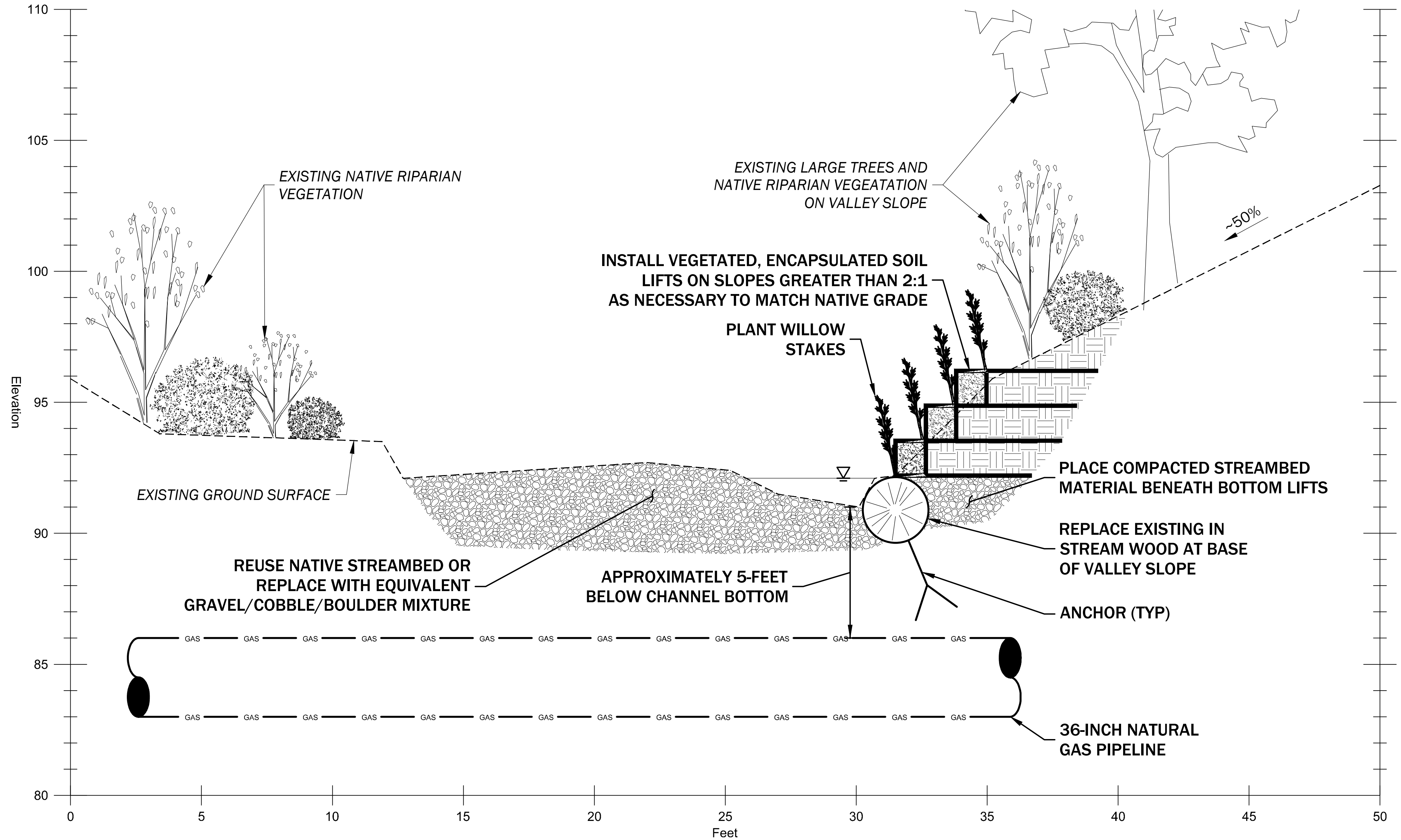
Site Specific Restoration Plan
MP 37.35 Trib to Big Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-3.2

P:\16\1672400_PDX\10\CAD\HIGH RISK SITES\MP 37.35 TRIB TO BIG CREEK.DWG\TAB:RESTORATION PLAN MODIFIED BY JSMITH ON FEB 12, 2015 - 14:30



SECTION A-A'

(LOOKING DOWNSTREAM)

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
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4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Section data generated from field collected topographic data on a project specific vertical datum.

HORIZONTAL SCALE: 1"= 5'
VERTICAL SCALE: 1"= 5'
VERTICAL EXAGGERATION: 1X

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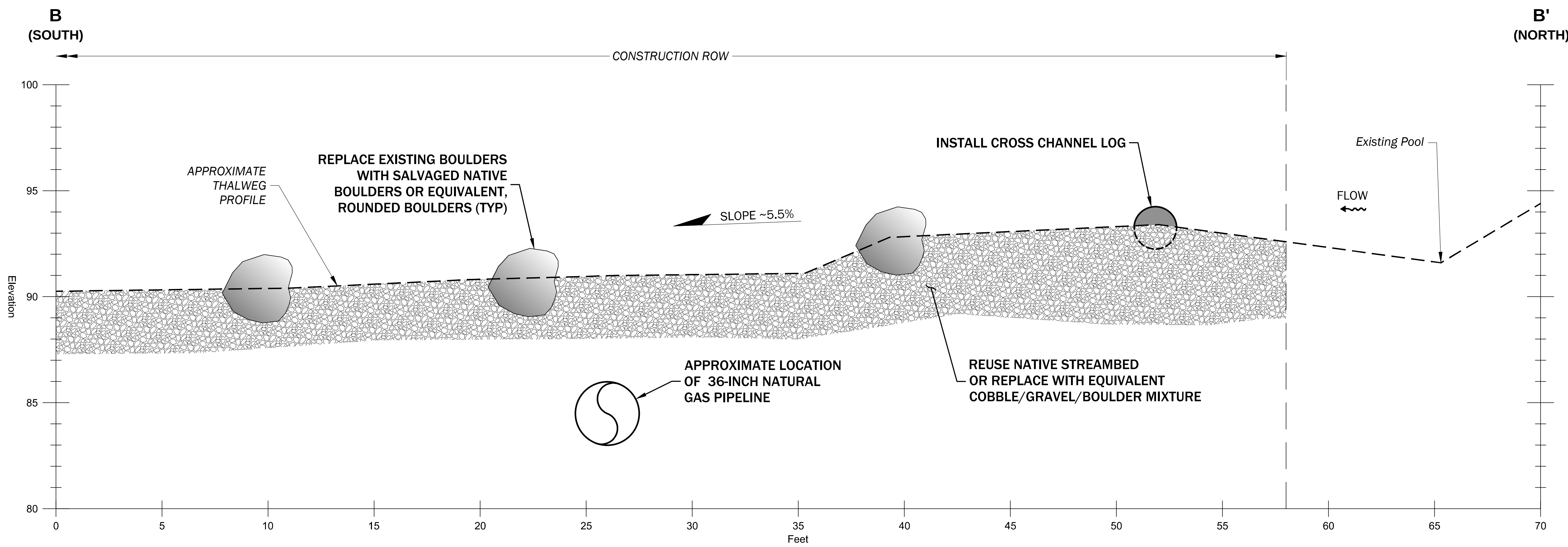
FEET

Site Specific Restoration Section A-A'
MP 37.35 Trib to Big Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-3.3



SECTION B-B'

Notes:

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Data Source: Section data generated from field collected topographic data on a project specific vertical datum.

HORIZONTAL SCALE: 1"= 5'
VERTICAL SCALE: 1"= 5'
VERTICAL EXAGGERATION: 1X

5 0 5
FEET

Site Specific Restoration Section B-B'
MP 37.35 Trib to Big Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-3.4

P:\16\1672400I_PDX\10\CAD\HIGH RISK SITES\MP 37.35 TRIB TO BIG CREEK.DWG\TAB:RESTORATION SECTION BB MODIFIED BY JSMITH ON FEB 12, 2015 - 13:42

EXHIBIT C-4
MP 44.21 Upper Rock Creek

Site Summary

Exhibit C-4 presents results and a site-specific design for restoration of Upper Rock Creek. Upper Rock Creek, located at MP 44.21, was initially ranked a moderate risk (Yellow management category) site. Upon field review, the site was reclassified as a high risk (Orange management category) stream, due to the following characteristics:

- Highly erodible banks,
- Evidence of overflow channels leading to a meander cutoff upstream from the crossing,
- Potential for lateral migration,
- Scour pool associated with woody debris and boulders,
- Deposition of fine to coarse bedload in the vicinity of the crossing,
- High quality habitat potential and riparian corridor, and
- Potential of crossing to lie within a channel migration zone (CMZ).

Site Photos

Photo 1. Looking upstream.

Photo 2. Looking downstream. Note the downstream cobble bar maintaining bed control.

Photo 3. Erodible bedload on channel edge.

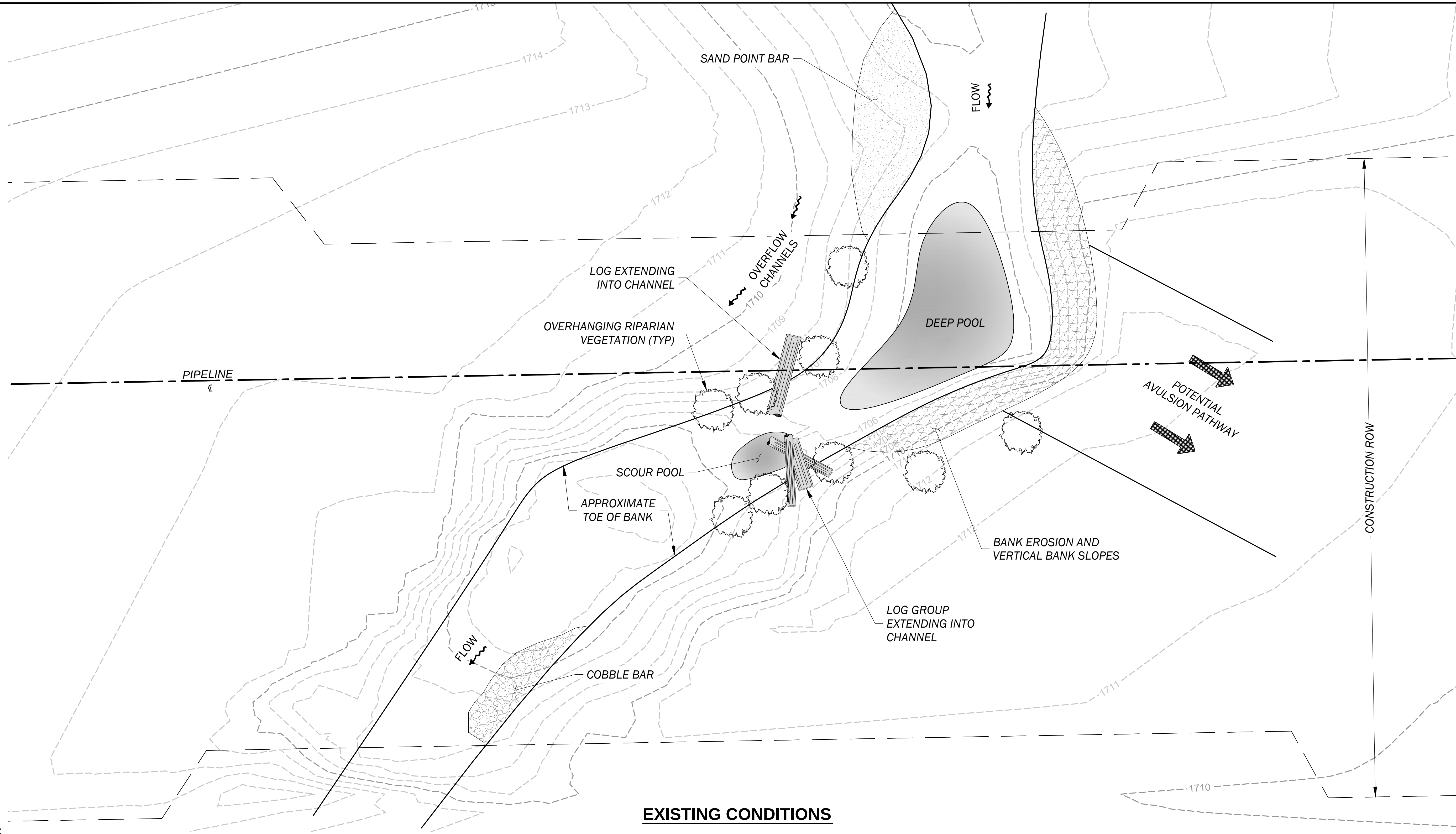
Photo 4. Sandy overbank deposits on inside of bend.

Photo 5. Lateral scour pool at meander bend apex associated with lateral bank migration.

Key Restoration Actions

- Install two meander jams along outside of meander on left bank, immediately upstream from the crossing to limit potential for lateral migration and stabilize banks.
- Install vegetated, encapsulated soil lifts and incorporate with downstream meander jam to stabilize erodible bank.

Maintain bed control and habitat units by installing mid-channel key logs. Avoid disturbing downstream cobble bar or replace in kind.



EXISTING CONDITIONS

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
3. The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Topographic contours and pipeline alignment provided by Williams Pipeline.

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FEET

Existing Conditions Plan View
MP 44.21 Upper Rock Creek

Pacific Connector Gas Pipeline
Oregon

GeoEngineers

Exhibit C-4.1

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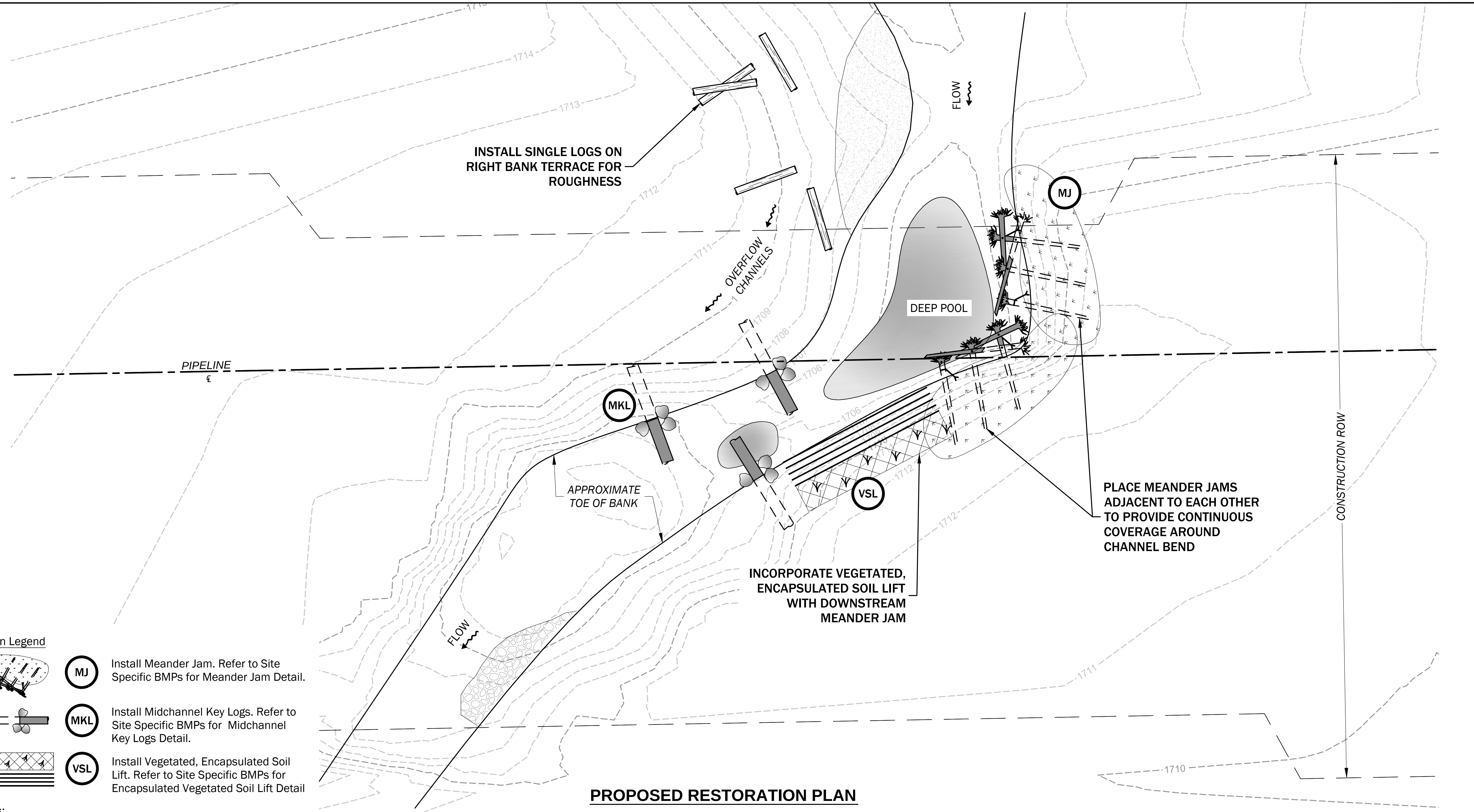
OFFICE: BAM



Design Legend

- MJ — Install Meander Jam. Refer to Site Specific BMPs for Meander Jam Detail.
- MKL — Install Midchannel Key Logs. Refer to Site Specific BMPs for Midchannel Key Logs Detail.
- VSL — Install Vegetated, Encapsulated Soil Lift. Refer to Site Specific BMPs for Encapsulated Vegetated Soil Lift Detail

PROPOSED RESTORATION PLAN

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
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Data Source: Topographic contours and pipeline alignment provided by Williams Pipeline.

N W E S

15 0 15
FEET

Site Specific Restoration Plan
MP 44.21 Upper Rock Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-4.2

EXHIBIT C-5
MP 109.47 Tributary to East Fork Cow Creek

Site Summary

Exhibit C-5 presents a site-specific design for restoration of East Fork Cow Creek. East Fork Cow Creek, located at MP 109.47, was initially ranked a moderate risk (Yellow management category) site. Upon completion of the preconstruction survey, the site was reclassified as a high risk (Orange management category) stream, due to the following characteristics:

- Unique habitat attributes and thermal control maintained by vegetated vertical banks and large substrate bed,
- Boulder cascade bedform needs to be maintained for vertical stability, and
- Critical location of logjam downstream of crossing to maintain vertical stability in the channel bed.

Site Photos

Photo 1. Looking downstream at large boulders. Note the mossy lining represents a stable environment.

Photo 2. Looking at banks armored with boulders.

Photo 3. Boulders and well armored channel floor.

Photo 4. Channel floor lined with cobbles and boulders.

Key Restoration Actions

- Replace existing approximately 3-foot-diameter boulders along toes of banks.
- Install parallel logs along toe of bank.
- Install vegetated, encapsulated soil lifts along bank slopes to recreate existing bank geometry.
- Avoid disturbance to downstream in-channel large wood and boulders.

Additional Recommendations to Address BLM/FS Resource Concerns

Mitigation recommendations to address BLM concerns about pipeline construction impacts are listed below. The proposed site-specific design is consistent with these recommendations:

- Not altering the gradient controlling feature at the inflection point below the crossing. The crossing appears to be on bedrock, but immediately downstream of the corridor the gradient of the channel steepens significantly.
- The site has been left mounded and abundantly covered with large woody debris so that water cannot run downhill without being intercepted.
- Dense willow, ninebark and other riparian brush species fully occupy the immediate site of the crossing and the permanent easement and provide shade and prevent bank erosion.
- Maintaining possible hyporheic (subsurface) flows at the toe of the earthflow where Hydrofeature G is located. Adjacent wetlands and temperature gradients on the East Fork Cow Creek suggest subsurface routing of water commonly associated with earth flow terrains. GeoEngineers ranked this crossing as "High Sensitivity" in their analysis of hyporheic flows indicating there is a functioning hyporheic zone at this crossing.
- Any large woody debris placed below the high-water mark has the rootwad attached so that the log does not move downstream.
- Streambed gradient, substrate composition and morphology have been restored to pre-crossing conditions.

P:\16\1672400_Pdx\10\CAD\High Risk Sites\MP 109.47 E Fork Cow Creek.dwg\TAB:Existing Plan 11x17 modified by jsmith on Feb 12, 2015 - 14:06

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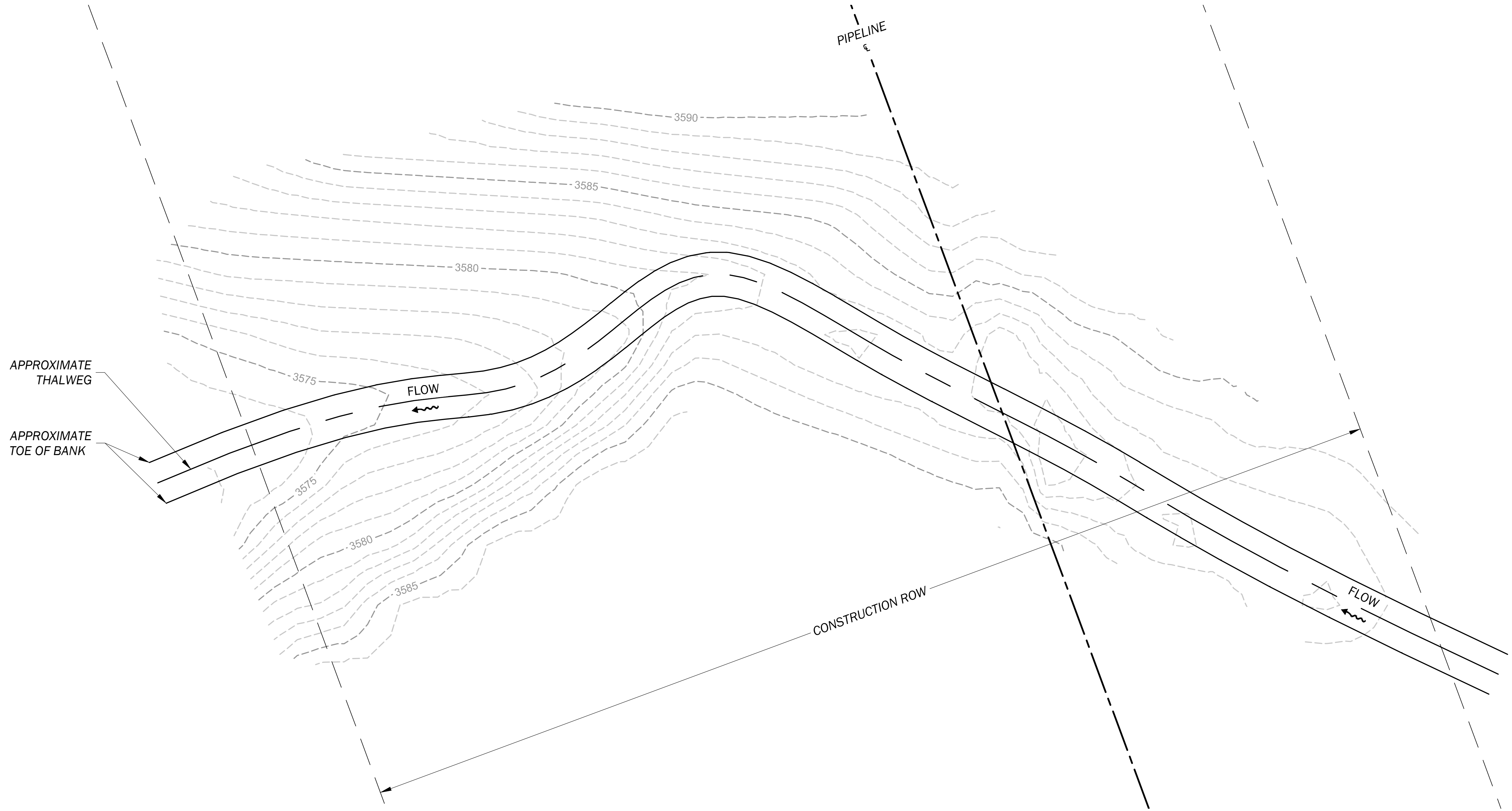
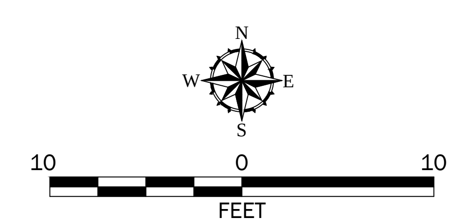


EXISTING CONDITIONS

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
3. The final configuration and location of all restoration elements shall be based on actual field conditions encountered at the time of construction, in consultation with the Environmental Inspector (EI) or authorized PCGP representative.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Topographic contours and pipeline alignment provided by Williams Pipeline.

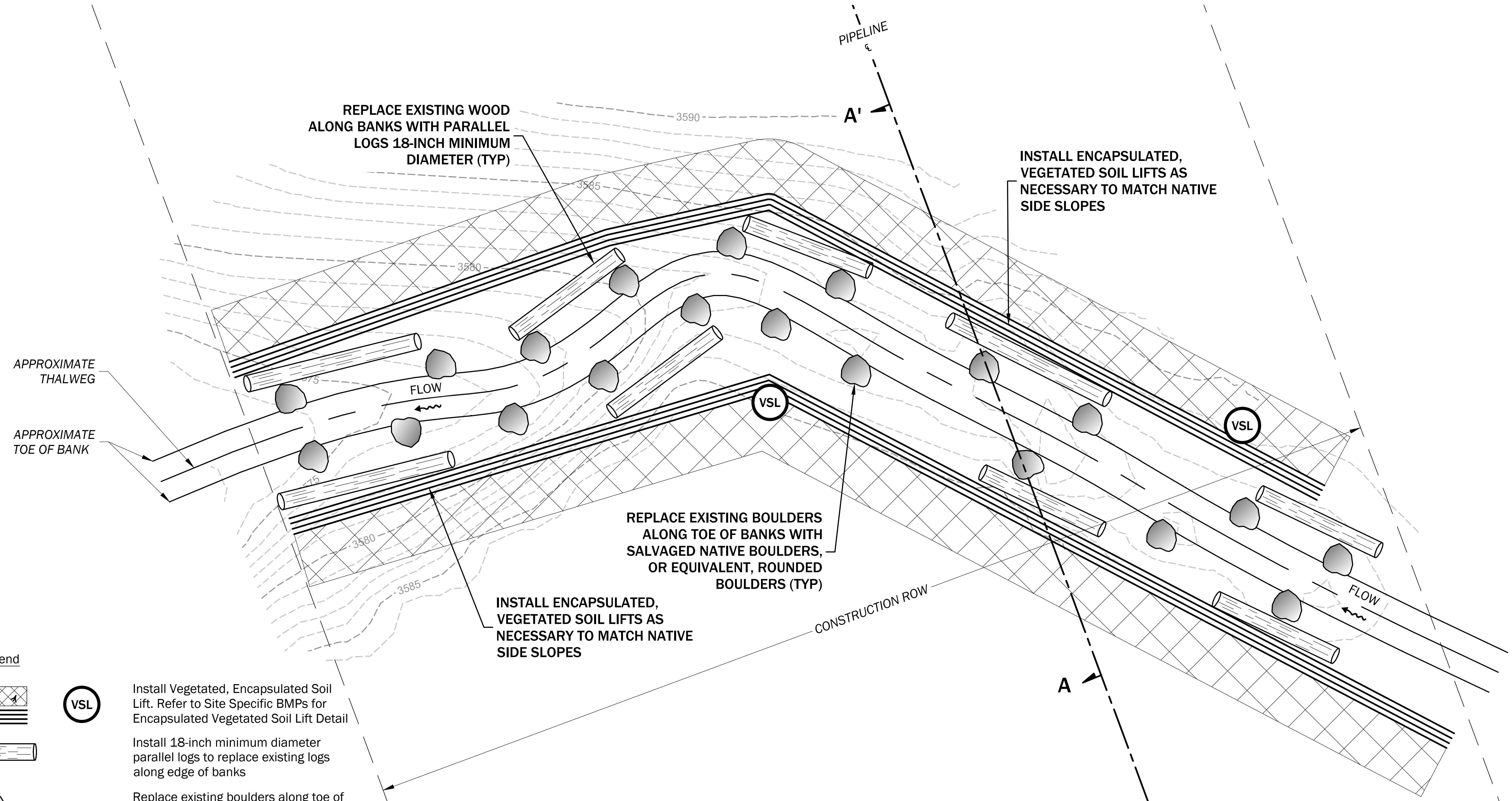


Existing Conditions Plan View
MP 109.47 East Fork Cow Creek

Pacific Connector Gas Pipeline
Oregon

GeoEngineers

Exhibit C-5.1



Design Legend

VSL	Install Vegetated, Encapsulated Soil Lift. Refer to Site Specific BMPs for Encapsulated Vegetated Soil Lift Detail
(log)	Install 18-inch minimum diameter parallel logs to replace existing logs along edge of banks
(boulder)	Replace existing boulders along toe of bank with salvaged native boulders or equivalent, rounded boulders

PROPOSED RESTORATION PLAN

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
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Data Source: Topographic contours and pipeline alignment provided by Williams Pipeline.

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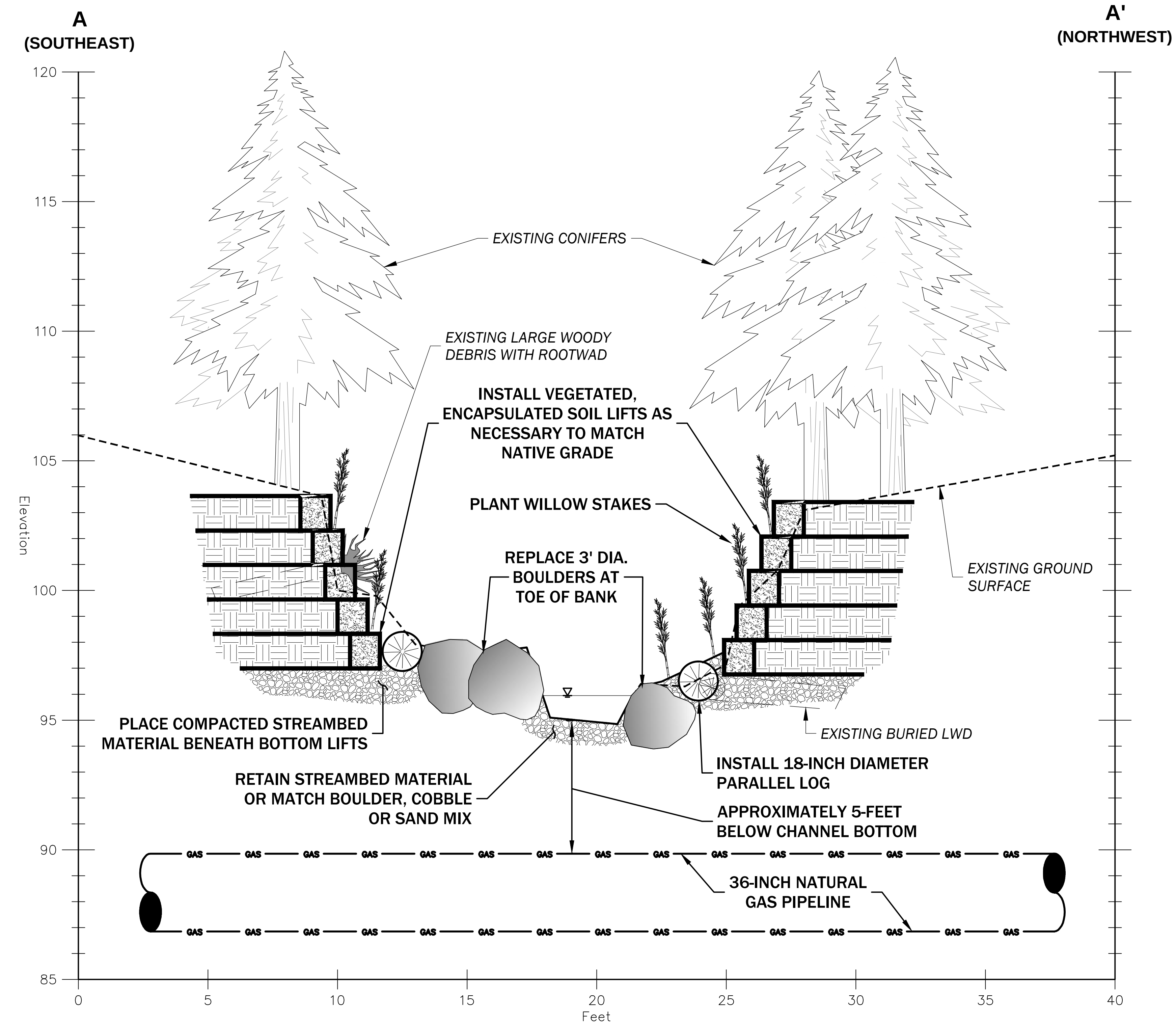
Site Specific Restoration Plan
MP 109.47 East Fork Cow Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-5.2

OFFICE: BAM P:\16\1672400_PDX\10\CAD\HIGH RISK SITES\MP 109.47 E FORK COW CREEK.DWG\TAB:RESTORATION PLAN PROPOSED 11X17 MODIFIED BY JSMITH ON FEB 12, 2015 - 14:08



SECTION A-A'
(LOOKING DOWNSTREAM)

Notes:

1. The locations of all features shown are approximate.
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Data Source: Section data generated from field collected topographic data on a project specific vertical datum.

HORIZONTAL SCALE: 1"= 5'
VERTICAL SCALE: 1"= 5'
VERTICAL EXAGGERATION: 1X

5 0 5
FEET

Site Specific Restoration Section A-A'
MP 109.47 East Fork Cow Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-5.3

OFFICE: BAM P:\16\1672400_Pdx\10\CAD\High Risk Sites\MP 109.47 E Fork Cow Creek.dwg\TAB:Section 11x17 modified by jsmith on Feb 12, 2015 - 14:10

EXHIBIT C-6
MP 118.89 West Fork Trail Creek

Site Summary

Exhibit C-6 presents a site summary and a conceptual restoration plan for the crossing of West Fork Trail Creek. The actual crossing for West Fork Trail Creek was not visited, and this plan is a concept based on a survey of site conditions present nearby. The West Fork Trail Creek, located at MP 118.89, was initially ranked a low risk (Blue management category) site. Upon completion of the preconstruction survey, the site was reassigned a high-risk stream (Orange management category), due to extremely unique site attributes, including the following characteristics:

- Perched water table supporting high quality riparian wetland complex and emergent species;
- Multi-thread stream channel created by bedrock along the channel bed; and
- Deep pools along the bedrock contacts creating cool water refuge and quality habitat.

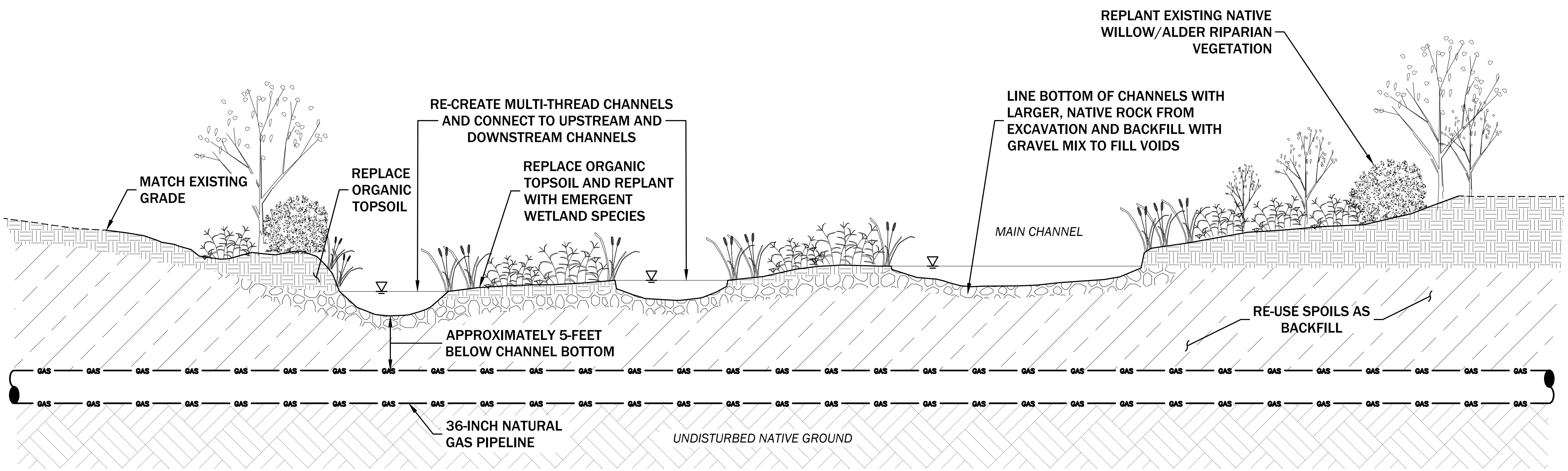
Site Photos

Photo 1. West Fork Trail Creek, bedrock channels and emergent wetland species.

Photo 2. West Fork Trail Creek, multi-thread, perched channel.

Key Restoration Actions

- Use native bedrock and import if necessary to recreate the porosity present in the pre-disturbed condition.
- Restore crossing to maintain multi-thread channel with access to wetland complexes along channel margins.
- Create deep pools along larger boulders along the channel margins.
- Specialized planting plan to maintain emergent wetland species.



TYPICAL CHANNEL SECTION

Notes:

1. The actual crossing location was inaccesible. Section here based on conditions observed slightly downstream of crossing.
2. The locations of all features shown are approximate.
3. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
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NOT TO SCALE

Site Specific Restoration Section MP 118.89 West Fork Trail Creek	
Pacific Connector Gas Pipeline Oregon	
GeoEngineers	Exhibit C-6.1

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EXHIBIT C-7
MP 162.45 South Fork Little Butte Creek

Site Summary

Exhibit C-7 presents site-specific design for restoration of South Fork Little Butte Creek. South Fork Little Butte Creek, located at MP 162.45, was initially ranked a high risk (Orange management category) site. Upon completion of the preconstruction survey, the site was confirmed a high-risk stream, due to the following characteristics:

- Very low lying alluvial terrace on the left bank;
- Complex bed controls;
- Presence of in-stream wood;
- Potential for lateral erosion;
- Low instream gradient;
- High quality habitat; and,
- Well-developed riparian corridor.

Site Photos

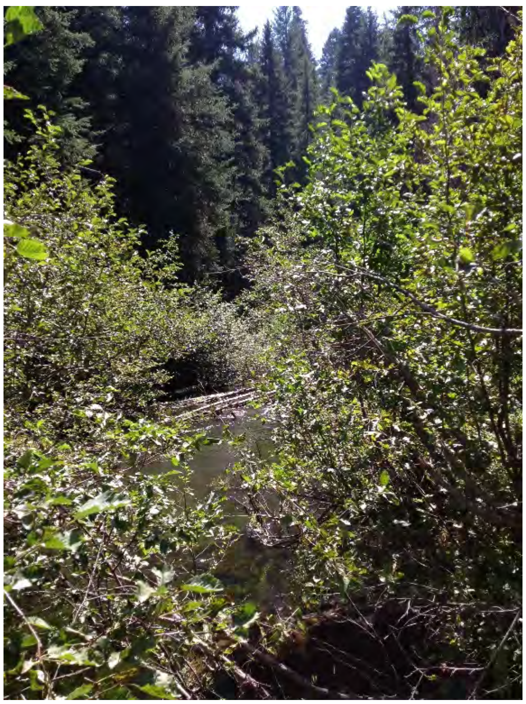


Photo 1. Looking upstream. Note the logjam along the banks.

Photo 2. Looking downstream.

Photo 3. Large boulders armoring the channel.

Photo 4. Low lying banks and flat terrace elevations. View towards left bank.

Photo 5. Rootwads providing structure and fish habitat along stream channel and banks.

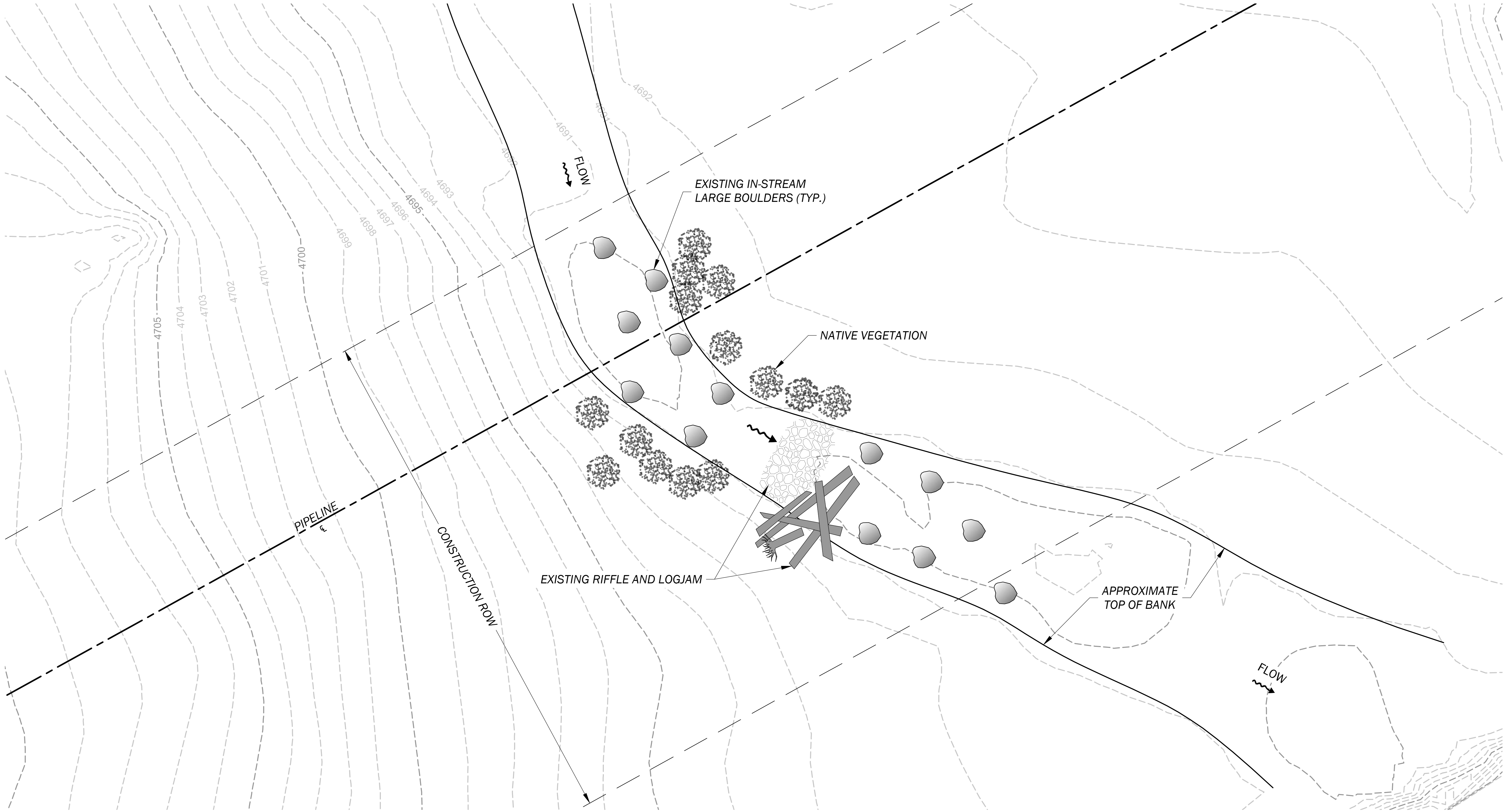
Key Restoration Actions

- Maintain habitat units through use of complex bed controls such as boulders and wood.
- Install a mini logjam along outside bank of meander bend to limit potential for lateral migration and maintain bank structure.
- Install boulder pocket water to armor the streambed and maintain bed grade control, replacing native boulder clusters removed during construction. Use native boulders removed during construction if feasible.

Additional Recommendations to Address BLM/FS Resource Concerns

- Avoid interception of surface flows during trenching (e.g., fracturing bedrock) through employment of appropriate backfill composition. Surface water management BMPs may also be employed (e.g., super sacks).
- Install large wood with a rootwad attached along the banks.
- Revegetation of disturbed soils, adhering to planting plan presented in the BLM/FS report.
- Replace existing terraces following construction activities.

- Liberally place large wood on slope adjacent to the channel to provide ground cover and intercept overland flows.
- Maintain water temperatures to preconstruction temperature regimes.
- A qualified geologic/geotechnical professional will be onsite during construction activities. The geo-professional will document the presence of fractured bedrock or lava tubes and make recommendations for backfill composition.
- Plan on effective discharge (bankfull) events to occur during wintertime construction activities.



EXISTING CONDITIONS

Notes:

1. The locations of all features shown are approximate.
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4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Topographic contours and pipeline alignment provided by Williams Pipeline.

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Existing Conditions Plan View
MP 162.45 Fork Little Butte Creek

Pacific Connector Gas Pipeline
Oregon

GeoEngineers

Exhibit C-7.1

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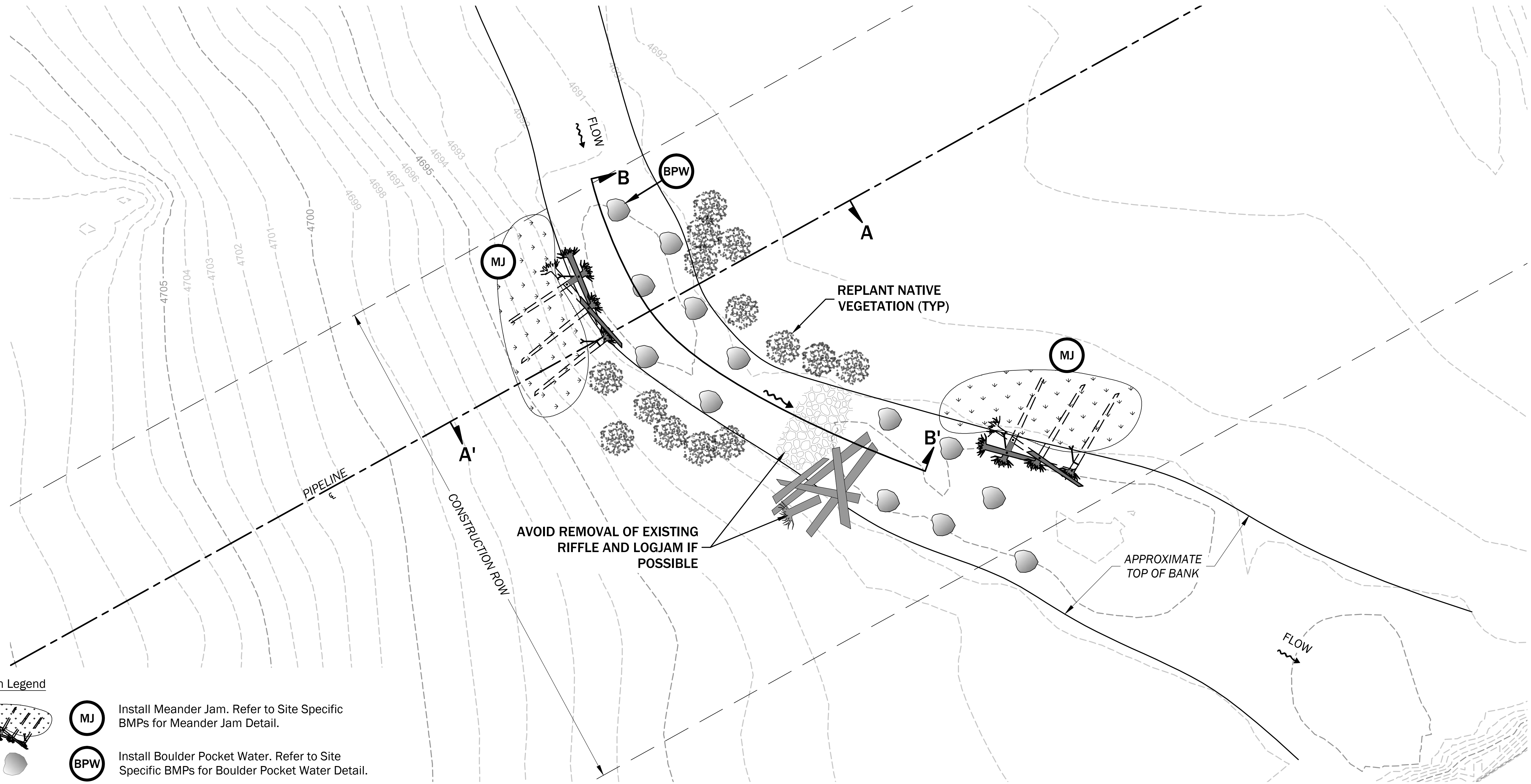

Design Legend

- MJ — Install Meander Jam. Refer to Site Specific BMPs for Meander Jam Detail.
- BPW — Install Boulder Pocket Water. Refer to Site Specific BMPs for Boulder Pocket Water Detail.

PROPOSED RESTORATION PLAN

Notes:

1. The locations of all features shown are approximate.
2. The restoration plan shown in these drawings will be modified in the field as necessary to account for actual field conditions encountered at the time of construction. The plans identify restoration features appropriate to restore site conditions and stabilize stream banks or stream bed throughout the entire construction right of way. The actual extent of disturbance is likely to be less than the full construction right of way; in these cases, the restoration will only be implemented over the true extent of disturbance/grading. Areas adjacent to construction limits will not be disturbed.
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Data Source: Topographic contours and pipeline alignment provided by Williams Pipeline.

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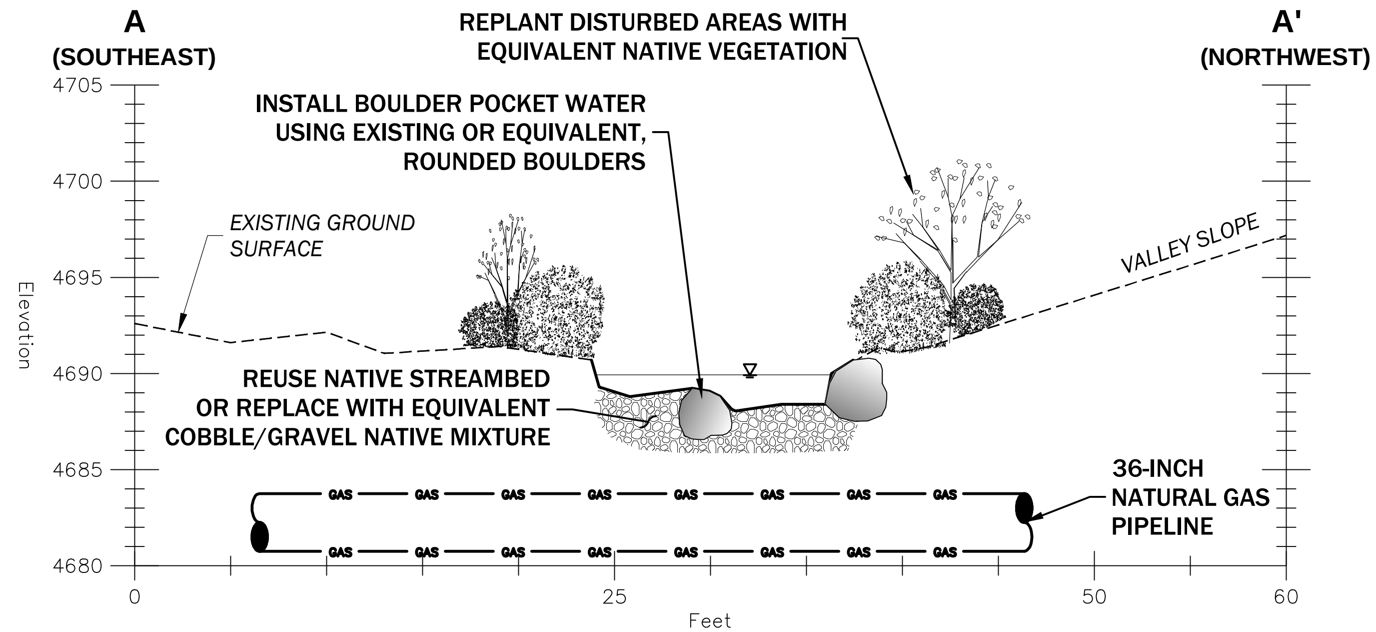
FEET

Site Specific Restoration Plan
MP 162.45 Fork Little Butte Creek

Pacific Connector Gas Pipeline
Oregon

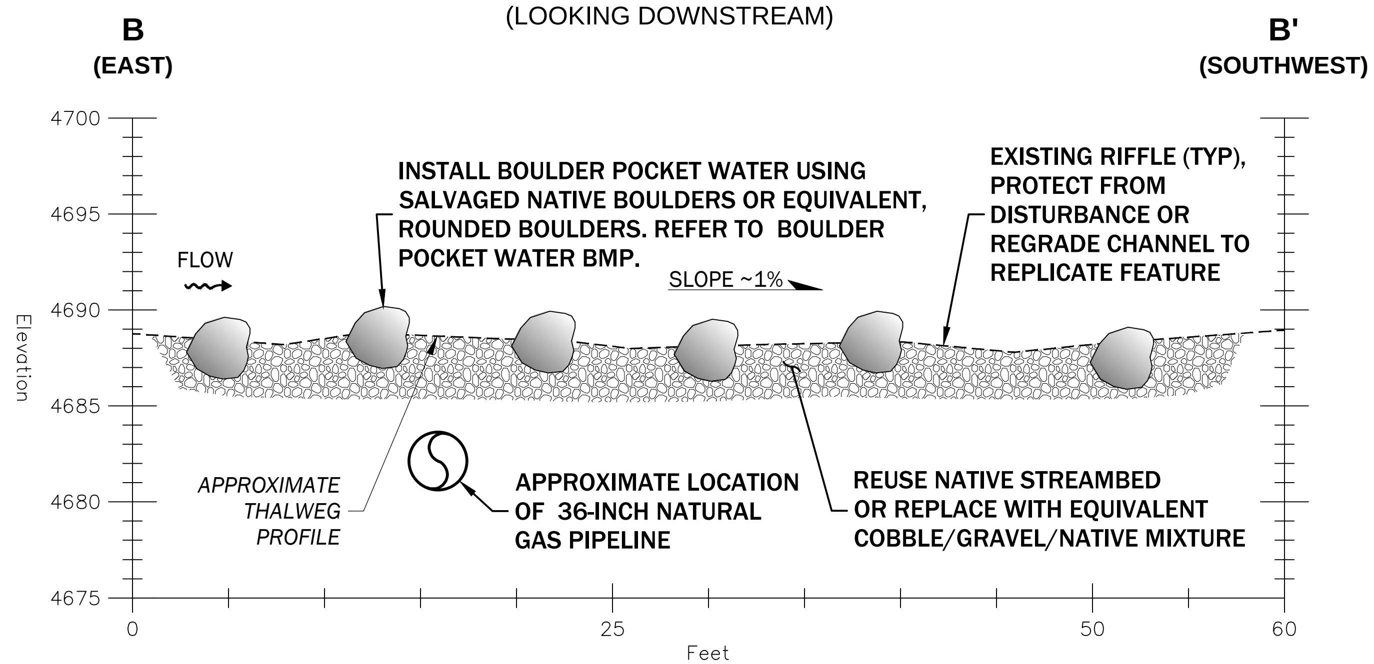
GEOENGINEERS

Exhibit C-7.2



SECTION A-A'

(LOOKING DOWNSTREAM)



SECTION B-B'

Notes:

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Data Source: Sections based on field collected topographic data by GeoEngineers.

HORIZONTAL SCALE: 1"= 10'
VERTICAL SCALE: 1"= 10'
VERTICAL EXAGGERATION: 1X

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FEET

Site Specific Restoration Sections
MP 162.45 Fork Little Butte Creek

Pacific Connector Gas Pipeline
Oregon

GEOENGINEERS

Exhibit C-7.3

P:\16\1672400I_Pdx\10\CAD\High Risk Sites\MP 162.45 SF Butte Creek.dwg\TAB:11x17 Section & Profile modified by jsmith on Feb 12, 2015 - 14:23

OFFICE: BAM

APPENDIX D
Report Limitations and Guidelines for Use

APPENDIX D
REPORT LIMITATIONS AND GUIDELINES FOR USE

This appendix provides information to help you manage your risks with respect to the use of this report.

Geologic Services Are Performed for Specific Purposes, Persons and Projects

This report has been prepared for use by Pacific Connector Gas Pipeline, LP and their authorized agents. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each study is unique, each report is unique, prepared solely for the specific client and project site. No one except Pacific Connector Gas Pipeline, LP should rely on this report without first conferring with GeoEngineers. This report should not be applied for any purpose or project except the one originally contemplated.

A Geologic Report is Based on a Unique Set of Project-Specific Factors

This report has been prepared for the PCGP located in Coos, Douglas, Jackson and Klamath County, Oregon. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- elevation, configuration, location, or orientation of the proposed pipeline;
- project ownership.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

Conditions Can Change

This geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by man-made events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

Most Geologic Findings Are Professional Opinions

Our interpretations of surface and subsurface conditions are based on published data and surficial observations. GeoEngineers reviewed office and field data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

Read These Provisions Closely

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering and engineering geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

Geotechnical, Geologic and Environmental Reports Should Not Be Interchanged

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study, and vice versa. For that reason, a geotechnical or engineering geologic report does not usually relate any environmental findings, conclusions or recommendations, e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

Special Conditions for Instream Habitat Design and Engineering Services

Instream Habitat Enhancement, Stabilization and/or Restoration Structures (Structures) may involve the placement of large logs, logs with root wads, large rocks and other natural or artificial materials and/or features in and adjacent to creeks, streams and rivers (streams). These Structures are designed for various purposes, including, but not limited to: improvement of aquatic and riparian habitat; stabilization of eroding stream banks and channels; creation or improvement of recreational uses; irrigation; and flood management. These Structures create potential hazards, including, but not limited to: humans falling from the Structures and associated injury or death; collisions of recreational users and their watercraft with the Structures and associated risk of injury or death, with partial or total damage of the watercraft; mobilization of a portion or all of the Structures during high water flow conditions and any subsequent related damage to downstream properties, utilities, roads, bridges and other infrastructure, and injury or death to humans; flooding; erosion; and channel avulsion.

The BMPs and Site Restoration plans presented for PCGP in this report are based on limited topographic data and full engineering analysis has not been completed. We recommend a GeoEngineers representative is on site during construction of all site-specific designs and site-specific BMPs to ensure the design intent is met.

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Appendix 7
Channel Migration and Scour Analysis and Figure 1

Channel Migration and Scour Analysis

Pacific Connector Gas Pipeline Project
Southern Oregon

for

Pacific Connector Gas Pipeline, LP

April 6, 2018

GeoEngineers
Earth Science + Technology

Channel Migration and Scour Analysis

Pacific Connector Gas Pipeline Project
Southern Oregon

for
Pacific Connector Gas Pipeline, LP

April 6, 2018

GeoEngineers

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Channel Migration and Scour Analysis

Pacific Connector Gas Pipeline Project
Southern Oregon

File No. 22708-001-00

April 6, 2018

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Table of Contents

1.0 INTRODUCTION

This report was prepared to support an application submitted to the Federal Energy Regulatory Commission (FERC or Commission) by Pacific Connector Gas Pipeline, LP (PCGP) to construct and operate the Pacific Connector Gas Pipeline Project (Project), a new, approximately 229-mile, 36-inch-diameter interstate natural gas transmission system and related facilities. The PCGP system will extend from the proposed Jordan Cove Liquefied Natural Gas (LNG) Import Terminal (Jordan Cove Terminal), being developed by Jordan Cove Energy Project, LP (JCEP) to interconnects with two interstate natural gas pipelines near Malin, Oregon. The Project is the proposed supply pipeline for the proposed Jordan Cove Terminal.

This report provides the results of channel migration and streambed scour analyses conducted at the stream crossing sites along the proposed Project route.

1.1. Project Background

Fluvial erosion represents a potential hazard to the proposed pipeline where streams are capable of exposing the pipe as a result of channel migration, avulsion, widening and/or streambed scour. For the purposes of this report, **channel migration** is defined as the lateral movement, over time, of an entire channel segment perpendicular to the direction of stream flow. **Channel avulsion** is the sudden abandonment of an active channel for a newly created or previously abandoned channel located on the floodplain. **Channel widening** is defined as erosion and subsequent recession of one or both stream banks that widens the channel without changing the channel location. **Streambed scour** is erosion of the streambed resulting in the development of deep pools and/or the systematic lowering of the channel floor elevation.

Stream crossings along the proposed PCGP pipeline alignment were evaluated with respect to potential future risk to the pipeline that could result from channel bed scour and/or lateral migration. The evaluation was conducted in two phases: Phase I involved a desktop evaluation in which all stream crossings were ranked for potential risk; Phase II involved detailed field reconnaissance and analyses of the stream crossings that were concluded to pose a risk of future pipeline exposure based on the Phase I study.

In Phase I, stream crossings were evaluated along the PCGP project alignment for potential migration, avulsion and/or scour using available aerial photos and geographic information system (GIS) data. Preliminary stream crossing evaluations were generated by collecting and evaluating data in a GIS and reviewing stereo aerial photos along the alignment. Geomorphic characteristics suggestive of migration, avulsion and/or scour were identified and evaluated. From this preliminary assessment, each stream crossing was assigned a numerical value of 0, 1 or 2. Level 0 crossings indicate streams not likely subject to migration, avulsion or scour. Level 1 stream crossings indicate streams with a moderate potential for migration, avulsion and/or scour. Level 2 crossings indicate streams with a high potential of migration, avulsion and/or scour. A cursory field reconnaissance was conducted to confirm general observations made during the desktop evaluation.

Phase II involved detailed assessments of Level 2 crossings identified in Phase I. Several Level 1 crossings were also evaluated at the request of PCGP's field staff. These crossings were subjected to detailed field reconnaissance and analyses of potential migration, avulsion and/or scour during Phase II.

2.0 PHASE I ANALYSES

2.1. Approach and Methods

Initially, pertinent GIS layers were collected and organized into a database including:

1. Aerial photographs (provided by PCGP)
2. 10-meter Digital Elevation Model (DEM) (United States Geological Survey [USGS])
3. Stream Layer (Pacific Northwest Hydrography Framework Clearinghouse)
4. Geology (USGS)
5. Soils (Natural Resources Conservation Service [NRCS])
6. Slopes (GeoEngineers, derived from 10-meter DEM)
7. Landslides (Oregon Department of Geology and Mineral Industries)
8. PCGP proposed alignment
9. Light Detection and Ranging (LiDAR) (Sanborn Mapping Co.)

The above data layers were analyzed in GIS to produce a shapefile of points representing the locations where the proposed alignment crossed streams identified in the hydrography layer, meanwhile incorporating the attributes (data) associated with each additional GIS layer. A GIS intersection tool was used to create the points, simultaneously populating them with attributes from the intersecting layers (streams, geology, soils and slopes). For example, the stream layer provided a unique stream identifier (LLID) and stream type (perennial, ephemeral, intermittent, unknown) at each crossing. Next, aerial photos were brought into the GIS map to identify observable features suggesting channel scour/incision, migration and avulsion. These features include channel patterns (braided channels, bends, straight channel sections), braid and side bar development, abandoned channels, human modifications and/or disturbances. Complex stream crossings were further evaluated with stereo-pairs of aerial photographs to identify and review finer topographic and geomorphic attributes.

Based on the GIS and stereo-pair analyses, the potential for channel migration, avulsion and/or scour was evaluated for each crossing. Potential for migration was determined based on valley and channel geometry, valley geology, channel meander patterns and floodplain characteristics. Channel crossings subject to potential avulsion were evaluated based on the presence of visible abandoned channels and sufficient downward gradient deviating from the current flow path. Channel crossings subject to potential scour were evaluated based on valley and channel geometry, valley geology, channel slope, visible evidence of scour/incision and/or steep slopes in the vicinity of a disturbance, such as a landslide or a timber harvest clearcut.

Each stream crossing was assigned a risk level of 0, 1 or 2. Level 0 crossings indicate streams not likely subject to migration, avulsion or scour and require no additional survey beyond the base centerline protocol. Level 1 stream crossings indicate small or uncomplicated channels with a moderate potential for migration, avulsion and/or scour. Level 2 crossings indicate large or complex channels with a high potential of migration, avulsion and/or scour and require site-specific analysis and survey guidelines.

2.2. Phase I Conclusions

The phase I analysis identified 10–Level 2 crossings, 36–Level 1 crossings and the remainder were identified as Level 0. Data associated with each crossing are provided in Appendix A (including County, NHD Reach Codes, Milepost, Stream Name, Stream Type, Geology, Risk Level, Potential Scour, Potential Migration and Potential Avulsion).

3.0 PHASE II ANALYSES

3.1. Approach and Methods

The primary goal of the Phase II evaluation was to estimate the potential extent of channel migration/avulsion/widening, referred to collectively as channel migration, and the potential scour depth at the 10–Level 2 crossings and 10–Level 1 crossings identified by PCGP as crossings of high concern (Table 1).

TABLE 1. PHASE II CROSSINGS

Physiographic Province	Watershed	Stream Name at Crossing	Approx. PCGP Milepost	Risk Level
Coast Range	Coos	Coos River	11.13R	1
Coast Range	Coquille River	North Fork Coquille River	23.06	1
Coast Range	Coquille River	Middle Creek	27.04	2
Coast Range	Coquille River	East Fork Coquille River	29.85	1
Coast Range	Coquille River	Elk Creek	32.40	1
Coast Range	Coquille River	South Fork Elk Creek	34.46	2
Coast Range	Coquille River	Big Creek	37.33	1
Coast Range	Coquille River	Middle Fork Coquille River	50.28	1
Klamath Mountains	South Umpqua	Olalla Creek	58.78	2
Klamath Mountains	South Umpqua	South Umpqua River Crossing No. 1	71.27	2
Klamath Mountains	South Umpqua	North Myrtle Creek	79.12	2
Klamath Mountains	South Umpqua	South Myrtle Creek	81.19	2
Klamath Mountains	South Umpqua	Woods Creek	84.17	1
Klamath Mountains	South Umpqua	Fate Creek	88.48	1
Klamath Mountains	South Umpqua	Days Creek	88.60	1
Klamath Mountains	South Umpqua	South Umpqua River Crossing No. 2	94.73	2
Cascade Range	Rogue River	West Fork Trail Creek	118.89	2
Cascade Range	Rogue River	Rogue River	122.65	2
Cascade Range	Rogue River	Indian Creek	128.61	1
Cascade Range	Rogue River	North Fork Little Butte Cr	145.69	2

The approach to evaluating potential migration and scour included three primary elements: (1) develop a geomorphic characterization for each site; (2) conduct detailed migration analyses as necessary; and (3) conduct detailed scour analyses as necessary. Steps 2 and 3 were conducted at only those sites where field reconnaissance confirmed the potential for migration and/or scour.

The detailed description of the analytical methods applied to determine migration and scour potential at each applicable channel crossing is provided in Appendix B.

3.2. Geomorphic Characterization

The geomorphic characterization involved the following elements:

- Evaluation of historical channel movement based on historical aerial photographs.
- Identification of key geomorphic features from review of LiDAR and stereo aerial photos.
- Completion of detailed field reconnaissance.

In order to effectively estimate migration distances and scour depths for a given crossing, the relationships between basin- and reach-scale characteristics were considered. Basin-scale conditions included climate/precipitation, regional topography, underlying geology and basin development. Reach-scale conditions included local terrain and geology, floodplain conditions, channel dimensions, sediment transport and bank/streambed composition.

The proposed alignment crosses four physiographic provinces. From west to east, the four provinces are: The Coast Range, Klamath Mountains, Cascade Range, and Basin and Range. The provinces are distinct in climate, terrain, geology and level of basin development. Each channel crossing reflects the conditions of the resident physiographic province. Detailed basin- and reach-scale geomorphic characterizations are provided in Appendix C.

Site reconnaissance was conducted at the Phase II channel crossings initially in October 2006 by a GeoEngineers field team consisting of one geologist and one geomorphologist. Select Phase II stream crossings were reevaluated in March 2009 if their crossing location moved as a result of route modifications. The purpose of the reconnaissance was twofold: (1) to observe site-specific conditions relative to scour and migration potential, and (2) to collect physical data for use in migration zone evaluation, scour calculations and other analyses. Note that Phase II reconnaissance could not be completed at three stream crossings (West Fork Trail Creek, Indian Creek, North Fork Little Butte Creek) due to landowner access restrictions. Therefore, no additional information for those sites is presented.

The results of the Phase II field reconnaissance and on-site assessment identified 10 stream crossings subject to channel migration (Table C-2) and 6 stream crossings subject to streambed scour that could pose a significant future risk of pipeline exposure (Table C-2). These streams were analyzed further to estimate the potential extent of migration at the 10 identified stream crossings and the potential depth of scour at the 6 identified stream crossings. No further analysis was performed on the streams found not to be subject to migration or scour.

3.3. Channel Migration Analyses

The detailed migration analysis included the following:

- Evaluation of long-term channel behavior from historical maps and aerial photos.
- Evaluation of geomorphic conditions at sites based on GIS data and site reconnaissance.
- Determination of the Historic Channel Occupation Tract (HCOT) based on a delineation of channel location from aerial photos spanning from 1939 to 2011, site depending.
- Calculation of migration rates for each time span between aerial photo years.
- Estimation of 25- and 50-year Channel Migration Zones (CMZs).

Based on the results of the geomorphic characterization and site reconnaissance, crossings were analyzed to quantify the width of potential migration zones. Channel migration zones were calculated for two periods of potential future migration: 25- and 50-year periods, based on averaged annual migration rates (obtained from historical aerial photographs) applied to the average rate of lateral movement of the channel over a specified period of time (for example, 25 years). This migration rate is applied to floodplain areas beyond the limits of the HCOT, and on both sides of the stream channel. This approach to defining the CMZ provides various levels of conservatism and potential redundancy into the estimates, as the river is not likely to migrate along the same section in both directions simultaneously. The approach for estimating a 25-year CMZ by applying a migration rate to both floodplains encompasses a 50-year span from edge to edge. The potential CMZ over a 100-year time span was not considered because: (1) predicting channel migration behavior over 100 years is considered unreliable; and (2) the design life of the pipeline project is 50 years.

The calculated widths of the migration periods were further evaluated to assess, qualitatively, how well the 25- and 50-year CMZ widths represent future channel behavior. Although the analysis assumed a constant rate of lateral migration over specified periods, actual rates of migration are known to decline with distance away from the channel. The decline in actual migration rates is typically caused by variations and changes in surface and subsurface conditions across floodplains and flood terraces. The typical changes can include the presence and elevation of buried bedrock, variations in soil density and cohesion, presence of man-made structures, and land use practices.

3.3.1. Channel Migration Zone Delineation and Results

The base width of the 25- and 50-year CMZs were delineated based on the approach discussed above. The shape of each CMZ boundary was then adjusted to account for the occurrence of local factors such as floodplain features, abandoned channels, directional trends of migration, possible shallow bedrock, and the presence of roads and other infrastructure representing physical migration boundaries. The results of the 25- and 50-year CMZ analyses are summarized in Appendix C, Table C-1 and presented on maps included in Figures 15 through 25. Each CMZ assessment is discussed in further detail and appropriate crossing geomorphic characterizations are provided in Appendix C.

3.4. Streambed Scour Analyses

A complete description of the scour analysis methods and results for the seven crossings identified during the Phase II study is presented in Appendices B and C. In general, the scour analysis consisted of the following:

- Surveying of several channel cross sections upstream, downstream and at the crossing.

- Modeling of hydrology and hydraulic conditions at each site.
- Estimation of depth to bedrock beneath channel crossings.
- Calculation of scour depths for multiple flow events based on the results of hydraulic modeling and verified through consultation with the geomorphic evaluation and observed field conditions.

Maximum streambed scour was calculated for 10-, 25-, 50- and 100-year flood recurrence interval flood events. Scour depths were derived from the application of Hydrologic Engineering Center-River Analysis System (HEC-RAS) model results to appropriate scour equations.

Scour depth analysis was completed unless field observations indicated bedrock was located at shallow depth below the streambed. Where depth to bedrock is unknown, it is assumed that alluvial material extends to the calculated depth of scour.

Shallow bedrock was observed in the vicinity of Middle Creek, South Umpqua River Crossing No. 1, South Umpqua River Crossing No. 2 and Rogue River stream crossings. At these crossings, depth to bedrock was interpreted based on observed bedrock contacts, outcrops and borings drilled nearby. For each of these crossings, bedrock is likely to be encountered at shallower depths than the calculated scour depths, which assumes erodible alluvium is present to scour depth. Therefore, it is assumed that the upper elevation of competent bedrock represents the limit of scour for all flows at these crossings.

A scour analysis was not completed for South Umpqua No. 1 because it is proposed to be crossed by direct pipe (DP) trenchless construction methods putting the pipe well into anticipated bedrock below potential scour depths.

3.4.1. Streambed Scour Results

The results of the scour analyses are provided below in Table 2. PCGP intends to bury the pipeline below the estimated 100-year scour depth or into competent bedrock, whichever threshold is shallower.

TABLE 2. SUMMARY OF SCOUR RESULTS

Stream Name at Crossing	Approx. PCGP Milepost	Scour Analysis Analyst	Expected Scour Depth Based on Interpreted Depth to Bedrock	Calculated Total Potential Scour Depth in Alluvium (10-/25-/50-/100-yr)
Middle Creek	27.04	GeoEngineers	2 - 7.0 ft[a,b]	7.0/9.0/9.0/10.5 ft[c]
South Fork Elk Creek	34.46	GeoEngineers	--	4.0/5.0/5.0/6.0 ft
Olalla Creek	58.78	GeoEngineers	--	6.0/7.0/7.0/7.5 ft
North Myrtle Creek	79.12	GeoEngineers	--	5.0/6.0/6.0/6.5 ft

Stream Name at Crossing	Approx. PCGP Milepost	Scour Analysis Analyst	Expected Scour Depth Based on Interpreted Depth to Bedrock	Calculated Total Potential Scour Depth in Alluvium (10-/25-/50-/100-yr)
South Umpqua River Crossing No. 2	94.73	GeoEngineers	0.7 - 8.7 ft[a,b]	11.0/13.5/16.0/18.0 ft[c]
Rogue River	122.65	GeoEngineers	0.9 - 6.9 ft[a,b]	13.5/16.5/18.5/20.5 ft[c]

Notes:

[a] Depth to bedrock interpreted from nearby boring logs and outcrops.

[b] Depth of scour is expected to be limited by bedrock.

[c.] Calculated depth of scour assumes absence of bedrock.

3.5. Stream Migration and Scour Hazard Avoidance and Minimization of Adverse Effects

The principal hazard resulting from channel migration and streambed scour is complete or partial exposure of the pipeline within the channel from streambed and bank erosion, or within the floodplain from channel migration and/or avulsion. Minimizing the effects of migration and scour hazards to the pipeline can be accomplished with the following approaches:

1. At each channel crossing, bury the pipe below the estimated depth of streambed scour. Where bedrock is encountered at shallower depths than the estimated scour depth, the elevation of competent bedrock represents the limit of scour.
2. Where feasible, place the pipe into bedrock.
3. Within floodplains adjacent to migrating channels, bury the pipe below the projected depth of the channel thalweg within the 50-year CMZ.

PCGP has proposed to cross four major stream crossings (Coos River, South Umpqua No. 1, Rogue River and Klamath River) by trenchless methods (HDD and DP). The depth and length of the planned trenchless crossings have been designed to avoid the potential risks associated with migration and scour hazards.

4.0 REFERENCES

GeoEngineers, Inc., Geologic Hazards and Mineral Resources Report, Pacific Connector Gas Pipeline Project, Coos Bay to Malin, Oregon. Prepared for Pacific Connector Gas Pipeline, LP, Portland, Oregon, August 21, 2017.

ICF Jones & Stokes, Proposed Pipeline Alignment Wetland Delineation Report, Pacific Gas Pipeline Project. ICF J&S 06250.06, Prepared for Pacific Connector Gas Pipeline, LP, ICF Jones & Stokes, Portland, Oregon, 2009.

Oregon GeoSpatial Enterprise Office (GEO), 2010. Oregon Spatial Data Library. http://spatialdata.oregonexplorer.info/GPT9/catalog/main/home.page Accessed variously May – September 2010.

FIGURES

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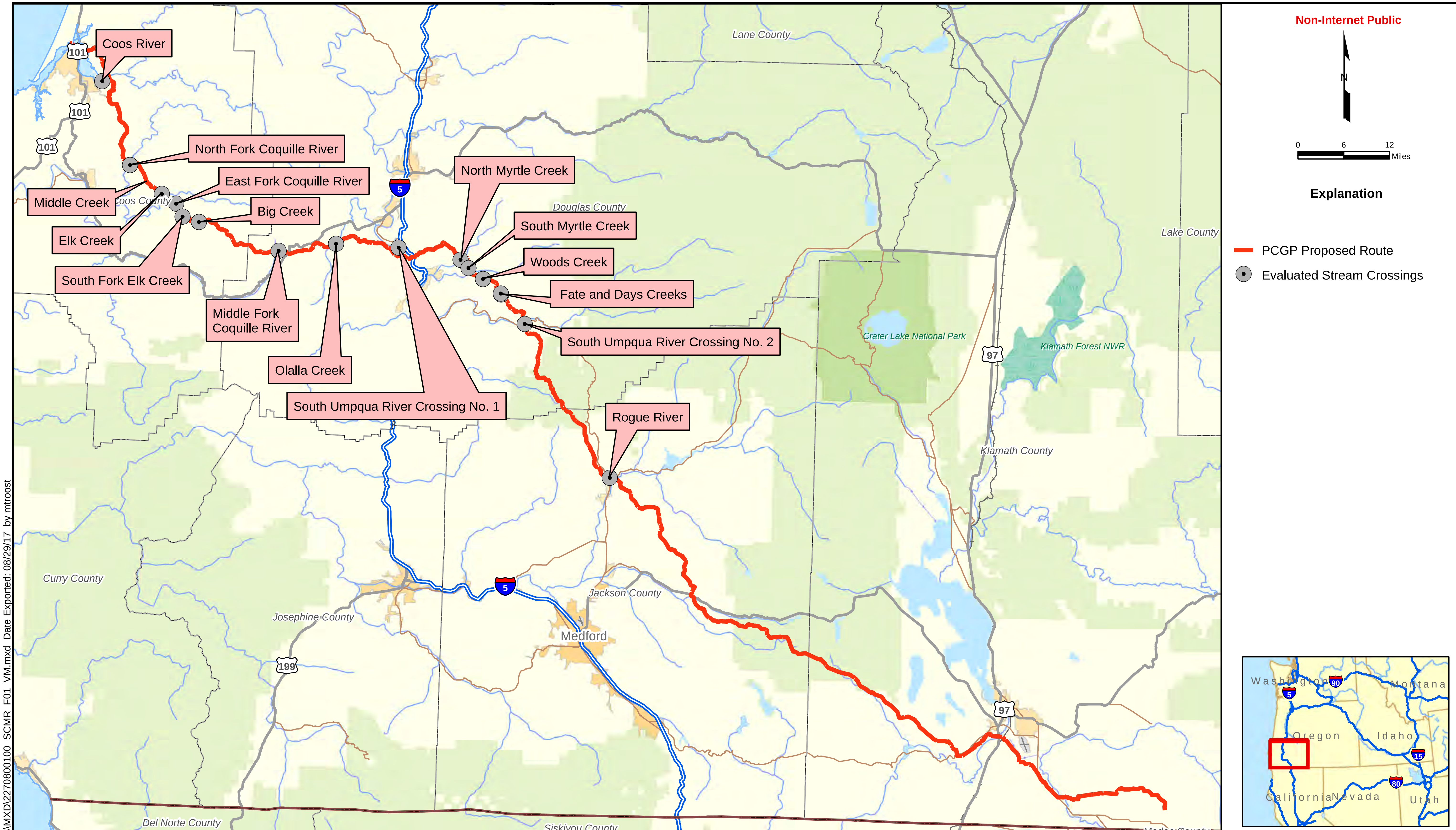

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Data Sources: Pipeline route from Pacific Connector Gas Pipeline L.P. Other data from ESRI Streetmap USA.

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PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

VICINITY MAP

FIGURE 1

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PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
Coos River

FIGURE 2

Non-Internet Public

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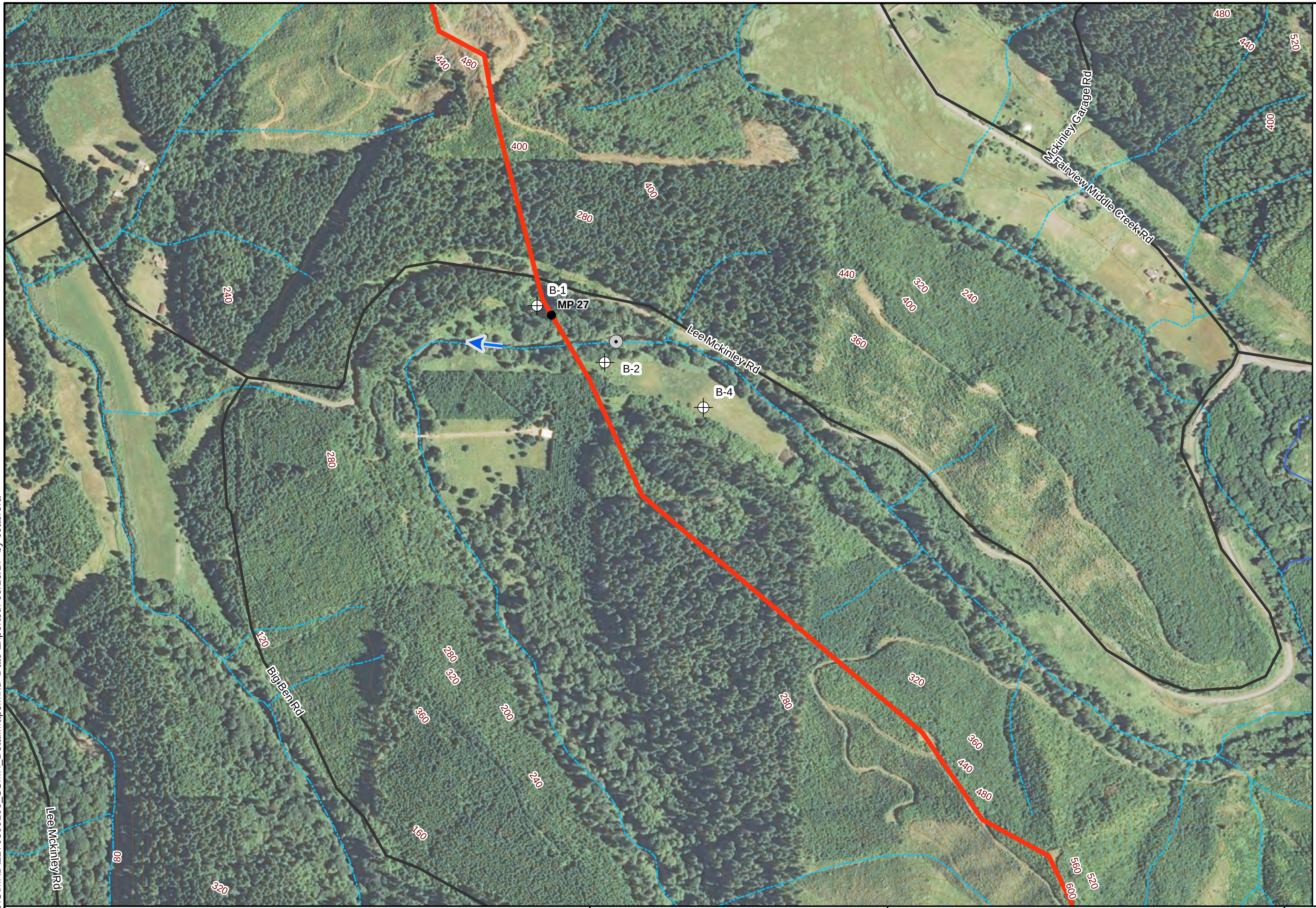
PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
North Fork Coquille River

FIGURE 3



Non-Internet Public

N

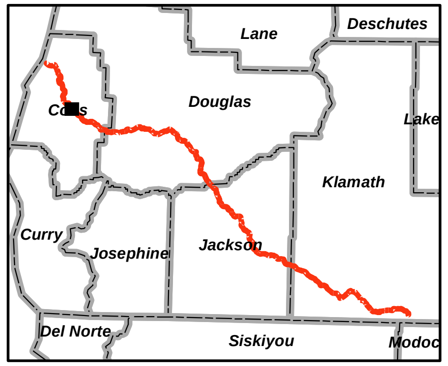
0 300 600 Feet

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Select Boring Locations
- Evaluated Stream Crossings
- Stream Flow Direction
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road
- Contours (40 foot)

Watercourses

- Perennial
- Ephemeral
- Intermittent



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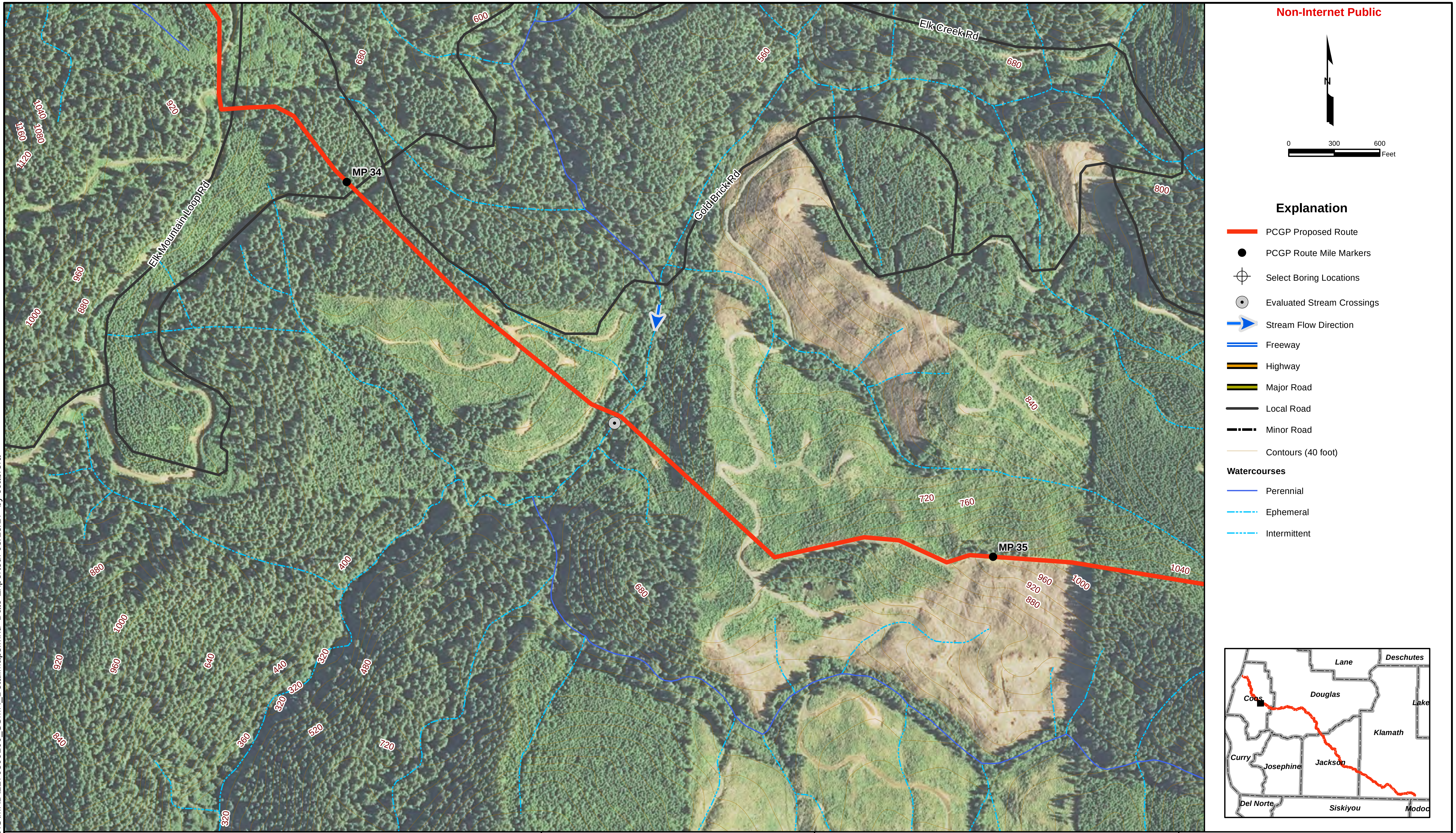
PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
Middle Creek

FIGURE 4



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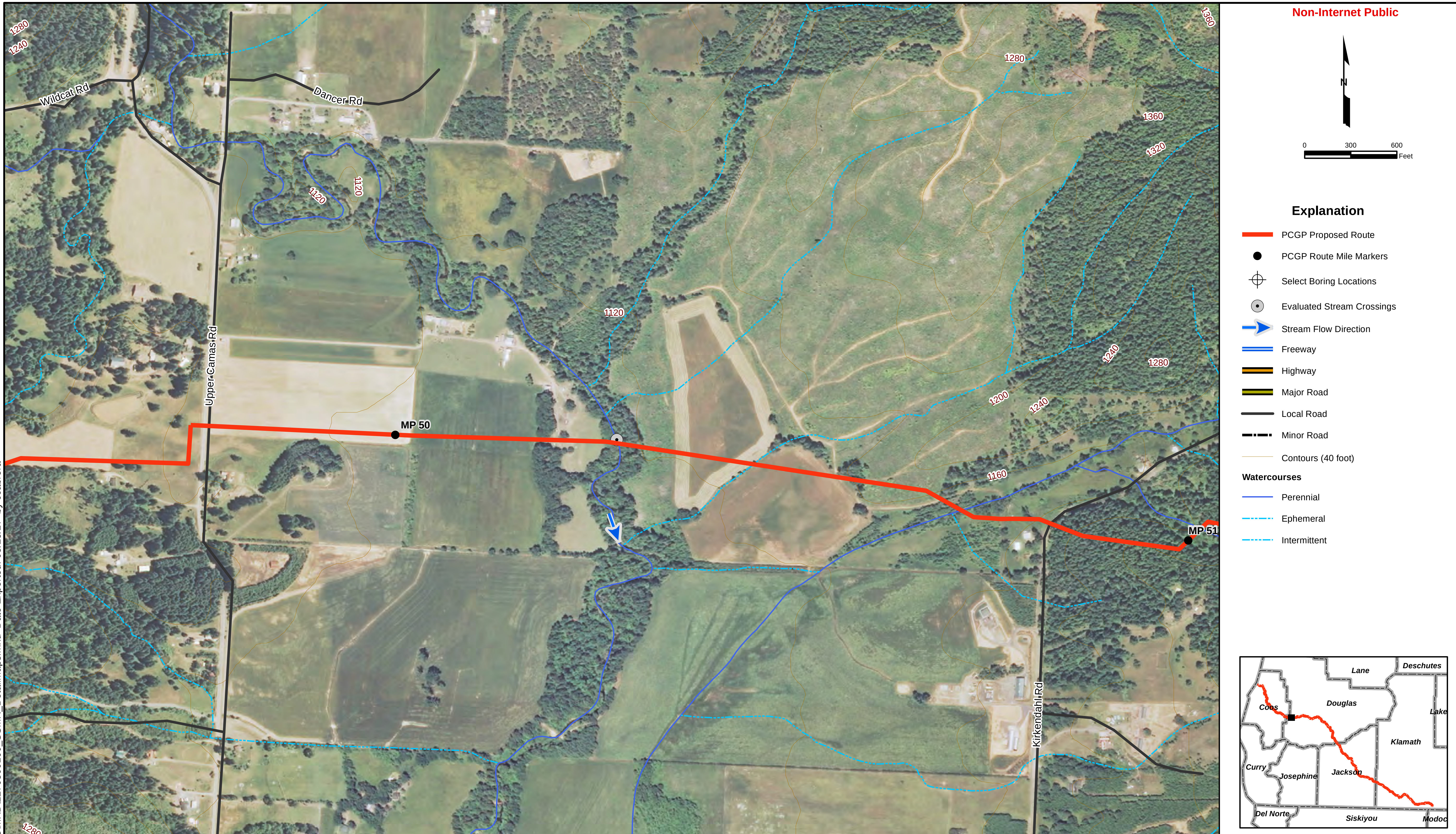
PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
South Fork Elk Creek

FIGURE 5



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PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
Middle Fork Coquille River

FIGURE 6

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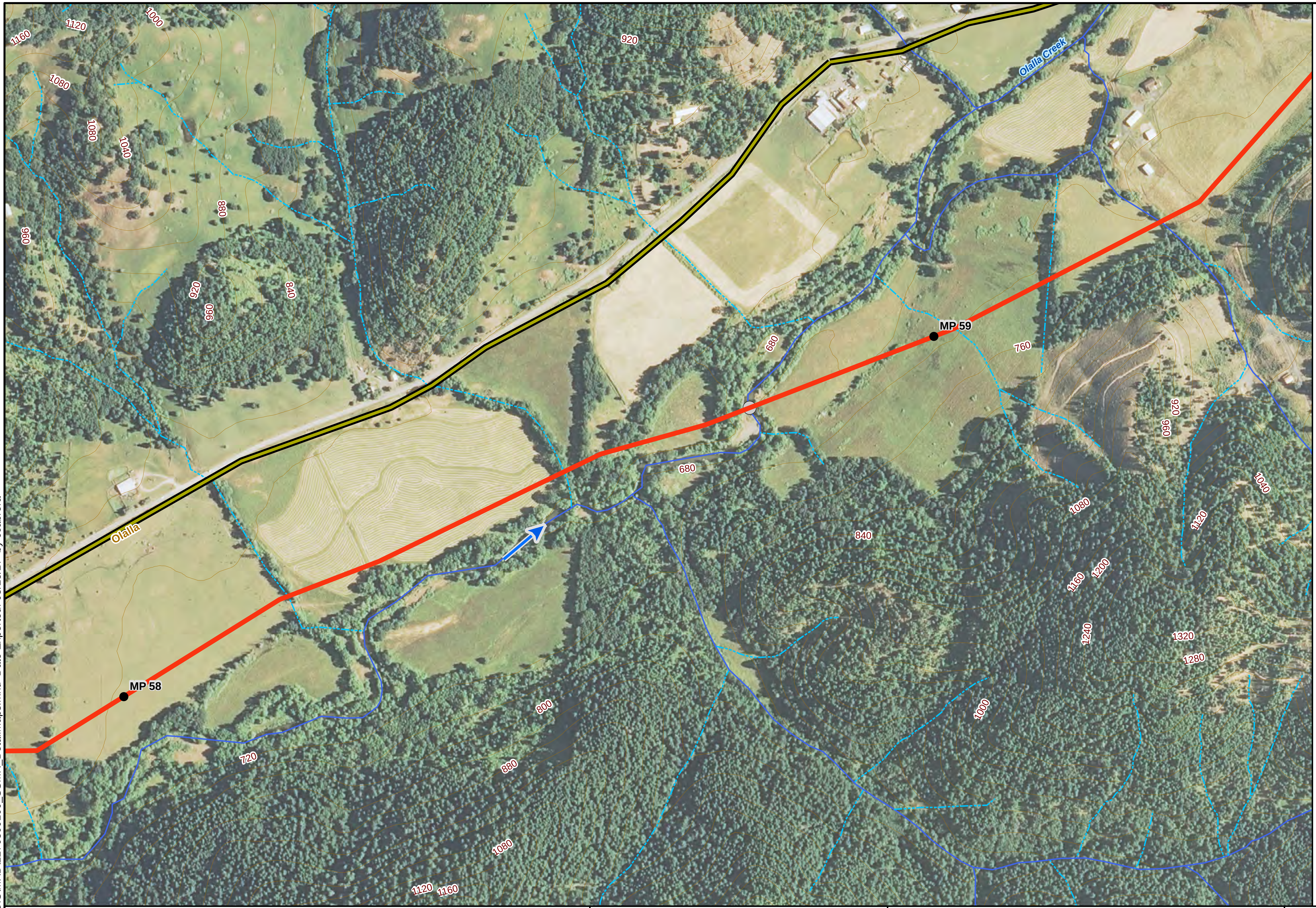


Non-Internet Public

N

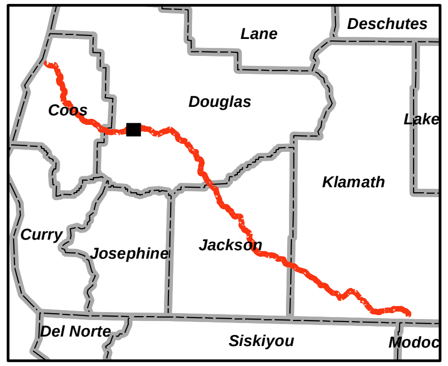
0 300 600 Feet

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Select Boring Locations
- Evaluated Stream Crossings
- Stream Flow Direction
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road
- Contours (40 foot)

Watercourses

- Perennial
- Ephemeral
- Intermittent



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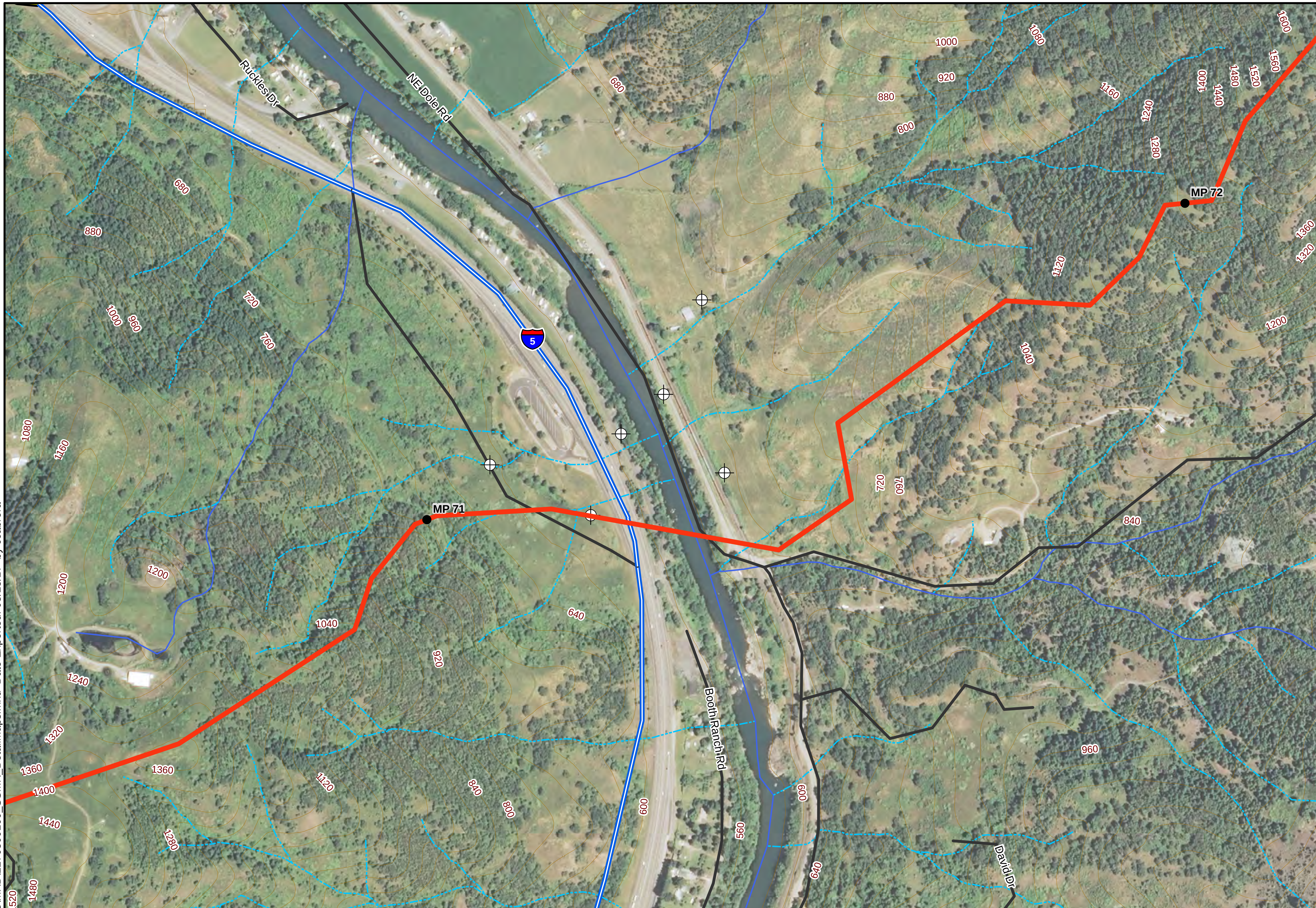
GEOENGINEERS

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
Olalla Creek

FIGURE 7

Non-Internet Public



N

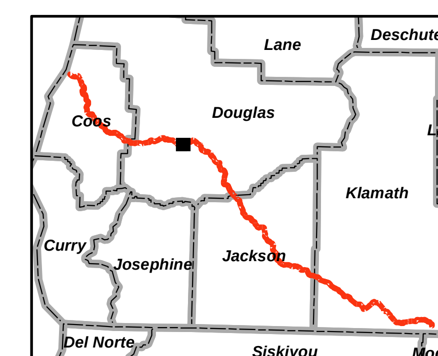
0 300 600 Feet

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Select Boring Locations
- Evaluated Stream Crossings
- Stream Flow Direction
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road
- Contours (40 foot)

Watercourses

- Perennial
- Ephemeral
- Intermittent



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GeoEngineers

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
South Umpqua River Crossing No. 1

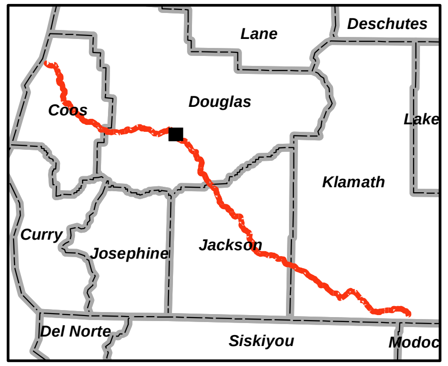
FIGURE 8

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Select Boring Locations
- Evaluated Stream Crossings
- Stream Flow Direction
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road
- Contours (40 foot)

Watercourses

- Perennial
- Ephemeral
- Intermittent



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PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
North Myrtle Creek

FIGURE 9

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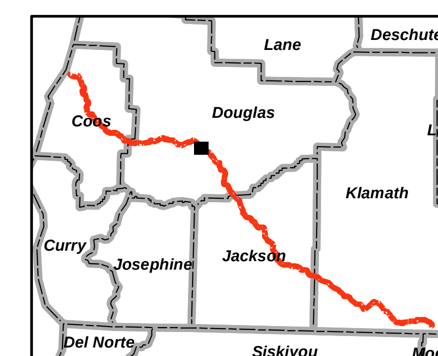
N
0 300 600 Feet

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Select Boring Locations
- Evaluated Stream Crossings
- Stream Flow Direction
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road
- Contours (40 foot)

Watercourses

- Perennial
- Ephemeral
- Intermittent



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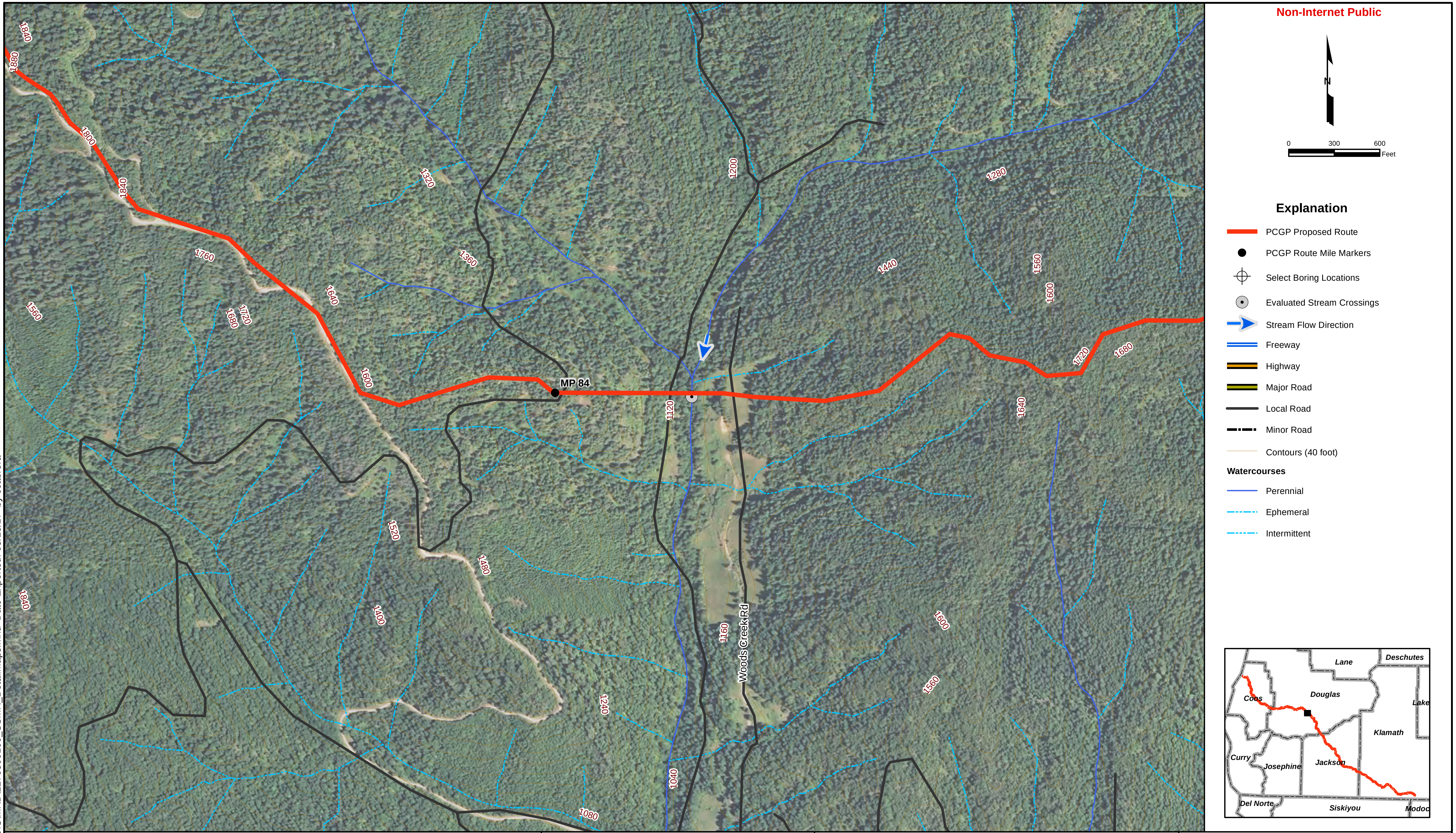
GeoEngineers

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
South Myrtle Creek

FIGURE 10

P:\22\2270800100_SSMR_DetailMaps.mxd Date Exported: 08/25/17 by ccabrera



P:\22\2270800100\GIS\MXD\2270800100_SSMR_DetailMaps.mxd Date Exported: 08/25/17 by ccabrera

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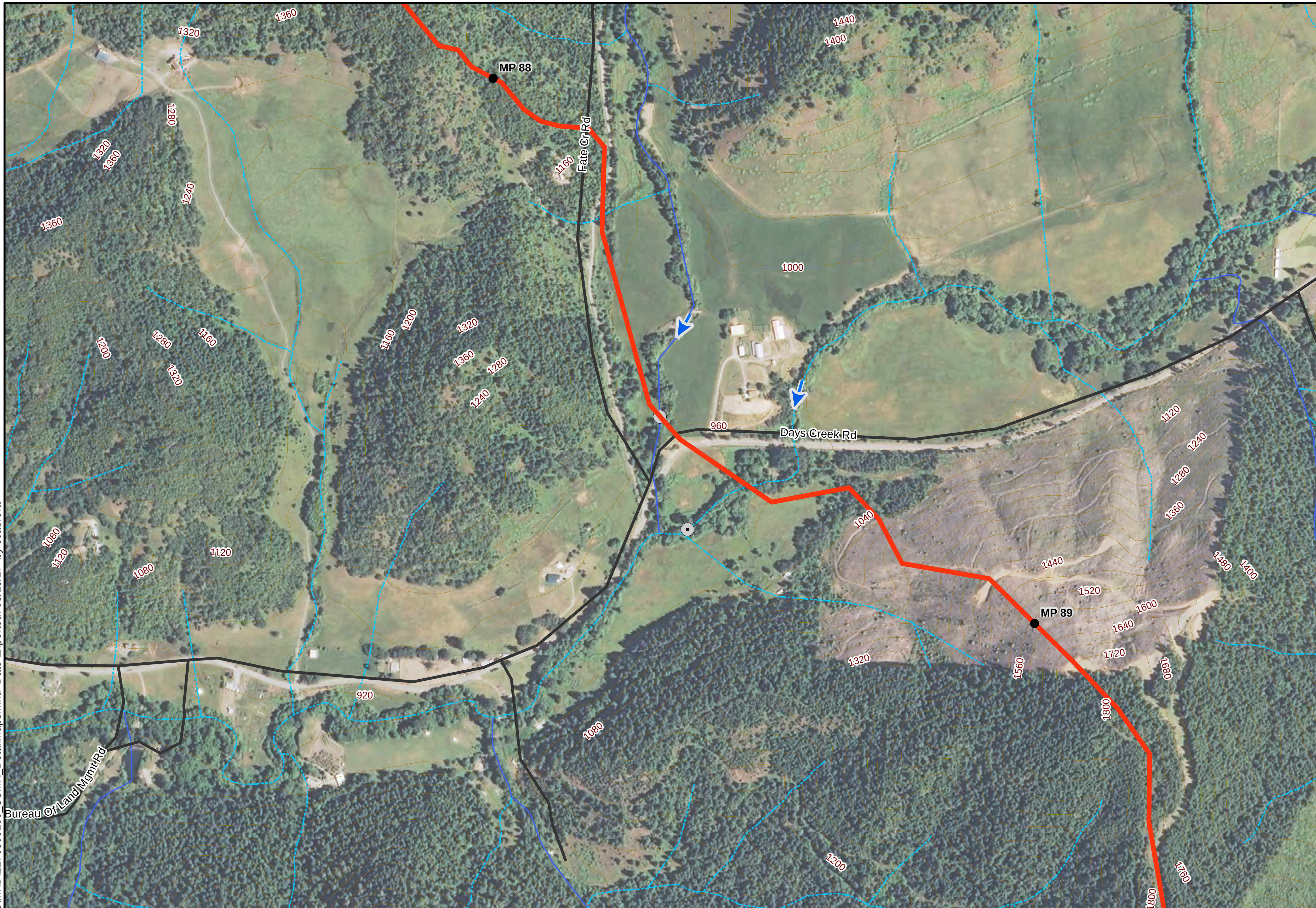
PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
Woods Creek

FIGURE 11

Non-Internet Public



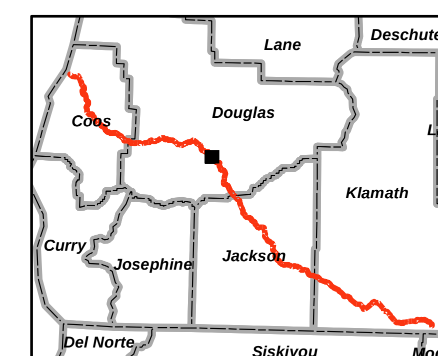
N
0 300 600 Feet

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Select Boring Locations
- Evaluated Stream Crossings
- Stream Flow Direction
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road
- Contours (40 foot)

Watercourses

- Perennial
- Ephemeral
- Intermittent



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Data Sources: 2012 NAIP Aerial Image; the rest of the data sources are detailed in attached document.

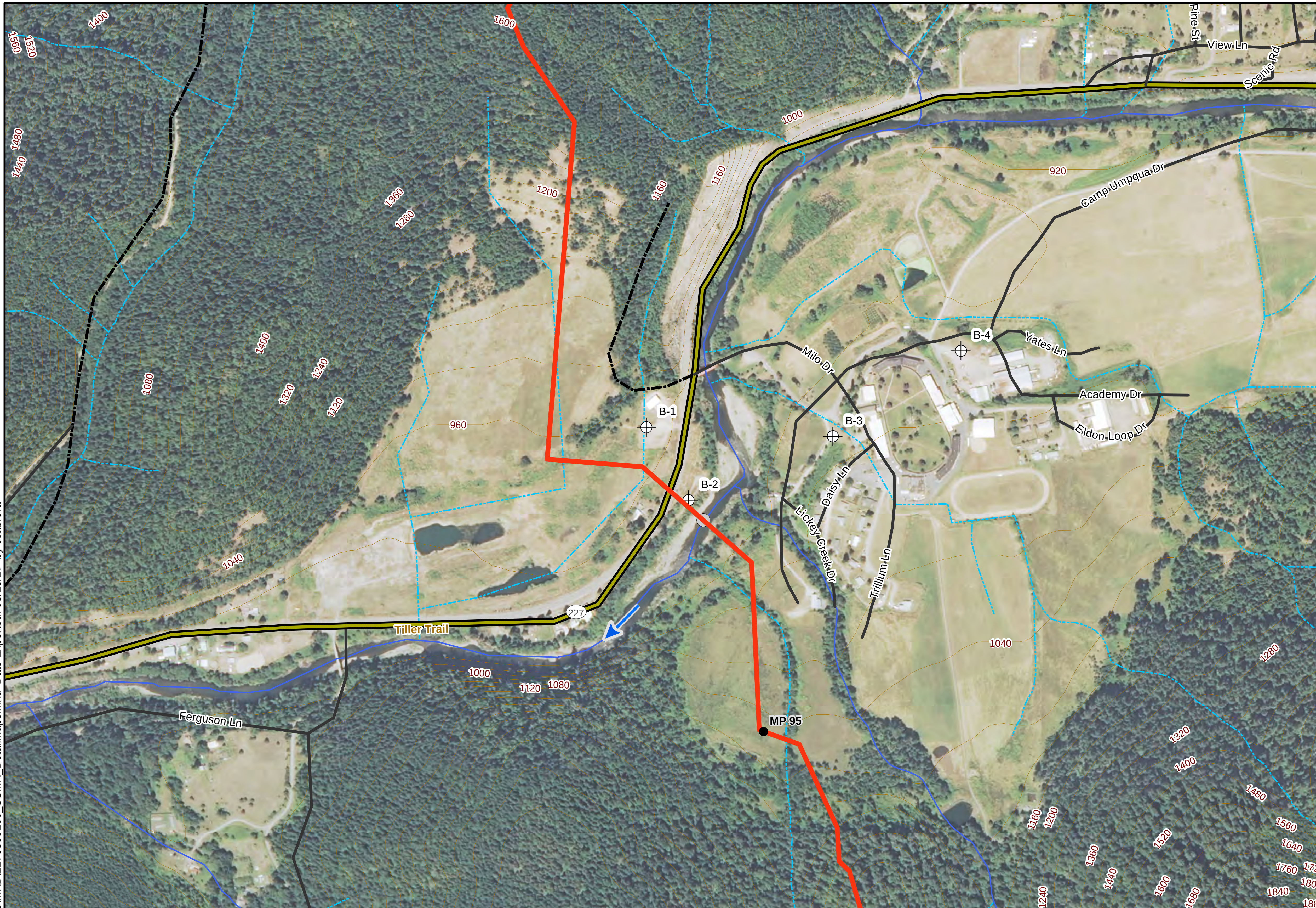
GeoEngineers

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
Fate and Days Creek

FIGURE 12

P:\22\22708001\GIS\MXD\2270800100_SSMR_DetailMaps.mxd Date Exported: 08/25/17 by ccabrera



Non-Internet Public

N

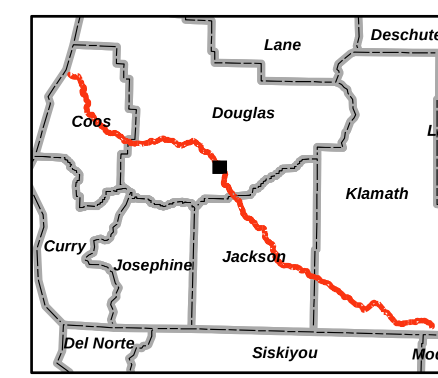
0 300 600 Feet

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Select Boring Locations
- Evaluated Stream Crossings
- Stream Flow Direction
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road
- Contours (40 foot)

Watercourses

- Perennial
- Ephemeral
- Intermittent



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Data Sources: 2012 NAIP Aerial Image; the rest of the data sources are detailed in attached document.

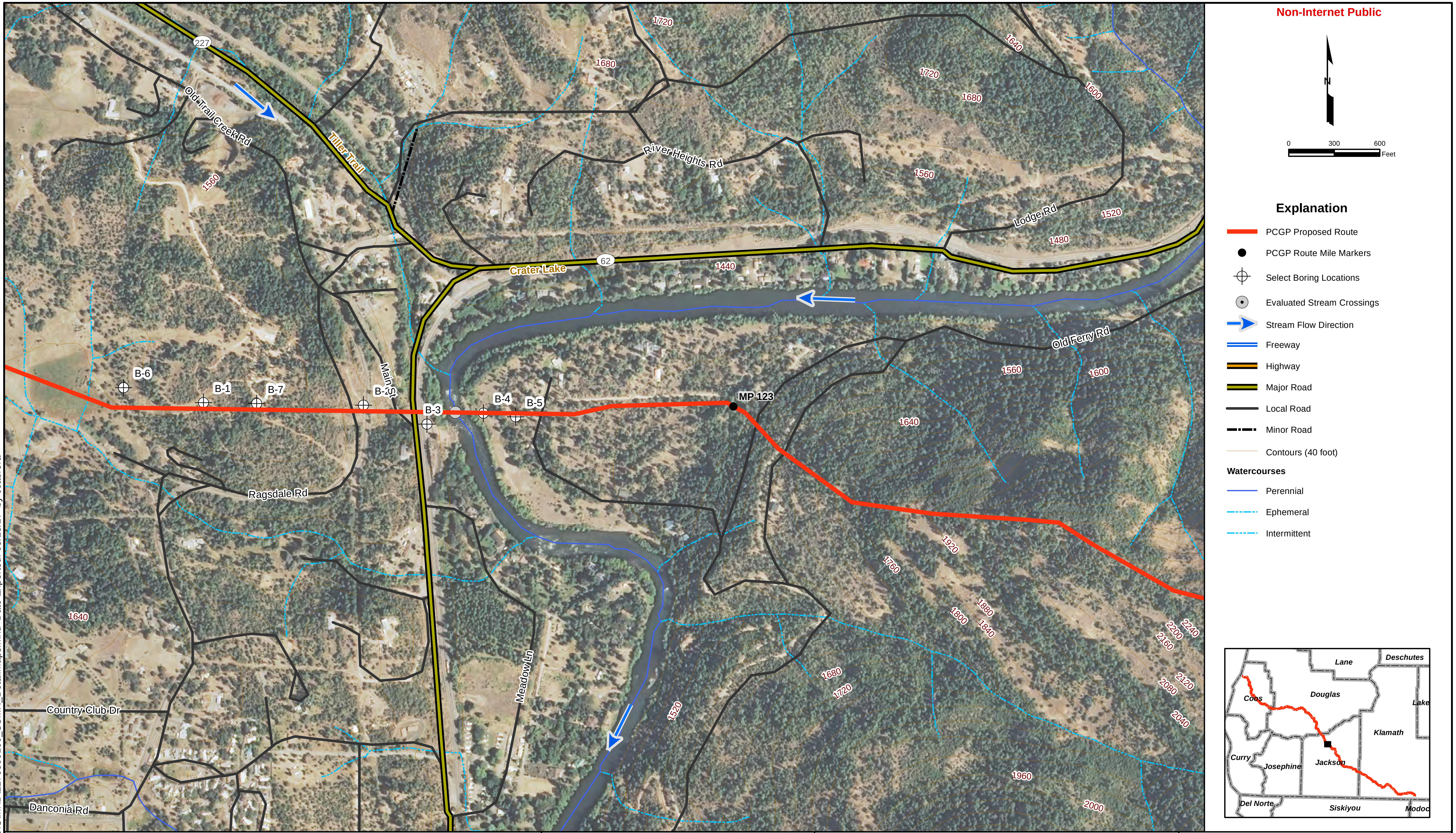
GEOENGINEERS

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
South Umpqua River Crossing No. 2

FIGURE 13

P:\22\22708001\GIS\MXD\2270800100_SSMR_DetailMaps.mxd Date Exported: 08/25/17 by ccabrera



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GEOENGINEERS

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP
Rogue River

FIGURE 14

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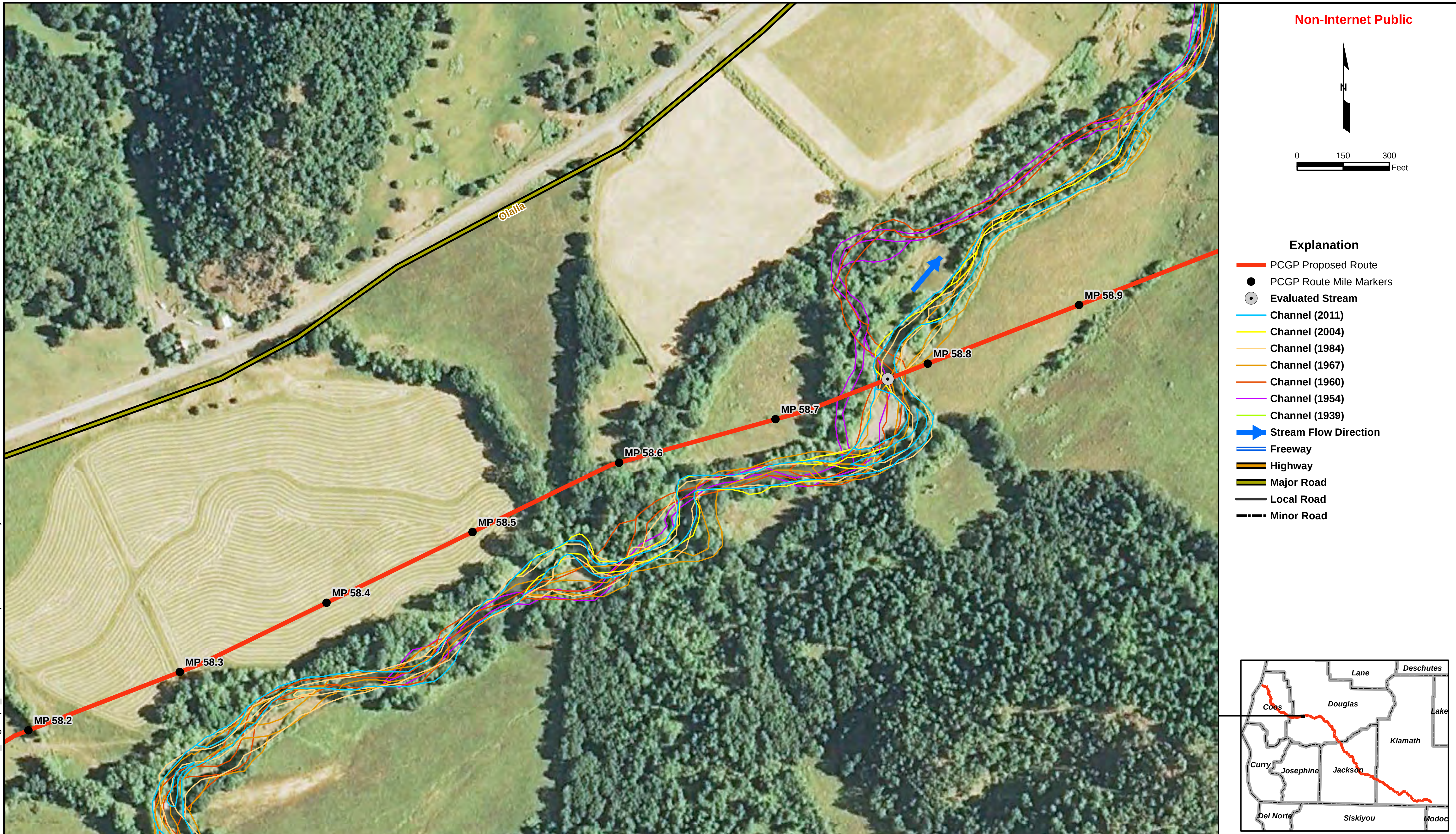

P:\22\2270800100\GIS\MXD\2270800100_MigMaps_Olalla.mxd Date Exported: 08/25/17 by ccabrera

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Roads from ESRI Streetmap 2006, All other layers were created internally.

GeoEngineers

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP: HISTORIC MIGRATION
Olalla Creek

FIGURE 15

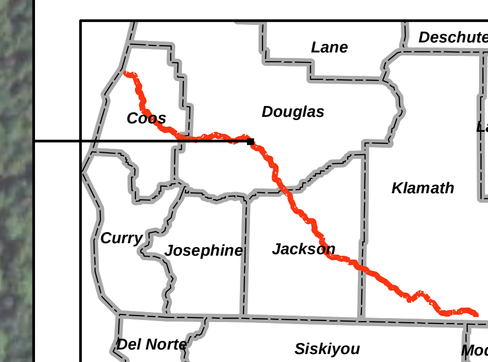
Non-Internet Public

N

0 150 300 Feet

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Evaluated Stream Crossings
- Channel (2011)
- Channel (2004)
- Channel (2000)
- Channel (1982)
- Channel (1952)
- Stream Flow Direction
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road



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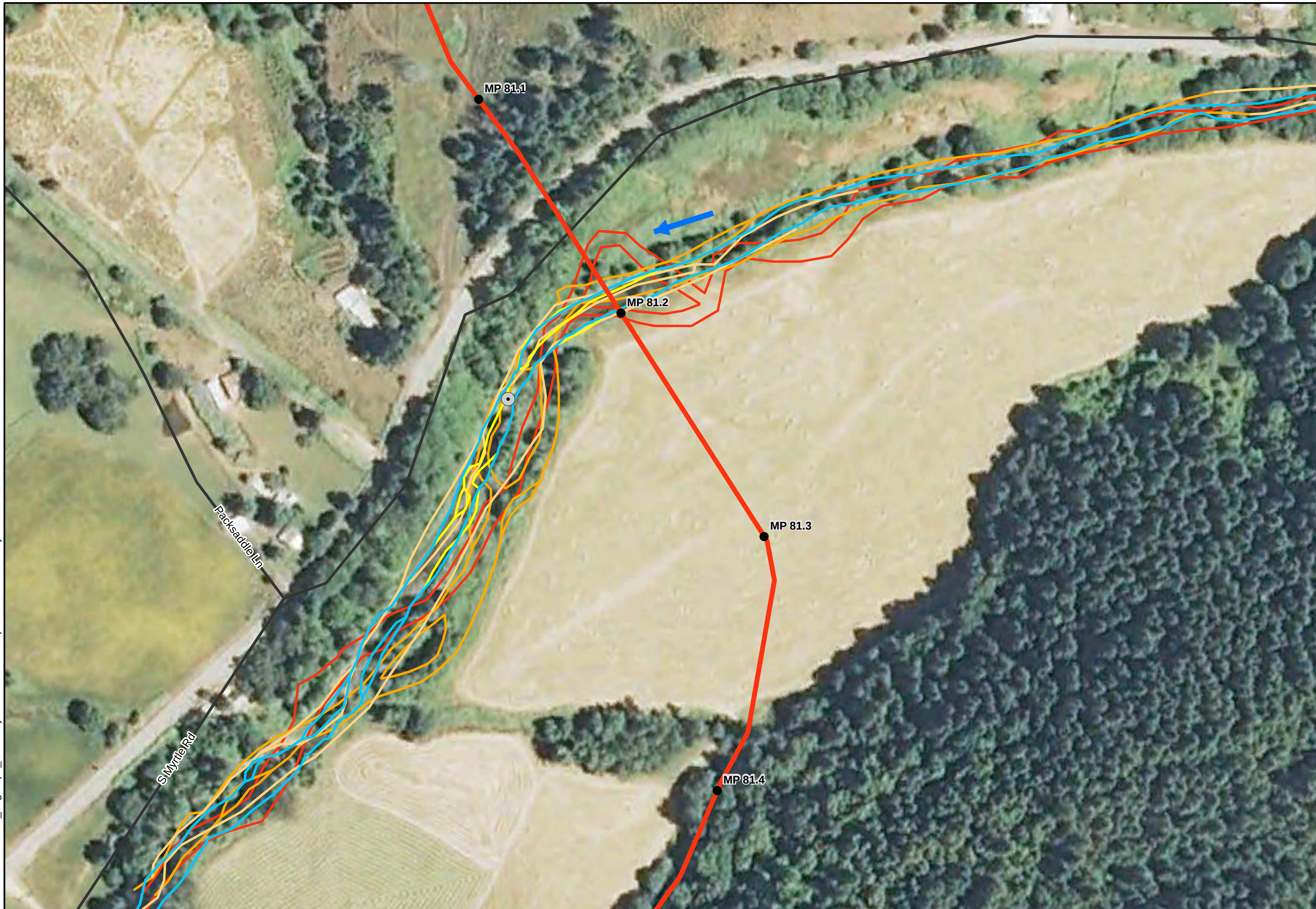
GEOENGINEERS

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

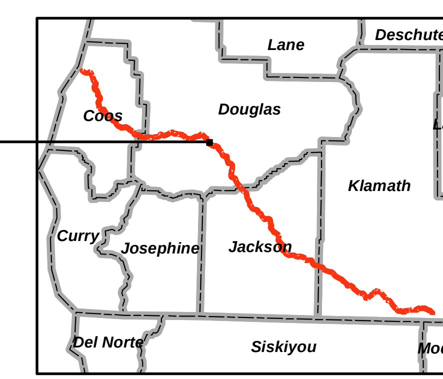
SITE MAP: HISTORIC MIGRATION
North Myrtle Creek

FIGURE 16

P:\22\2270800100\GIS\MXD\2270800100_MigMaps_NorthMyrtle.mxd Date Exported: 08/25/17 by ccabrera



Explanation



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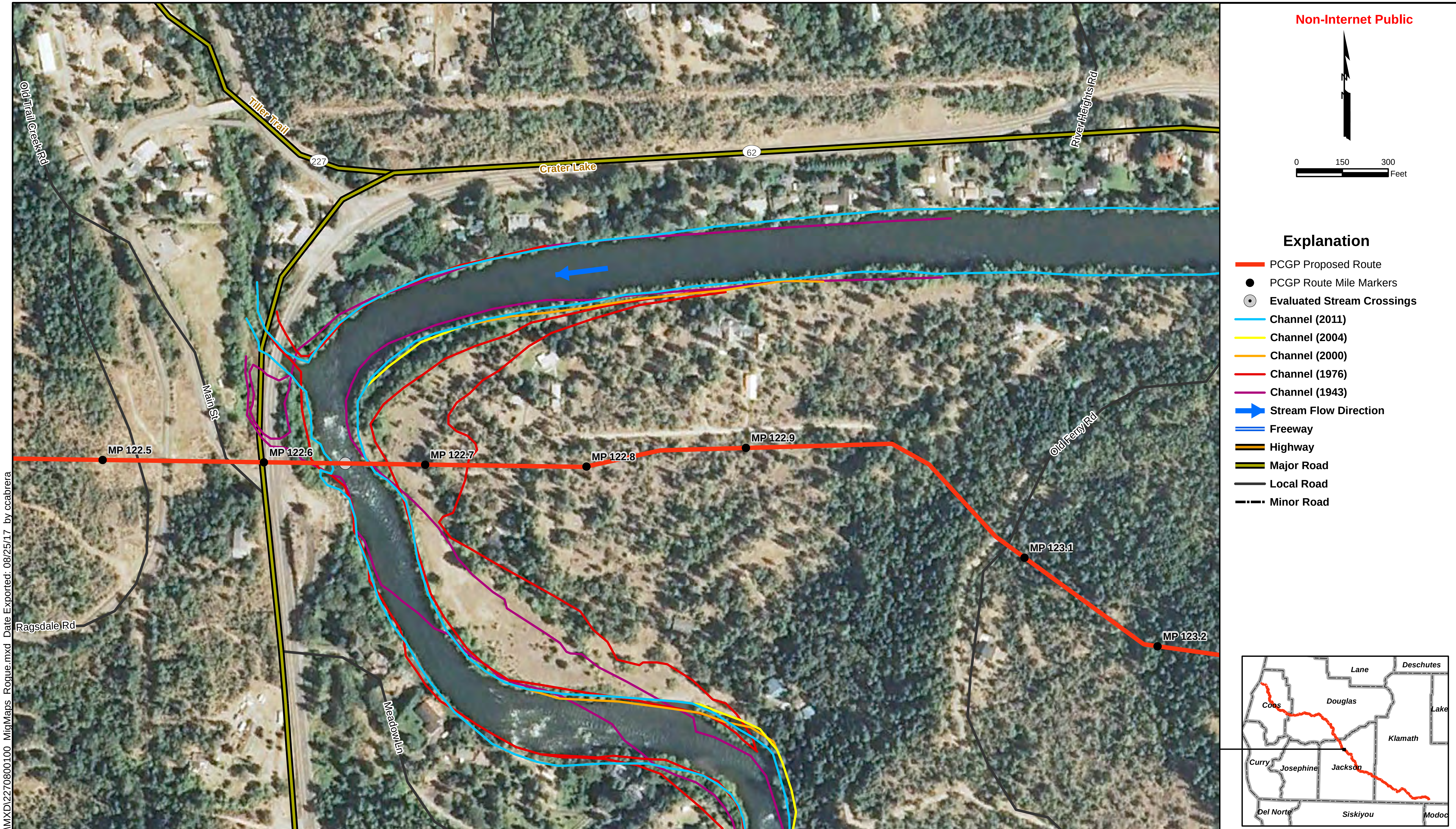
GeoEngineers

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP: HISTORIC MIGRATION
South Myrtle Creek

FIGURE 17

P:\22\2270800100\GIS\MXD\2270800100_MigMaps_SouthMyrtle.mxd Date Exported: 08/25/17 by ccabrera



P:\22\22708001\GIS\MXD\2270800100_MigMaps_Rogue.mxd Date Exported: 08/25/17 by ccabrera

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GeoEngineers

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossings Evaluation

SITE MAP: HISTORIC MIGRATION
Rogue River

FIGURE 18

TOPOGRAPHIC PLAN VIEW

Non-Internet Public

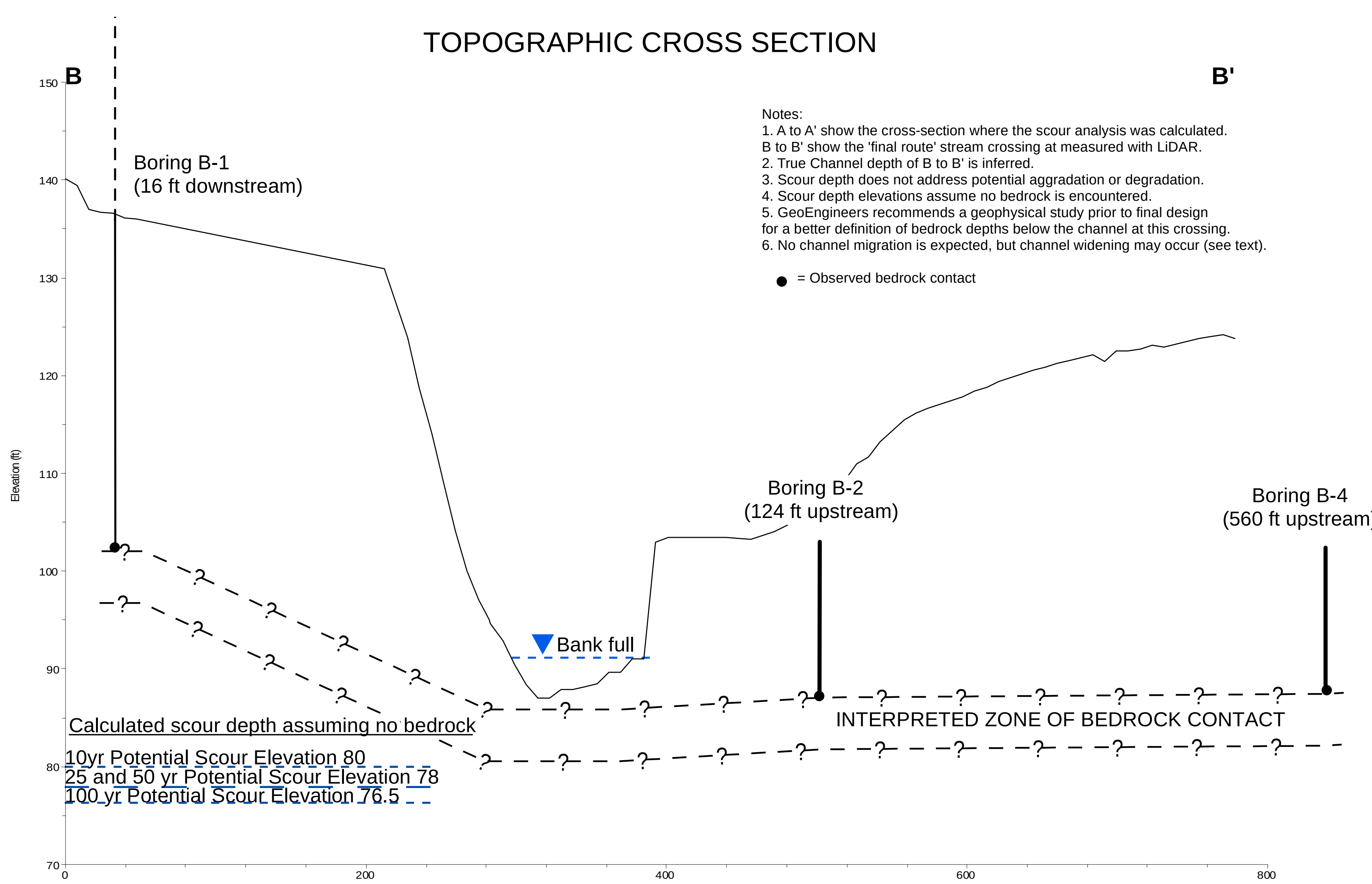
N

0 100 200 400 Feet

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Evaluated Stream Crossings
- Boring Locations
- Pipeline Cross Section
- Flow Direction
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road

TOPOGRAPHIC CROSS SECTION



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P:\22\22708001\GIS\MXD\2270800100_ElevMaps_MiddleCreek.mxd Date Exported: 08/25/17 by ccabrera

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PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossing Evaluation

RESULTS: MIGRATION & SCOUR
Middle Creek

FIGURE 19

TOPOGRAPHIC PLAN VIEW

Non-Internet Public

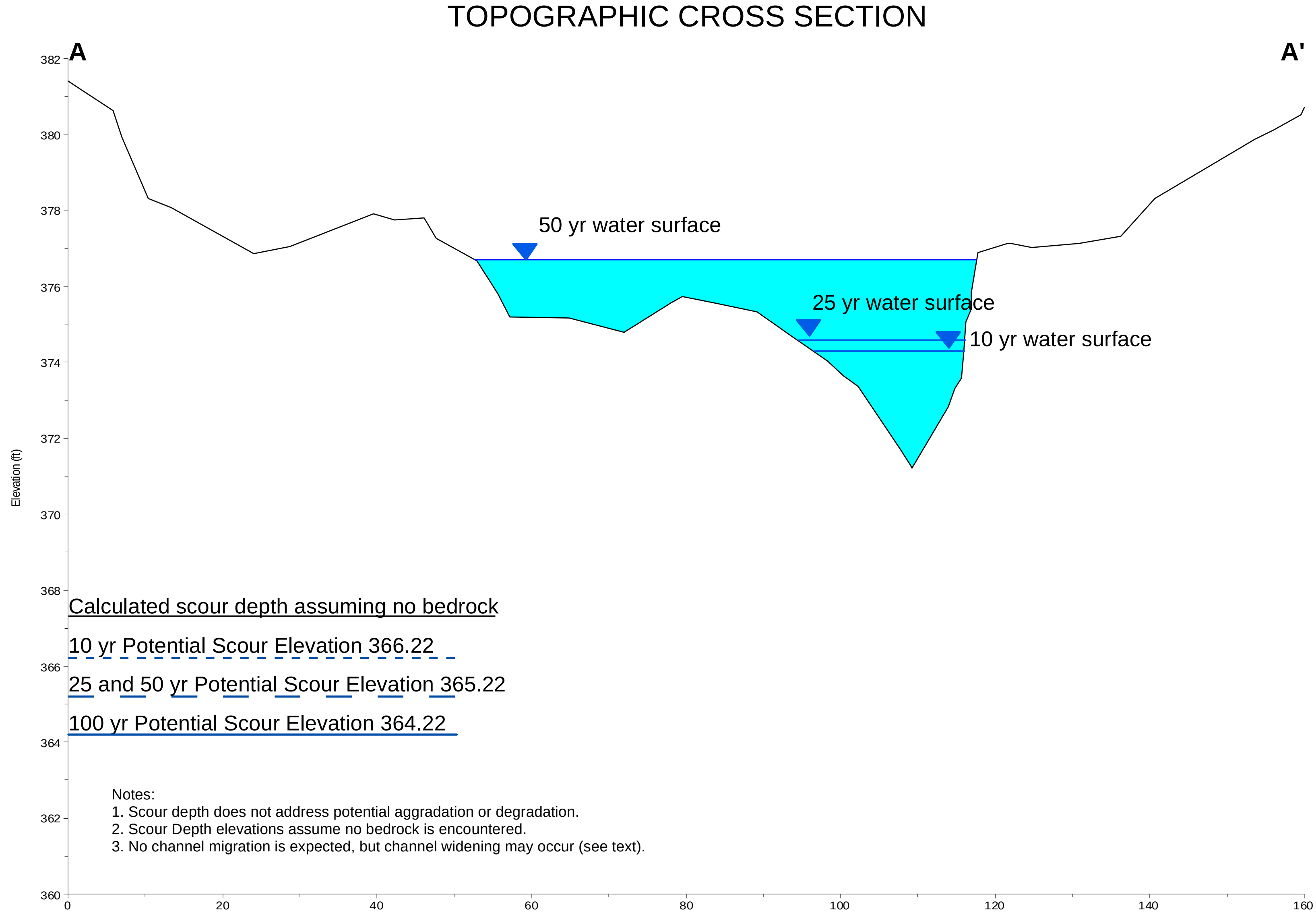
Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Evaluated Stream Crossings
- Pipeline Cross Section
- Flow Direction
- Watercourses
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road

N

0 100 200 400 Feet

TOPOGRAPHIC CROSS SECTION



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PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossing Evaluation

RESULTS: MIGRATION & SCOUR
South Fork Elk Creek

FIGURE 20

TOPOGRAPHIC PLAN VIEW

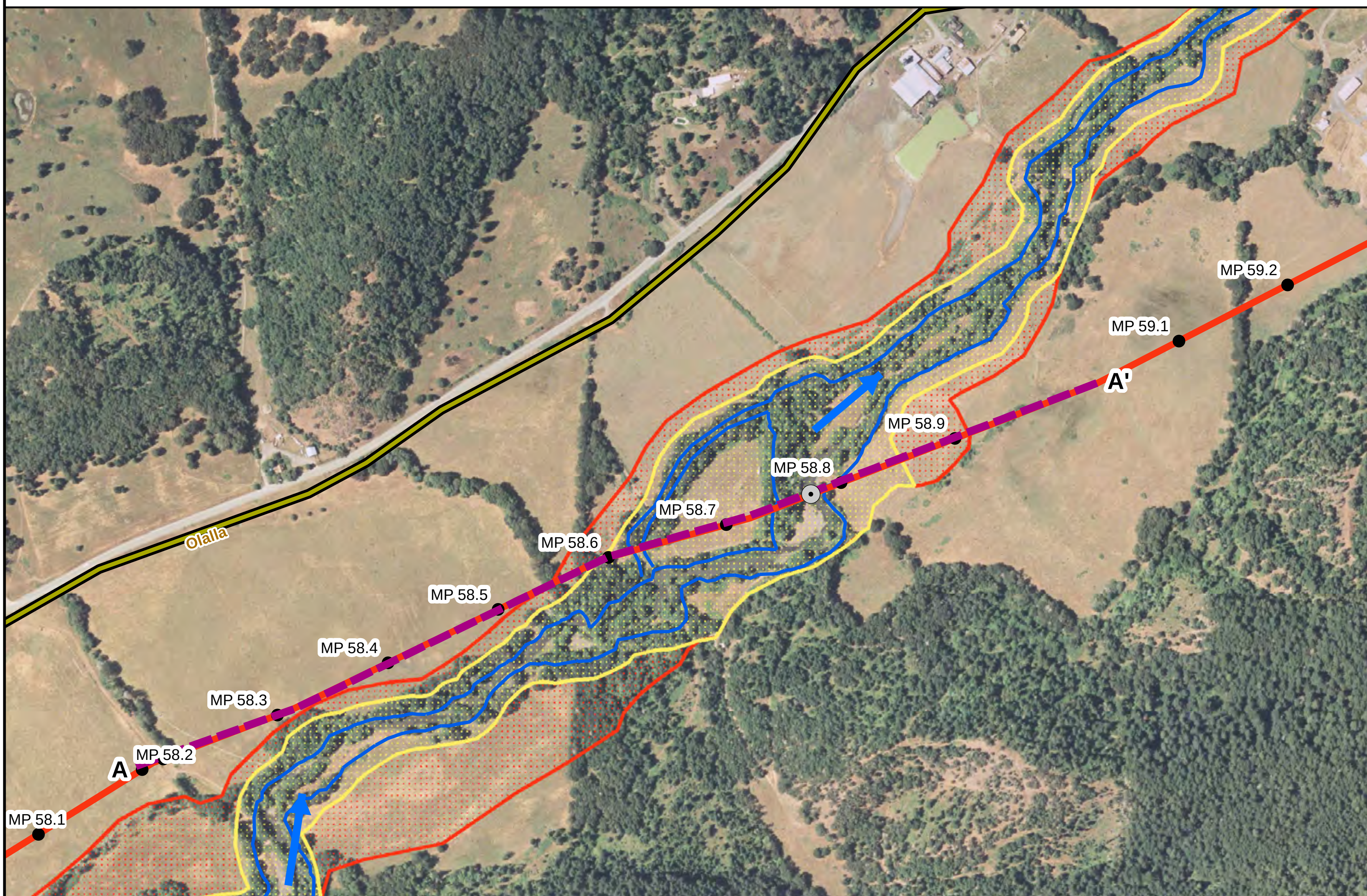
Non-Internet Public

N

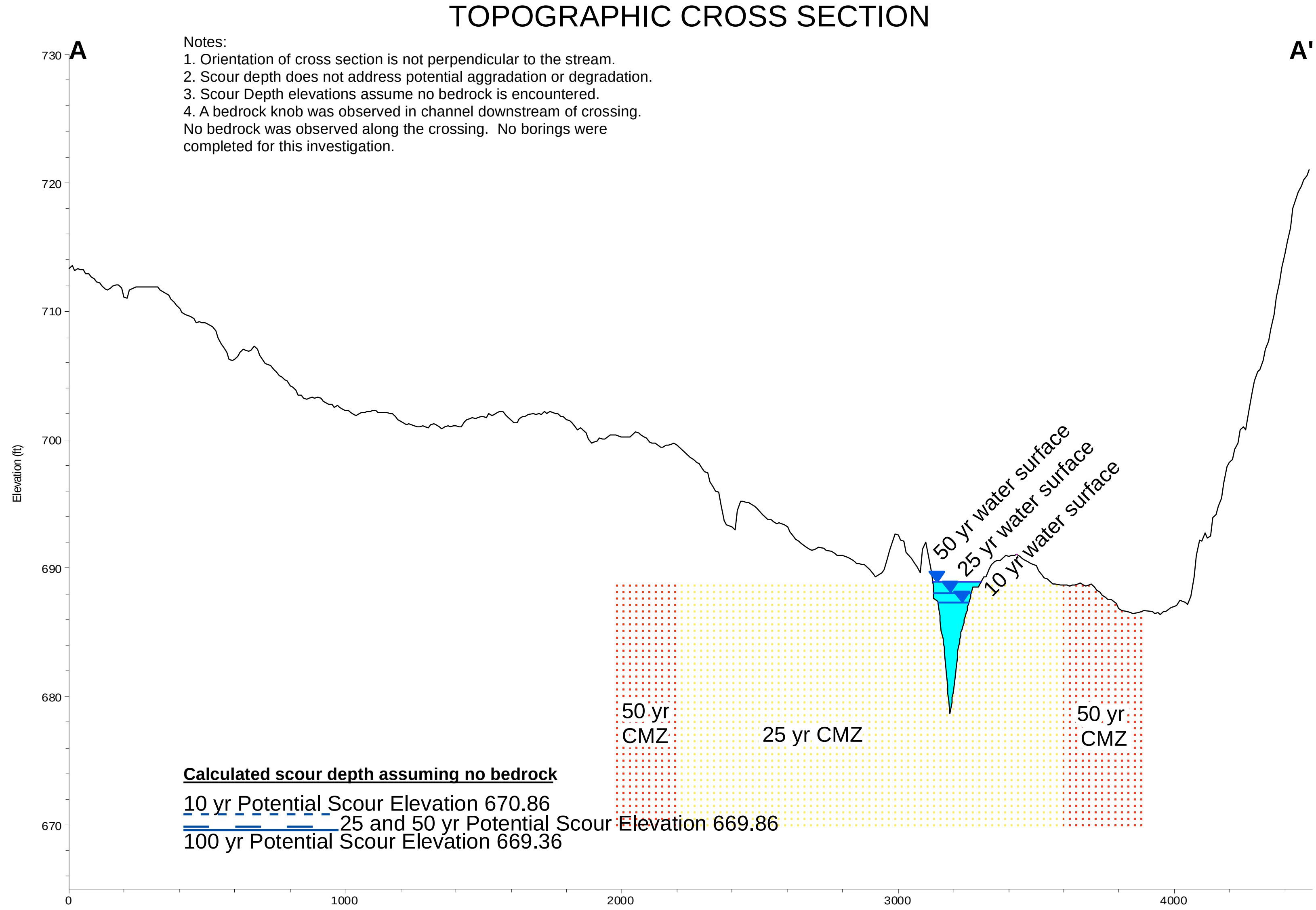
0 300 600 1,200 Feet

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Evaluated Stream Crossings
- Pipeline Cross Section
- Historic Channel Occupation Track
- Flow Direction
- 25yr CMZ
- 50yr CMZ
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road



TOPOGRAPHIC CROSS SECTION



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PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossing Evaluation

RESULTS: MIGRATION & SCOUR
Olalla Creek

FIGURE 21

TOPOGRAPHIC PLAN VIEW

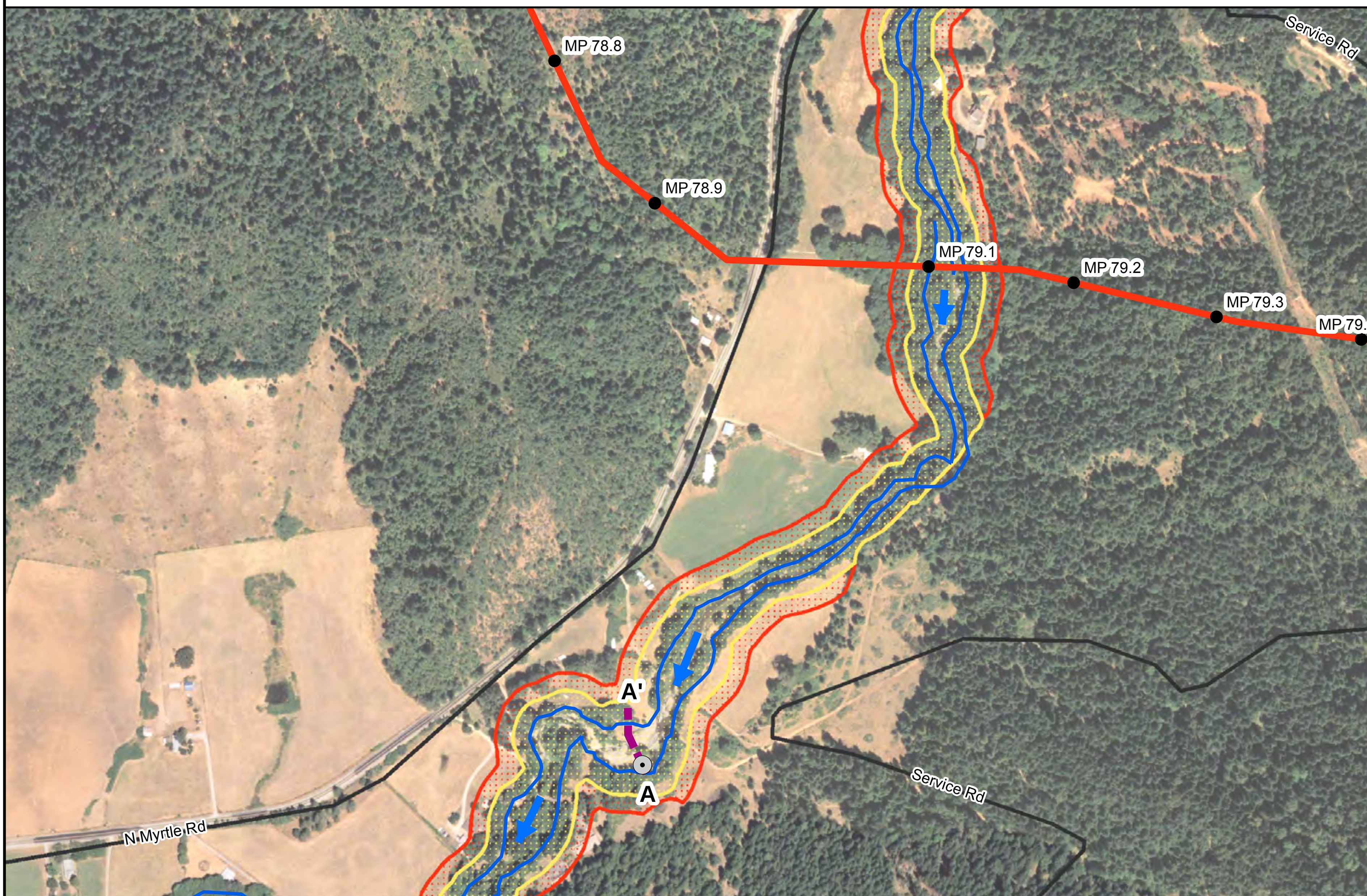
Non-Internet Public

N

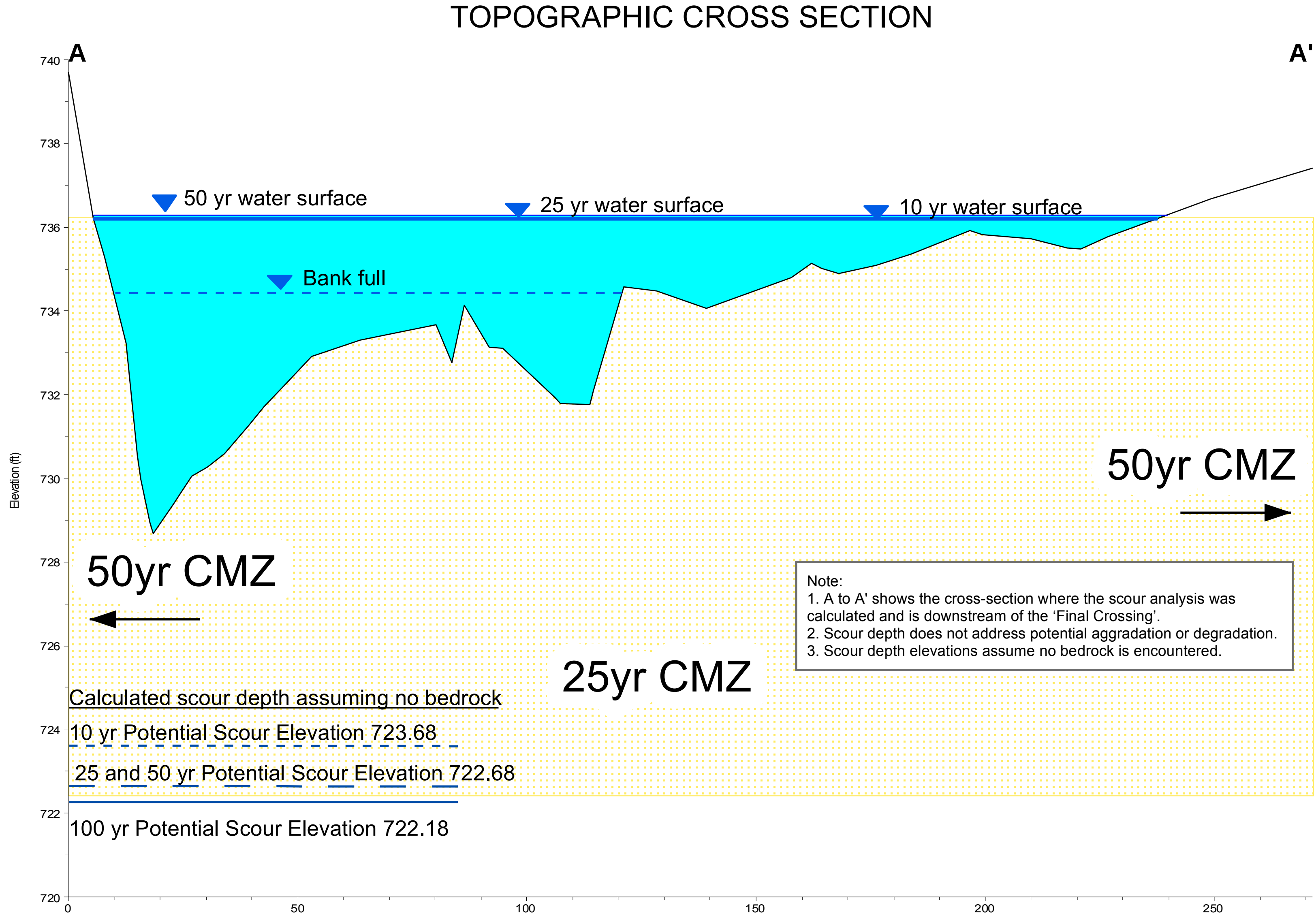
0 250 500 1,000 Feet

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Evaluated Stream Crossings
- Pipeline Cross Section
- Historic Channel Occupation Track
- Flow Direction
- 25yr CMZ
- 50yr CMZ
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road



TOPOGRAPHIC CROSS SECTION



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PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossing Evaluation

RESULTS: MIGRATION & SCOUR
North Myrtle Creek

FIGURE 22

TOPOGRAPHIC PLAN VIEW

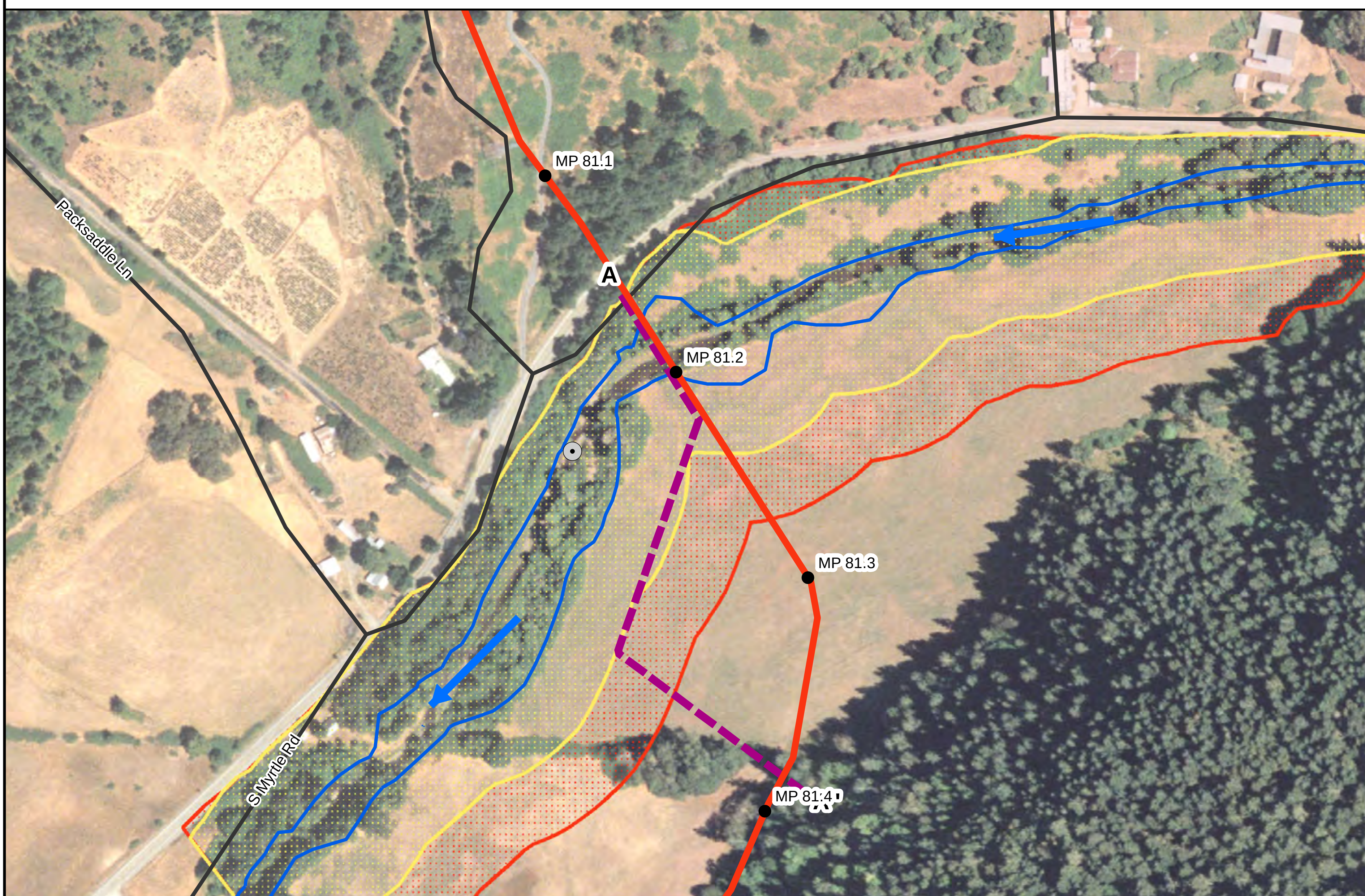
Non-Internet Public

N

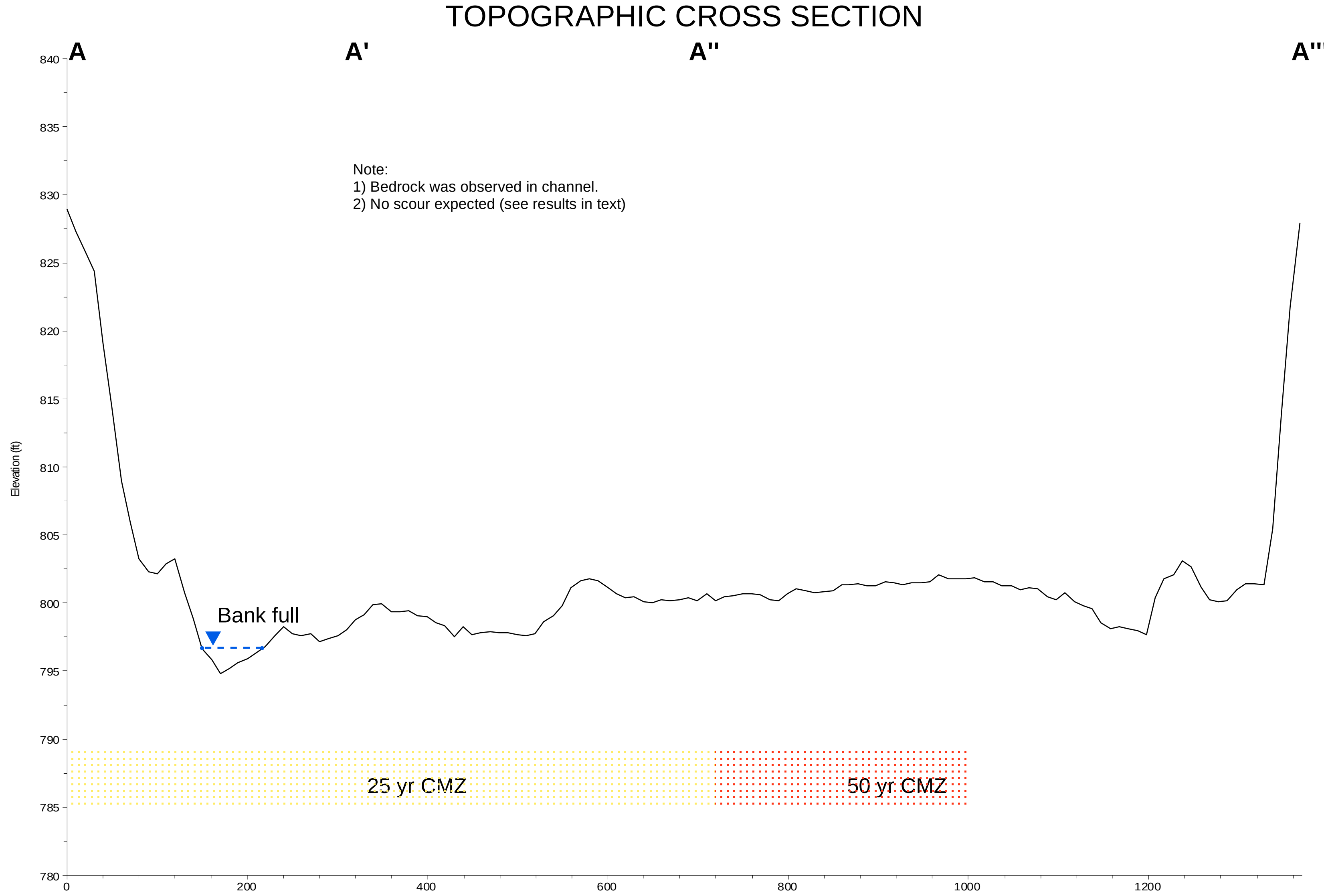
0 150 300 600 Feet

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Evaluated Stream Crossings
- Pipeline Cross Section
- Historic Channel Occupation Track
- Flow Direction
- 25yr CMZ
- 50yr CMZ
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road



TOPOGRAPHIC CROSS SECTION



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GEOENGINEERS

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossing Evaluation

RESULTS: MIGRATION & SCOUR
South Myrtle Creek

FIGURE 23

TOPOGRAPHIC PLAN VIEW

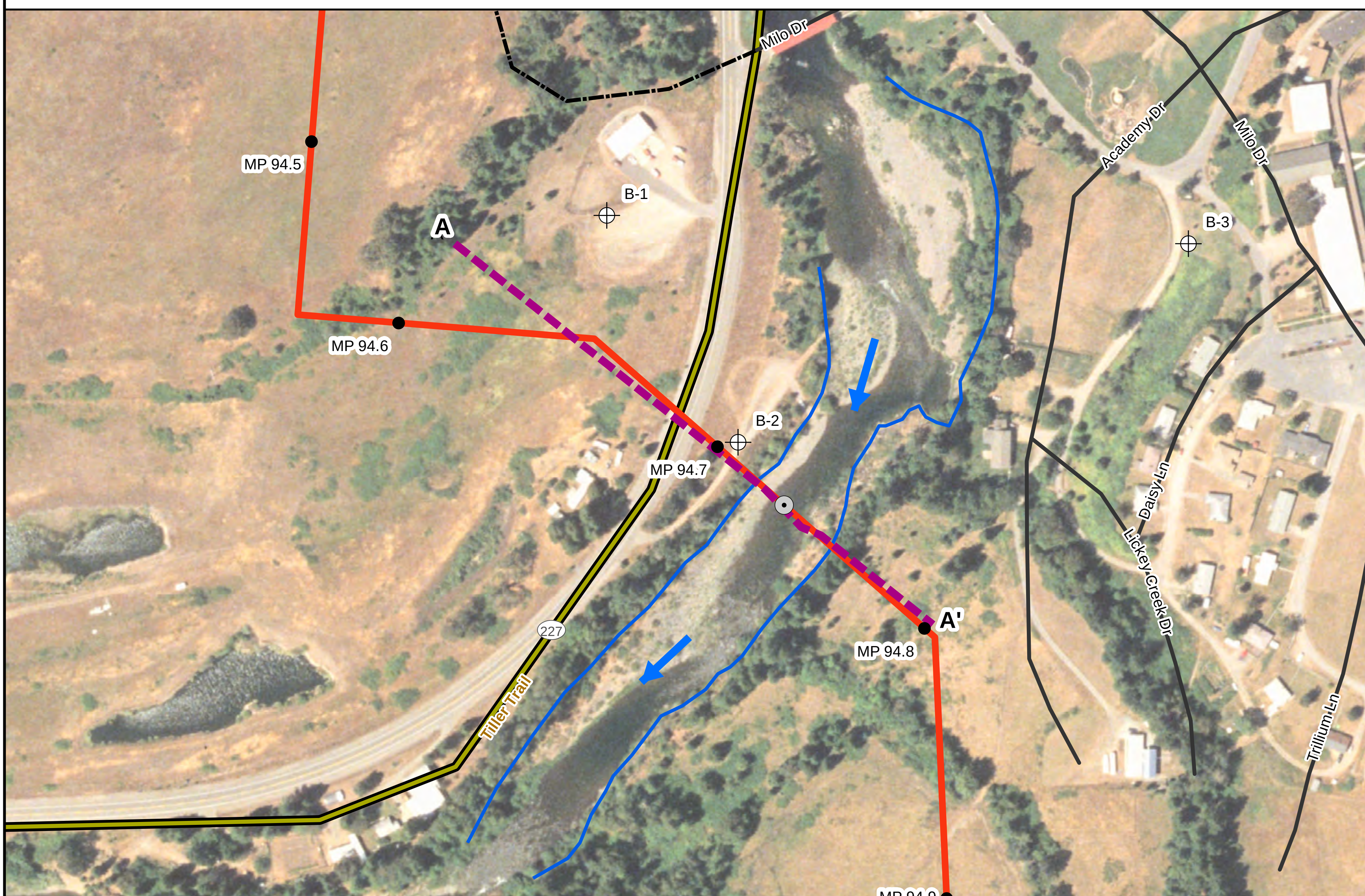
Non-Internet Public

Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Evaluated Stream Crossings
- Boring Locations
- Pipeline Cross Section
- Historic Channel Occupation Track
- Flow Direction
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road

N

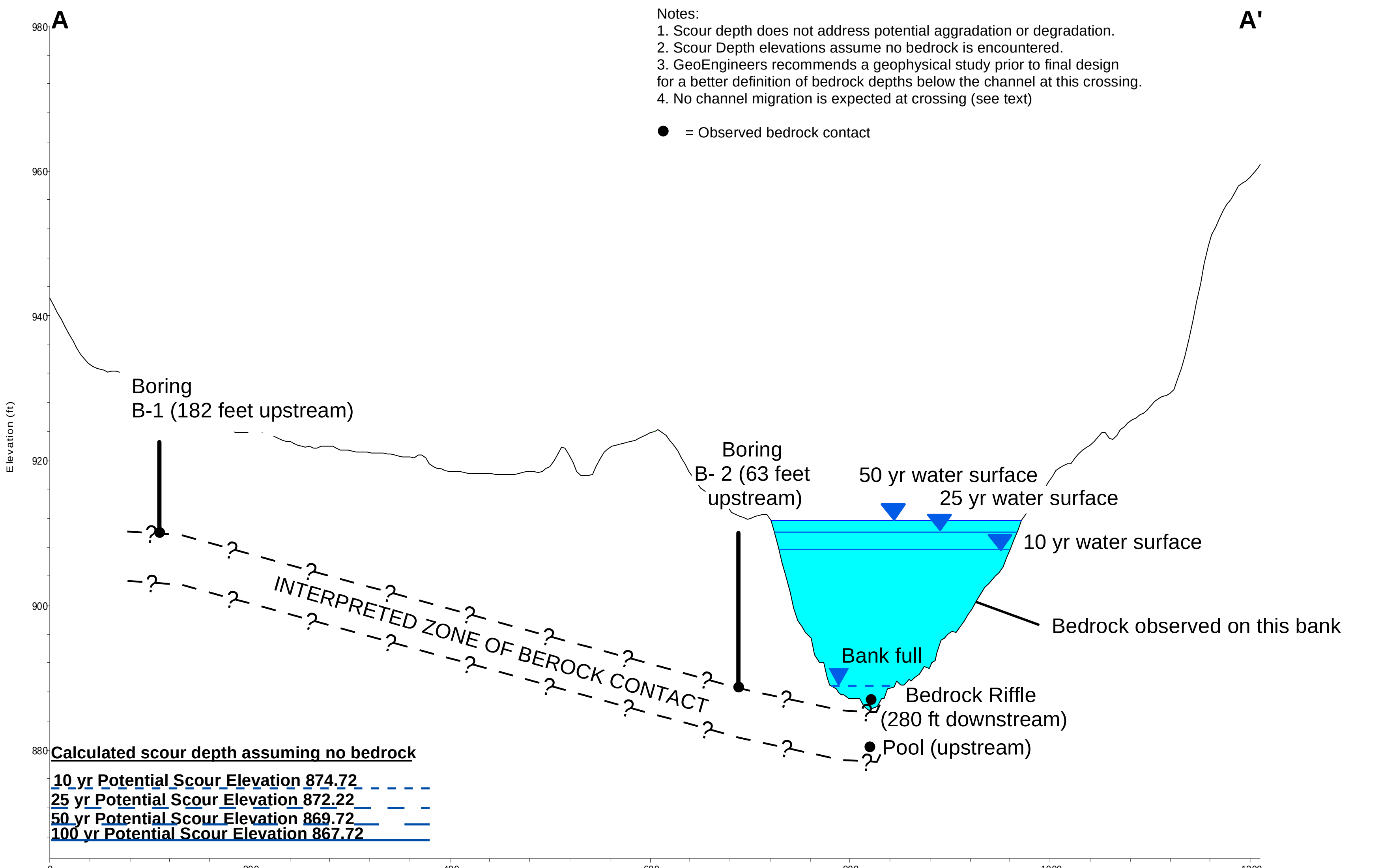
0 100 200 400 Feet



TOPOGRAPHIC CROSS SECTION

Notes:
1. Scour depth does not address potential aggradation or degradation.
2. Scour Depth elevations assume no bedrock is encountered.
3. GeoEngineers recommends a geophysical study prior to final design for a better definition of bedrock depths below the channel at this crossing.
4. No channel migration is expected at crossing (see text)

● = Observed bedrock contact



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GEOENGINEERS

PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossing Evaluation

RESULTS: MIGRATION & SCOUR
South Umpqua River Crossing No. 2

FIGURE 24

TOPOGRAPHIC PLAN VIEW

Non-Internet Public

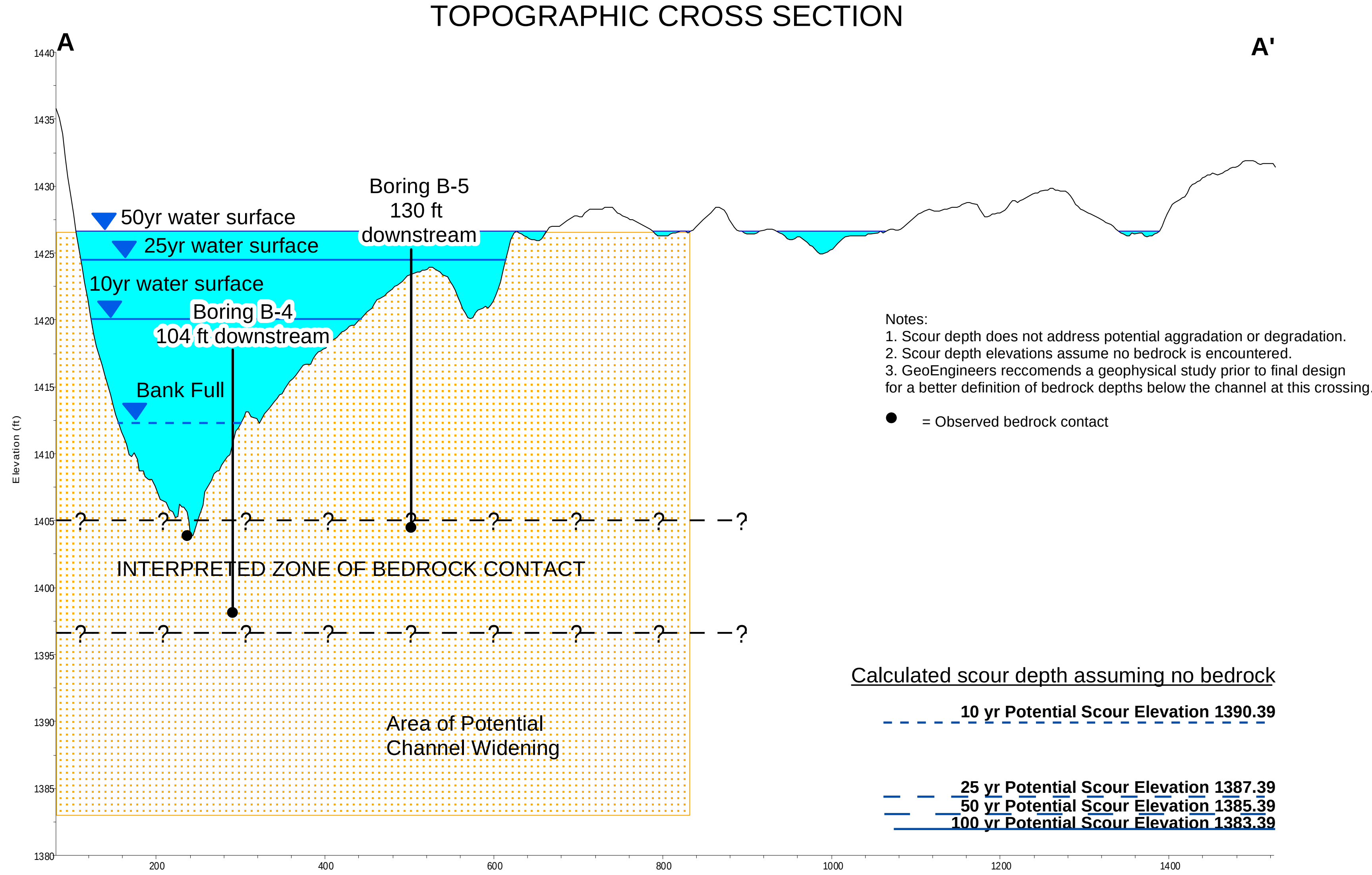
Explanation

- PCGP Proposed Route
- PCGP Route Mile Markers
- Evaluated Stream Crossings
- Boring Locations
- Pipeline Cross Section
- Historic Channel Occupation Track
- Area of Potential Channel Widening
- Flow Direction
- Freeway
- Highway
- Major Road
- Local Road
- Minor Road

N

0 100 200 400 Feet

TOPOGRAPHIC CROSS SECTION



Notes:
1. Scour depth does not address potential aggradation or degradation.
2. Scour depth elevations assume no bedrock is encountered.
3. GeoEngineers reccomends a geophysical study prior to final design for a better definition of bedrock depths below the channel at this crossing.

● = Observed bedrock contact

Calculated scour depth assuming no bedrock

10 yr Potential Scour Elevation 1390.39

25 yr Potential Scour Elevation 1387.39

50 yr Potential Scour Elevation 1385.39

100 yr Potential Scour Elevation 1383.39

Notes:
1. The locations of all features shown are approximate. 2. This drawing is for information purposes. GeoEngineers, Inc. cannot guarantee the accuracy and content of this map. 3. It is unlawful to copy or reproduce all or any part of this document whether for personal use or resale, without permission.

Data Sources: 2006 Digital Orthophoto from Sanborn Mapping Co.; Roads from ESRI Streetmap 2006, All other layers were created internally.

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PACIFIC CONNECTOR GAS PIPELINE PROJECT
PACIFIC CONNECTOR GAS PIPELINE LP
Stream Crossing Evaluation

RESULTS: MIGRATION & SCOUR
Rogue River

FIGURE 25

P:\22\22708001\GIS\MXD\2270800100_ElevMaps_RogueBedrock2.mxd Date Exported: 08/25/17 by ccabrera

Western Oregon Region 1 Regression Equation
Middle Creek

$Q_{fp}=aA^{b}I24\text{-}2^{c}MxJanT^{d}SoilC^{e}SoilP^{f}$

$Q_{(n)}$: discharge in cubic feet per second for the n-year recurrence interval
Area: drainage area, in square miles
I24-2: 2-year 24-hour precipitation intensity, in inches
MxJanT: mean maximum January temperature, in degrees Fahrenheit
Soil C: soil storage capacity, in inches
Soil P: soil permeability, in inches

Event	Constant	Coefficients					Std. Error
	a	b	c	d	e	f	(%) (+/-)
2yr	0.05056	0.9489	1.36	1.28	-0.4421	-0.1576	26.8
5yr	0.01316	0.9385	1.272	1.738	-0.5026	-0.2234	25.3
10yr	0.008041	0.9324	1.226	1.926	-0.5267	-0.2552	25.6
25yr	0.005122	0.9258	1.179	2.109	-0.5484	-0.2888	26.6
50yr	0.003888	0.9215	1.151	2.223	-0.5605	-0.3111	27.8
100yr	0.003048	0.9176	1.126	2.325	-0.5701	-0.3319	29.1
500yr	0.00189	0.9099	1.078	2.527	-0.5855	-0.377	32.6

Input Parameters		
Area	46	GIS
I24-2	2.5	Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon
MxJanT	52	Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon
Soil C	0.15	Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon
Soil P	1.5	Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon

Calculated Flows		Flows Adjusted to Standard Error	
	Peak	Low	High
Q_{2}	2269	1661	2877
Q_{5}	3492	2609	4376
Q_{10}	4341	3230	5452
Q_{25}	5470	4015	6926
Q_{50}	6334	4573	8095
Q_{100}	7225	5122	9327
Q_{500}	9348	6301	12396

Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon, Richard M Cooper
Scientific Investigations Report 2005-5116
U.S. Department of the Interior, U.S. Geological Survey

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PEAK DISCHARGE EQUATION RESULTS
MIDDLE (PARK) CREEK
PACIFIC CONNECTOR GAS PIPELINE PROJECT
LEVEL 2 STREAM CROSSING EVALUATION

FIGURE 26

Western Oregon Region 1 Regression Equation
South Fork Elk Creek

$Q_{fp}=aA^{b}I24\text{-}2^{c}MxJanT^{d}SoilC^{e}SoilP^{f}$

$Q_{(n)}$: discharge in cubic feet per second for the n-year recurrence interval
Area: drainage area, in square miles
I24-2: 2-year 24-hour precipitation intensity, in inches
MxJanT: mean maximum January temperature, in degrees Fahrenheit
Soil C: soil storage capacity, in inches
Soil P: soil permeability, in inches

Event	Constant	Coefficients					Std. Error
	a	b	c	d	e	f	(%) (+/-)
2yr	0.05056	0.9489	1.36	1.28	-0.4421	-0.1576	26.8
5yr	0.01316	0.9385	1.272	1.738	-0.5026	-0.2234	25.3
10yr	0.008041	0.9324	1.226	1.926	-0.5267	-0.2552	25.6
25yr	0.005122	0.9258	1.179	2.109	-0.5484	-0.2888	26.6
50yr	0.003888	0.9215	1.151	2.223	-0.5605	-0.3111	27.8
100yr	0.003048	0.9176	1.126	2.325	-0.5701	-0.3319	29.1
500yr	0.00189	0.9099	1.078	2.527	-0.5855	-0.377	32.6

Input Parameters		
Area	3	GIS
I24-2	3	Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon
MxJanT	52	Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon
Soil C	0.13	Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon
Soil P	2.4	Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon

Calculated Flows		Flows Adjusted to Standard Error	
	Peak	Low	High
Q_2	216	158	273
Q_5	329	246	412
Q_{10}	407	303	511
Q_{25}	511	375	648
Q_{50}	591	427	755
Q_{100}	673	477	868

Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon, Richard M Cooper
Scientific Investigations Report 2005-5116
U.S. Department of the Interior, U.S. Geological Survey

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PEAK DISCHARGE REGRESSION EQUATION RESULTS
SOUTH FORK ELK CREEK
PACIFIC CONNECTOR GAS PIPELINE PROJECT
LEVEL 2 STREAM CROSSING EVALUATION

FIGURE 27

Western Oregon Region 2B Regression Equation
Olalla Creek

$Q_{fp}=aA^bSlope^cI24\text{-}2^d$

$Q_{(n)}$: discharge in cubic feet per second for the n-year recurrence interval
Area: drainage area, in square miles
Slope: mean watershed slope, in degrees
I24-2: 2-year 24-hour precipitation intensity, in inches

Event	Constant	Coefficients			Std. Error
	a	b	c	d	(%) (+/-)
2yr	9.136	0.9004	0.4695	0.8481	32.6
5yr	14.54	0.9042	0.4735	0.7355	32.4
10yr	18.49	0.9064	0.4688	0.6937	33
25yr	23.72	0.9086	0.4615	0.6578	34.1
50yr	27.75	0.9101	0.4559	0.639	35.1
100yr	31.85	0.9114	0.4501	0.6252	36.2

Input Parameters		
Area	68	GIS
Slope	18	GIS
I24-2	2.5	Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon

Calculated Flows		Flows Adjusted to Standard Error	
	Peak	Low	High
Q_2	3448	2324	4572
Q_5	5088	3440	6737
Q_{10}	6201	4155	8247
Q_{25}	7607	5013	10201
Q_{50}	8661	5621	11702
Q_{100}	9706	6193	13220

Estimation of Peak discharges for Rural, Unregulated Streams in Western Oregon, Richard M Cooper
Scientific Investigations Report 2005-5116
U.S. Department of the Interior, U.S. Geological Survey

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PEAK DISCHARGE REGRESSION EQUATION RESULTS
OLALLA CREEK
PACIFIC CONNECTOR GAS PIPELINE PROJECT
LEVEL 2 STREAM CROSSING EVALUATION

FIGURE 28

APPENDICES

APPENDIX A
Stream Crossing Evaluations

TABLE A-1

Stream Crossing Summary (July 2017 Alignment)

Pacific Connector Gas Pipeline

Coos, Douglas, Jackson and Klamath Counties, Oregon

County	NHD Waterbody Reach Code[1]	Approximate 2017 Milepost	Stream Name	Waterbody ID[6]	Stream Type[2]	Geology	Hazard Level[3]	Hazard Determination		
								Scour	Migration	Avulsion
Coos	17100304000767	6.39R	Trib. to Coos Bay	S1-01 (EE-6)	per	Qal	0	None	None	None
Coos	17100304001393	8.27R	Willanch Slough	S1-04 (EE-7 (MOD)	per	Qal	0	None	None	None
Coos	*	8.46R	Trib. to Willanch Slough	GDX-30	int	Tc	0	None	None	None
Coos	17100304005045	10.21R	Trib. to Cooston Channel (Echo Creek)	SS-100-002	int	Tec	0	None	None	None
Coos	17100304000093	11.13R	Coos River	BSP-119	per	Qal	1	Moderate[4]	Low	None
Coos	17100304005031	11.55BR	Vogel Creek	SS-100-005 (BR-S-02)	per	Qal	0	None	None	None
Coos	17100304000507	15.11BR	Stock Slough	BR-S-36	int	Qal	0	None	None	None
Coos	17100304000507	15.32BR	Stock Slough	EE-SS-9068	int	Qal	0	None	None	None
Coos	17100305000361	20.20BR	Steinnon Creek	SS-500-003 (BR-S-63)	per	Qmt	0	None	None	None
Coos	17100305000339	23.06	North Fork Coquille River	BSP-207	per	Qft	1	Low	Low/Widening	None
Coos	17100305000361	24.32	Steinnon Creek	BR-S-63	per	Ter	0	None	Low	None
Coos	17100305012832	25.18	Trib. to Middle Creek	EE-SS-9073	int	Ter	0	None	None	None
Coos	*	27.01	Trib. to Middle Creek	BSI-137	int	Ter	0	None	None	None
Coos	*	27.03	Trib. to Middle Creek	BSI-135	per	Ter	0	None	None	None
Coos	17100305000323	27.04	Middle Creek	BSP-133	per	Ter	2	Mod-High[5]	Low/Widening	None
Coos	17100305002504	28.86	Trib. To E. Fork Coquille	BSP-77	per	Ter	1	None	None	None
Coos	17100305002598	29.30	Trib. To E. Fork Coquille	BSP-74	int	Tmms	0	None	None	None
Coos	17100305002647	29.47	Trib. To E. Fork Coquille	BSI-76	int	Qf	0	None	None	None
Coos	17100305000286	29.85	East Fork Coquille River	BSP-71	per	Qf	1	Low	Low/Widening	None
Coos	*	30.22	Trib. to E. Fork Coquille	SS-003-007A	int	Qf	0	None	None	None
Coos	17100305002813	30.29	Trib. to E. Fork Coquille	SS-003-007B	int	Twst	0	None	None	None
Coos	17100305018097	31.64	Trib. to E. Fork Coquille	BSI-70	int	Tw	0	None	None	None
Coos	17100305000284	32.40	Elk Creek	BSP-57	per	Tcv	1	Low	Low	None
Coos	17100305003267	32.44	Trib. To Elk Creek	BSP-55	per	Tcv	0	None	None	None
Coos	17100305021871	32.56	Trib. To Elk Creek	SS-100-030	int	Tcv	0	None	None	None
Coos	17100305021865	32.63	Trib. To Elk Creek	SS-100-031	int	Tcv	0	None	None	None
Coos	17100305003372	33.00	Trib. To Elk Creek	BSP-49	per	Tw	0	None	None	None
Coos	17100305003372	33.02	Trib. To Elk Creek	BSP-50	per	Tw	0	None	None	None
Coos	17100305000591	34.46	South Fork Elk Creek	CSP-5	per	Tw	2	Moderate	Low/Widening	None
Coos	17100305021783	35.51	Trib. To S. Fork Elk Creek	BSI-251	int	Tcv	0	None	None	None
Coos	17100305025781	35.87	Trib. To Big Creek	BLM-35.87/CSP-2	int	Tcv	0	None	None	None
Coos	17100305026477	36.48	Trib. To Big Creek	BLM 36.48	int	Tcv	0	None	None	None
Coos	17100305004068	36.54	Trib. To Big Creek	GSI025/BSI253	int	Tcv	0	None	None	None
Coos	17100305025748	36.85	Trib. To Big Creek	BLM 36.85	int	Tcv	0	None	None	None
Coos	17100305004061	36.92	Trib. To Big Creek	BSI-252	int	Tcv	0	None	None	None
Coos	17100305026126	37.32	Trib. to Big Creek	ESI-19	int	Tcv	0	None	None	None
Coos	17100305000606	37.35	Trib. to Big Creek	ESP-20	per	Tcv	1	Low	Low	None
Coos	17100305000252	44.21	Upper Rock Creek	BSP-41	per	Ttbs	1	None	None	None
Douglas	17100305005585	46.56	Trib. to Trib. to Upper Rock Creek	S3-07(BW-38)	per	Ttbs	0	None	None	None
Douglas	*	48.21	Ditch	S3-06	int	Tcv	0	None	None	None
Douglas	17100305005863	48.27	Deep Creek	BSP-257(MOD)	per	Tcv	1	None	None	None
Douglas	17100305000232	50.28	Middle Fork Coquille River	BSP-30	per	Qf	1	Low	Low/Widening	None
Douglas	17100305005874	50.45	Trib. to Middle Fork Coquille	GDX-36 (BS-66/67)	int	Twc	0	None	None	None
Douglas	17100305000706	50.71	Belieu Creek	GSI-37 (BSP-61)	per	Twc	0	None	None	None
Douglas	17100305022784	51.02	Trib. to Middle Fork Coquille	S1-07 (GSI-38)	int	Twc	0	None	None	None
Douglas	*	51.71	Unnamed Creek	SS-222-006	int	Tcv	0	None	None	None
Douglas	17100302001821	55.90	Trib. to Shields Creek	BSI-202	int	Qf	1	None	None	None
Douglas	17100302001894	55.94	Trib. to Shields Creek	BSI-203	int	Tm	0	None	None	None
Douglas	17100302044091	56.28	Trib. to Shields Creek	DA-13	int	Tm	0	None	None	None
Douglas	17100302044013	56.34	Trib. to Shields Creek	DA-14	int	Tm	0	None	None	None
Douglas	17100302048489	57.11	Trib. to Olalla Creek	BSI-140	int	KJdm	0	None	None	None
Douglas	*	57.14	Trib. to Olalla Creek	BSI-140	int	KJdm	0	None	None	None
Douglas	17100302002187	57.31	Trib. to Olalla Creek	BSI-138	int	Qf	0	None	None	None
Douglas	17100302002221	57.84	Trib. to Olalla Creek	EE-12 (BSI-147)	int	Qf	0	None	None	None
Douglas	17100302002311	58.20	Trib. to Olalla Creek	BSI-151	int	Qf	0	None	None	None
Douglas	17100302002420	58.55	Trib. to Olalla Creek	BSP-159	per	Qf	0	None	None	None
Douglas	17100302000047	58.78	Olalla Creek	BSP-155	per	Qf	2	High	High	Moderate
Douglas	17100302002576	59.02	Ditch Trib. to Olalla Creek	BDX153	int	Qft	0	None	None	None
Douglas	17100302002635	59.29	Trib. to Olalla Creek	BSI-132	int	Qft	0	None	None	None
Douglas	17100302000705	59.65	Trib. to Olalla Creek	BSI-129	int	Qft	0	None	None	None
Douglas	17100302002838	60.13	Trib. to McNabb Creek	NSP-14	per	Kjda	0	None	None	None
Douglas	17100302002924	60.48	McNabb Creek	NSP-13	per	Kjda	1	None	None	None
Douglas	17100302000075	63.97	Kent Creek	BSP-240	per	Qf	1	None	None	None
Douglas	17100302003968	63.97	Trib. To Kent Creek	BSI-241	per	Qf	1	None	None	None
Douglas	17100302000079	65.76	Rice Creek	BSP-227	per	Qf	1	None	None	None
Douglas	17100302004832	66.87	Trib. to Willis Creek	BSI-230	int	KJdm	0	None	None	None

County	NHD Waterbody Reach Code[1]	Approximate 2017 Milepost	Stream Name	Waterbody ID[6]	Stream Type[2]	Geology	Hazard Level[3]	Hazard Determination		
								Scour	Migration	Avulsion
Douglas	17100302000083	66.95	Willis Creek	BSP-168	per	Qf	1	None	None	None
Douglas	17100302048422	67.00	Trib. to Willis Creek	BSI-169	int	Qf	0	None	None	None
Douglas	17100302049984	69.10	Trib. to South Umpqua River	SS-005-001 (SS-100-011)	int	KJdd	0	None	None	None
Douglas	17100302005610	69.29	Trib. to South Umpqua River	SS-004-004 (SS-100-012)	per	KJdd	0	None	None	None
Douglas	17100302000727	69.35	Trib. to South Umpqua River	SS-004-005 (SS-100-013)	per	KJdd	0	None	None	None
Douglas	17100302005693	69.57	Trib. to South Umpqua River	SS-004-006 (SS-100-014)	int	KJdd	0	None	None	None
Douglas	17100302000086	71.27	South Umpqua River	BSP-26	per	Qf	2	High[5]	High	None
Douglas	17100302035572	71.35	Trib. to South Umpqua River	SS-005-008 (SS-100-016)	int	KJd2	0	None	None	None
Douglas	17100302006366	71.51	Trib. to South Umpqua River	SS-005-008 (SS-100-016)	int	KJd2	0	None	None	None
Douglas	17100302047304	71.69	Trib. to South Umpqua River	SS-005-008 (SS-100-016)	int	KJd2	0	None	None	None
Douglas	17100302006590	73.04	Trib. to South Umpqua River	SS-005-009 (SS-100-019)	int	KJd2	0	None	None	None
Douglas	17100302050160	73.51	Trib. to South Umpqua River	SS-005-013 (SS-100-020)	int	KJd2	0	None	None	None
Douglas	17100302049674	73.56	Trib. to South Umpqua River	SS-005-011 & 012 (SS-100-021)	int	KJd2	0	None	None	Low
Douglas	*	73.73	Unnamed Creek	SS-005-010	per	KJd2	0	None	None	None
Douglas	17100302007335	75.33	Rock Creek	EE-SS-9032	per	KJrc	0	None	None	None
Douglas	17100302001061	75.34	Trib. to Rock Creek	EE-SS-9033	per	KJrc	0	None	None	None
Douglas	17100302000605	76.38	Bilger Creek	BSP-1	per	Qf	1	None	None	None
Douglas	17100302001073	77.71	Little Lick	BSP-6	per	KJr	1	None	None	None
Douglas	17100302008039	77.93	Trib. to Little Lick Creek	BSI-8	int	KJr	0	None	None	None
Douglas	17100302008047	78.02	Trib. to Little Lick Creek	BSI-10	int	KJr	0	None	None	None
Douglas	17100302000541	79.12	North Myrtle Creek	NSP-37	per	Qf	2	High	High	None
Douglas	17100302008397	79.15	Trib. to North Myrtle Creek	NSP-38	per	KJi	0	None	None	None
Douglas	17100302045565	79.17	Trib. to North Myrtle Creek	EE-SS-9023	int	Qf	0	None	None	None
Douglas	17100302045117	79.19	Trib. to North Myrtle Creek	EE-SS-9024	int	KJi	0	None	None	None
Douglas	1232847430231	81.19	South Myrtle Creek	BSP-172	per	Qf	2	Low	High	None
Douglas	17100302000521	81.38	Trib. to S. Myrtle Creek	BSP-259	int	Qf	0	None	None	None
Douglas	17100302008772	81.45	Trib. to S. Myrtle Creek	SS-100-023	int	Qf	0	None	None	None
Douglas	17100302008917	81.93	Trib. to S. Myrtle Creek	EE-SS-9074	int	KJi	0	Low	None	None
Douglas	17100302001104	84.17	Wood Creek	BSP-226	per	m	1	Low	Low	None
Douglas	17100302009881	85.69	Trib. to Wood Creek	EE-SS-9041	int	Jri	0	None	None	None
Douglas	17100302001103	85.71	Trib. to Wood Creek	EE-SS-9042	per	Jri	0	None	None	None
Douglas	17100302036276	86.07	Trib. to Wood Creek	EE-SS-9044	int	Jri	0	None	None	None
Douglas	17100302036007	88.20	Trib. to Fate Creek	BSI-236	int	KJm	0	None	None	None
Douglas	17100302036007	88.23	Trib. to Fate Creek	BSI-238 (MOD)	int	KJm	0	None	None	None
Douglas	17100302001124	88.48	Fate Creek	BSP-232	per	KJg3	1	Low[5]	Low	None
Douglas	17100302000511	88.60	Days Creek	BSP-233	per	KJg3	1	Low[5]	Low/Widening	None
Douglas	17100302011280	92.62	Saint John Creek	ASP-303	per	Jms	1	None	None	None
Douglas	17100302011516	94.73	South Umpqua River	ASP-196	per	Qal	2	High[5]	Low	None
Douglas	17100302011517	94.85	Trib. to South Umpqua River	ASI-193 (ASI-191)	int	Qal	0	None	None	None
Douglas	17100302011517	95.03	Trib. to South Umpqua River	ASI-193 (ASI-191)	int	Qt	0	None	None	None
Douglas	17100302038007	98.46	Trib. to South Umpqua River	ASI-190	int	KJg1	0	None	None	None
Douglas	*	105.41	Ditch (Beaver Creek)	CDX-50	int	Ki	0	None	None	None
Douglas	17100302034497	109.33	Trib. to East Fork Cow Creek	GSI-16 (FS-HF-F)	int	Qls	0	None	None	None
Douglas	17100302013838	109.47	East Fork Cow Creek	GSP-19 (ASP-297/FS-HF-G)	per	Toev	0	None	None	None
Douglas	17100302013839	109.69	East Fork Cow Creek	GSP-22 (ASP-297/FS-HF-M)	per	Toev	0	None	None	None
Douglas	17100302012765	109.69	Trib. to East Fork Cow Creek	FS-HF-J	per	Toev	0	None	None	None
Douglas	17100302012789	109.78	Trib. to East Fork Cow Creek	FS-HF-K	per	Toev	0	None	None	None
Douglas	17100302034587	110.96	Trib. to East Fork Cow Creek	FS-HF-N (ESI068)	int	Tbc	0	None	None	None
Jackson	17100307015563	118.80	Trib. to W. Fork Trail Creek	SS-100-032	int	Tb1	1	None	None	None
Jackson	17100307000492	118.89	West Fork Trail Creek	ASP-202	per	Tb1	2	Low[5]	Moderate	None
Jackson	17100307002143	119.84	Trib. to Trail Creek	S1-06 (DA-16 (MOD))	int	Tb1	0	None	None	None
Jackson	17100307000501	120.45	Canyon Creek	NSP-11	per	Ti1a	1	None	None	None
Jackson	17100307009101	120.90	Trib. to Trail Creek	ASI-205	int	Ti1a	0	None	None	None
Jackson	17100307002356	121.57	Trib. to Trail Creek	ASI-206	int	Ti1a	0	None	None	None
Jackson	17100307002397	122.07	Cricket Creek	ESI-70	int	Tb1	0	None	None	None
Jackson	17100307000156	122.65	Rogue River	ASP-235	per	Qal	2	High[5]	Moderate	None
Jackson	17100307014756	125.91	Trib. to Indian Creek	ASI-223	int	Tr	0	None	None	None
Jackson	17100307016576	125.98	Trib. to Indian Creek	ASI-222	int	Tr	0	None	None	None
Jackson	17100307008662	126.53	Trib. to Indian Creek	RS-4	int	Trt	0	None	None	None
Jackson	17100307000826	126.56	Trib. to Indian Creek	ASI-221	int	Trt	0	None	None	None
Jackson	17100307006079	128.49	Deer Creek	ASP-307	per	Tb2	0	None	None	None
Jackson	17100307003031	128.61	Indian Creek	AW-278	per	Tb2	1	None	Moderate	None
Jackson	17100307017016	128.68	Trib. to Indian Creek	ASP-310	per	Tb2	0	None	None	None
Jackson	*	129.13	Trib. to Indian Creek	ASI-400	int	Tb2	0	None	None	None
Jackson	*	129.21	Trib. to Indian Creek	ASI-306	int	Tb2	0	None	None	None
Jackson	17100307017444	129.46	Trib. to Indian Creek	ASI-277	int	Tb2	0	None	None	None
Jackson	17100307011767	130.81	Trib. to Neil Creek	AW-245	int	Tb2	0	None	None	None
Jackson	17100307010117	130.83	Trib. to Neil Creek	AW-244	int	Tb2	0	None	None	None
Jackson	*	130.86	Trib. to Neil Creek	ASI-246	int	Tb2	0	None	None	None
Jackson	17100307018233	131.37	Trib. to Neil Creek	ASI-251	int	Tb2	0	None	None	None
Jackson	*	132.03	Irrigation Ditch (Trib. to Neil Creek)	S2-02 (ADX-253 (MOD))	int	Tb2	0	None	None	None

County	NHD Waterbody Reach Code[1]	Approximate 2017 Milepost	Stream Name	Waterbody ID[6]	Stream Type[2]	Geology	Hazard Level[3]	Hazard Determination		
								Scour	Migration	Avulsion
Jackson	17100307006088	132.12	Neil Creek	ASP-252	per	Tb2	1	None	None	None
Jackson	*	132.75	Trib. to Quartz Creek	S5-01 (ASI-265)	int	Tb2	0	None	None	None
Jackson	17100307000857	132.77	Quartz Creek	S5-02 (AW-264)	int	Tb2	0	None	None	None
Jackson	*	133.35	Trib. to Quartz Creek	ASP-241	per	Tb2	0	None	None	None
Jackson	17100307006008	133.38	Medford Aqueduct	ASP-240	per	Tub	0	None	None	None
Jackson	17100307000892	137.48	Whiskey Creek	ASI-207	int	Ql	0	None	None	None
Jackson	17100307012488	138.26	Trib. to Lick Creek	ASI-208	int	Ql	0	None	None	None
Jackson	17100307003986	138.44	Trib. to Lick Creek	SS-GM-10	int	Ql	1	Low	Low	Low
Jackson	17100307003986	138.50	Trib. to Lick Creek	ASI-210	int	Ql	0	None	None	None
Jackson	17100307000884	138.55	Trib. to Lick Creek	SS-GM-11	int	Ql	1	Low	Low	None
Jackson	*	138.74	Trib. to Lick Creek	SS-GM-13	int	Ti3a	0	None	Low	None
Jackson	17100307008463	139.07	Trib. to Lick Creek	SS-GM-14	int	Ti3a	0	None	Low	None
Jackson	*	139.21	Trib. to Lick Creek	SS-GM-15	int	Ti3a	0	None	Low	None
Jackson	*	139.28	Trib. to Lick Creek	SS-GM-16	int	Ti3a	0	None	Low	None
Jackson	*	139.42	Trib. to Lick Creek	ASI-217	int	Ti3a	0	None	None	None
Jackson	17100307019116	139.59	Trib. to Lick Creek	ASI-226	int	Ti3a	0	None	None	None
Jackson	17100307019116	139.63	Trib. to Lick Creek	ASI-227	int	Ti3a	0	None	None	None
Jackson	17100307019116	139.68	Trib. to Lick Creek	ASI-228	int	Ti3a	0	None	None	None
Jackson	17100307019116	139.72	Trib. to Lick Creek	ASI-229	int	Ti3a	0	None	None	None
Jackson	17100307009090	139.83	Trib. to Lick Creek	ASI-232	int	Twwt	0	None	None	None
Jackson	*	139.91	Trib. to Lick Creek	SS-GM-19	int	Twwt	0	None	None	None
Jackson	17100307000130	140.27	Lick Creek	ASI-233	int	Twf	1	None	None	None
Jackson	17100307004291	141.48	Trib. to Salt Creek	ASI-188	int	Twf	0	None	None	None
Jackson	17100307004291	141.49	Trib. to Salt Creek	RS-17	int	Twf	0	None	None	None
Jackson	17100307014306	141.95	Trib. to Salt Creek	ESI-30	int	Tmh3	0	None	None	None
Jackson	17100307018645	142.32	Trib. to Salt Creek	ESI-31	int	Tmh1	0	None	None	None
Jackson	17100307018645	142.35	Trib. to Salt Creek	ESI-31	int	Tmh2	0	None	None	None
Jackson	17100307000121	142.57	Salt Creek	ESP-34	per	Tmh2	1	None	None	None
Jackson	17100307014301	143.12	Trib. to Salt Creek	ESI-37	int	Tmh3	0	None	None	None
Jackson	17100307009770	143.51	Trib. to Long Branch Creek	ESI-38	int	Tmh3	0	None	None	None
Jackson	17100307011758	143.74	Trib. to Long Branch Creek	ESI-39	int	Twbt	0	None	None	None
Jackson	17100307009083	143.77	Trib. to Long Branch Creek	ESI-40	int	Twbt	0	None	None	None
Jackson	17100307000921	144.11	Long Branch Creek	ESI-38	int	Tsf1	0	None	None	None
Jackson	17100307004586	144.70	Trib. to S. Fork Long Branch Creek	GSP-5 (ESP-48)	per	Tmh3	0	None	None	None
Jackson	17100307004616	145.27	South Fork Long Branch Creek	GSI-6 (ESP-59)	int	Tsf1	0	None	None	None
Jackson	17100307004636	145.54	Trib. to S. Fork Long Branch Creek	ESI-61	int	Tsf1	0	None	None	None
Jackson	17100307000113	145.69	North Fork Little Butte Creek	ESP-66	per	Qya	2	Requires Field Visit		
Jackson	17100307004681	146.05	Trib. to N. Fork Little Butte Creek	ESI-56	int	Tsf1	0	None	None	None
Jackson	17100307004702	146.38	Trib. to N. Fork Little Butte Creek	ESI-55	int	Tsf1	0	None	None	None
Jackson	17100307000108	162.45	South Fork Little Butte Creek	ASP-165	per	Tpais	1	None	None	None
Jackson	17100307000107	166.21	Daley Creek	ESI-76 (ESI-84)	int	Tpbdp	0	None	None	None
Klamath	18010206000968	171.07	Spencer Creek	WW-001-013 (EW-85)	int	Qbbb	0	None	None	None
Klamath	18010206005900	171.57	Trib. to Spencer Creek	GSP-7	per	Tparc	0	None	None	None
Klamath	18010206000678	173.74	Trib. to Spencer Creek	ESI-106a	int	Qbbp	0	None	None	None
Klamath	18010206000677	176.54	Trib. to Spencer Creek	ESI-69	int	Qbuc	0	None	None	None
Klamath	18010206000677	176.56	Trib. to Spencer Creek	GSI-10	int	Qbuc	0	None	None	None
Klamath	18010206000330	177.76	Clover Creek	SS-502-EW103	int	Qbbp	1	None	None	None
Klamath	18010206000330	177.76	Clover Creek	GSI-11	int	Qbbp	1	None	None	None
Klamath	18010206002774	186.61	Trib. to Klamath River	ESI-97	int	Qal	0	None	None	None
Klamath	18010206000682	186.65	Trib. to Klamath River	ESI-99	int	Qal	0	None	None	None
Klamath	*	186.74	Trib. to Klamath River	ESI-100	int	Toat	0	None	None	None
Klamath	18010204003103	188.90	Trib. to Klamath River	SS-001-001 (SS-100-025)	int	Trnd	0	None	None	None
Klamath	18010204003315	192.67	Irrigation Ditch	S2-07 (ADX-63 (MOD))	int	Qvs	0	None	None	None
Klamath	18010204003303	194.64	Irrigation Ditch	WW-001-010 (ADX-78)	int	Qvs	0	None	None	None
Klamath	18010204003183	196.78	Irrigation Ditch	ADX-38	int	Qvs	0	None	None	None
Klamath	18010204002564	199.38	Klamath River	ASP-151	per	Qal	1	Moderate	Moderate	None
Klamath	18010204003246	200.54	Irrigation Canal; No. 1 Drain	ADX-294	int	Qvs	0	None	None	None
Klamath	*	201.63	Irrigation Ditch; C-4-E Lateral	ADX-96	int	Ts	0	None	None	None
Klamath	18010204001225	204.12	Irrigation Canal; C-4 Lateral	ADX-100	int	Qvs	0	None	None	None
Klamath	18010204001222	204.33	Irrigation Canal; C-4-F Lateral	ADX-101	int	Qvs	0	None	None	None
Klamath	18010204003757	204.74	Ditch; No. 3 Drain	ADX-105	int	Qvs	0	None	None	None
Klamath	18010204001218	205.50	Ditch; C-4-C Lateral	ADX-109	int	Qvs	0	None	None	None
Klamath	18010204004021	205.96	Canal (C Canal)	ADX-111	int	Qvs	0	None	None	None
Klamath	18010204009070	205.97	Wetland Ditch	ADX-112	int	Qvs	0	None	None	None
Klamath	*	206.51	Irrigation Ditch; 2-D Lateral	ADX-113	int	Qvs	0	None	None	None
Klamath	18010204004039	207.26	Roadside Drainage Ditch; 5-A-Drain	ADX-115	int	Qvs	0	None	None	None
Klamath	18010204001229	207.40	Irrigation Lateral; C-4-7 Lateral	ADX-116	int	Qvs	0	None	None	None
Klamath	18010204001237	207.42	Drainage Ditch; Irrigation 5-A Drain	ADX-117	int	Qvs	0	None	None	None
Klamath	18010204001237	207.60	Drainage Ditch; Irrigation 5-A Drain	ADX-118	int	Qvs	0	None	None	None
Klamath	18010204001237	207.99	Drainage Ditch; Irrigation 5-A Drain	ADX-119	int	Qvs	0	None	None	None
Klamath	18010204001237	208.18	Drainage Ditch; Irrigation 5-A Drain	ADX-123	int	Qvs	0	None	None	None

County	NHD Waterbody Reach Code[1]	Approximate 2017 Milepost	Stream Name	Waterbody ID[6]	Stream Type[2]	Geology	Hazard Level[3]	Hazard Determination		
								Scour	Migration	Avulsion
Klamath	18010204001229	209.02	Irrigation Drain; 5-K Drain	ADX-130	int	Qvs	0	None	None	None
Klamath	*	209.15	Irrigation Lateral; C-9 Lateral	ADX-134	int	Qvs	0	None	None	None
Klamath	*	209.16	Irrigation Ditch	ADX-135	int	Qvs	0	None	None	None
Klamath	18010204004367	210.26	Irrigation Ditch; No. 5 Drain (Trib. to Lost River)	SS-003-001 (ADX-143)	int	Qvs	0	None	None	None
Klamath	18010204015577	210.85	Irrigation Ditch; 5-H Drain (Trib. to Lost River)	ADX-260	int	Qvs	0	None	None	None
Klamath	18010204004545	212.07	Lost River	SS-003-005 (NSP-1)	per	Qal	1	None	None	None
Klamath	18010204001228	214.18	G Canal	ADX-275	int	Qvs	0	None	None	None
Klamath	18010204004618	216.10	Unnamed Creek	ASI-51	int	Qal	0	None	None	None
Klamath	18010204004618	216.11	Unnamed Creek	ASI-52	int	Qal	0	None	None	None
Klamath	18010204004617	216.30	Unnamed Creek	ASI-50	int	Qal	0	None	None	None
Klamath	18010204004627	216.44	Unnamed Creek	ASI-49	int	Qal	0	None	None	None
Klamath	18010204001993	218.09	Trib. to D Canal	ASI-136	int	Ts	0	None	None	None
Klamath	18010204004701	218.46	Trib. to D Canal	ASI-137	int	Ts	0	None	None	None
Klamath	18010204004701	219.69	Trib. to D Canal	ASI-291	int	Thv	1	None	None	None
Klamath	18010204001318	225.96	Trib. to V Canal	ASI-140	int	Ts	1	None	None	None

Notes:

[1] National Hydrography Framework Clearinghouse Waterbody longitude/latitude unique identifier number.

[2] int = intermittent; eph = ephemeral; per = perennial; unk = unknown

[3] Stream crossings were initially evaluated along the project alignment for potential scour, migration and/or avulsion using available aerial photos and GIS data. Each stream was assigned a numerical value of 0, 1 or 2. Level 0 = stream crossings not likely subject to scour, migration and/or avulsion; 1 = stream crossing with a moderate potential for scour, migration and/or avulsion; 2 = stream crossing with a high potential for scour, migration and/or avulsion. Some streams identified as Level 1 and all identified as Level 2 were further evaluated with a site reconnaissance and site-specific analyses during the Phase 2 evaluation. The proposed route was reevaluated for potential scour, migration and/or avulsion using GIS data including aerial photos, LiDAR, geology maps, soils maps, and applicable field notes from our Phase 2 Analysis.

[4] Results of Coast & Harbor Scour Evaluation, August 2007.

[5] It is assumed that depth of scour is expected to be limited by bedrock.

[6] Edge Environmental waterbody identification.

*These waterbody features were delineated in the field, but not associated with a Pacific Northwest Hydrography Framework Clearinghouse unique stream longitude/latitude identifying number

APPENDIX B
Methods

APPENDIX B
1.0 METHODS

1.1 Field Reconnaissance

1.1.1 Introduction

In the first phase of this project (GeoEngineers Stream Crossing Assessment Report, June 15, 2006) a geographic information systems (GIS) database and stereo aerial photos were used to identify stream crossings displaying migration, avulsion and/or scour potential. The GIS database includes the following layers derived from the stated sources:

1. Aerial orthorectified photographs – PCGP
2. 10-meter Digital Elevation Model (DEM) – United States Geological Survey (USGS)
3. Stream Layer – Pacific Northwest Hydrography Framework Clearinghouse
4. Geology – USGS: Walker and MacLeod, 2002
5. Soils – Natural Resources Conservation Service (NRCS)
6. Slope Inclinations – GeoEngineers (derived from 10-meter DEM)
7. Landslides – Oregon Department of Geology and Mineral Industries (primarily)
8. PCGP proposed alignment
9. Light Detection and Ranging (LiDAR) – Sanborn Mapping Co.

1.1.2 Field Observations

Site reconnaissance was conducted at 17 Phase II crossings by a GeoEngineers field team consisting of one geologist and one geomorphologist. The purpose of the reconnaissance was twofold: (1) evaluate whether physical conditions and processes at the site are sufficient to cause or support channel migration, avulsion and/or scour; and (2) assess whether or not a detailed topographic survey was needed to complete a migration and/or scour analysis.

Field observations were made at each crossing to supplement the migration and scour analyses and to serve as a means of ground-truthing numerical output from scour equations. Field observations and measurements were separated into four categories: (1) general; (2) scour; (3) migration; and (4) avulsion.

General observations included, at a minimum, channel geometry, presence of bedrock, the composition of bed, bank and floodplain soils, and streambed conditions. The crossing conditions were documented in photographs and sketches to aid the migration and scour analyses.

Scour observations included depths of the deepest streambed pools, evidence of scour/erosion, evidence of deposition, the locations of bedrock outcrops in the vicinity of the crossing, and estimated roughness values for the streambed and floodplain (Manning's n). An estimation of D_{50} (medium grain size in a stream) with a pebble count was performed for gravel- or cobble-dominated systems and a bulk sample was collected and analyzed in the GeoEngineers soils lab for grain size distribution at sand-dominated sites.

Migration observations included locations of bars, channel confinement and bank erosion (if any), as well as land use, human modifications and vegetation.

Avulsion observations included locations of abandoned channels, high-flow channels, side channels (if any) and the relative elevations of all channel streambeds.

The proposed alignment was modified after the October 2006 site reconnaissance (Figure 1). Each crossing was re-evaluated with respect to the new alignments and is discussed in detail in Appendix C.

1.2 Migration Analysis

1.2.1 Introduction

Completion of the migration analysis required the project team to compile large volumes of information. The information included historical photos dating back to the early 1900s, recent aerial photographs, printed topographic and geologic maps, and digitized data, all of which are published in different scales and formats. The evaluation necessitated bringing the information into a common coordinate system in order to accurately compare and review of individual streams and crossings. In order to achieve the flexibility required, the project approach utilized GIS technology for review and evaluation of the database, and as an analytical tool. GIS also provided the tools for generating the 25-year, 50-year and 100-year Channel Migration Zone (CMZ) boundaries. The calculated widths of the migration periods were further evaluated to assess, qualitatively, how well the 25-, 50-, and 100-year CMZ widths represent future channel behavior. The 100-year CMZ is least representative of future channel migration potential and channel location for all crossings. Based on all input factors described above, the 100-year CMZ was eliminated from the analysis for all crossings.

1.2.2 Data Collection, Review and Selection

Information collected for this project included written reports, current and historical maps and aerial photographs, orthophotographs, soils and geologic maps, and GIS electronic data. The existing GIS layers were reviewed to identify key information with regard to geology, topography, soils, land use and infrastructure. The information provided a framework for evaluating channel and land use changes.

Available maps and photographs dating from 1939 through 2011 were reviewed. To manage the volume of data for the analysis, aerial photographs and maps suitable to project goals were selected. Hard copies of photos and maps were converted into the GIS database via electronic georeferencing and rectification. The criteria for selection and inclusion of aerial photographs and maps in the GIS database included: (1) obtaining the earliest and most recent flight year coverage; (2) the extent of coverage; (3) changes in channel position or other significant features; and (4) condition and visual quality of photograph and maps. Based on these criteria, photographs from several flight years were selected and scanned (Appendix C, Table C-3). A total of 118 photographs and/or historical maps were reviewed. Of those, 52 were georeferenced and/or rectified into the GIS database.

1.2.3 GIS Data Development

Two major types of GIS data were developed: (1) digital georeferenced and/or rectified aerial photographs; and (2) delineated CMZ boundaries. All GIS data development and analysis were completed using ESRI's ArcGIS version 10.1 software.

The aerial photographs were scanned or downloaded from available Bing Maps aerial photography files and georeferenced and/or rectified to 2010 orthophotography. Due to inherent distortions when georeferencing and/or rectifying older photographs to current orthophotographs, the target Route Mean

Square (RMS) error of all the control points was equal to or less than 4 feet. In some cases, only a portion of the photograph was georeferenced and/or rectified.

The development of GIS data included digitizing and attributing points, lines and polygons with critical information from scanned aerial photographs. Digitizing was completed at a scale of approximately 1:6,000 (or 1 inch = 500 feet). Critical information was digitized into three GIS shape files, also referred to as GIS layers: (1) active channel locations; (2) Historic Channel Occupation Tracts (HCOTs); and (3) CMZ boundaries.

Active channels are defined as the wetted channel width observed on the aerial photographs and are generally correlative with the low flow channel. Attributes were added to the channel layer within GIS in order to distinguish the different aerial photograph years.

HCOT is defined as the zone within which the active channel has been located from the earliest photo of record to the most recent photo. By definition, the width of the HCOT is equal to or greater than the width of any single active channel. The HCOT also includes areas occupied by the channel during historical peak flows.

CMZ boundaries are defined as the distance the channel edge could migrate laterally or downstream away from the HCOT at a measured rate of erosion over specified periods of time.

1.2.4 Geomorphic Evaluation

A key element of the CMZ analysis included identifying the geomorphic processes operating throughout the project area and evaluating the effects of those processes on migration. Channel migration is a dynamic process driven by the interaction of physical characteristics and geomorphic processes operating at both local and watershed scales. Physical characteristics include topography, geology, regional and local gradient, channel dimensions, and the composition of riverbank and streambed materials. Primary geomorphic processes include basin- and reach-scale flow dynamics, sediment supply and delivery, sediment transport capacity, and erosion and deposition within the channel.

A principal objective of the geomorphic evaluation was to identify the type and character of migration operating at both the local and river reach scales. The approach involved the following steps: (1) conduct a geomorphic evaluation on a reach scale; (2) calculate migration rates over the length of observed record for each reach; and (3) evaluate reaches for regional geomorphic changes.

1.3 CMZ Delineation

1.3.1 Calculation of Unconfined Migration Rates

Total rates of migration were calculated for each reach by dividing measured distances between observed channel positions by the number of years between channel positions. Measurements were made directly from channel positions digitized from dated aerial photographs scanned and georeferenced and/or rectified into the GIS database. Migration distances were measured at sites deemed representative of the dominant type and character of channel migration observed throughout the reach. Both lateral and downstream migration rates were documented throughout the study areas.

1.3.2 CMZ Delineation

The CMZ was delineated assuming the absence of levees and revetments, and based on several factors including the following:

- The HCOT over the observable period of record;
- The character of migration identified in each reach;
- The maximum rate of lateral and downstream migration for each reach; and
- The locations of ancient and historical abandoned channels.

The delineation approach assumes that in the absence of channel constraints, the future rate and character of migration will be similar to those of the past, given similar water and sediment discharge conditions. The width of the CMZ identifies the distance the channel could travel in a specific period of time, such as 25 or 50 years, in the absence of confining structures. Based on the character of unconfined migration, the distance of lateral migration in each direction was calculated by multiplying the maximum annual rate of migration for each reach by 25 and 50 years in a single direction. Migration distances were measured from the outside edges of the observed HCOT.

1.3.3 Exceptional Conditions

The width of the CMZ may be modified from the minimum calculation defined above, based on factors requiring geologic interpretation and professional judgment. These factors include the proximity of the channel corridor to valley walls and/or hard, erosion-resistant geologic units, and the proximity of roadways and/or railroad embankments or other obstructions that are likely to be maintained over the life of the project.

The results of CMZ analyses were further evaluated to assess, qualitatively, how well the 50-year CMZs represent future channel behavior. For example, calculated rates of migration typically decline with distance away from the existing channel. In addition, dominant trends of downstream migration can significantly reduce the long-term ability of the channel to migrate laterally.

CMZs were delineated for Olalla Creek, North Myrtle Creek and South Myrtle Creek. A summary of the CMZ delineations for these crossings is presented in Appendix C (Table C-1) and in Figures 15, 16 and 17.

1.4 Scour Analysis

1.4.1 Introduction

An estimation of potential streambed scour was conducted at six stream crossing locations along the proposed PCGP route. Streambed scour is a function of channel geometry, peak flow volumes, bed composition and any man-made structures placed in the stream that may induce scour. In the absence of structures placed by man, natural streambed scour is most severe when associated with restrictions in river widths, caused by morphological channel changes, and influenced by erosive flow patterns resulting from channel alignment such as a bend in a meandering stream (Pemberton and Lara, 1984). The sites selected for analysis in this study do not have man-made structures placed in the stream that may induce increased scour; rather, they are subject to natural streambed scour associated with meander bends and channel constrictions.

In the absence of long-term empirical data or observations on degradation at each stream crossing, this study applied the best available science to estimate streambed scour stochastically. The methods and analyses are described in detail in the following sections.

Quantitative scour analysis was conducted for each of the six sites selected for detailed study (). Results of the analyses provide specific information regarding the potential depth of vertical channel degradation.

1.4.2 Topographic Survey

Topographic and bathymetric survey data were collected at each of the six sites, in addition to Coos River, which was analyzed for tidal scour. GeoEngineers subcontracted with David Evans and Associates (DEA) to complete the survey program. A set of specific instructions was provided to DEA by GeoEngineers with the intention of efficient transfer of topographic data into a hydraulic model.

Based on an aggressive production schedule and a limited availability of surveyors, the extent of area included in the survey was limited to an approximately 1,000-foot reach with the pipeline crossing in the middle. At some crossings, the survey could not be completed as planned due to access restrictions by a landowner, or because of swift water conditions or extremely dense vegetation. In cases where this occurred, survey points were interpolated between measured points to complete the survey coverage. DEA collected survey data with a combination of global positioning system (GPS)-based and conventional survey methods.

Cross section locations at each crossing were located on georeferenced maps and aerial photos. These were provided to DEA to assist in locating the appropriate cross section locations. Based on observations of field conditions and channel geometry, additional cross section locations were flagged by the GeoEngineers field team for survey.

Survey data for each crossing was delivered to GeoEngineers in both ASCII file format and Triangular Irregular Network (TIN) format.

1.4.3 Hydraulic Model Development

Upon receipt of the survey data, a one-dimensional hydraulic model was developed for each of the six sites. Hydrologic Engineering Center-River Analysis System (HEC-RAS) was selected for this application to streamline hydraulic computations at each crossing. HEC-RAS is freeware developed by the U.S. Army Corps of Engineers to perform one-dimensional steady and unsteady flow river hydraulics calculations. Inputs required for HEC-RAS include in-channel bathymetry, floodplain topography, channel boundary conditions, channel roughness coefficients and hydrologic data.

In addition to the survey data provided by DEA, LiDAR data provided by Sanborn Mapping Co. was used to extend the floodplain topography where necessary. HEC-GeoRAS, a GIS interface with HEC-RAS, was used to export survey data from the TIN format into the hydraulic model. In addition, geometry data such as stream centerline, in-channel and overbank flow paths, bank stations and cross sections were extracted from the TIN using HEC-GeoRAS software. These data were then imported into the HEC-RAS model for processing.

Based on field observations, site photos and surveyed topographic features, channel and floodplain roughness values were calculated following the procedures outlined in the HEC-RAS User's Manual (U.S.

Army Corps of Engineers, 2002). The key factors in the determination of the roughness values consists of channel bed material, degree of irregularity, variations of the cross section, effect of obstruction, condition of vegetation and the degree of channel meandering. The calculated roughness (Manning's n) values for each site are presented below in Table B-1. Given the typically short stream reach for each model, a uniform roughness value was applied to each cross section within each model.

TABLE B-1. MANNING'S n VALUES SUMMARY

Site Name	Manning's n			Downstream Slope
	Left Bank	Channel	Right Bank	
South Fork Elk Creek	0.062	0.045	0.062	0.0076
Rogue River	0.065	0.038	0.055	0.0093
Olalla Creek	0.057	0.045	0.061	0.0096
South Umpqua No. 2	0.062	0.039	0.062	0.0010
North Myrtle Creek	0.065	0.044	0.070	0.0066
Middle Creek	0.060	0.040	0.060	0.0026

Normal depth (downstream slope, see Table B-1) was used as the downstream boundary condition for each model. This was selected due to the absence of obstructions and the dominance of normal flow or sub-critical flow conditions at each stream reach. The average channel slopes computed based on the surveyed topographical data were used as the normal depth boundary condition. Where necessary, localized ineffective flow areas were identified based on the contour data created from the TIN and LiDAR DEM data.

Hydraulic output from HEC-RAS was used to evaluate stream scour for the 10-, 25- and 50-year peak flow events. Parameters calculated in HEC-RAS such as water depth, width of flow, velocity and Froude number were applied as input variables to a selected suite of empirically based equations for estimating depth to scour.

1.4.4 Hydrology

Based on the availability of historical streamflow data for each site, one of two methods were used to develop peak discharge estimates for each stream or river in the scour study: (1) regional regression equations; or (2) peak discharge statistics from a nearby USGS gauging station. Accurate peak discharge estimates for each stream crossing are critical for reliable model output and streambed scour calculations.

For sites with no or limited applicable gage data, regional equations were applied (Cooper, 2005). Regression equations are developed by analyzing broad sets of streamflow data and developing regional understandings of streamflow response to rainfall. Application of the equations requires user-selected input parameters such as drainage area, precipitation intensity, soil storage capacity and soil permeability. Certain variables were selected from the supporting documentation in the USGS report (Cooper, 2005), and basin areas were calculated using GIS. The regression analyses for each of the three applicable sites (Middle Creek, South Fork Elk Creek, Olalla Creek), including equations and input variables, are presented in Figures 26 through 28.

For sites with USGS stream gages nearby in the watershed, peak discharge estimates were calculated using statistical analysis. The USGS report by Cooper presents a method to analyze gage data that accounts for regional variables. This method was selected for the study. The discharge values for gauging stations throughout Oregon are provided in Appendix D of the Cooper (2005) report but were not used in this study for two reasons. First, the results presented in the report reflect the statistical evaluation of the historical flow records only through 2001. Flow data after 2001 were not covered in that study. Second, the flow data at some stations were generated with an assumption that the flow is not regulated by upstream structures. In fact, flows at Rogue River and Olalla Creek are regulated by upstream dams.

USGS gage annual peak data through water year 2005 were downloaded from the USGS website for the statistical analysis for five sites (Rogue River, North Myrtle Creek, Olalla Creek, South Umpqua River Crossing No. 1 and South Umpqua River Crossing No. 2). The gage information of these five stations is presented in Table B-2.

TABLE B-2. GAUGING STATION SUMMARY

Stream Crossing	USGS Gage Name	Gage Number	Location	Drainage Area (sq mi)	Period of Record	Years of Record	Generalized Skew	Mean Square Error
Olalla Creek	Olalla Creek near Tenmile	14311200	Lat. 43°02'20" Long.123°32'35"	61.30	1956 – 1972	17	-0.20	0.112
North Myrtle Creek	North Myrtle Creek near Myrtle Creek	14311000	Lat. 43°02'30" Long.123°15'30"	54.2	1956 – 1986	31	-0.20	0.112
South Umpqua River Crossing No. 2	South Umpqua River at Tiller	14308000	Lat. 42°55'50" Long.122°56'50"	449	1910 - current	67	-0.20	0.112
Rogue River	Rogue River at Dodge Bridge	14339000	Lat. 42°01'30" Long.122°50'30"	1,215	1938 – current	29	-0.20	0.112

Note:

Data copied from USGS stream gage http://waterdata.usgs.gov/or/nwis/measurementswebpage.

The Log Person Type III method outlined in USGS Bulletin 17B (USGS, 1981) was used for the frequency statistical analyses, and the analyses were performed using a computation software – HEC-SSP (U.S. Army Corps of Engineers, 2006). The required parameters in the computation include the skew coefficient and Mean-Square Error (MSE) for each station. In this study, the generalized skew coefficients provided in the Oregon hydrology study (Cooper, 2005) were used instead of the station skew calculated from flow records of a single gage station.

It should be noted that two stations out of the five required special treatment in the frequency analysis. The USGS stream gage website and the field survey data indicate the flow at the Rogue River station and the Olalla Creek station is regulated by upstream reservoirs. The existence of the dams is also mentioned in the report by Cooper. Neither the report nor the USGS website provides the necessary information to evaluate the impacts of the dams on the stream flow at the gage stations. The efforts of obtaining data from other sources failed to produce any usable information.

According to the USGS gage station information, the flow at the Rogue River station has been regulated by the Lost Creek Lake dam since February 1977; thus, the annual peak flow records before 1977 were removed from the analysis. As for the Olalla Creek station, the regional regression equation method was used due to the lack of necessary information about the upstream dam. The result of gage data analysis provides a quality control on the regression output, which was selected as the final hydrology for this site.

The final peak discharges were further adjusted before performing hydraulic analysis. The first adjustment was made following the procedure outlined in the Cooper study. USGS, 1981, which recommends using the weighted average discharge of the statistical analysis result (S) and the result from the appropriate prediction equation as the estimate of peak discharge at the gage station. The reason is that the variance of the weighted average discharge is less than the variance of discharges predicted by either method alone. The weighted average discharge is calculated as:

$$Q_w = \frac{(Q_S N + Q_R E)}{(N + E)}$$

Where

Q_w = the weighted discharge,

Q_S = the discharge from the Pearson type III distribution fitted to logarithms of the annual peak discharges at the gage station,

Q_R = the discharge estimated from the regional regression analysis,

N = the number of years of peak discharge record, and

E = the equivalent years of record.

The regional regression equations used to predict the peak discharges were provided in the Cooper report. The equivalent years of record (E) for each station were also provided in the report.

The second adjustment is based on the drainage area ratios. The measured basin areas of the watersheds at the stream crossing are generally different than the USGS gage basin areas. The area ratios were calculated and are presented in Table B-3.

TABLE B-3. HYDROLOGY DATA SUMMARY

Site Name	PCGP Milepost[1]	Basin Area (sq mi)	Gage Data (Y/N)	Gage Basin Area (sq mi)	Basin Area Ratio	Western Oregon Regression EQ Region
Middle Creek	27.04	46	N	–	–	1
South Fork Elk Creek	34.46	3	N	–	–	1
Olalla Creek	58.78	67	Y	61	1.10	2B
North Myrtle Creek	79.12	41	Y	54	0.76	2B
South Umpqua River Crossing No. 2	94.73	572	Y	449	1.27	2A
Rogue River	122.65	1,143	Y	1,215	0.94	2A

Notes:

[1] Milepost based on April 2017 proposed alignment.

The peak discharges determined for the USGS gage site were then adjusted by multiplying the calculated values by the appropriate basin area ratio. The final hydrology results are presented in Table B-4.

TABLE B-4. PEAK FLOW ESTIMATION SUMMARY

Stream Crossing	PCGP Milepost[1]	Calculated Recurrence Interval					
		2-year (cfs)	5-year (cfs)	10-year (cfs)	25-year (cfs)	50-year (cfs)	100-year (cfs)
Middle Creek[2]	27.04	2,269	3,492	4,341	5,470	6,334	7,225
South Fork Elk Creek[2]	34.46	216	329	407	511	591	673
Olalla Creek[2,3]	58.78	3,448	5,088	6,201	7,607	8,661	9,706
North Myrtle Creek[3]	79.12	1,481	2,070	2,474	3,005	3,405	3,815
South Umpqua River Crossing No. 2[3]	94.73	21,677	34,220	43,058	54,772	63,826	73,204
Rogue River[3]	122.65	15,949	27,213	35,641	47,259	56,557	66,384

Notes:

[1] Milepost based on April 2017 proposed alignment.

[2] Flows calculated using regression equations.

[3] Flows calculated using peak discharge statistics from gauging stations.

cfs = cubic feet per second

1.4.5 Application of Scour Equations

The equations selected for streambed scour analysis are empirically derived for use in the estimation of general scour. General scour is the degradation of the channel bottom that typically results from:

1. Removal of sediments from flow by an upstream reservoir or gravel mining in rivers or floodplains (Przedwojski and Blazejewski, 1995);
2. Long contractions in river width causing an increase in specific discharges and flow velocities (Przedwojski and Blazejewski, 1995);

3. Increase in discharge, depths and water surface slopes during flood flows (Przedwojski and Blazejewski, 1995); and
4. Increased velocities and shear stress along the outer banks of bends, which causes a difference between sediment load entering and exiting a channel bend (Maynord, 1996).

The streambed scour estimated for the six stream crossings focuses on channel degradation induced by processes 2 and 4 listed above, which are referred to as contraction scour and bend scour, respectively. At most crossings, bend scour is the dominant process. Two crossings demonstrate conditions supporting contraction scour (Middle Creek and South Umpqua River Crossing No. 2). Scour is an additive process, meaning that the streambed may be subject to multiple scour types. In these cases, bend scour and contraction scour are combined to yield total potential scour depth.

Bend scour requires the estimate of a bend radius at each site. Bend radii were determined with GIS using an aerial photograph of each stream reach. Multiple bend radii were calculated to offer a greater representation of the stream reach as a whole. The bend radius selected for final analysis at each crossing was based on the value that demonstrated the greatest applicability to the hydraulic conditions expected at each crossing. In some instances, bend radii were adjusted to simulate changes in flow patterns at various peak flows, as dominant flow pathways tend to shift depending on flow volumes, water depth and cross section geometry.

At two crossings (Rogue River and Olalla Creek), dam operations could potentially affect scour by starving stream flow of sediment. Typically, sediment budgets are calculated to account for any altered sediment supply. However, long-term sediment budgets were not calculated to account for sediment starvation resulting from dam operations. This approach is justified by the fact that neither site demonstrates severe incision. The upstream distance to the reservoir on the Rogue River (8 miles) appears sufficient to reduce the effect of sediment starvation on the stream crossing location. On Olalla Creek, the reservoir is located on a tributary stream and affects only a limited portion of the total watershed sediment supply.

Application of scour equations requires selection of hydraulic parameters at two cross sections, one located upstream, and one located at the proposed pipeline crossing. The approach section is used to define the incoming hydraulic variables, and scour depth is calculated at the crossing. The approach cross section that most accurately depicts typical upstream flow and hydraulic conditions was selected from the HEC-RAS model. Where the pipeline is proposed to cross at an angle perpendicular to streamflow, the cross section directly along the pipeline was selected for analysis. Where the proposed alignment crosses the stream at an acute or obtuse angle, a cross section with the deepest thalweg elevation was chosen for analysis.

Scour analysis was calculated using the 10-year, 25-year, 50-year and 100-year peak flow events, presented in Table B-4 and in the peak discharge equation results (Figures 26 through 28). Hydraulic output from HEC-RAS models for each crossing was exported to a scour equation workbook developed by GeoEngineers for this project. The scour workbook subjects each stream crossing to a range of bend scour and contraction scour equations. Each equation is designed for a specific and different set of site conditions and includes a different set of implicit assumptions. The final results for each crossing were selected based on the best match between actual site conditions and the model assumptions. In some cases, multiple equations were used and then averaged to develop a broader range of scour estimates.

Results of the scour analysis are presented in Table 2, in Appendix C (Table C-2) and in the scour workbooks shown in Appendix E. All input variables for each scour equation are shown along with a summary of the results for each of the seven crossings. In Figures 19 through 25, the scour depths for the 10-, 25-, 50- and 100-year flood events are presented as elevations below the streambed along each crossing. The scour elevations presented in the figures were calculated by subtracting the estimated scour depths form the lowest point of the streambed. In instances where a channel bend and its relatively deeper pool are likely to propagate downstream and intersect the crossing, potential scour depth is estimated by subtracting the calculated scour depth from the pool depth and applying resulting elevation to the pipeline crossing.

1.4.6 Estimation of Bedrock Depth below Stream Crossings

Depth to bedrock was estimated at crossings where drilling data and/or rock outcrops are available. The crossings with available drilling data include the Middle Creek, South Umpqua River Crossing No. 2 and Rogue River crossings. The range of estimated depths at which bedrock could be encountered was interpreted for each crossing site based on the elevations of bedrock contacts encountered in the borings, and outcrop exposures within and adjacent to the stream channels. Where borings represent the only available bedrock data, a range of 5 feet was assumed.

The physical presence of bedrock outcrops within the channel corridor, upstream and/or downstream of the crossing, typically indicates that bedrock is likely present at depths much shallower than calculated scour depths. At these crossings, and at other crossings where bedrock is encountered at depths shallower than the estimated scour depths, bedrock is considered to be the limit for scour.

2.0 QUALITY CONTROL/QUALITY ASSURANCE

Each component of the data collection and analysis described above received multiple levels of quality control. The final results of each element of this study rely on multiple data sources, modeling results, and professional geomorphic and engineering judgment. The geomorphic characterization and channel migration results were reviewed by senior level geomorphologists and licensed geologists.

Hydrology results were reviewed by a Senior Hydrologist and Senior Hydraulic Engineer to verify accuracy and consistency with the methods outlined in the Oregon Water Resources Report (Cooper, 2005).

HEC-RAS models were developed by both staff engineers and senior engineers. Each model was reviewed by up to five scientists and hydraulic engineers. Items such as flow inputs, Manning's n value selection, bank station locations and boundary conditions were reviewed for accuracy, consistency and application of the highest level of professional standards.

Scour equation results were verified through the comparison of field observations of pool depth relative to the thalweg. Reporting of scour depth is rounded to the nearest half-foot, because the analysis process does not warrant reporting to any additional significant figures.

Scour results were reviewed by each member of the project team for an additional level of quality assurance. In particular, members of the field team were requested to compare the computed scour results with observations made in the field and their general understanding of geomorphic trends at each stream reach.

3.0 REFERENCES

Cooper, R.M., 2005, Estimation of Peak Discharges for Rural, Unregulated Streams in Western Oregon, USGS Scientific Investigations Report 2005-5116, p. 134.

Hoffmans, G.J.C.M. & Verheij, H.C., 1997, Scour Manual, A.A. Balkema: Rotterdam.

Maynord, S.T., 1996, Toe-Scour Estimation in Stabilized Bendways, ACEC, Volume 122, No. 9, August 1996.

Pemberton, E. L. and Lara, J. M., 1984, Computing degradation and local scour, Technical Guideline for Bureau of Reclamation, Bureau of Reclamation Sedimentation and River Hydraulics Section, Denver, Colorado.

Przedwojski, B., K. Blazejewski, and K.W. Pilarczyk, 1995, River Training Techniques: Fundamentals, Design and Applications, A.A. Balkema: Rotterdam.

United States Geological Survey, 1981, Guidelines for Determining Flood Flow Frequency. Bulletin No. 17B of Hydrology Subcommittee.

United States Geological Survey, 2008, Streamflow Measurements for Oregon. http://waterdata.usgs.gov/or/nwis/measurements

U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2002, HEC-RAS, River Analysis System, User's Manual, Version 3.1.

U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2005, HEC-GeoRAS, GIS Tools for Support of HEC-RAS Using ArcGIS, User's Manual, Version 4.0.

U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2006, HEC-SSP, Statistical Software Package, User's Manual, Version Beta 1.0.

Walker, G.W. and N.S. MacLeod, 2002. Spatial Digital Database for the Geologic Map of Oregon, USGS Open-File Report 03-67, Digital database by Robert J. Miller, Gary L. Raines, and Katherine A. Connors, v2.0, http://geopubs.wr.usgs.gov/open-file/of03-67/.

APPENDIX C
Geomorphic Characterization

APPENDIX C
1.0 GEOMORPHIC CHARACTERIZATION

1.1 Introduction

A variety of large-scale processes influence the character of the proposed pipeline stream crossings. Geologic and climatic processes, on a regional scale, mold the landscape into unique landforms with distinct drainage characteristics. Basin-scale conditions and processes strongly influence the character of watersheds, including the performance and behavior of drainage channels. The purpose of this appendix is to document the observed characteristics and processes that form the basis for evaluating channel behavior and migration at the 17 accessible stream crossings selected for Phase II evaluation.

1.2 Physiographic Provinces

The PCGP pipeline alignment crosses four distinct physiographic provinces. From west to east, the provinces include: The Coast Range, the Klamath Mountains, the Cascade Range, and the Basin and Range.

The Oregon Coast Range physiographic province extends more than 200 miles from the Columbia River south past Coos Bay to the Klamath Mountains. The Coast Range receives more rainfall than physiographic provinces farther east, averaging around 100 inches per year on its western slopes (Burns, 1998). Because of the proximity to the Pacific Ocean, the Coast Range experiences more moderate temperatures in both the winter and the summer than the rest of Oregon. The moderate temperatures and wet environment provide the ideal setting for the thickly vegetated forests of the Coast Range (Orr and Orr, 2012).

The Klamath Mountain physiographic province extends from the southern end of the Coast Range south into California. It is bounded by the Pacific Ocean to the west and the Cascade Mountains to the east. The mild, subhumid climate of the Klamath Mountains is characterized by lengthy summer droughts. Precipitation is generally greatest near the coast, decreasing to the east. The region's annual rainfall ranges from 25 to 45 inches in the Oak Savannah foothills to 35 to 70 inches in the Inland Siskiyous Mountains.

The Cascade Range physiographic province extends from north to south across the entire state and separates western Oregon's wet, high-precipitation environment from the drier environment of eastern Oregon. The Cascade Range receives 60 to 100 inches of precipitation annually on its western slopes while the eastern slopes lie in a rain shadow and receive considerably less precipitation (Orr and Orr, 2012). Because of the difference in rainfall, the streams flowing from western slopes of the Cascade Mountains generally have a higher discharge than those flowing from the eastern slopes.

The Basin and Range physiographic province extends through much of the western United States, from California east into Utah, and from Oregon south to the border with Mexico. In Oregon, the province accounts for most of the southeastern quadrant of the state. This part of the study area receives only 10 to 18 inches of rainfall per year in the Klamath and Goose Lake basins, and 25 to 40 inches per year in the southern Cascade mountain slopes.

Within the four physiographic provinces, the pipeline crosses five major watersheds: The Coquille and Coos watersheds in the Coast Range, the South Umpqua watershed in the Klamath and Cascade Mountains, the Rogue watershed in the Cascade and Klamath Mountains, and the Klamath watershed in the Klamath Basin and Range provinces.

1.3 Major Watersheds

1.3.1 Coos River Watershed

The Coos River watershed covers approximately 627 square miles. The watershed is drained by numerous water courses, including the South Fork Coos River. The South Fork Coos River extends approximately 60 miles in length from its headwaters in the Coast Range to Coos Bay along the Pacific coast. The Coos River watershed lies between the Umpqua River watershed to the north and east and the Coquille watershed to the south.

The steep, forested headwaters of the Coos River watershed are an important timber-producing region of Oregon's Coast Range. The main tributaries of the Coos originate as steep, narrow and relatively straight streams in the uplands that coalesce downstream where the basins transition to broader valleys with a generally meandering channel pattern. Development of the floodplains for pastureland and agriculture has been extensive during the past century. The proposed pipeline crosses the Coos River and several of its tributaries in the lower Coos watershed.

1.3.2 Coquille Watershed

The Coquille River watershed covers 1,059 square miles of the Coastal and Klamath Ranges between the Coos River watershed to the north and the Rouge River watershed to the south. The Coquille River watershed encompasses the North, South, Middle and East Forks of the Coquille River and extends approximately 100 miles in length from its headwaters on the South Fork to its mouth at the Pacific Ocean where it drains to a small estuary at Bandon, Oregon.

The steep, forested headwaters of the watershed are historically important timber-producing areas of southwest Oregon. The four main forks of the Coquille that originate in these uplands join one another downstream where the basin transitions to broad, low gradient, flat-bottomed, incised valleys with wide meanders (such as where the proposed pipeline crossings are located). The floodplains of the lower basin have been developed extensively during the past century for pastureland and agriculture. The proposed pipeline crosses the North Fork, Middle Fork and East Fork of the Coquille River and several of their tributaries in the middle and upper watershed.

1.3.3 South Umpqua River Watershed

The South Umpqua River watershed covers approximately 1,843 square miles of the southern Cascade Range and Klamath Mountains. The watershed encompasses numerous tributaries that include North and South Myrtle Creeks, Elk Creek, and Olalla Creek. The South Umpqua River extends approximately 95 miles in length from its headwaters in the southern Cascades to its confluence with the Umpqua River, which in turn drains to Winchester Bay at Reedsport, Oregon.

The tributaries of the South Umpqua watershed originate in highly dissected, folded mountains and foothills as steep, narrow, forested headwater streams and join downstream where the basin transitions to a broad valley with wide meanders. The South Umpqua River valley became an important timber-producing region in the 20th century; the floodplains of the lower basin have since been utilized for pasture and agriculture. The proposed pipeline crosses the South Umpqua in two locations and crosses several of the South Umpqua's tributaries in the middle and upper watershed.

1.3.4 Rogue River Watershed

The Rogue River watershed covers approximately 2,552 square miles of the southern Cascade Ranges and Klamath Mountains where it lies between the South Umpqua watershed to the north and the Klamath watershed to the south. The Rogue River watershed encompasses Little Butte Creek, Bear Creek, and the North, South and Middle Forks of the Rogue River. The Applegate and Illinois Rivers flow from the Klamath Mountains to the Rogue west of Grants Pass. The main Rogue River extends approximately 215 miles in length from its highest headwaters in the southern Cascades to the Pacific Ocean in Gold Beach, Oregon.

The narrow and relatively steep forested headwaters of the Rogue's tributaries exit the southern Cascade Mountains and flow into the Medford Valley. The proposed pipeline crosses the Rogue River and several of its tributaries in the transition zone between the upper Rogue basin and the Medford Valley. West of Medford, the channel carves through the Klamath Mountains in a narrow, relatively high-gradient valley. There are dams located above the Medford Valley.

1.3.5 Klamath River Watershed

The Klamath River watershed covers approximately 673 square miles of the Klamath and southern Cascade Ranges. The Klamath River watershed extends approximately 250 miles in length from its highest headwaters in the south Cascades Mountains to the Pacific Ocean near the community of Klamath, California.

The Upper Klamath originates from Upper Klamath Lake in the semi-arid Basin and Range physiographic province east of the Cascades Mountains in southern Oregon. Downstream of Upper Lake Klamath, the Klamath River flows southwesterly across a broad valley occupied by irrigated agricultural fields. This is where the proposed pipeline crossing is located. The river then enters the Siskiyou Mountains where the valley becomes steep and narrow. The Klamath River passes through several dams in route to the Pacific Ocean.

2.0 SITE-SPECIFIC RESULTS OF CHANNEL MIGRATION AND SCOUR ANALYSES

2.1 Pipeline/Channel Crossings

In mid-October 2006, GeoEngineers sent two teams, each consisting of one geologist and one geomorphologist, to perform field reconnaissance at 17 stream crossing sites. Provided below is a discussion summarizing the geomorphic character of each crossing and the results of the migration analysis and scour analysis. The results of the migration and scour analysis applied to selected crossings are presented in Tables C-1 and C-2. Aerial photographs reviewed for each crossing are described in Table C-3. Those crossings with significant historical migration are shown in Figures 15 through 19. Additional physical information regarding each crossing is provided in Table C-4. All boring logs referenced in the crossing discussions or shown in figures are presented in Appendix D.

2.1.1 Coos River

The Coos River crosses the proposed pipeline at Milepost (MP) 11.13R. The site can be accessed from the South Coos River Highway near the town of Coos Bay in Coos County, Oregon (Figure 2).

BASIN INFORMATION. The Coos River watershed, described above, is one of the largest watersheds of the southern Oregon Coast Range. The crossing is located in the lower portion of the watershed, less than 1 mile from the Coos Bay estuary. In this area, the Coos River channel is subject to tidal influences well upstream of the crossing. EPA ReachFile™ estimates mean flow of the stream segment containing the crossing to be 853 cubic feet per second (cfs), based on an estimated channel gradient of 0.0 percent.

CROSSING INFORMATION. The stream banks are composed of cohesive silt and armored with large angular boulder-sized riprap. The channel is confined by levees on both banks. Geotechnical borings near the site indicate that the substrate consists of soft silt, sand and peat to depths of at least 50 feet below sea level. Wooden piles have been installed at the base of both the right and left banks. The channel floor was not observable at the time of the site reconnaissance, but is likely composed of sand, silt and clay given the results of the borings and the low-energy tidal environment.

MIGRATION ANALYSIS. The Coos River has a low potential for channel migration at the proposed crossing location based on the following information:

- The crossing is located in a low-energy reach.
- The river banks are composed of erosion soils and protected by riprap.
- River migration was not observed over the period of record presented in historical aerial photos (Table C-3).

SCOUR ANALYSIS. Scour analysis was not completed for the Coos River crossing because the pipeline will be installed at significant depth below the channel using HDD trenchless methods.

2.1.2 North Fork Coquille River

The North Fork Coquille crosses the pipeline at MP 23.06. The site can be accessed from Sumner-Fairview Road, near the town of Fairview in Coos County, Oregon (Figure 3).

BASIN INFORMATION. The North Fork Coquille basin lies within and midway up the greater Coquille River watershed. The North Fork River drains a small southwest-trending valley, which broadens before merging with Middle Creek and the East Fork Coquille River. The upper basin is primarily composed of mountainous, forested land that was partially logged in the recent past. The lower valley bottoms have been cleared for pastures and rural development.

The nearest United States Geological Survey (USGS) stream gage is no. 22597, located at stream MP 55. EPA ReachFile™ estimates mean flow at the crossing to be 310 cfs, based on an estimated channel gradient of 0.01 percent.

CROSSING INFORMATION. The river flows southward through a terraced, flat valley floor. In the vicinity of the crossing, the stream has incised valley-floor alluvium to a maximum depth of 22 feet, effectively forming terraces on both sides of the channel. The streambed is composed of erosion resistant sedimentary bedrock dipping at roughly 6 feet to the northeast. Several emergent sand and gravel bars overlie the bedrock in the channel and along the insides of bends. The river banks, composed primarily of sand and gravel, are steeply inclined and extend to the tops of both terraces. Bank erosion, coupled with several soil slumps were observed in places along the banks, especially along the outsides of channel bends.

MIGRATION ANALYSIS. The North Fork Coquille River has a low potential for channel migration at the crossing location, but a relatively high potential for channel widening based on the following observed geomorphic conditions:

- The channel is deeply incised in valley floor alluvium.
- Little or no channel migration was observed over the period of the historical aerial photo record (Table C-3).
- Erosion and sloughing observed along both banks indicate ongoing channel widening.

Based on these results, a more detailed migration analysis was not conducted at this site. However, a 22-foot-wide zone has been applied to both banks – equal to the height of the terraces – to account for future bank erosion and channel widening.

SCOUR ANALYSIS. The North Fork Coquille River has a low potential for channel scour at the crossing location based on the following information:

- The channel floor is predominately composed of bedrock and resistant to scour.

2.1.3 Middle Creek

Middle Creek crosses the pipeline at MP 27.04. Middle Creek is also called Park Creek in some references. The site can be accessed from the Lee-McKinley Road, near the town of McKinley in Coos County, Oregon (Figure 4). The proposed pipeline alignment has been modified since the October 18, 2006, field reconnaissance, moving the Middle Creek crossing approximately 275 feet downstream, to the west. The old and current crossing locations are both located within the same geomorphic setting; therefore, observations and conclusions from the October 2006 field reconnaissance have been applied to the new crossing location.

BASIN INFORMATION. Middle Creek is a subbasin of the larger Coquille River watershed. The Middle Creek basin drains a relatively small, southwest-trending valley (46 square miles) parallel to, and east of, the North Fork Coquille River. There is roughly 2,600 feet of relief in the Middle Creek basin above the crossing location. The upper basin consists primarily of mountainous forest lands, most of which have been harvested. The lower basin consists of a broad valley bottom that has been cleared for pastures and rural development. Although the channel appears to be incised in some areas, no artificial river channelization is observable in the aerial photos,

The nearest USGS stream gage is no. 22361, located on Middle Creek at river mile 38. EPA ReachFile™ estimates the mean flow of the stream segment containing the crossing to be 130.22 cfs, based on an estimated channel gradient of 1.3 percent. A regression analysis was conducted to estimate peak flows at the Middle Creek crossing (Figure 26). Results for the 2-, 5-, 10-, 25-, 50- and 100-year peak discharges are presented in Appendix B, Table B-4.

CROSSING INFORMATION. Middle Creek flows west across a terraced valley floor at an elevation of approximately 104 feet at the crossing location. The creek has incised through non-cohesive silt and sand to bedrock, creating steep banks up to 10 feet high. The moderately hard, sedimentary bedrock is exposed along the lower stream banks and on the streambed upstream of the crossing.

Field evidence indicates that the stream banks failed recently within the study area, widening the active channel up to 60 feet (roughly 30 feet on each bank) at several locations. Debris from the failures apparently obstructed the channel temporarily, creating deep slack-water ponds upstream of the failures. The bed at the crossing is composed of sand and gravel. Although no bedrock is observable at the pipeline crossing, bedrock outcrops are present on the streambed and in the banks upstream of the crossing. Extrapolation of the exposed outcrops, along with geotechnical borings located near the site, indicate that bedrock may be present at depths ranging from 2 to 7 feet beneath the channel floor at the crossing. The shallow depth to bedrock likely affects channel performance in the vicinity of the pipe crossing in two ways: (1) it limits future channel incision to the elevation of the bedrock, and (2) bedrock exposed on the channel floor diverts flow energy from the streambed to the banks, causing erosion and channel widening.

MIGRATION ANALYSIS. Middle Creek has a low potential for channel migration but a high potential for channel widening, based on the following observed geomorphic conditions:

- The channel is deeply incised.
- Erosion and sloughing observed along both banks indicate channel widening (Table C-1).
- No measurable channel migration was observed in the historical aerial photo record (Table C-3).

Based on these results, a channel migration analysis was not conducted at this site.

The potential for continued channel widening was addressed by evaluating bank erosion and recession characteristics. Based on site conditions, a 30-foot zone of potential widening on both banks, equal to areas of observed bank recession and widening, was applied to the existing edges of both banks.

SCOUR ANALYSIS. If bedrock is not present at a shallow depth beneath the channel at the crossing, the stream would have a high potential for scour. A detailed scour analysis was completed at the original (October 25, 2006 alignment) crossing location.

The crossing is subject not only to bend scour but also to constriction scour, largely in response to the narrowing of the stream channel width adjacent to mass wasting deposits. These processes at the stream reach level were observed and assume that similar morphology can be expected at the proposed crossing location. Middle Creek is a fine-grained system, with a calculated D_{50} of 3.7 mm. Thus, the Maynord equation was selected as the most appropriate (Maynord, 1996). Results indicate scour depths of 7.0 feet for the 10-year flow, 9.0 feet for the 25-year flow, 9.0 feet for the 50-year flow and 10.5 feet for the 100-year flow (Table 2, Table C-2).

The total depth of potential scour for any recurrence interval flow should be taken as either the calculated scour depth or the presence of competent bedrock, whichever of the two represents the higher elevation. The interpreted depth to bedrock and calculated scour depths, relative to the elevation of the channel floor, are shown in Figure 19. A detailed summary of the scour analysis is presented in the scour workbooks in Appendix E.

2.1.4 South Fork Elk Creek

The proposed pipeline crosses South Fork Elk Creek at MP 34.46 and can be accessed from Big Creek Road, near the town of Bridge, or from Gold Brick Road, near the town of Dora in Coos County, Oregon (Figure 5).

BASIN INFORMATION. South Fork Elk Creek is a subbasin of the East Fork Coquille River within the larger Coquille River watershed. The South Fork Elk Creek basin is situated midway up the western Coquille watershed and drains a relatively small area between the East Fork Coquille to the north and Big Creek to the east. This subbasin drains a small southwest-trending valley, which broadens before merging with the East Fork Coquille River. The upper basin consists of mountainous forestland that has been harvested for timber in the past. The lower basin is relatively broad and flat and has been cleared for pastures and rural development. Although the channel appears to be incised in several areas, no evidence of artificial river channelization was observed.

There is roughly 2,320 feet of vertical relief in the South Fork Elk Creek subbasin. The estimated catchment area above the crossing is relatively small (3 square miles). The nearest USGS stream gage is no. 22361, located at river mile 38. EPA ReachFile™ estimates mean flow at the crossing to be 62.07 cfs, based on an estimated channel gradient of 1.0 percent. Regional regression analysis was selected for estimating peak flows at South Fork Elk Creek due to the lack of adequate gauging data (Figure 27. Results for the 2-, 5-, 10-, 25-, 50- and 100-year peak flow estimates are presented in Appendix B, Table B-4.

CROSSING INFORMATION. At the crossing location, South Fork Elk Creek flows southwest through a narrow, forested floodplain. The channel forms a small-radius, S-curve bend, entrenched in floodplain terraces up to 5 feet high. Erosion-resistant sedimentary bedrock is exposed on the channel floor roughly 400 feet upstream of the crossing location. Elsewhere, the streambed is composed of well embedded cobbles and gravel overlying sand and gravel; occasional scour pools as deep as 2.5 feet are present upstream and downstream of the crossing. The depth to bedrock is unknown at the crossing location but is likely shallow based on nearby bedrock exposures. The stream banks are composed of ancient alluvium and/or debris flow deposits consisting primarily of sand and gravel. Minor bank erosion was observed on the outside of one bend. A large bank failure was observed 300 feet upstream of the crossing.

MIGRATION ANALYSIS. South Fork Elk Creek has a low potential for channel migration at the crossing location, but a relatively high potential for channel widening, based on the following observed geomorphic characteristics:

- The channel is confined by densely vegetated terraces composed of coarse bank material in a relatively narrow valley.
- Erosion and sloughing observed along both banks indicate potential channel widening likely associated with incision (Table C-1).
- No measurable channel migration was observed in the historical aerial photo record (Table C-3).

Based on these results, a channel migration analysis was not conducted at this site.

The potential for continued channel widening was addressed by evaluating bank erosion and recession characteristics. Based on site conditions, a 10-foot-wide zone equal to areas of observed bank recession and widening was applied to the existing edge of bank.

SCOUR ANALYSIS. The depth to bedrock is unknown at the crossing location, although bedrock is exposed on the streambed both upstream and downstream of the crossing. Consequently, a detailed scour analysis was completed at this location due to the potential for bend scour. The overall potential for scour is moderate due to the embedded layer of gravel and cobble armoring, which is indicative of resistant or immobile bed material. The analysis assumes that erodible material extends below scour depth.

Bend scour equations were applied to South Fork Elk Creek and multiple equations were averaged to produce the final scour depth estimate. Field observations indicate pool depths throughout this reach at least 2.5 feet deep. Scour results indicate depths of 4.0 feet at the 10-year flow, 5.0 feet at the 25-year flow, 5.0 feet at the 50-year flow, and 6.0 feet at the 100-year flow (Table 2, Table C-2).

Bedrock may be present at shallow depths beneath the channel. If erosion-resistant bedrock is encountered at depths shallower than the calculated scour depths, that elevation should be considered the total depth of potential scour for all flows. The calculated scour depths, relative to the elevation of the channel floor, are shown in Figure 20. A detailed summary of the scour analysis is presented in the scour workbooks in Appendix E.

2.1.5 Middle Fork Coquille River

The Middle Fork Coquille crosses the proposed pipeline at MP 50.28. The site can be accessed from Upper Camas Road, near the town of Camas Valley in Douglas County, Oregon (Figure 6).

BASIN INFORMATION. The Middle Fork Coquille is a subbasin of the larger Coquille watershed. The Middle Fork Coquille basin, located high in the westernmost confines of the Coquille watershed, drains a small isolated south/southwest-trending valley called the Camas Valley. The valley-bottom is flat and broad within steep, dissected mountains with 500 to 1,600 feet of relief. The valley slopes have been logged, and the valley bottom has been partially cleared for agriculture and/or homesteads. Two small reservoirs (Kinman Lake and an unnamed pond) are both about 1.5 miles upstream of the pipeline crossing. Dams presumably impound the reservoirs; however, neither the condition of the dams nor their capacity to trap sediment was evaluated. No artificial river channelization was observed.

The estimated catchment area above the crossing is relatively small. The nearest USGS stream gage is no. 22348, located at river mile 41. EPA Reach File™ estimates mean flow of the stream segment to be 53 cfs, based on an estimated channel gradient of 0.5 percent.

CROSSING INFORMATION. At the crossing location, the river flows south through a terraced valley floor. The small, broadly sinuous channel has incised up to 18 feet through cohesive alluvium to erosion-resistant bedrock. The channel incision has formed steep terraces along both banks, which confine the stream. Several small slumps and associated scarps were observed on the faces of the terraces, especially along the outsides of bends. Bedrock exposed on the channel floor throughout the reach is relatively uniform and flat with no identifiable dip direction.

MIGRATION ANALYSIS. Middle Fork Coquille River has a low potential for channel migration at the crossing location, but a relatively high potential for channel widening, based on the following geomorphic conditions:

- The channel is deeply incised.
- Little or no channel migration was observed in the historical aerial photo record (Table C-3).

- Bank erosion and sloughing observed at the crossing indicate ongoing channel widening (Table C-1).

Based on these results, a more detailed migration analysis was not conducted at this site.

The potential for continued channel widening was addressed by evaluating bank erosion and recession characteristics. Based on observed site conditions, an 18-foot-wide zone of potential widening was applied along both banks – equal to the height of the 18-foot-high terraces.

SCOUR ANALYSIS. The Middle Fork Coquille River has a low potential for channel scour at the crossing location based on the following information:

- The bed of the channel is predominately bedrock and resistant to scour.

Based on these results, a more detailed scour analysis was not conducted at this site.

2.1.6 Olalla Creek

Olalla Creek crosses the pipeline at MP 58.78. The site can be accessed from Olalla Road, near the town of Tenmile, in Douglas County, Oregon (Figure 7).

BASIN INFORMATION. The Olalla Creek basin lies midway up the South Umpqua River watershed. Olalla Creek drains a north-trending valley, fed partially by Ben Irving Reservoir. Neither the condition of the dam impounding Ben Irving Reservoir nor its capacity to trap sediment was evaluated. The forested watershed has been logged historically, and much of the valley bottom has been cleared for pasture and/or homesteads.

The estimated catchment area above the crossing is relatively moderate in size (67 square miles). The creek is ungaged. EPA Reach File™ estimates mean flow of the stream segment to be 120 cfs, based on an estimated channel gradient of 0.3 percent. Regional regression analysis was selected for estimating peak flows at Olalla Creek due to lack of a sufficient record of gauging data (Figure 28). Results for the 2-, 5-, 10-, 25-, 50- and 100-year peak flow estimates are presented in Appendix B, Table B-4.

CROSSING INFORMATION. Olalla Creek flows northeast, across a broad, flat valley floor developed as pastureland. The banks along the outsides of bends are nearly vertical and measure up to 7 feet high. Bank soils are composed of silt and sand underlain by sandy gravel and bedrock. The streambed is composed of irregular sedimentary bedrock, covered in places by varying deposits of sandy gravel. On the left floodplain, two high-flow channels extend through timber and pastureland. The high-flow channels are scoured to bedrock at their outlets and appear to be head-cutting upstream. Immediately upstream of the crossing, the main channel is split by a vegetated bar. At this location, the right stream bank is undergoing significant erosion (toward the south and east).

MIGRATION ANALYSIS. Olalla Creek has a high potential for migration, based on the following observations and conditions:

- Historical photos reveal that the channel has a history of migration and avulsion. Bends along this section of the river migrate downstream (maximum rate of 13 feet per year) and laterally (maximum rate of 3.07 feet per year). Bar formation has led to two avulsions. Channel avulsion occurred in response to a large influx of sediment observed between 1960 and 1968 photos (Table B-3, Figure 15).

- Bank erosion, split flows and high-flow channels were observed during site reconnaissance. These features are indicative of channel migration processes.

A detailed channel migration analysis was conducted for this crossing for 25 and 50 years of steady channel movement. The width of the Channel Migration Zone (CMZ) was measured from the ordinary high-water line extending along the pipeline route into the right and left floodplains. The width and shape of the CMZs account for both downstream and lateral migration and for the area the channel could occupy in the event of another avulsion.

The historical migration analysis, however, suggests that the creek is more likely to remain within the 25-year zone, even over much longer time periods. This assessment is based on two observed historical migration characteristics: (1) the tendency of channel bends to migrate downstream; and (2) the tendency of the channel to avulse to former channels. Both of these characteristics will likely hold the channel within the Historic Channel Occupation Tract (HCOT). Lateral migration beyond the HCOT will occur initially at rates of 3 feet per year. This rate is expected to hold within the 25-year CMZ but will almost certainly decrease outside 25-year CMZ, due to channel migration characteristics, changes in floodplain conditions and changes in valley floor gradient (perpendicular to the stream). For this crossing, the 25-year CMZ represent the most likely channel movement scenario.

The migration results are summarized in Table C-1. The 25- and 50-year CMZs are presented in Figure 21.

SCOUR ANALYSIS. Olalla Creek has a high potential for scour. The creek near the stream crossing is extremely dynamic, with high potential for shifting. Occasional bedrock exposure was observed in the area, but it is highly irregular and difficult to predict. Pool depths observed were about 3 feet, but the topographic survey shows pool depths to be nearly 5 feet. Olalla Creek displays a tight, sinuous meander pattern that is subject to intense bend scour.

The results of the scour analysis indicate potential depths of 6.0 feet for the 10-year event, 7.0 feet for the 25-year event, 7.0 feet for the 50-year event and 7.5 feet for the 100-year event (Table 2, Table C-2). The downstream migration of bends upstream of the crossing may increase the risk of scour at the pipeline crossing. If competent bedrock is encountered at depths shallower than the calculated scour depths, that elevation should be considered the total depth of potential scour for all flows. The calculated scour depths, relative to the elevation of the channel floor, are shown in Figure 21. A detailed summary of the scour analysis is presented in the scour workbooks in Appendix E.

2.1.7 South Umpqua River Crossing No. 1

The South Umpqua River Crossing No. 1 is located at MP 71.27. The site can be accessed from Exit 112 on Interstate Highway 5 to Dillard Road (Route 99), near the town of Myrtle Creek in Douglas County, Oregon (Figure 8). The South Umpqua River No. 1 crossing will be accomplished by DP trenchless methods that will place the pipeline in bedrock below scour depth.

2.1.8 North Myrtle Creek

North Myrtle Creek crosses the proposed pipeline at MP 79.12 and can be accessed from North Myrtle Creek Road, near the town of Myrtle Creek in Douglas County, Oregon (Figure 9).

Since the time of the field reconnaissance (October 23, 2006), the proposed pipeline alignment was shifted approximately 2,350 feet upstream. Follow-up field reconnaissance was performed at the new crossing on January 24, 2007 but did not include surveyed cross sections.

BASIN INFORMATION. North Myrtle Creek is a tributary of the South Umpqua River. North Myrtle Creek drains a relatively straight, south-trending, flat-bottomed valley with steep, forested slopes. Rural development and active pastureland comprise the majority of the valley bottom.

The estimated catchment area above the new crossing is 41 square miles. Peak flow estimates for this site were developed through statistical analysis from USGS stream gage 14311000, located downstream near the town of Myrtle Creek. The drainage area above the new crossing comprises 54 percent of the drainage area at the USGS gage. The mean annual flow at the gauging station is 73 cfs. Estimates for the 2-, 5- 10-, 25-, 50- and 100-year peak discharge volumes are presented in Appendix B, Table B-4.

CROSSING INFORMATION. At the new crossing location, North Myrtle Creek flows south through a small terraced valley with high-flow areas along the lowermost terrace. The channel bed is composed primarily of gravel and cobbles grading to predominantly gravel and sand farther downstream (at the old crossing location). A local resident indicated he encountered bedrock at depths of roughly 5 feet below the ground surface near the new crossing. Small gravel bars are present at the new crossing site, primarily along the insides of bends. The banks on the outsides of bends are eroding and typically steep to vertical, up to 10 feet high, and composed primarily of loose alluvial floodplain deposits (silt/sand over sandy gravel). The banks on the insides of stream bends are composed of sand and gravel and have minimal topographic relief. Large woody debris (LWD) was observed in the channel, associated with scour pools up to 3 feet deep.

The channel character at the new crossing location transitions from supply limited (erosion/scour) to transport limited (deposition), as indicated by the decreasing grain sizes and increasing size and frequency of bars as one moves downstream through the project reach.

MIGRATION ANALYSIS. North Myrtle Creek has a high potential for channel migration at the new crossing location based on the following information:

- River migration was observed in the historical aerial photos throughout the reach. In general, the stream migrates rapidly across the low-lying valley floor, and into alluvial terraces (Table C-3, Figure 16).
- Growing bars and bank erosion has occurred along channel bends.

A detailed channel migration analysis was conducted at the new crossing for 25 and 50 years of steady channel movement. Migration rates were measured both laterally (maximum of 2.5 feet per year) and downstream (maximum of 2.41 feet per year). The width of the CMZ (shown in Tables 2 and B-1 and in Figure 22) was measured from the HCOT extending along the pipeline route into the right and left floodplains.

The migration character of North Myrtle Creek suggests that channel bends are as likely to migrate downstream as they are to migrate laterally. This characteristic will likely hold the channel within the HCOT. Lateral migration beyond the HCOT will occur initially at rates of 2.5 feet per year. This rate will likely hold over a 25-year period of time; however, the rate of migration is expected to decrease with time outside 25-year CMZ, due to downstream migration of bends, changes in floodplain conditions, and changes in valley floor gradient and proximity of the left valley wall to the active channel. The 25- and 50-year CMZs are presented in Figure 22.

SCOUR ANALYSIS. Surveyed channel cross sections were not completed at the proposed crossing. However, field reconnaissance indicated that both crossings have significant scour potential due to the lack of observed bedrock and the presence of pools scoured into alluvial material. Field observations suggest that the new crossing may be slightly more sensitive to scour than the original crossing location.

A thorough scour analysis was completed at the original (October 2006) crossing. Results of the scour analysis are presented in the scour workbooks in Appendix E. Results indicate potential scour depths of 5.0 feet at the 10-year flow, 6.0 feet at the 25-year flow, 6.0 feet at the 50-year flow and 6.5 feet at the 100-year flow (Table 2 and Table C-2). The scour depths calculated for the original site represent the minimum potential scour depths for the new site. However, the depth to bedrock is likely shallower than the minimum scour depth. The depth to bedrock should be considered the total depth of potential scour for all flows. The calculated scour depths, relative to the elevation of the channel floor at the original crossing, are shown in Figure 22.

2.1.9 South Myrtle Creek

South Myrtle Creek crosses the proposed pipeline at MP 81.19. The site can be accessed from South Myrtle Creek Road, near the town of Myrtle Creek in Douglas County, Oregon (Figure 10).

Since the time of the field reconnaissance (October 20, 2006), the proposed pipeline alignment was shifted approximately 330 feet upstream. The old and new crossings lie within the same geomorphic reach; therefore, conditions and characteristics observed at the original site were applied to the new crossing location.

BASIN INFORMATION. The South Myrtle Creek basin drains a portion of the South Umpqua River Watershed. The basin upstream of the crossing is moderately-sized and consists of forested valley walls and headwater drainage channels. Downstream from the crossing, the basin consists of a relatively flat valley with rural development and pastureland.

The nearest USGS stream gage is no. 22359, located on South Myrtle Creek approximately 1 mile downstream of the pipeline crossing. EPA ReachFile™ estimates mean flow of the stream to be 98 cfs, based on an estimated channel gradient of 0.6 percent.

CROSSING INFORMATION. South Myrtle Creek flows west through a broadly curving single-stem channel positioned against the right valley wall. A broad floodplain terrace is situated on the left bank. A narrow, high-flow channel is perched above the active channel on the left floodplain. The high-flow channel is an abandoned section of the 1938 active channel.

The main channel streambed is generally composed of hard, erosion-resistant, relatively flat, sedimentary bedrock, overlain in places by a thin layer of cobbles and gravel. Several small side channel bars, composed of sand, and a small cobble bar, were situated along the left bank at the time of the site visit. The left stream bank is composed of alluvial sand and gravel; bedrock is exposed along the right bank. The high-flow channel streambed consists of 2 feet of fine sand underlain by gravel.

Although the channel form displayed several tight bends in the 1938 aerial photo, channel movement appears to have been contained to the center of the HCOT since at least 1983. The apparent containment is likely the result of decreased sediment deposition and bar building, which are necessary components of migration. This condition may be caused by a decrease in the supply of sediment from upstream sources, and/or by a change in transport regime from depositional, prior to 1983, to transport dominated.

MIGRATION ANALYSIS. South Myrtle Creek has potential for channel migration at the proposed crossing, based on the following observed geomorphic conditions:

- Channel migration is observable in the historical aerial photo record (Table C-3, Figure 17).
- Historical photos reveal that bends along this section of the river have migrated laterally at a maximum rate of 6.0 feet per year. Bar formation has also continued throughout the photo record, possibly driving the observed migration.
- The channel may be subject to abrupt avulsion.

A detailed channel migration analysis was conducted for this crossing for 25 and 50 years of steady channel movement. The width of the CMZ (shown in Tables 2 and C-1 and in Figure 23) was measured from the HCOT extending along the pipeline route into the right and left floodplains.

The 25- and 50-year CMZs were delineated based on a steady rate of migration estimated over the full period of the aerial photographic record. However, the recent migration character of the South Myrtle Creek suggests that channel movement is likely to remain well within the HCOT, based on the apparent change in transport regime. If the channel movement reactivates in the near future, migration would be expected to occur at the estimated rate of 6 feet per year, although it's unlikely that this rate could hold beyond the 25-year zone. This is due, at least in part, to the likely presence of bedrock buried in the floodplains, and changes in valley floor gradient and proximity of the right left valley wall to the active channel. The 25- and 50-year CMZs are presented in Figure 23.

SCOUR ANALYSIS. South Myrtle Creek has a low potential for channel scour due to the relatively smooth, erosion-resistant bedrock bed observed in the creek.

A scour analysis was not completed at this location.

2.1.10 Woods Creek

Woods Creek crosses the pipeline at MP 84.17. The site can be accessed from Woods Creek Road, near the town of Days Creek in Douglas County, Oregon (Figure 11).

BASIN INFORMATION. Woods Creek is a tributary of Days Creek, which lies midway up the South Umpqua watershed. The upper portion of the Woods Creek basin consists of a V-shaped headwater valley with steep, forested walls. The lower valley, near the confluence with Days Creek, is developed as rural pastureland. Historical aerial photos indicate that much of the watershed has been logged over the past several decades.

The nearest USGS stream gage is no. 22357, located approximately 3.6 miles downstream of the crossing, on Days Creek. EPA ReachFile™ estimates the gradient of Woods Creek in the vicinity of the crossing to be approximately 3.8 percent. Mean stream discharge is relatively low.

CROSSING INFORMATION. The channel is narrow and generally straight. Upstream of the crossing, the stream has cut through an ancient debris flow that extends onto the valley floor; up to 3 feet of incision was observed at the time of the field reconnaissance. Small sand and gravel bars composed of reworked debris flow sediment have formed in the vicinity of the crossing. At the crossing, the streambed and banks are composed of sand, gravel and occasional buried logs. Hard, erosion-resistant, relatively flat sedimentary bedrock was observed approximately 100 feet downstream of the crossing, suggesting that overlying alluvium and debris flow deposits at the crossing may be relatively thin. The banks and valley walls are densely vegetated with timber and brush.

MIGRATION ANALYSIS. Woods Creek has a low potential for channel migration at the proposed crossing location, based on the following observed geomorphic conditions:

- The channel in confined within a V-shaped valley.
- Appreciable creek migration was not observed in the historical aerial photo record (Table C-3).
- The dense bank vegetation inhibits erosion and migration.

Based on these results, a detailed migration analysis was not conducted for this site.

SCOUR ANALYSIS. Woods Creek has a low potential for bed scour at the proposed crossing location based on the following information:

- Observed shallow bedrock 100 feet downstream of the crossing.
- Low stream power associated with the low-order, headwater stream.

Based on the above information, a detailed scour analysis was not conducted at this crossing.

2.1.11 Fate Creek and Days Creek

Fate and Days Creeks cross the pipeline at MPs 88.48 and 88.6, respectively. Both sites can be accessed from Days Creek Road, near the town of Days Creek in Douglas County, Oregon (Figure 12).

Since the time of the field reconnaissance (October 19, 2006), the proposed pipeline alignment has shifted, moving the Days Creek crossing approximately 450 feet upstream to the northeast. The old and new Days Creek crossings lie within the same geomorphic environment; therefore, conditions and characteristics observed at the original site were applied to the new crossing location.

BASIN INFORMATION. The Fate and upper Days Creek stream join to form the main stem Days Creek channel, which is a tributary to the South Fork Umpqua River. The pipeline alignment crosses Fate and Days Creeks just upstream of their confluence. Fate Creek, which drains the smaller of two basins, flows in a broad, linear, southwest-trending valley. The upper Days Creek basin is similar in form but is roughly twice the size of the Fate Creek basin. Both basins consist of moderately steep forested valley walls and headwaters and rounded valley bottoms occupied by rural development and pastureland. Both basins have been logged, as documented in 1952 photos. No dams or channel modifications were noted in the historical photo and map review.

The nearest USGS stream gage is no. 22357, located approximately 4 miles downstream from the crossings on the main stem Days Creek channel. EPA ReachFile™ estimates the mean flow on Days Creek containing the crossing to be 42.5 cfs, based on an estimated channel gradient of 1.8 percent.

CROSSING INFORMATION. Fate Creek flows south towards the confluence with Days Creek. Fate Creek flows across gravel alluvium and bedrock within a narrow corridor defined by roughly 8- to 12-foot-high terraces along both banks. The thickness of streambed alluvium overlying the bedrock was measured at roughly 3 feet or less. The stream banks are composed of sand and gravel and are well vegetated with grass and shrubs above the ordinary high-water line (OHWL). Minimal bank erosion was observed at the crossing location.

Days Creek flows southwest through a flat, terraced valley floor. The channel, which is narrow and relatively straight, has incised roughly 8 to 10 feet through sandy gravel alluvium to bedrock. A thin mantle of gravel and cobbles covers the bedrock in places. The banks are composed of sand and gravel, and are relatively well vegetated, although portions of both banks are subject to severe erosion and recession. The recession has resulted in channel widening, as indicated by current channel dimension (10 to 15 feet wide and 1.8 feet deep).

MIGRATION ANALYSIS. Fate and Days Creeks both have low potentials for channel migration at the proposed crossing locations, based on the following geomorphic conditions:

- Channel migration was not observed in the historical aerial photo period (Table C-3).
- The channels are confined by banks and high terraces.
- Bank erosion observed near the Days Creek crossing indicates ongoing channel widening (Tables 2 and C-1).

Based on these results, a detailed migration analysis was not conducted at the Fate or Day Creek crossings.

The potential for continued Days Creek channel widening was addressed by evaluating bank erosion and recession characteristics. Based on observed site conditions, a 10-foot zone of potential widening was applied on both banks – equal to the height of the 10-foot-high terraces.

SCOUR ANALYSIS. Potential scour is limited to the depth of alluvium covering erosion-resistant bedrock in both Fate and Days Creeks (between 0 and 3 feet). A detailed scour analysis was not completed at either location.

2.1.12 South Umpqua River Crossing No. 2

South Umpqua River Crossing No. 2 is located at MP 94.73. The site can be accessed from Route 227/Tiller Trail Road, near the town of Milo in Douglas County, Oregon (Figure 13).

BASIN INFORMATION. The upper South Umpqua River drains numerous steep valleys and foothills of the southern Cascades. Peak flow estimates for this site were developed through statistical analysis from USGS stream gage 14308000, located at Tiller, Oregon. The mean annual flow at the gage site, from 1910 to 2005, is 1,019 cfs. Peak discharge estimates for the 2-, 5-, 10-, 25-, 50- and 100-year recurrence storms are presented in Appendix B, Table B-4. South Umpqua River Crossing No. 2 carries the second highest hydrologic flow of all crossings evaluated for this study.

CROSSING INFORMATION. In the vicinity of the crossing, the South Umpqua River is a very dynamic stream. Upstream of the crossing, the river follows a broad curving bend, adjacent to Route 227. About 400 feet upstream of the crossing, the stream impinges against the left valley wall and deflects southwest towards the crossing. A large cobble and gravel bar has developed along the right bank at the bend and extends to the center of the channel.

The channel appears to be confined by bedrock, which is exposed along both right and left banks. Bedrock outcrops are also exposed on the channel floor roughly 280 feet downstream from the crossing. At the crossing, the streambed consists of occasional deep pools (maximum depth of 15 feet), extended riffle sections and side channel bars composed of gravel and cobbles. Although bedrock is not observable on the streambed at the pipeline crossing, geotechnical borings located near the site suggest that bedrock may underlie the channel floor at very shallow depths. Although these borings (B-2 and B-3) (Appendix D, Figures D-20 and D-21) are not immediately adjacent to the crossing location, extrapolation of the bedrock contacts derived from the borings, and exposed outcrops in the channel, indicate that bedrock is likely present from 0.7 to 8.7 feet below the existing channel floor.

The banks and terraces are composed of alluvial gravel and cobbles, underlain by bedrock. The right bank, which abuts a flat alluvial terrace and the Route 227 embankment, is steep (45 percent) and approximately 20 feet high. The left bank is 13 feet high and abuts a narrow floodplain and a 20-foot-high terrace. A collection of large angular boulders lie on the left bank and in the channel.

MIGRATION ANALYSIS. South Umpqua River Crossing No. 2 has a low potential for channel migration at the proposed crossing based on the following observed geomorphic conditions:

- No measurable channel movement was observed in the historical aerial photo record (Table C-3).
- The river is confined by bedrock banks.
- The channel is entrenched.

Based on these results, a detailed migration analysis was not conducted at this site.

SCOUR ANALYSIS. The potential for channel scour at South Umpqua River Crossing No. 2 is high within alluvial substrate. At the crossing location, the river channel appears to be fully entrenched in bedrock due to erosive scour that has prevailed over the course of thousands to millions of years. Because of the lengthy time periods involved, the full extent of scour pits and channel incision in bedrock can be very great. However, identifying the elevation of bedrock contacts can be difficult since deeply scoured channels often serve as sites of thick alluvial deposits.

If bedrock is not present at a shallow depth (0.7 to 8.7 feet) beneath the channel at the crossing, it is possible that localized alluvial sediment has filled a portion of the incised bedrock channel. The alluvium has a high scour potential and will mobilize during high stage flow events. A detailed scour analysis was completed to identify alluvial scour depths in the absence of bedrock.

Results indicate potential scour depths of 11.0 feet at the 10-year flow, 13.5 feet at the 25-year flow, 16.0 feet at the 50-year flow, and 18.0 feet at the 100-year flow (Table 2, Table C-2).

The total depth of potential scour for any recurrence interval flow should be taken as either the calculated scour depth or the presence of competent bedrock, whichever of the two is first encountered.

The interpreted depth to bedrock and calculated scour depths, relative to the elevation of the channel floor, are shown in Figure 24. A detailed summary of the scour analysis is presented in the scour workbooks in Appendix E.

2.1.13 Rogue River

The Rogue River crosses the proposed pipeline at MP 122.65 and can be accessed from Route 62, near the town of Trail in Jackson County, Oregon (Figure 14).

BASIN INFORMATION. The crossing is roughly two-thirds of the way up the Rogue River watershed, 152 miles from the mouth. The crossing lies within the Middle Rogue Watershed, which collects flow from many tributaries that drain the foothills of the southern Cascade Mountains. The forested watershed is a mix of protected wilderness and timber production.

The majority of flow at the crossing is regulated by a flood control dam (W. L. Jess Dam) and reservoir (Lost Creek Lake Reservoir) located in the upper watershed, operated by the U.S. Army Corps of Engineers. The estimated catchment area above the crossing is approximately 1,143 square miles. Peak flow estimates for this site were developed through statistical analysis from USGS stream gage 14339000, located at Dodge Bridge. The drainage area for the proposed crossing represents 94 percent of the drainage area at the USGS gage. The mean annual flow at the gauging station, which has been operating since construction of the upstream reservoir, is 2,362 cfs. Estimates for the 2-, 5-, 10-, 25-, 50- and 100-year peak discharge volumes are presented in Appendix B, Table B-4.

CROSSING INFORMATION. The pipeline crosses the Rogue River at a sharp meander bend. Immediately upstream of the crossing, a bedrock outcrop deflects the river against the right bank (Figure 14). The inside of this meander (river left) is a terraced point bar with historical high-flow channels cutting across its surface.

Trail Creek flows into the Rogue River (river right) 150 feet upstream of the crossing. Trail Creek valley is physically separated from the Rogue by a large (20 to 30 feet high) prism of road fill (Route 62) that fills the gap between bedrock exposed on both sides of the Trail Creek Valley.

The Rogue River streambed is composed of basalt/breccia bedrock, partially covered by a deposit of cobbles and boulders. Bedrock is exposed along on the right valley wall and much of the right river bank. Geotechnical borings located on the terraced point bar encountered 13 to 23 feet of alluvium underlain by bedrock (Appendix D, Figures D-23 through D-29).

The banks along the inside of the bend (left bank) have a gentle to moderate slope, are 2 to 7 feet high, and are composed of silt/sand over cobble and gravel. No evidence of recent erosion was observed along the left bank. The right bank consists of a 20- to 50-foot-wide terrace, above which either basaltic bedrock outcrops or a riprap embankment is present. Both features are steeply inclined and at least 30 feet high. The mouth of Trail Creek, where the Route 62 Bridge spans the creek, is protected by riprap on both sides of the bridge.

The left bank consists of a floodplain with two terraces. The lowest terrace (4 to 6 feet above the low-flow channel) is composed of alluvial gravel deposited between 1938 and 1968. Hydraulic analysis indicates the low terrace is flooded at the 5- to 10-year flood recurrence interval. The higher terraces (10 to 15 feet high) are composed of cobbles and gravel overlain by sand. Light Detection and Ranging (LiDAR) imagery reveals that this higher terrace has a series of high-flow channels cutting across it. These high-flow channels do not appear to be active or likely to result in scour during future floods.

MIGRATION ANALYSIS. The Rogue River crossing has a moderate potential for channel migration based on the following geomorphic conditions:

- Established terraces and regulated flow from the W.L. Jess Dam were observed. Flow control dams typically influence downstream channel performance in two ways: (1) the dam cuts off the sediment supply; and (2) flow management prevents downstream flooding. The common result of these controls is the entrenchment of downstream channel sections.
- Historical photos of this area show results similar to that of other documented flow-regulated river systems. The oldest photos show that the tip of the bend, a point bar, changes over time (migration occurred). The greatest change in channel position occurred between 1943 and 1976. The gravel banks upstream and downstream appear to stabilize (vegetation took hold) following the installation of the dam upstream in 1974. The photo evaluation and the site reconnaissance suggest that the river channel has entrenched. Review of the boundary shear stress in the left overbank channel (output from HEC-RAS) indicates that only gravel and small-sized sediments on the lower terrace would mobilize during low-frequency (50- and 100-year) floods (Table C-3, Figure 25).

Based on these results, no further migration analyses were conducted for this crossing.

The potential for continued channel widening was addressed by evaluating bank erosion and recession characteristics. Based on observed site conditions, a 200-foot-wide bank erosion zone, measured from the HCOT, is applied along left bank.

SCOUR ANALYSIS. The Rogue River has a high potential for channel scour at the proposed crossing location. Although the bed material consists of coarse-grained material, indications are that bed material is easily transported in low-frequency flood events. The Rogue River crossing is subject to extremely high peak flow volumes, with the 100-year flow calculated as 66,384 cfs. Additionally, channel geometry induces scour processes; the site is located between two tight meander bends that contribute to bend scour, and downstream of a tributary confluence with Trail Creek.

Results indicate potential scour depths of 13.5 feet at the 10-year flow, 16.5 feet at the 25-year flow, 18.5 feet at the 50-year flow and 20.5 feet at the 100-year flow. Estimates of observed pool depths during the field reconnaissance were between 8 and 12 feet (Table 2, Table C-2).

Where erosion-resistant bedrock is encountered at depths shallower than the calculated scour depths, the elevation of the bedrock should be considered the total depth of potential scour for all flows. Based on observations of known contacts in adjacent rock cores, and the locations of upstream and downstream riffles, bedrock is interpreted to be present between 0.9 and 6.9 feet below the streambed along the proposed crossing. The interpreted depth to bedrock and calculated scour depths, relative to the elevation of the channel floor, are shown in Figure 25. A detailed summary of the scour analysis is presented in the scour workbooks in Appendix E.

2.1.14 Other Streams

Three of the Level 1 sites were included in the analysis and field reconnaissance at the request of PCGP. The sites included the East Fork Coquille River (MP 29.85), Elk Creek (MP 32.40) and Big Creek (MP 37.33) (Figure 1).

CROSSING INFORMATION: BIG CREEK AND ELK CREEK

Big Creek and Elk Creek are low order, steep gradient streams that flow through densely forested headwater valleys. The bed and banks of both channels are composed of ancient debris flow materials including boulders and cobbles, embedded in silt and sand.

MIGRATION ANALYSIS: BIG CREEK AND ELK CREEK

Big Creek and Elk Creek each have low potentials for migration, based on the following field observations:

- The streams are confined by their valleys.
- The stream banks are composed of erosion-resistant boulders and cobbles.
- The stream banks are covered with dense, well-established vegetation.

No channel migration analysis was conducted at either crossing.

CROSSING INFORMATION: EAST FORK COQUILLE RIVER

The East Fork Coquille River is a larger stream that has incised roughly 30 feet through non-cohesive alluvial deposits consisting of sand and silt. The streambed consists of hard, erosion-resistant, relatively flat, sedimentary bedrock.

MIGRATION ANALYSIS: EAST FORK COQUILLE RIVER

The East Fork Coquille River has a low potential for migration but potential for channel widening based on the following information obtained during the field reconnaissance:

- Steep banks composed of non-cohesive materials have a high potential for bank failure and widening. Based on observed site conditions a 30-foot zone of potential widening was applied on both banks – roughly equal to the height of the terraces on both banks.

No channel migration analysis was conducted at this crossing.

SCOUR ANALYSIS. The East Fork Coquille River, Elk Creek and Big Creek have a low potential for scour based on the following information obtained during the field reconnaissance:

- Elk Creek and Big Creek have well armored streambeds composed of erosion-resistant boulders and cobbles.
- The East Fork Coquille River has a streambed composed of relatively flat, hard, erosion-resistant bedrock.

More detailed scour analyses were not conducted for these three crossings.

All three sites remain Level 1 crossings.

TABLE C-1. SUMMARY OF MIGRATION AND SCOUR RESULTS

Stream Name at Crossing	Approx. PCGP Milepost	Migration Analysis	Migration Results (LB/RB)[a]	
			25-yr (ft.)	50-yr (ft.)
North Fork Coquille River	23.06	Widening	22/22	22/22
Middle Creek	27.04	Widening	30/30	30/30
East Fork Coquille River	29.85	Widening	30/30	30/30
South Fork Elk Creek	34.46	Widening	10/10	10/10
Middle Fork Coquille River	50.28	Widening	18/18	18/18
Olalla Creek	58.78	Migration Measured	935/381	1194/696
North Myrtle Creek	79.12	Migration Measured	78/146	143/211
South Myrtle Creek	81.19	Migration Measured	204/148	833/148
Days Creek	88.60	Widening	10/10	10/10
Rogue River	122.65	Widening	562/134	562/134

Notes:

[a] Left Bank/Right Bank measured from stream centerline; includes zone of potential channel widening.

TABLE C-2. SUMMARY OF SCOUR RESULTS

Stream Name at Crossing	Approx. PCGP Milepost	Scour Analysis	Expected Scour Depth Based on Interpreted Depth to Bedrock[a]	Calculated Total Potential Scour Depth in Alluvium (10-/25-/50-/100-yr)
Middle Creek	27.04	HEC-RAS	2 - 7.0 ft[b]	7.0/9.0/9.0/10.5 ft[c,d]
South Fork Elk Creek	34.46	HEC-RAS	--	4.0/5.0/5.0/6.0 ft.
Olalla Creek	58.78	HEC-RAS	--	6.0/7.0/7.0/7.5 ft.
North Myrtle Creek	79.12	HEC-RAS	--	5.0/6.0/6.0/6.5 ft[c]
South Umpqua River Crossing No. 2	94.73	HEC-RAS	0.7 - 8.7 ft[b]	11.0/13.5/16.0/18.0 ft[d]
Rogue River	122.65	HEC-RAS	0.9 - 6.9 ft[b]	13.5/16.5/18.5/20.5 ft[d]

Notes:

[a] Depth to bedrock interpreted from nearby boring logs and outcrops.

[b] Depth of scour is expected to be limited by bedrock.

[c] Minimum scour depth calculated crossing location.

[d] Calculated depth of scour assumes absence of bedrock.

TABLE C-3. HISTORICAL PHOTOS/MAPS

Stream Name at Crossing	Approx. PCGP Milepost	Migration Analysis	Historical Photos[1] and (Maps)	Orthorectified Photos	Observed Channel Migration
Coos River	11.13R	Field and Photo review	1954[2], 1984[2]	2004[5], 2006[6]	No
North Fork Coquille River	23.06	Field and Photo review	1942[2], 1980[2]	2004, 2006	No
Middle Creek	27.04	Field and Photo review	1942[2], 1969[2]	2004, 2006	No
East Fork Coquille River	29.85	Field only	–	2004, 2006	No
Elk Creek	32.40	Field only	–	2004, 2006	No
South Fork Elk Creek	34.46	Field and Photo review	1952[2], 1976[2]	2004, 2006	No
Big Creek	37.33	Field only	–	2004, 2006	No
Middle Fork Coquille River	50.28	Field and Photo review	1952[2], 1984[2]	2004, 2006	No
Olalla Creek	58.78	Migration Measured	1939[2], 1954[2], 1960[2], 1967[2], 1984[2]	2000, 2004, 2006	Yes
North Myrtle Creek	79.12	Migration Measured	1952[2], 1982[2]	2000, 2004, 2006	Yes
South Myrtle Creek	81.19	Migration Measured	1939[2], 1983[2]	2000, 2004, 2006	Yes
Woods Creek	84.17	Field and Photo review	1952, 1982	2004, 2006	No
Fate Creek	88.48	Field and Photo review	1952[2], 1982[2]	2004, 2006	No
Days Creek	88.60	Field and Photo review	1952[2], 1982[2]	2004, 2006	No
South Umpqua River Crossing No. 2	94.73	Field and Photo review	1943[2], 1982[2]	2000, 2006	No
Rogue River	122.65	Field and Photo review	1943[2], 1976[2]	2000, 2004, 2006	Yes

Notes:

[1] Scanned from archives at the University of Oregon, Knight Library.

[2] Geo-rectified by GeoEngineers.

[3] Acquired from USDA. 4 Acquired from Surdex. 5 Acquired from USGS and Terraserver.

TABLE C-4. REACH DESCRIPTION TABLES

COOS RIVER (MP 11.13R)

Characteristic	Description
Valley	3,000 feet wide; flat-bottomed; pasture; steep forested walls.
Channel	625 feet wide; straight; approximately 0 percent gradient; against right valley wall; tidally influenced.
Bed	Bed material not observable; no bars present.
Banks	Silt with clay; Steeply sloping below high-tide line; grass and shrub vegetation above ordinary high water line (OHWL).
Floodplain	Silt with clay; drainage ditches and relict dendritic drainage pattern since converted to pasture; grass vegetation; approximately 1.6 feet above OHWL.
Human Modifications	Levees on both banks; road on top of left bank levee; bridge immediately upstream of site; old riprap embedded into banks; piles in bed at base of banks; historical dredging in vicinity of crossing.
Assessment	Not subject to significant migration or scour.
Other	

NORTH FORK COQUILLE RIVER (MP 23.06)

Characteristic	Description
Valley	3,000 feet wide; flat-bottomed; pasture and agriculture; steep forested walls.
Channel	57 feet wide; broad meanders; gradient estimated to approximately 0.01 percent; bedrock controlled riffle pool morphology; incised
Bed	Bedrock with gravel in places; small sand and gravel bars in high-flow eddies.
Banks	Right bank = fine sand with silt and gravel; left bank = bedrock with some sand and gravel; near vertical; dense forest vegetation above OHWL; minor bank erosion at high flow.
Floodplain	Sand with silt; floodplain re-entry channel upstream of crossing; grass vegetation; approximately 22-foot-high floodplain terraces.
Human Modifications	Bridge upstream (not a constriction); forest vegetation cleared in valley bottom.
Assessment	Subject to possible widening.
Other	

MIDDLE CREEK (MP 27.04)

Characteristic	Description
Valley	850 feet wide; flat-bottomed; forested with scattered rural development; steep forested walls.
Channel	35 feet wide; broad meanders controlled by regional geology; approximately 1.3 percent gradient; low-energy riffle pool morphology; channel against valley wall on right bank.
Bed	Gravel and sand; few small bars downstream of bank failures; bedrock observed in the bed upstream and downstream of the crossing site.
Banks	Sand with silt and occasional organic material; bedrock exposed in right bank; near vertical; dense forest vegetation and blackberries above OHWL; significant bank erosion resulting in large bank failures.
Floodplain	Sand with silt; dense forest vegetation and grass/blackberries; approximately 15-foot-high floodplain terrace on left bank.
Human Modifications	Logging on valley walls; road cut into right bank valley wall.
Assessment	Subject to channel widening and/or scour.
Other	Bank failures dam the channel in several places and locally raise the bed elevation with loose, easily erodible, silt/sand/gravel with wood and other debris.

SOUTH FORK ELK CREEK (MP 34.46)

Characteristic	Description
Valley	150 feet wide; flat-bottomed; forested valley bottom and steep valley walls.
Channel	10 feet wide; small radius bends connected by straight stretches; approximately 1.0 percent gradient; riffle-pool morphology; channel confined by low terraces.
Bed	Cobbles with gravel; no bars; well embedded cobble armored surface; bedrock exposed in bed upstream and downstream (approximately 400 feet upstream and approximately 1,000 feet downstream).
Banks	Sand with silt overlying gravel and cobbles; dense forest vegetation above OHWL; bank erosion on right bank; large bank failures upstream (approximately 300 feet).
Floodplain	Sand with silt; 2 to 3 feet of overbank deposits over ancient alluvium; dense forest vegetation.
Human Modifications	Abandoned logging road crosses stream (culvert/bridge has been removed); significant logging on valley walls.
Assessment	Subject to scour and minor widening.
Other	Several slope failures observed on valley walls.

MIDDLE FORK COQUILLE RIVER (MP 50.28)

Characteristic	Description
Valley	3,750 feet wide; broad; flat-bottomed; pasture; timbered valley walls.
Channel	26 feet wide; large- and small-diameter bends with straight stretches between; 0.5 percent gradient.
Bed	Bedrock with a thin veneer of coarse gravel in places; one large emergent gravel bar on inside of bend.
Banks	Silt, sand and clay with occasional lenses of gravel; well vegetated deciduous timber above OHWL; undercut left bank (approximately 10 inches of recession); steep slopes; scattered shallow bank failures.
Floodplain	Silt and sand; approximately 18-foot-high floodplain terrace on both banks; floodwater reentry channel on right side.
Human Modifications	Bridge/weir constriction and grade control upstream approximately 500 feet; valley bottom has been cleared of most timber.
Assessment	Subject to channel widening.
Other	

OLALLA CREEK (MP 58.78)

Characteristic	Description
Valley	1,900 feet wide; flat valley bottom; pastures; steep forested valley walls.
Channel	30 feet wide; short radius bends with straight stretches, abandoned channels and split flow in places; 0.3 percent gradient; riffle-pool morphology with bedrock controls.
Bed	Gravel and sand with discontinuous/uneven bedrock in places; large, accreting gravel point bar on inside of bend at crossing.
Banks	Silty sand with gravel; grass and deciduous tree vegetation above OHWL; erosion on outside of most bends.
Floodplain	Sand with silt; multiple abandoned/high-flow channels; grass and deciduous tree vegetation; roughly 7-foot-high floodplain terraces on both sides.
Human Modifications	Cattle accessing stream; dam upstream controls flow and traps sediment.
Assessment	Subject to historical migration; subject to scour.
Other	Avulsion between 1960 and 1967.

NORTH MYRTLE CREEK (MP 79.12)

Characteristic	Description
Valley	860 feet wide; flat valley bottom; agriculture, pasture, riparian forest and rural development; forested valley slopes; site is located near the outlet of a narrow constriction as the valley begins to widen.
Channel	15 feet wide; channel transitions from straight to broad radius bends with occasional tight radius bends; approximately 2 percent gradient; riffle-pool morphology.
Bed	Gravel with sand; moderately armored; occasional sand deposition; numerous gravel and sand bars downstream.
Banks	Sand with gravel and silt; left bank is undercut and eroding; deciduous riparian forest.
Floodplain	Sand with silt; riparian forest and pasture; isolated terraces.
Human Modifications	Partial valley clearing for agriculture and pasture; scattered cable-log revetments and riprap bank armoring.
Assessment	Subject to historical migration; subject to scour.
Other	This table represents data extrapolated from a field visit to the original crossing site approximately 2,350 feet downstream and GIS data.

SOUTH MYRTLE CREEK (MP 81.19)

Characteristic	Description
Valley	1,000 feet wide; broad, flat valley bottom; pasture; steep forested valley walls.
Channel	18 feet wide; straight with one small-radius bend; 0.6 percent gradient; riffle pool; bedrock controlled.
Bed	Bedrock with occasional veneer of cobbles/gravel; occasional small cobble/gravel side-channel bars.
Banks	Bedrock on right bank; sand on left bank (inside of bend); grass and shrub vegetation with occasional trees above OHWL.
Floodplain	Sand; grass with a buffer of deciduous trees; approximately 10-foot-high floodplain terrace on left side; sand deposition in high-flow channel on left floodplain terrace.
Human Modifications	Highway cut into valley wall on right bank; valley bottom has been cleared for pasture.
Assessment	Subject to historical migration.
Other	Floodwater reentry drainage on left bank floodplain is well vegetated and shows no recent signs of scour (large trees growing in channel).

WOODS CREEK (MP 84.17)

Characteristic	Description
Valley	45 feet wide; V-shaped; steep forested valley walls; scattered timber harvesting.
Channel	5 feet wide; straight; approximately 3.8 percent gradient; small headwater stream.
Bed	Coarse sand and fine gravel; bedrock exposed downstream approximately 100 feet; channel has incised approximately 3 feet into ancient debris flow deposits upstream approximately 50 feet; several small side-channel sand bars forming below debris flow deposit.
Banks	Sand and silt; up to 3 feet high; nearly vertical; well vegetated with mature trees above OHWL.
Floodplain	N/A; V-shaped valley.
Human Modifications	Logging on valley walls.
Assessment	Not subject to significant migration or scour.
Other	

FATE CREEK (MP 88.48)

Characteristic	Description
Valley	1,425 feet wide; flat-bottomed valley near confluence with Days Creek; pasture on valley bottom; steep forested valley walls.
Channel	12 feet wide; straight with small-radius bends; approximately 1.8 percent gradient; riffle-pool morphology; primarily bedrock controlled.
Bed	Approximately 3 feet of coarse gravel with sand over bedrock; occasional small, emergent, side-channel gravel bars.
Banks	Sand and gravel; well vegetated with grass and trees.
Floodplain	Sand; no abandoned channels observed; grass vegetation with scattered trees above OHWL; floodplain terraces approximately 10 feet high.
Human Modifications	Road and associated bridge downstream approximately 100 feet; channel is bedrock controlled in this location.
Assessment	Not subject to significant migration or scour.
Other	Landowner has observed high flow on the floodplain-terraces, although there is no evidence of recent scour or deposition.

DAYS CREEK (MP 88.60)

Characteristic	Description
Valley	1,425 feet wide; flat-bottomed valley near confluence with Fate Creek; pasture on valley bottom; steep forested valley walls.
Channel	20 feet wide; straight with several well-defined eddies forming small, extremely tight-radius bends; riffle-pool morphology; bedrock controlled.
Bed	Bedrock; occasional cobble/gravel veneer; large side-channel and point bars forming upstream (downstream of highway bridge).
Banks	Sand and coarse gravel; near vertical; undercut 0.5 to 1.0 feet in places; well vegetated with mature trees above OHWL.
Floodplain	Sand with fine sand; vegetated with grass and mature timber buffering stream.
Human Modifications	Highway bridge upstream of crossing; most of the floodplain has been cleared for pasture.
Assessment	Subject to minor channel widening.
Other	

SOUTH UMPQUA RIVER CROSSING NO. 2 (MP 94.73)

Characteristic	Description
Valley	1,800 feet wide; relatively broad valley immediately downstream of narrow V-shaped valley; flat bottomed; terraced; agriculture and pasture; steep forested valley walls.
Channel	185 feet wide; large-radius bends with straight stretches between; riffle pool morphology; approximately 0.2 percent gradient.
Bed	Cobbles and gravel; well armored; granitic bedrock exposed along the outside of bends; large emergent gravel bar.
Banks	Gravel and cobbles; bedrock exposed in the left bank; terrace on both banks; well vegetated above OHWL.
Floodplain	Sand with gravel; pasture beyond terrace on left bank; ancient gravel bar and road beyond terrace on right bank.
Human Modifications	Road on right bank; pasture on left bank.
Assessment	Not subject to significant migration; subject to scour.
Other	Uneven bedrock; deepest pool measured at 15 to 20 feet below thalweg.

ROGUE RIVER (MP 122.65)

Characteristic	Description
Valley	1,742 feet wide; flat valley bottom with steep, bedrock controlled valley walls; sparse vegetation (trees and grass); rural development.
Channel	Approximately 120 feet wide; low-radius bends with straight stretches between; approximately 3 percent gradient; riffle-pool morphology.
Bed	Small cobbles and occasional bedrock knobs; inactive point bar on left bank.
Banks	Bedrock exposed on right bank; cobbles with gravel on left bank; sparsely vegetated above OHWL.
Floodplain	Bedrock on right floodplain; cobbles on left floodplain; road and bedrock on right; sparse forest and houses on left; left floodplain is an inactive point bar.
Human Modifications	Two dams within 3 miles upstream; road and revetments on right bank; bridge constricting tributary immediately upstream of crossing.
Assessment	Subject to migration and scour.
Other	Borings and exposures of bedrock suggest shallow bedrock at crossing.

EAST FORK COQUILLE RIVER (MP 29.85)

Characteristic	Description
Valley	Broad valley; pasture.
Channel	Incised; large radius bends; riffle-pool morphology; low gradient.
Bed	Composed of bedrock.
Banks	Composed of sand; blackberries.
Floodplain	Composed of sand; pastures.
Human Modifications	Cattle accessing stream and causing bank instability.
Assessment	Subject to channel widening.
Other	

ELK CREEK (MP 32.40)

Characteristic	Description
Valley	Narrow; steep walls; forested.
Channel	Straight; continuous riffle; high gradient (approximately 7 percent).
Bed	Composed of boulders, cobbles, gravel, sand and scattered LWD (ancient debris runout).
Banks	Composed of boulders, cobbles, gravel; vegetated with mature trees above the OHWL.
Floodplain	N/A
Human Modifications	Logging in the drainage basin.
Assessment	Not subject to significant migration or scour.
Other	

BIG CREEK (MP 37.33)

Characteristic	Description
Valley	Narrow valley with flat bottom 50 to 100 feet wide; dense old growth timber.
Channel	Single channel approximately 15 feet wide; straight channel pattern; riffle-pool morphology.
Bed	Boulders, cobbles, gravel, sand, LWD (ancient debris flow).
Banks	Boulders, cobbles, gravel, sand, LWD (ancient debris flow); well vegetated with brush and old-growth forest above the OHWL.
Floodplain	Composed of boulders, cobbles, gravel, sand and LWD (ancient debris flow); old growth forest.
Human Modifications	N/A
Assessment	Not subject to significant migration or scour.
Other	

3.0 REFERENCES

Burns, S.F., 1998. Geologic and Physiographic Provinces of Oregon, in Environmental, Groundwater and Engineering Geology – Applications in Oregon, S.F. Burns, editor, pp. 3-14, Starr Publishing Co., Belmont, California.

Maynord, S.T., 1996, Toe-Scour Estimation in Stabilized Bendways, ACEC, Volume 122, No. 9, August 1996.

Orr, E.L. and W.N. Orr, 2012. Geology of Oregon, sixth edition. Oregon State University Press, p. 304.

APPENDIX D
Exploration Logs

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% RETAINED ON NO. 200 SIEVE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	CC	Cement Concrete
	AC	Asphalt Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Measured groundwater level in exploration, well, or piezometer

Groundwater observed at time of exploration

Perched water observed at time of exploration

Measured free product in well or piezometer

Stratigraphic Contact

Distinct contact between soil strata or geologic units

Gradual change between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

Laboratory / Field Tests

%F	Percent fines
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
OC	Organic content
PM	Permeability or hydraulic conductivity
PP	Pocket penetrometer
SA	Sieve analysis
TX	Triaxial compression
UC	Unconfined compression
VS	Vane shear

Sheen Classification

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
NT	Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

GEOENGINEERS

Figure D-1

Date(s) Drilled	06/14/06 - 06/15/06	Logged By	JLL	Checked By	ABA
Drilling Contractor	Boart Longyear Company	Drilling Method	Mud Rotary / HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop Autohammer	Drilling Equipment	CME 800 Track Rig
Total Depth (ft)	98.5	Surface Elevation (ft)	17.51	Groundwater Elevation (ft)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Elevation feet	Depth feet	SAMPLES: Recovered (in)	SAMPLES: Blows/foot	SAMPLES: Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
	0					SP	Dark gray poorly graded medium sand with trace wood fragments (very loose, wet)			
15										
	5	67	3	1						
10										
	10	100		2						Push
5						ML	Dark gray silt with trace fine sand (soft, wet)			
	15	100	4	3			Becomes grayish brown with occasional organic matter at 16 feet			
0										
						PT	Brown peat with trace silt and sand (soft, moist)			
	20	100	3	4						OC=16%
-5						ML				
	25	0	7	5			No recovery at 25 feet; gray silt on outside of sampler			
-10										
	30	100	2	6			Gray silt with occasional sand and silt interbeds with trace organic matter (very soft to medium stiff, moist)			Push
-15										
	35									

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-1 (Coos River)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Depth feet	Recovered (in)	Blows/foot	Sample Number	Group Symbol	Material Description	Moisture Content %	Dry Unit Weight, lbs/ft³	Other Tests and Notes
35	17	7	7			91	49	
				OL	Gray organic silt with trace fine sand, green vegetation, occasional layers of sandy silt (soft, moist)			
40	100	4	8					OC=20%
				SP/GP	Dull action indicates sand and gravel at 42 feet			
				MH	Interbedded gray elastic silt with gray silty sand and brown peat, fine sand (stiff, moist)			
45	100	8	9					AL
50	89	4	10					
				MH	Yellow-gray elastic silt with trace fine sand and siltstone fragments (stiff, moist)			
55	78	10	11					AL
				SSTN	Dark gray sandstone, slightly weathered, moderately strong, medium fractured, trace shell fragments			
	100	50/5"	12					
60	92							
65	100							
				SILTSTON	Grades to sandy siltstone			
				SSTN	Grades to sandstone			
70	97							
					Fractured zone at 73 feet			
75	100							
					Medium fractured			

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LOG OF BORING B-1 (Coos River) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Figure D-2
Sheet 2 of 3

Elevation feet	Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
	80		100									
-65												
	85		88									
-70												
	90		100						Very fine sand			
									Dark gray sandstone; slightly weathered, moderately strong, close to medium fractured, trace silt and shell fragments Fractured zone from 91 to 92 feet			
-75			93									
	95											
-80												

Bottom of hole at 98.5 feet
Groundwater not determined due to drilling fluid

Depth feet: 100, 105, 110, 115, 120
Elevation feet: -85, -90, -95, -100

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LOG OF BORING B-1 (Coos River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Date(s) Drilled	06/13/06	Logged By	JLL	Checked By	ABA
Drilling Contractor	Boart Longyear Company	Drilling Method	Mud Rotary / HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop Autohammer	Drilling Equipment	CME 800 Track Rig
Total Depth (ft)	100	Surface Elevation (ft)	25.00	Groundwater Elevation (ft)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Elevation feet	Depth feet	SAMPLES: Interval / Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
25	0					SP	Dark gray poorly graded medium sand with trace silt, shell and wood fragments (loose to very loose, moist)			
20	5	67	4	1						
						SM	Very dark gray silty sand with occcasional wood and organic fragments (very soft, moist)			
15	10	78	0	2				50		%F=31
						ML				
10	15	17	10	3			Sandy silt (medium stiff)	57	69	
5	20	100	3	4			Dark grayish brown silt with occasional organic debris, wood fragments (very soft, moist)			
0	25	89	4	5			Occasional layers of peat and silty sand (soft to very soft)			
						SM	Interbedded silty sand and poorly graded sand with trace organic fragments (loose, wet)			
-5	30	100	6	6				54		%F=33
						SP				
-10	35									

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-2 (Coos River)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Figure D-3
Sheet 1 of 3

Elevation feet	Depth feet	Recovered (in)	Blows/foot	Sample Number	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
-10	35	100	21	7		Dark gray poorly graded medium sand with occasional organic debris (medium dense, moist)			
					ML	Gray sandy silt (medium stiff, moist)			
-15	40	89	6	8	PT/SM	Brown peat and silty sand (loose, moist)			
					CL	Yellow-gray lean clay (medium stiff to stiff, moist)			
-20	45	0	21	9		No recovery - yellow-gray clay on outside of sampler			
-25	50	0	12	10a					
		100	7	10					
-30	55	0	11	11					
					MH				
-35	60	72	14	12		Blue-gray and yellow elastic silt with trace fine sand (stiff, moist)			AL
-40	65	67	20	13		Dark gray and brown mottling (very stiff)			
-45	70	100 100	50/3"	14	SSTN	Dark gray sandstone, slightly weathered, moderately strong, medium fractured			0-50 degree from horizontal
-50	75	100				Medium to widely fractured			subhorizontal/closed fractures

LOG OF BORING B-2 (Coos River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Figure D-3
Sheet 2 of 3

Elevation feet	Depth feet	SAMPLES: Interval Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
-55	80	97									
								Fractured zone 3 to 4 inches wide at 82 feet			
								Widely fractured			
-60	85	97									
								2 inches open fracture at 89.2 feet			
-65	90	100									
		100									
-70	95	100									
								Fractured zone at 98.6 feet			
-75	100							Bottom of hole at 100 feet Groundwater not determined due to drilling liquid			
-80	105										
-85	110										
-90	115										
-95	120										

LOG OF BORING B-2 (Coos River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Date(s) Drilled	05/10/06 - 05/11/06	Logged By	JLL	Checked By	ABA
Drilling Contractor	Subsurface Technologies, Inc.	Drilling Method	Mud Rotary / HQ-3	Sampling Methods	SPT / D&M
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Diedrich D-50
Total Depth (ft)	126.5	Surface Elevation (ft)	4.79	Groundwater Elevation (ft)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Elevation feet	Depth feet	Samples: Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
	0							ML	Dark gray silt with trace charcoal, organic matter, and fine sand (very soft, wet)			
0	5		18	0	1							
-5	10		18	0	2				With trace organic matter and occasional 1 to 2 inch interbeds of silty sand			
-10	15		18	3	3			SP	6 inches interbed of gray-green poorly graded fine sand			
								ML	Dark gray silt (soft, wet)	57		%F=45
								SP	Gray-green poorly graded fine sand, trace silt (medium dense, moist)			
-15	20		18	34	4					28	95	
-20	25		18	18	5							
								SM	Silty fine sand with very thin horizontal bedding with occasional organic fragments, wood fibers, charcoal (medium dense, moist)			
-25	30		14	12	6					38		%F=21
								SP	Dark gray-green poorly graded fine sand, occasional			
-30	35											

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-3 (Coos River)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Elevation feet	Depth feet	Interval Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
	35	12	11	7				layers of organics, trace silt and charcoal (medium dense, wet)	37		
-35	40	18	18	8							
-40	45	14	22	9					38		
-45	50	18	32	10					40		
							SM	Gray-green silty fine sand with trace organics, charcoal and mica flakes (medium dense, moist)			
-50	55	14	17	11					39		%F=25
-55	60	16	20	12							
-60	65	18	21	13				Same to silty fine sand with occasional organic layers	39		%F=23
							SP	Dark gray-green poorly graded sand, trace silt and charcoal, occasional layers of organic fragments (medium dense, wet)			
-65	70	12	22	14							
-70	75	18	27	15							

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LOG OF BORING B-3 (Coos River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Elevation feet	Depth feet	Recovered (in)	Blows/foot	Sample Number	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
-75	80	18	53	16			31	88	
-80	85	12	25	17		Grades to dark gray fewer organic layers			
-85	90	14	33	18		Becomes dense grades with trace organic matter	27		
					SM	Dark gray to dark gray-green silty fine sand, trace organic matter (medium dense, moist)			
-90	95	18	16	19					
-95	100	18	12	20		Gray silty fine sand, very thin bedded, occasional beds of sandy silt, trace organic matter (medium dense, moist)			%F=44
						Gray silty fine sand with trace charcoal (dense, moist)			
-100	105	18	46	21					
-105	110	18	18	22		Becomes medium dense	40		
-110	115	18	25	23					
					ML				
-115	120	18	43	24		Dark gray to dark gray-green very fine sandy silt, trace organic matter (very stiff, moist)	40	73	%F=53

LOG OF BORING B-3 (Coos River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Elevation feet	Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
-120	125		18	27	25							

Bottom of hole at 126.5 feet
Groundwater not determined due to drilling liquid

Elevation scale: -120, -125, -130, -135, -140, -145, -150, -155, -160
Depth scale: 125, 130, 135, 140, 145, 150, 155, 160, 165

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LOG OF BORING B-3 (Coos River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Figure D-4
Sheet 4 of 4

Date(s) Drilled	05/11/06 - 05/12/06	Logged By	JLL	Checked By	ABA
Drilling Contractor	Subsurface Technologies, Inc.	Drilling Method	Mud Rotary / HQ-3	Sampling Methods	SPT / D&M
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Diedrich D-50
Total Depth (ft)	126.5	Surface Elevation (ft)	3.61	Groundwater Elevation (ft)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Elevation feet	Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
	0							ML	Dark gray sandy silt, occasional organic fragments (very soft to soft, wet)			
0												
	5		14	2	1							
-5												
	10		10	3	2							
-10								SM	Dark gray-green silty fine sand, with interbedded layers of organic matter (loose, moist)			
	15		18	12	3					35	85	%F=33
-15												
	20		18	6	4							
-20												
	25		18	17	5				Becomes medium dense			
								PEAT	1-inch thick layer of peat at 26 feet	45		%F=32
								SP	Dark green poorly graded fine sand with trace silt (medium dense, wet)			
-25												
	30		14	17	6							
-30												
	35											

Note: See Figure D-1 for explanation of symbols.

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LOG OF BORING B-4 (Coos River)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Elevation feet	Depth feet	Recovered (in)	Blows/foot	Sample Number	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
	35	14	14	7		Occasional thin layer of organic matter			
-35									
	40	18	25	8		Dark green-gray poorly graded fine sand, occasional very thin interbed of peat, trace silt (medium dense, wet)	33		
-40					SM	Dark gray-green silty fine sand, interbedded with 1/4 to 1-inch thick beds of sandy silt and peat (loose, wet)			
	45	15	8	9			60		%F=44
-45									
	50	4	7	10		Grades with organic fragments, wood and peat			
-50					SP	Dark green-gray poorly graded fine sand, trace silt, occasional interbed of peat or organic fragments (medium dense, wet)			
	55	18	24	11					
-55									
	60	18	43	12			31	90	
-60					SM	Dark gray silty very find sand with trace organic matter (medium dense, very stiff, moist)			
	65	5	24	13			49		%F=42
-65					SP-SM	Dark gray silty fine sand to fine sand with silt with scattered organic fragments			
	70	6	11	14					
-70					SP	Grades to dark gray fine sand with trace organic matter, trace silt (dense, wet)			
	75	10	40	15			25		
-75									

LOG OF BORING B-4 (Coos River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Figure D-5
Sheet 2 of 4

Elevation feet	Depth feet	Recovered (in)	Blows/foot	Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
	80	12	30	16		SM	Gray green poorly graded silty fine sand, occasional very thin interbeds of brown peat and sandy silt (medium dense, wet)			
-80										
	85	11	16	17		ML	Brown sandy silt with organics (very stiff, moist)	53		
						SP	Gray-green poorly graded sand, trace silt and organic matter (medium dense, moist to wet)			
-85										
	90	0	14	18						No recovery at 90 feet
						MH	Dark gray elastic silt with trace fine sand, trace organic matter (stiff, moist)			
-90										
	95	16	13	19						AL
-95										
	100						Dark gray silt with trace fine sand, trace organic matter (stiff, moist)			
-100						SP	Gray-green poorly graded sand, trace organic matter, trace silt with interbedded layers of silt (medium dense, moist)			
	105	18	31	20				49	64	
-105										
	110					MH	Dark gray elastic silt with trace fine sand (stiff, moist)			
-110										
	115	18	15	21						AL
-115										
	120									

LOG OF BORING B-4 (Coos River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Figure D-5
Sheet 3 of 4

Elevation feet	Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample	Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
-120	125	■	18		↕	22				Grades to dark gray silt with fine sand and occasional organic matter (very stiff, moist)	42		

Bottom of hole at 126.5 feet
Groundwater not determined due to drilling fluid

Elevation scale: -120, -125, -130, -135, -140, -145, -150, -155, -160
Depth scale: 125, 130, 135, 140, 145, 150, 155, 160, 165

LOG OF BORING B-4 (Coos River) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Coos River
Project Number: 8169-021-00

Date(s) Drilled	05/09/06	Logged By	JLL	Checked By	ABA
Drilling Contractor	Crux Drilling	Drilling Method	6" HWT / HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	116	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Recovered (in)	SAMPLES: Blows/foot	SAMPLES: Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0						ML	Dark grayish brown silt, trace fine sand, trace organic fibers (very soft, wet)			
5	56	2	1							
10	67	1	2							
15	100	2	3					89		
20	100	2	4				Without organics			
25	100	2	5					73		
30	100	6	6					82	50	
35	100	3	7				Grades to soft			

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-1 (Catching Slough)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Figure D-6
Sheet 1 of 3

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35											
40		100	2	8				Dark gray silt with trace fine sand and organic matter (very soft, wet)			
45		100	6	9							
50		100	1	10							
55		100	2	11				Clayey silt with trace sand below 55 feet			
60		100	3	12				Grades to soft			
65		100	6	13							
70		100	3	14							
75		100	3	15							

LOG OF BORING B-1 (Catching Slough) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Figure D-6

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80		100	4	16				Dark gray silt with some clay and trace fine sand (soft, wet)			
85		100	12	17				Grades to stiff With trace to some sand			
90		100	4	18				Becomes soft			
95		100	10	19				Light gray silt with trace sand (stiff, wet)			
100		100	5	20				Grades to medium stiff			
105		100	12	21				Light gray sandy silt (stiff, wet)			
		50					SILTSTON	Olive gray siltstone with trace fine sand; highly weathered, weak, very closely fractured			
		17									
		58									
110		100						Moderately strong, closely fractured below 111 feet			
115											

Bottom of hole at 116 feet
Groundwater not determined due to drilling liquid

120

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LOG OF BORING B-1 (Catching Slough) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Date(s) Drilled	05/08/06 - 05/09/06	Logged By	JLL	Checked By	ABA
Drilling Contractor	Crux Drilling	Drilling Method	6" HWT / HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	125	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0					ML	Dark gray mottled reddish brown with silt, trace fine sand (very soft, moist)			
	78	2	1						
5									
	56	2	2			Becomes dark gray, trace organic matter (wet)			
10									
						Grades without organic matter			
	89	2	3				85	48	
15									
					MH	Gray elastic silt with trace organic matter and charcoal (soft, moist)			
	78	2	4				87		AL
20									
	89	2	5				77		
25									
					ML	Silt with fine sand and organic fragments (very soft, wet)			
	100	2	6						
30									
					MH	Dark gray elastic silt, trace fine sand, no organic matter			
	100	2	7				59		AL
35									

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-2 (Catching Slough)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Depth feet	Interval / Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35										
	100	2	8							
40							Dark gray elastic silt, trace fine sand and organic matter (very soft, wet)			
	100	3	9					91	47	
45										
	100	2	10							
50										
	100	2	11					80		
55										
	100	2	12							
60							Dark gray elastic silt, trace fine sand and charcoal (very soft, wet)			
	100	2	13					82		AL
65										
	100	3	14				Becomes soft			
70										
	100	7	15				Becomes medium stiff	79	50	
75										
	100	3					Becomes soft			

LOG OF BORING B-2 (Catching Slough) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
80	■			16			Dark gray elastic silt, trace fine sand, trace organic matter (soft, wet)			
	■	100	3	17			1 to 2 inch thick occasional interbeds of sandy silt	63		
85										
	■	100	4	18						
90							Dark gray elastic silt with trace organic matter and charcoal (soft, moist)			
	■	100	5	19			Becomes medium stiff			
95										
						ML	Grayish green fine sandy silt (loose, wet)			
	■	100	14	20				46	68	%F=52.7
100										
						MH	Grayish green elastic silt with trace fine sand (medium stiff, moist to wet)			
	■	100	5	21			Much organic matter from 104 to104.5 feet	53		AL
105										
						SM	Light gray silty sand, weakly cemented (very dense, moist)			
	■	100	72/5"	22				26		%F=38.8
110		100				SSTN	Grayish green sandstone, highly weathered, weak			
						ML				closely fractured
						SM	10 to 12 inches open fracture with clay and sand infilling			
		71				SSTN	Grayish green sandstone, moderately weathered, moderately strong, very closely fractured			
115		100								
							Grades to widely fractured			
120		100								

LOG OF BORING B-2 (Catching Slough) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Figure D-7
Sheet 3 of 4

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
125											
								Bottom of hole at 125 feet Groundwater not determined due to drilling liquid			
130											
135											
140											
145											
150											
155											
160											
165											

LOG OF BORING B-2 (Catching Slough) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Figure D-7

Date(s) Drilled	05/04/06 - 05/05/06	Logged By	JLL	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	6" HWT / HQ-3	Sampling Methods	SPT
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	100	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Interval	SAMPLES: Recovered (in)	SAMPLES: Blows/foot	SAMPLES: Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0							ML	Dark gray silt with organics with occasional wood and plant fibers (very soft, wet)			
5		10	1	1							
10		12	1	2					109		
15		12	2	3							
20		12	2	4				Grades to trace organics	87		
25		12	2	5							
30		2	3	6				Becomes soft with trace fine sand and no organic matter	68		
35		4	2	7							

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-3 (Catching Slough)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample	Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
35									Becomes very soft			
40		3	2		8					91		
45		5	3		9				Becomes soft			
50		6	2		10				Becomes very soft	84		
55		18	3		11				Becomes soft			
60		18	3		12					91		
65		18	2		13				Becomes very soft			
70		0	3		14				Becomes soft			
75		2	4		15				Grades with trace fine sand			

LOG OF BORING B-3 (Catching Slough) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample	Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80		18	3		16				Dark gray silt with fine sand, trace organic fragments (soft, wet)			
85		0	3		17							
90		0	5		18				Becomes medium stiff			
95		0	6		19							
100		12	4		20							

Bottom of hole at 100 feet
Groundwater not determined due to drilling fluid

Depth scale: 105, 110, 115, 120

LOG OF BORING B-3 (Catching Slough) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Figure D-8
Sheet 3 of 3

Date(s) Drilled	05/04/06	Logged By	JLL	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	6" HWT / HQ-3	Sampling Methods	SPT / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	100	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0							OL	Dark gray organic silt (very soft, wet)			
5	■	100	0	1							
~7							ML	Dark gray silt with trace organics (very soft, wet)			
10	■	100	2	2					84		
15	■	78	2	3							
20	■	72	2	4					78		
~21								Dark gray silt with trace organic fibers (very soft, wet)			
25	■	94	3	5				Buried log at 25 to 25.6 feet			
30	■	67	2	6					94		
35	■	78	2	7							

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-4 (Catching Slough)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Figure D-9
Sheet 1 of 3

Depth feet	Recovered (in)	Blows/foot	Sample Number	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35								
40	44	2	8		Dark gray silt with trace wood fragments (very soft, wet)	219		mix of silt and wood fibers and fragments in core at 40 feet
				MH	Light gray with orange mottling elastic silt with trace organics (soft, moist)			
45	100	4	9			50		
50	0	7	10		Becomes yellow (medium stiff)			
55	56	4	11		Yellowish gray (soft to medium stiff)	51		
				ML	Dark gray clayey silt with occasional fine sand (stiff, moist)			
60	67	17	12					
				SM	Dark green silty sand (medium dense, moist)			
					Becomes very dense (weathered sandstone)			
65								
	100			SSTN	Dark gray silty sandstone, slighty weathered, weak, medium fractured			
70	102				Dark gray sandstone, slightly weathered, moderately strong, very widely fractured			massive with subhorizontal bedding without partings
75	92				2 to 6 inch thick gray poorly graded sand layer at 76 feet Becomes strong at 76.5 feet			

LOG OF BORING B-4 (Catching Slough) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80		98						Dark gray sandstone, slightly weathered, very widely fractured			massive with subhorizontal bedding without partings
								1 1/2-inch thick coarse sand layer at 81.5 feet			
85		102									
								1/2-inch open clay-filled fracture at 88 feet			
90								Becomes moderately strong from 90 to 93 feet			
								Becomes strong from 93 to 95 feet			
95								Closely fractured with quartz infilling at 93.5 feet (high angle)			high angle fractures
								Moderately strong from 95 to 96 feet			
											numerous shell fragments and coal lenses from 98 to 100 feet
100								Bottom of hole at 100 feet Groundwater not determined due to drilling fluid			
105											
110											
115											
120											

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LOG OF BORING B-4 (Catching Slough) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Catching Slough
Project Number: 8169-001-00

Date(s) Drilled	06/20/06 - 06/23/06	Logged By	JLL	Checked By	TNH
Drilling Contractor	Boart Longyear Company	Drilling Method	HQ-3 Core	Sampling Methods	SPT / D&M / Coring
Auger Data		Hammer Data	140 lb hammer/30 in drop Autohammer	Drilling Equipment	CME-850
Total Depth (ft)	99	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0							SM	Brown silty fine sand, trace charcoal (loose, moist)			
5		100	9	1							
							CL	Red-brown, tan and black lean clay (hard, moist)			
10		67	36	2							relict rock texture with angular fracturing
							CLAYSTON	Dark gray claystone (hard, moist)			
15		100	50/4"	3							No recovery - gray clay in cuttings
		130						Dark gray claystone, moderately weathered mud rolled weak to moderately strong, medium fractured			
20		91						Moderately strong			
								Medium to closely fractured			
								4 inch shattered zone at 24 feet			
25		93									
30		90									
35								Medium fractured			

Note: See Figure D-1 for explanation of symbols.

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LOG OF BORING B-1 (North Fork Coquille River)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: North Fork Coquille River
Project Number: 8169-021-00

Figure D-10
Sheet 1 of 3

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
35		93						3 inch sandy interbed			
40		90						Dark gray claystone; lightly weathered, moderately strong, medium fractured			
45		108						4 inch shattered zone at 46 feet			
50		80						5 inch very closely fractured zone at 52 feet			
55		100						Close to medium fractured			
								2 inch shattered zone at 58.6 feet			
60		90						Very closely fractured			
								Widely fractured			
65		95									
70		98						Very fractured zone at 69 feet			
								Dark gray claystone; slightly weathered, moderately strong, widely fractured, massive to very weak through bedding			
75		93						Very fractured zone at 73.2 feet			

LOG OF BORING B-1 (North Fork Coquille River) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: North Fork Coquille River
Project Number: 8169-021-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample	Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80		100										
85		98										
90		101										
95		94										
100									Traces of coal Bottom of hole at 99 feet Groundwater not determined due to drilling fluid			
105												
110												
115												
120												

LOG OF BORING B-1 (North Fork Coquille River) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: North Fork Coquille River
Project Number: 8169-021-00

Figure D-10

Date(s) Drilled	05/23/06 - 05/24/06	Logged By	JLL	Checked By	TNH
Drilling Contractor	Subsurface Technologies, Inc.	Drilling Method	Mud Rotary / HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tricone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Diedrich D-50
Total Depth (ft)	100	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0							ML				
5		12	25	1				Brown to gray silt, trace fine sand and occasional gravel-sized angular siltstone fragments (very stiff, moist)			
10		18	25	2				Becomes stiff with siltstone fragments	25	100	
15		18	14	3				Becomes gray			
20		14	17	4				Dark gray silt with coarse sand to small gravel-sized angular siltstone fragments (very stiff, moist)	18		
25		10	43	5				Becomes hard, trace angular sandstone fragments to 1/4 inch			
							SSTN				
30		18	54	6				Dark gray siltstone, completely weathered, weak, massive, medium fractured	12	125	
							ML				
35											

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-1 (Middle Creek)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Middle Creek
Project Number: 8169-021-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35		12	27	7				Dark gray silt with broken siltstone fragments to 1/4 inch (very stiff, moist)			
40		10	23	8				Dark gray silt with much angular siltstone fragments to 1/4 inch (very stiff, moist)	17		
45		10	46	9				Becomes hard			
50		14	51	10					18		
55		8	92/4"	11							
		30					SILTSTON	Dark gray siltstone, completely weathered to residual soil, weak, closely fractured			
60		100						Becomes highly weathered, moderately weak to weak, closely fractured along bedding planes (high angle)			high angle fractures
65		100						Completely weathered to residual soil, weak 65 to 67 feet			
								Becomes highly weathered, moderately weak to weak, very closely fractured (high angle)			high angle fractures
70		100									
75		100						Closely fractured			

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LOG OF BORING B-1 (Middle Creek) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Middle Creek
Project Number: 8169-021-00

Figure D-11
Sheet 2 of 3

Depth feet	Interval / Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80	100					ML	12-inch thick layer of gray silty clay (stiff, wet)			
	100					SILTSTON	Dark gray siltstone, highly weathered, moderately weak to weak, medium fractured 1 to 2 inch span fracture at 83.5 feet, clay soil in sampler			
85	0					ML	No recovery 85 to 90 feet - clay soil in sampler			
90	2						trace recovery 90 to 95 feet, broken siltstone fragments 1/2 to 3 inches			
95	63.3									
						SILTSTON	Dark gray siltstone, highly weathered, moderately weak to weak, medium fractured			
100							Bottom of hole at 100 feet Groundwater not determined due to drilling liquid			
105										
110										
115										
120										

LOG OF BORING B-1 (Middle Creek) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Middle Creek
Project Number: 8169-021-00

Figure D-11

Date(s) Drilled	05/23/06 - 05/24/06	Logged By	JLL	Checked By	TNH
Drilling Contractor	Subsurface Technologies, Inc.	Drilling Method	Mud Rotary / HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tricone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Diedrich D-50
Total Depth (ft)	100	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Recovered (in)	Blows/foot	Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0					ML	Brown clayey silt with trace fine sand (medium stiff, moist)			
5	10	5	1				34		
					SM	Brown silty fine sand (very loose, wet)			
10	18	2	2				34		%F=36
					SP	Red-brown to brown poorly graded sand with rounded gravel, trace to some silt (dense, wet)			
15	16	104/4"	3		SILTSTON	Dark gray siltstone, highly weathered, weak	16	118	
20	2	50/3"	4			Mix of loose gravel and siltstone, as above, very hard and dense			
						Dark gray siltstone (hard, moist)			
25	2	95/10"	5		SP	Poorly graded sand with trace gray clayey siltstone, (completely weathered to residual soil)			
30	92				SILTSTON	Dark gray siltstone, completely weathered, weak, medium fractured			subhorizontal fractures
						2-inch wide open fracture with quartz infilling			
						1 inch wide shattered zone			
35						4 inch wide shattered zone			

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-2 (Middle Creek)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Middle Creek
Project Number: 8169-021-00

Depth feet	SAMPLES: Interval Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35	83.3									
40	103						3 inch thick clay soil layer Becomes moderately weathered, moderately weak, very close to closely fractured, subhorizontal to 60° to 70° from horizontal			
							1-1/2 to 2 inch shattered zone			
45	96.6									
							2 to 3 inch highly fractured zone			
50	100						Dark gray siltstone, moderately weathered, moderately weak, medium fractured, massive to weak thin bedding			
										UC=733 psi
55	91.6						2 to 3 inch shattered zone at 55 feet Close to medium fractured			
60	91.6						8 inch shattered zone at 60 feet			
							2 inch fractured zone			
65	100									
							2 inch shattered zone			
70	100									
							1 inch open fracture with gravel-sized infilling 2 inch shattered zone			
75	100						1/2 inch open fracture with gravel infilling Close to very close horizontal to 30° from horizontal fractures			

LOG OF BORING B-2 (Middle Creek) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Middle Creek
Project Number: 8169-021-00

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
80		100						Dark gray siltstone, moderately weathered, moderately weak, medium fractured, massive to weak subhorizontal bedding			
85		109									
								2 to 3 inch shattered zone, brown staining			
90		100						2 inch fractured zone			
								Closely fractured			
								Strong sandy siltstone bed 93 to 93.6 feet			
95								Becomes moderately strong, close to medium fractured			
								Weak, clayey at 99.2 to 99.6 feet			
100								Bottom of hole at 100 feet Groundwater not determined due to drilling liquid			
105											
110											
115											
120											

LOG OF BORING B-2 (Middle Creek) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Middle Creek
Project Number: 8169-021-00

Date(s) Drilled	05/23/06 - 05/24/06	Logged By	JLL	Checked By	TNH
Drilling Contractor	Subsurface Technologies, Inc.	Drilling Method	Mud Rotary / HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tricone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Diedrich D-50
Total Depth (ft)	88	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	Recovered (in)	Blows/foot	Sample Number	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0				ML	Brown silt (soft, moist)			
5	100	4	1					
10	0	6	2					
				GP	10 to12 inches gravel (and sand?)			
15	60	50/5"	3	SILTSTON	Dark gray siltstone, moderately weathered, moderately weak, closely fractured (hard, moist)			
	<1							
20								
					Becomes very closely fractured			
	76.8							
25								
	76.6							
30					Grades with occasional sandstone interbeds			
	100							
35								

Note: See Figure D-1 for explanation of symbols.

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LOG OF BORING B-4 (Middle Creek)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Middle Creek
Project Number: 8169-021-00

Depth feet	Interval Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
35	90						Dark gray siltstone; slightly weathered, moderately weak, closely fractured			UC=1,228 psi
40	96.6									
45	100									
50	80									
55	100									
60						SSTN	8-inch thick sandstone bed			
	100					SILTSTON				
65	97.5									
70	97.5						Dark gray siltstone, slightly weathered, moderately weak to moderately strong, close to medium fractured, weak thru bedding, occasional sandstone interbeds			
75							Close to very closely fractured			
	100						Highly fractured zone 78 to 80 feet			

LOG OF BORING B-4 (Middle Creek) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Middle Creek
Project Number: 8169-021-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
80								Many high angle fractures along bedding plane			
								Highly fractured zone 81 to 82 feet			
		95.8									
85											
								Bottom of hole at 88 feet Groundwater not determined due to drilling fluid			
90											
95											
100											
105											
110											
115											
120											

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LOG OF BORING B-4 (Middle Creek) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Middle Creek
Project Number: 8169-021-00

Figure D-13

Date(s) Drilled	05/15/06 - 05/16/06	Logged By	JLL	Checked By	TNH
Drilling Contractor	Subsurface Technologies, Inc.	Drilling Method	Mud Rotary / HQ-3	Sampling Methods	SPT / D&M
Auger Data	Tricone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Diedrich D-50
Total Depth (ft)	100	Surface Elevation (ft)		Groundwater Level (ft. bgs)	8
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0							ML	Orange-brown silt with trace fine sand (soft, moist)			
5		78	4	1							AL
8					▽		SP	Gray poorly graded sand with trace silt (loose, wet)			
10		80	13	2					26	96	
14							SILTSTON	Dark gray siltstone; moderately weathered, weak, closely fractured			
15		25	50/4"	3							
20		100 100	50/2"	4				Highly weathered to decomposed from 20 to 22 feet			40-60 degree angle from horizontal
25		100									
30		98						Gray clayey silt soil zone 30 to 30.6 feet			
								1/2 inch fractured zone at 31.5 feet			
								1/4 inch open fracture with clay in filling at 33 feet			
35											

Note: See Figure D-1 for explanation of symbols.

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LOG OF BORING B-1 (East Fork Coquille River)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: East Fork Coquille River
Project Number: 8169-021-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35		100						Dark gray siltstone, moderately weathered, weak, closely fractured			UC=588 psi 40-60 degree angle from horizontal
								Becomes highly weathered from 38 to 39.5 feet			
40		100						1/2 to 1 inch open fracture with sandy clay unfilling			
								1 to 2 inch crushed zone			
45		100						4 inch fractured zone			
								Widely fractured from 47 to 49 feet			
50		100						1 1/2 inches wide open fracture with sandy clay infilling			
								1/2 inch wide fracture zone with clay infilling			
55		100						1 inch open fracture with clay infilling			
								Becomes weak to moderately weak			
								2 inch crushed zone with sandy clay infilling			
60		100						Becomes slightly weathered, moderately weak			
								2 inch crushed zone			
65		100						1 to 1-1/2 inch wide open fracture filled with rounded silt chunks and open voids			
								1 inch crushed zone			
70		95									
								Closely fractured			high angle fractures
75		100									

LOG OF BORING B-1 (East Fork Coquille River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: East Fork Coquille River
Project Number: 8169-021-00

Figure D-14
Sheet 2 of 3

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Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80		100						Dark gray siltstone, slightly weathered, moderately strong, very close to widely fractured 1 to 2 inch open highly fractured zone with clay infilling 1 to 1-1/2 inch open fractures with sandy clay infilling Highly fractured/shattered zone 83.5 to 85			bedding is 30-40 degrees from horizontal
85		100									
90		100						1/2 to 1 inch open fracture with sandy clay infilling Highly fractured zone from 94.3 feet to 94.9 feet			
95		100						Closed fracture on quartz infilling			
100								Bottom of hole at 100 feet Groundwater level not determined Perched water at 8 feet			
105											
110											
115											
120											

LOG OF BORING B-1 (East Fork Coquille River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: East Fork Coquille River
Project Number: 8169-021-00

Date(s) Drilled	05/16/06 - 05/17/06	Logged By	JLL	Checked By	TNH
Drilling Contractor	Subsurface Technologies, Inc.	Drilling Method	Mud Rotary / HQ-3	Sampling Methods	SPT / D&M
Auger Data	Tricone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Diedrich D-50
Total Depth (ft)	100	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Recovered (in)	Blows/foot	Sample Number	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0				ML	Tan-brown silt with fine sand (soft, moist)			
5	56	4	1			34		AL
				SM				
10	67	4	2		Tan-brown silty fine sand (soft, wet)	29		%F=40
				SM	Yellowish-brown silty sand with trace gravel and charcoal			
15	89	7	3					
				SILTSTON	Dark yellow decomposed siltstone, trace fine sand (medium stiff, moist)			
20	34	50/3"	4		becomes dark gray, very hard			
	72			SP	12" sand cavings			
				SILTSTON	Dark gray siltstone; highly weathered, weak, medium fractured			very thin bedding 30-40 degree from horizontal
25	79							
					2" shattered zone			
30	100				becomes slightly weathered, moderately weak, 2" open fracture with crushed siltstone infilling			
35					1" open fracture with clay and crushed siltstone			

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-2 (East Fork Coquille River)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: East Fork Coquille River
Project Number: 8169-021-00

Figure D-15
Sheet 1 of 3

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
35		96						infilling			
								Dark gray siltstone, highly weathered, weak, close to medium fractured			thin bedding 30-40 degrees from horizontal
								becomes highly weathered, weak, close to moderately fractured			
								highly fractured/decomposed zone from 35.3 to 35.9 feet			
40		100						highly fractured decomposed from 40 to 42 feet			
45		100					CL	becomes completely decomposed to clay			
							SILTSTON	highly weathered, weak			
								residual soil			
								calate veins			
50		100						Dark gray siltstone; highly weathered, weak, closely fractured			thin bedding 30-40 degrees from horizontal
55		96						becomes moderately weathered, moderately weak, medium fractured			
											UC=971 psi
60		100						from 61.5 to 62 feet becomes moderately weak, closely fractured			
								1/4" coal seam in 4-5" inch thick layer			
								4" highly fractured zone			
65		77						approximately 12-14" washout and rounded siltstone gravels to 2" with sand matrix			
70		100						very close fractures 70-71"			
								highly fractured/decomposed zone with trace quartz infilling			
								becomes moderately weak, moderately fractured			
75		100						1-2" highly fractured/decomposed zone			

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LOG OF BORING B-2 (East Fork Coquille River) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: East Fork Coquille River
Project Number: 8169-021-00

Depth feet	Interval / Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80	97						Dark gray siltstone; slightly weathered, moderately weak, widely fractured			thin bedding 30-40 degrees from horizontal
85	100									
90	93									
							very close fractures 92-93.6 feet			
							4" shattered zone, decomposed to clay 93.6-94.6 feet			
95	100									
							becomes highly weathered, weak, very closely fractured - shattered zone 96.3-97.7; very closely fractured 98.6-100 degrees with clay infilling			
100							Bottom of hole at 100 feet Groundwater not determined			
105										
110										
115										
120										

LOG OF BORING B-2 (East Fork Coquille River) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: East Fork Coquille River
Project Number: 8169-021-00

Figure D-15

Date(s) Drilled	05/15/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	6" HWT / /HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	100	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	Recovered (in)	Blows/foot	Sample Number	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0				ML	Brown gravelly silt with some fine to coarse sand (very stiff, moist to wet)			
5	100	18	1					
~8				GM	Brown silty gravel with fine to coarse sand (very dense, moist)			
10	100	59	2					
~13				SSTN	Gray and green hydrothermically altered greywacke sandstone and schist; fresh, moderately strong, closely fractured			
16	70 50	50/5.5"	3					
21	100				Very weak to moderately strong below 21 feet			
23					Sheared zones between 23 and 24.5 feet			
25					Strong below 24.8 feet			
26	100				Very weak sheared zones at 26.6, 27.5, 29 and 30 feet			
29					Sheared zone at 29 feet			
31	100				Moderately strong			
35								

Note: See Figure D-1 for explanation of symbols.

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LOG OF BORING B-1 (South Umpqua River No. 1)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 1
Project Number: 8169-021-00

Figure D-16
Sheet 1 of 3

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample	Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35		100							Gray fine grained graywacke sandstone and schist; fresh, moderately strong, closely fractured			
40		100							Weak to moderately strong below 41 feet			
									Very weak shear zone with slickensides on fractures between 42.5 feet and 43.2 feet			
45									Moderately strong below 43.2 feet			
		100							Closely fractured 46.5 to 46.8 feet			
50									Closely to very closely fractured below 49.5 feet			
		100							Closely fractured below 51 feet			
55		100							Slickensides on fracture surfaces			
60		100										
									Closely to very closely fractured between 63.2 and 64.1 feet			
65		100							Very closely fractured between 66.6 and 67.1 feet			
									Very closely fractured between 68.1 and 68.6 feet			
70		100										
									Very closely fractured below 74 feet			
75		100										UC=5,310 psi
									Very closely to closely fractured between 77 and 78.1 feet			

LOG OF BORING B-1 (South Umpqua River No. 1) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 1
Project Number: 8169-021-00

Depth feet	Interval Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80	100						Gray graywacke sandstone and schist; fresh, strong, closely fractured			
							Very closely fractured between 81 and 83 feet			
85	100									
							Very closely fractured at 89.2 feet			
90	100									
							Very closely fractured between 93 to 93.5 feet and between 94.5 to 95 feet			
95	100						Very closely fractured between 95 and 96 feet			
100							Bottom of hole at 100 feet Groundwater not determined due to drilling fluid			
105										
110										
115										
120										

LOG OF BORING B-1 (South Umpqua River No. 1) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 1
Project Number: 8169-021-00

Figure D-16

Date(s) Drilled	05/11/06 - 05/12/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	6" HWT / /HQ-3	Sampling Methods	SPT / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	100	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0							GP-GM	Brown sandy gravel with silt and cobbles (loose, moist)			
5		33	8	1							
10		11	40	2				becomes dense with trace silt			
15		100 / 100	75/3"	3			SSTN	Gray to green hydrothermally altered graywacke sandstone and schist; fresh to slightly weathered, strong, closely fractured			
20		100									
25		100						becomes strong, fresh			
30		100						Shear zone at 30.5 feet with quartz infilling fractures			
35											

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-2 (South Umpqua River No. 1)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 1
Project Number: 8169-021-00

Depth feet	Interval / Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
35	100						Gray graywacke sandstone and schist; fresh, strong, closely fractured			
							Strong and moderately fractured below 37 feet			
							Widely fractured below 39 feet			
40	100									
							Closely fractured below 43 feet			
							Slickensides on fracture surfaces			
45	100						Moderately strong to strong below 46 feet			
							Weak, intensely sheared between 48 and 50 feet			
50	100						Intensely sheared between 50 to 51 feet			
							Moderately strong to strong			
55	100						Strong below 56 feet			
							Moderately weak to moderately strong below 59 feet			
60	100						Slicnensides on fracture surfaces			
65	100						Moderately strong below 66 feet			UC=1,463 psi
70	80						Strong below 71 feet			
75	100						Weak, intensely sheared between 75 to 77.1 feet			

LOG OF BORING B-2 (South Umpqua River No. 1) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 1
Project Number: 8169-021-00

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80		81						Gray graywacke sandstone and schist; fresh, moderately strong to strong, closely fractured Strong below 80.2 feet			
		100									
85		100									
								Very closely to closely fractured below 88 feet			
90		100						Closely fractured below 91 feet Intensely sheared between 92 to 93 feet			
95		88						Weak, very closely fractured below 95 feet Intensely sheared zone between 95 to 96.5 feet Strong, closely fractured below 98 feet			
100								Bottom of hole at 100 feet Groundwater not determined due to drilling fluid			
105											
110											
115											
120											

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LOG OF BORING B-2 (South Umpqua River No. 1) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 1
Project Number: 8169-021-00

Date(s) Drilled	05/13/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	6" HWT / /HQ-3	Sampling Methods	SPT / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	100	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0							GP-GM	Brown sandy gravel with silt (dense, dry to moist)			
							GP	Brown to gray sandy gravel (very dense, moist)			
5		33	40	1							
10		29	50/3.5"	2							
		98					SSTN	Gray to green hydrothermically altered graywacke sandstone and schist; fresh, moderately strong, closely fractured			
15								Sheared zone			
		100									
20		100						Medium fractured, very strong below 21.5 feet			
								Brecciated zone between 22.6 to 23.6 feet			
25		100						Very strong to extremely strong			
								Closely fractured below 29 feet			
30		100						Medium fractured below 31 feet			
35											

Note: See Figure D-1 for explanation of symbols.

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LOG OF BORING B-3 (South Umpqua River No. 1)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 1
Project Number: 8169-021-00

Figure D-18
Sheet 1 of 3

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35		100						Gray graywacke sandstone and schist; fresh, moderately strong, closely fractured			UC=897 psi
40		100						Gray fine-grained basalt; fresh, strong, closely fractured			
								Very closely fractured between 42.5 and 44 feet, weak			
45		100									
50		100						Very closely fractured between 52.9 feet and 53.5 feet			
55		100									
60		100						Strong below 61 feet			
65		100						Very closely fractured between 67.3 and 67.8 feet			
								Brecciated zone between 68.5 to 69.5 feet			
70		100						Moderately strong below 71 feet			
75		100						Strong below 76 feet			
								Very weak between 76.5 to 77.1 feet			

LOG OF BORING B-3 (South Umpqua River No. 1) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 1
Project Number: 8169-021-00

Depth feet	Interval Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80							Gray graywacke sandstone and schist; fresh, strong, closely fractured			
	80						Very closely to closely fractured below 81 feet			
85	85						Very weak below 85 feet, closely fractured, intensely sheared zone at 85 to 86.5			
							Sheared zone at 89 to 90.5 feet			
90	100						Moderately strong below 90.5 feet			
							Very weak, sheared zone 91.5 to 91.6 feet			
							Very weak, sheared zone 93.5 to 94.5 feet			
							Very weak, sheared zone 94.8 to 95 feet			
95	100						Very weak, below 95.5 feet, very closely to closely fractured, and intensely sheared			
100							Bottom of hole at 100 feet Groundwater not determined due to drilling fluid			
105										
110										
115										
120										

LOG OF BORING B-3 (South Umpqua River No. 1) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 1
Project Number: 8169-021-00

Figure D-18
Sheet 3 of 3

Date(s) Drilled	05/18/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	6" HWT / HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	100.5	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Recovered (in)	SAMPLES: Blows/foot	SAMPLES: Sub-Sample Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0					ML	Brown gravelly silt with some sand (stiff, moist) (fill)			
5	56	9	1						
10	67	10	2						
					GM	Brown sandy fine gravel with silt and occasional cobbles (medium dense, wet)			
15	56	25	3						
					SSTN	Dark gray to green hydrothermically altered graywacke sandstone and schist; fresh, moderately strong, very closely to closely fractured			
20	100	50/3.5"	4						
	100								
25						Intensely sheared between 25.8 to 26 feet Moderately strong below 26 feet			
	65								
30	88					Intensely sheared between 30.5 to 31 feet Very closely fractured below 31 feet			
	72					With 2 to 4 inch thick quartz veins			
35									

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-1 (South Umpqua River No. 2)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 2
Project Number: 8169-021-00

Figure D-19
Sheet 1 of 3

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
35		100						Intensely sheared, very weak			
								Extremely to very closely fractured below 37 feet			
		94						Closely fractured below 38.3 feet, strong			
40											UC=384 psi
		100						Extremely closely fractured and sheared below 40.7 to 41.2 feet			
								Very closely fractured below 42 feet			
		100						Closely fractured below 43.2 feet, very strong			
45		100									
50								Dark gray graywacke sandstone and schist			
		62						Fresh strong to very strong, closely fractured			
		100						Intensely sheared and very weak between 52.1 to 54.1 feet			
55		100						Intensely sheared and very weak between 54.5 to 56 feet			
								Moderately strong to strong below 57.2 feet			
60		100									
								Very closely fractured below 64.5 feet			
65		100						Strong below 64.8 feet			
								Very closely fractured between 65.8 to 66.1 feet			
								Very closely fractured below 67.5 feet			
								Intensely sheared below 69.4 feet			
70		100						Strong to very strong below 69.4 feet; closely fractured			
		100									
75		100						Intensely sheared between 75.5 to 75.7 feet			

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LOG OF BORING B-1 (South Umpqua River No. 2) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 2
Project Number: 8169-021-00

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80		95						Gray greywacke sandstone and schist; fresh, moderately strong to strong, closely fractured			
85								Very closely fractured between 84.3 to 84.6 feet			
		100									
		100						Moderately strong below 88 feet Intensely sheared between 88.9 to 91.5 feet			
90		100						Very closely fractured between 91 to 91.3 feet			
95								Very closely fractured between 95 to 95.5 feet			
		100						Very closely fractured between 95.5 to 101.1 feet			
100											

Bottom of hole at 100.5 feet
Groundwater not determined due to drilling fluid

105

110

115

120

LOG OF BORING B-1 (South Umpqua River No. 2) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 2
Project Number: 8169-021-00

Figure D-19
Sheet 3 of 3

Date(s) Drilled	05/16/06 - 05/17/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	6" HWT / HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	100.5	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0							GM	Brown to gray sandy gravel with cobbles and some silt (very dense, dry to moist)			
5		6	79/2"	1							
		0	50/0"	2							
10								Becomes cobbly below 10 feet			
15											
							GP	Generally gray below 15 feet, lacks silt			
20								Gray cobbly gravel with sand (very dense, moist)			
		98					SSTN	Dark gray graywacke sandstone and schist; fresh, extremely strong, closely fractured			
							QTZT	Light gray to white muscovite rich quartzite; fresh, very strong to extremely strong, closely fractured			
25		100									
30		100					SSTN	Gray to green hydrothermally altered graywacke sandstone and schist; fresh, very strong to extremely strong; closely fractured			
35											

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-2 (South Umpqua River No. 2)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 2
Project Number: 8169-021-00

Depth feet	Interval Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
35							Very closely fractured below 35 feet			
	100						Closely fractured below 36.1 feet			
40										
	100									
							Very closely fractured between 43.4 to 44.1 feet			
45										
	100						Very closely fractured between 46 to 46.5 feet			
							Medium fractured between 47.6 to 49.5 feet			
50										
	100									
							Very closely fractured between 53.5 to 55 feet			
55										
	100									
							Grades to granite below 59 feet; from closely fractured very strong to extremely strong			
60							Very closely fractured between 59.5 to 60 feet			
	100									
65										
	100						Closely to medium fractured below 66 feet			
	100									
70										
	100									
							Dark gray below 73 feet			
75										
	100									
							Light gray below 78.5 feet			

LOG OF BORING B-2 (South Umpqua River No. 2) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 2
Project Number: 8169-021-00

Figure D-20
Sheet 2 of 3

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
80							GRAN	Light gray medium grained granite; fresh, very strong to extremely strong, closely to medium fractured			
		100						Gray below 81 feet			
85											
		100						Olive gray below 86 feet, medium fractured			
90											
		100									
95											
		100									
100											
								Bottom of hole at 100.5 feet Groundwater not determined due to drilling fluid			
105											
110											
115											
120											

LOG OF BORING B-2 (South Umpqua River No. 2) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 2
Project Number: 8169-021-00

Date(s) Drilled	06/29/06 - 06/30/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	6" HWT / HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	100.5	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Recovered (in)	SAMPLES: Blows/foot	SAMPLES: Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0					SM	Brown silty sand (loose, moist)			
3					RX	Highly to completely weathered granitoid (weak rock/dense soil) (moist)			
4.5	18	39	1						
9.5	0.4	50-1/4"	2						
10.5	83					Gray granitoid; slightly to moderately weathered, moderately, closely fractured			
15	87					Very closely to closely fractured below 15 feet			
20.5	12								
22	100					Slightly weathered and strong below 23 feet; closely fractured below 23 feet			
26	100								
27	100					Fresh below 27 feet; strong to extremely strong			
31.5	100								
34						Very closely fractured from 34 to 34.5 feet			

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-3 (South Umpqua River No. 2)

GeoEngineers

Project:	Pacific Connector Gas Pipeline Project
Project Location:	South Umpqua River No. 2
Project Number:	8169-021-00

Depth feet	SAMPLES: Interval / Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
35										
	100						Closely to medium fractured below 36 feet			
40										
	100									
45										
	100						Closely fractured below 46 feet			
							Very closely fractured from 48 to 48.5 feet			
50										
	100						Very closely to closely fractured below 51 feet			
	100									
	100									
55										
	100						Medium fractured below 56 feet			
60										
	100						Medium to closely fractured below 60.5 feet			
65							Closely fractured below 64.8 feet			
	100						Medium fractured from 66.2 to 67.8 feet			
	100						Very closely fractured below 68 feet Closely to medium fractured below 68.5 feet			
70										
	100									
75							Medium fractured below 75 feet			
	100									

LOG OF BORING B-3 (South Umpqua River No. 2) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 2
Project Number: 8169-021-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample	Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
80		100							Very closely fractured from 79.5 to 80 feet; closely to medium fractured below 80 feet			
		100										
85									Closely fractured below 84.8 feet			
		100										
		100							Very closely fractured from 87.5 to 88.3 feet			
90									Medium fractured below 90.7 feet			
		100										
95												
		100							Closely to medium fractured below 98.5 feet			
100												

Bottom of hole at 100.5 feet
Groundwater not encountered due to drilling fluid

Depth scale: 105, 110, 115, 120

LOG OF BORING B-3 (South Umpqua River No. 2) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 2
Project Number: 8169-021-00

Date(s) Drilled	05/19/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	6" HWT / HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tri-Cone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	101	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Recovered (in)	SAMPLES: Blows/foot	SAMPLES: Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
0					ML	Dark gray sandy silt with clay (medium stiff, moist)			
5	100	6	1						
8					GP	Brown sandy gravel with cobbles (very dense)			
10	100 / 71	61/5.5"	2						
14	100								
15	100	50/0.5"	3		GRAN	Gray granite, highly weathered, moderately weak, very closely fractured - closely fractured below 15 feet			
16	100								
17						Fresh, strong to extremely strong below 16 feet			
18						Very closely fractured from 18 to 19.5 feet			
21	100					Very closely to closely fractured below 21 feet			
25	100								
26	100								
31	100					Closely fractured below 31 feet			
35									

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-4 (South Umpqua River No. 2)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 2
Project Number: 8169-021-00

Depth feet	Interval / Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
35	100						Very closely to closely fractured below 36 feet			
40	100									
45	100						Very closely fractured from 46 to 47.8 feet			
							Closely fractured and strong below 47.8 feet			
50	100									
55	100						Very closely to closely fractured below 56 feet			
60	100						Very closely fractured from 61 to 61.8 feet			
							Very closely fractured from 63.7 to 64.7 feet			
65	100						Closely fractured below 66 feet			
70	100									
75	100									

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LOG OF BORING B-4 (South Umpqua River No. 2) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 2
Project Number: 8169-021-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample	Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
80												
		100										
									Closely to medium fractured below 82 feet			
85												
		100							Closely fractured below 86 feet			
90												
		100							Very closely to closely fractured below 91 feet			
									Closely fractured below 94 feet			
95												
		100										
									Medium fractured below 99 feet			
100												

Bottom of hole at 101 feet
Groundwater not determined due to drilling fluid

105

110

115

120

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LOG OF BORING B-4 (South Umpqua River No. 2) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: South Umpqua River No. 2
Project Number: 8169-021-00

Figure D-22
Sheet 3 of 3

Date(s) Drilled	05/22/06 - 05/23/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	HWT/HQ-3	Sampling Methods	SPT / D&M / Coring
Auger Data	Tricone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	101	Surface Elevation (ft)	1,569.25	Groundwater Elevation (ft)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Elevation feet	Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
	0							CL	Red sandy clay with gravel and occasional cobbles (hard, moist)			
1565	5		0	50/0.5"	1				No Recovery			
								GP-GM	Gray sandy gravel with some silt and occasional cobbles (very dense, moist)			
1560	10		50	73/3"	2							
1555	15		100	74/5.5"	3			GM	Brown and red silty gravel (very dense, moist)			
								CL	Brown-orange-white mottled sandy clay (hard, moist)			
1550	20		100	50/5.5"	4							
1545			100	50	5							
	25							SSTN	Brown and red silty sandstone; highly weathered, moderately strong, closely fractured			
			100									
1540			83						Very weak between 28.5 to 29 feet			
	30		93									
1535			94									
	35											

Note: See Figure D-1 for explanation of symbols.

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LOG OF BORING B-1 (Rogue River)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Elevation feet	Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
	35		100						Gray below 35 feet			
			95									
									Moderately weak to moderately strong and brown below 37 feet			
1530	40											
			100									
1525	45								Red, completely weathered and weak between 45 and 46.1 feet; weak to moderately weak and clayey below 46.1 feet			
			67									
			100									
1520	50											
			100									
									Gray below 52 feet and moderately strong			
1515	55											
			100									
1510								BREC	Gray pyroclastic breccia; fresh, moderately strong, close to medium fractured			
	60											
			100									
1505	65											
			100						Medium fractured below 66 feet			
1500	70											
			97									
			97									
1495									Closely fractured below 74 feet			
	75											
			93									

LOG OF BORING B-1 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Elevation feet	Depth feet	SAMPLES: Interval / Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
1490											
	80										
		97						Medium fractured below 81 feet, moderately weak to moderately strong			
1485								Closely fractured below 84 feet			
	85										
		100									
								Very closely fractured between 87.5 and 89 feet			
1480											
	90										
		90						Closely to medium fractured below 91 feet			
1475											
	95										
		97									
1470											
	100										UC=990 psi

Bottom of hole at 101 feet
Groundwater not encountered during drilling

Elevation feet	Depth feet
1465	105
1460	110
1455	115
1450	120

LOG OF BORING B-1 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Figure D-23
Sheet 3 of 3

Date(s) Drilled	05/25/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	HWT/HQ-3	Sampling Methods	Coring
Auger Data	Tricone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	101	Surface Elevation (ft)	1,479.49	Groundwater Elevation (ft)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Elevation feet	Depth feet	SAMPLES: Interval Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
	0						GM	Light brown to brown fine to coarse sand fine to coarse gravel with silt and basalt particles			No samples taken, observed drill behavior and cuttings
		89					BRX	Gray basalt; slightly weathered, extremely strong, medium fractured			
1475	5										
		96									
1470	10										
		100						Fresh and closely fractured below 11 feet			
1465	15										
		98									
1460	20										
		100						Medium fractured below 21.5 feet			
1455	25										
		95									
1450	30							Closely fractured between 31 and 34.5 feet			
		83									
		78									
1445	35	100									

Note: See Figure D-1 for explanation of symbols.

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LOG OF BORING B-2 (Rogue River)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Figure D-24

Elevation feet	Depth feet	Recovered (in)	Blows/foot	Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
	35									
		100								
1440	40						Closely to medium fractured below 39.5 feet			
		97								
1435	45									
		100								
1430	50	100								
1425	55	100								
		95								
1420	60						Gray-brown basalt, moderately weathered, strong			
		98								
1415	65									
		100								
1410	70									UC=12,660 psi
		100					Closely fractured below 71 feet			
1405	75									
		100								
		33				RBL	Rubble from previous coring run			
						BRX	Very closely fractured between 77.5 and 78.2 feet			

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LOG OF BORING B-2 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Figure D-24

Elevation feet	Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
1400	80		100									
			100						Widely fractured below 81.3 feet			
1395	85		100									
1390	90								Gray basaltic flow breccia; fresh, moderately strong to strong, closely fractured			
			100						Gray basalt; fresh, strong to extremely strong, closely fractured Widely fractured below 91.5 feet Closely fractured between 93.9 to 94.2 feet			
1385	95		97									
1380	100											

Bottom of hole at 101 feet
Groundwater not encountered during drilling

1375 105
1370 110
1365 115
1360 120

LOG OF BORING B-2 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Date(s) Drilled	05/31/06 - 06/01/06	Logged By	ABA	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	HWT/HQ-3	Sampling Methods	Grab / SPT / Coring
Auger Data	Tricone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	101	Surface Elevation (ft)	1,432.53	Groundwater Elevation (ft)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Elevation feet	Depth feet	SAMPLES: Recovered (in)	Blows/foot	Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
	0	6		1		SM	Brown to red-brown silty fine to coarse sand with gravel (medium dense, moist)			
1430										
	5	0		2						
		68				BSLT	Dark gray medium grained basalt; moderately weathered, moderately strong, closely fractured			
1425		100					Crushed zone from 6.6 to 8.5 feet with red silt and sand infilling			
	10	100								
1420							Very closely fractured at 11 to 12 feet Becomes medium fractured			
	15	100					Closed high angle fractures between 16.5 to 18.5 feet			
1415							Very closely fractured from 17 to 18 feet			
	20	100								
1410							Very closely fractured from 22 to 23 feet with silt infilling			
	25	100					Very dark gray fine-grained basalt; fresh, strong, medium fractured			
1405		100				BREC	Dark blue-gray breccia; fresh, moderately strong, widely fractured			
	30	100					Closed, quartz-filled fracture at 36.5 feet			
1400										
	35									

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-3 (Rogue River)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Figure D-25

Elevation feet	Depth feet	Samples: Interval / Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
	35										
		100									
1395											
	40										
		100									
1390											
								80° fracture with calcite mineralization at 43.5 feet			
	45							25 to 40° very thin quartz-filled veins			
		98									
1385								Closed fracture at 48.7 feet			
	50										
		100									
1380											
	55							Becomes strong			
		100									
1375											
								Becomes weak, completely weathered, very closely fractured from 59.8 to 60 feet			
	60							Multi-colored breccia, moderately weathered, weak, medium fractured Sheared/highly fractured zone from 60 to 61 feet Highly fractured/sheared zone from 61 to 61.7 feet			
		100									
1370											
	65							Decomposed zone from 65 to 65.5 feet			
		100 96									
1365								Sheared fractures 68.2 and 68.5 feet			
	70										
		100						Completely decomposed zone at 71 to 72.2 feet			
1360								Highly weathered from 72.2 to 73.5 feet			
		100						Gray breccia; slightly weathered, moderately strong, closely fractured			
	75										
		95									
1355											

LOG OF BORING B-3 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Figure D-25
Sheet 2 of 3

Elevation feet	Depth feet	Interval Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
	80	100						Crushed zone at 79.2 to 80 feet fracture faces slicken sided			UC=2,410 psi
1350											
	85	100						Becomes dark blue altered breccia; slightly weathered, moderately strong, medium fractured			
1345											
	90	100									
1340											
	95	100						Becomes widely spaced fractures			
1335											
	100										UC=4,040 psi
								Bottom of hole at 101 feet Groundwater not measured			
1330											
	105										
1325											
	110										
1320											
	115										
1315											
	120										

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LOG OF BORING B-3 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Figure D-25
Sheet 3 of 3

Date(s) Drilled	06/02/06 - 06/03/06	Logged By	ABA	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	HWT/HQ-3	Sampling Methods	Grab / SPT / Coring
Auger Data	Tricone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	101	Surface Elevation (ft)	1,417.68	Groundwater Elevation (ft)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth scale (feet): 0, 5, 10, 15, 20, 25, 30, 35
Elevation scale (feet): 1415, 1410, 1405, 1400, 1395, 1390, 1385

Elevation feet / Depth feet	SAMPLES: Interval / Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0	100		1		GW	Medium brown fine to coarse gravel with cobbles, boulders, sand and silt (very dense, moist)			
5	100		2						
	100		3						
10	50		4						
1405	50		5						
	100				BREC	Dark gray altered breccia; slightly weathered, moderately strong, medium fractured			
	100								
	100					Becomes widely to very widely fractured			
	96								
						Becomes widely fractured			
	110					Becomes medium fractured			
35						Fracture with 1/2-inch wide crushed zone at 34.8 feet			

Note: See Figure D-1 for explanation of symbols.

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LOG OF BORING B-4 (Rogue River)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Figure D-26

Elevation feet	Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
	35		100									
1380									Sheared fracture at 38.5 feet			
	40		100						Sheared/highly fractured zone (40° angle) at 39.3 to 39.9 feet Becomes medium to widely fractured			
1375												
	45		100									
1370									Crushed zone from 48.3 to 48.5 feet			
	50		98									
1365									Fracture with 1/2 inch crushed zone at 54 feet			
	55		100						Becomes closely to medium fractured; 2 inches crushed zone at 56.2 feet; 1 inch crushed zone at 56.7 feet			
1360												
	60		100						Becomes medium fractured			
1355									Becomes medium to widely fractured			
	65		100						1.5-inch zone of crushed rock at 66.6 feet			
1350									Becomes widely fractured			UC=3,220 psi
	70		100									
1345												
	75		100						Crushed rock infilling fractures at 75.5 feet			
1340												

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LOG OF BORING B-4 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Elevation feet	Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
	80											
			100									
1335									Becomes medium fractured			
	85											
			100						Becomes widely fractured			
1330												
	90											
			100									
1325												UC=3,430 psi
	95											
			100									
1320												
	100											
									Bottom of hole at 101 feet Groundwater not measured			
1315												
	105											
1310												
	110											
1305												
	115											
1300												
	120											

LOG OF BORING B-4 (Rogue River) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Figure D-26

Date(s) Drilled	06/03/06 - 06/05/06	Logged By	ABA	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	HWT/HQ-3	Sampling Methods	Grab / Coring
Auger Data	Tricone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	31.5	Surface Elevation (ft)	1,425.23	Groundwater Elevation (ft)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Elevation feet	Depth feet	SAMPLES: Recovered (in)	Blows/foot	Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
1425	0					GW	Light brown fine to coarse gravel with cobbles, 6-inch boulders, sand and silt (very dense, moist) (alluvium)			
1420	5	100		1						
		100		2						
		100		3						
1415	10	100		4						
1410	15	100		5						
1405	20	100		6						
		100		7						
1400	25	100		8						
		100								
						BREC	Highly weathered breccia			
		100					Dark blue breccia; slightly weathered, moderately strong, very close to closely fractured			
1395	30						Sheared fracture at 31 feet			
							Bottom of hole at 31.5 feet			
							Groundwater not determined due to drilling fluid			
	35									

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-5 (Rogue River)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Figure D-27
Sheet 1 of 1

Date(s) Drilled	06/26/06	Logged By	BCR	Checked By	TNH
Drilling Contractor	Crux Drilling	Drilling Method	HWT/HQ-3	Sampling Methods	SPT / Coring
Auger Data	Tricone	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Burley 4000 Track Rig
Total Depth (ft)	101	Surface Elevation (ft)	1,524.20	Groundwater Elevation (ft)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Elevation feet	Depth feet	Recovered (in)	Blows/foot	Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
	0					CL	Brown-yellow sandy clay with some fine gravel (very stiff, moist) (residual claystone?)			
1520	5	100	22	1			Tan to light gray below 5.5 feet			
1515	10	100	34	2			Brown-yellow below 11 feet (hard)			
1510	15	100	52	3		RX	Light gray to tan completely weathered claystone (hard, moist)			
1505	20	100	69	4		BREC	Brown-green completely weathered (weak, moist) (volcanic breccia)			
		80					Brown-green volcanic breccia; highly weathered, (very weak, closely fractured)			
1500	25	103					Moderately weak below 23. 5 feet			
		100								
		95								
1495	30	100								
1490	35						Slightly weathered to fresh and moderately strong and blue-gray below 33.2 feet			

Note: See Figure D-1 for explanation of symbols.

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LOG OF BORING B-6 (Rogue River)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Elevation feet	Depth feet	Interval Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
	35										
		90						Blue below 36 feet			
											UC=470 psi
1485											
	40	100									
		100						Fresh below 41 feet			
1480	45										
		100									
								Widely fractured between 47 to 49.5 feet			
1475	50										
		100									
1470								Weak to moderately weak below 54 feet			
	55							Very closely fractured from 54 to 55 feet			
		100									
1465	60										
		100						Blue claystone; fresh, moderately strong, weak) closely fractured			
								Blue volcanic breccia; fresh, moderately strong, closely fractured			
1460	65										
		100									
								Very closely fractured from 67.8 to 69.5 feet			
1455	70										
		100									
1450	75							Very closely fractured from 75.5 to 76 feet			
		88						Widely fractured below 76 feet			

LOG OF BORING B-6 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Figure D-28
Sheet 2 of 3

Elevation feet	Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
1445	80		107									
1440	85		100						Moderately weak below 85 feet			
									Closely fractured below 88.8 feet			
1435	90		100									
									Very closely to closely fractured below 92.5 feet			
1430	95		100						Moderately strong below 95 feet Closely fractured below 96 feet			
1425	100								Very closely fractured from 99.3 to 99.6 feet			
									Bottom of hole at 101 feet Groundwater not encountered due to drilling fluid			
1420	105											
1415	110											
1410	115											
1405	120											

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LOG OF BORING B-6 (Rogue River) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Figure D-28

Date(s) Drilled	10/18/06	Logged By	BCR	Checked By	APB
Drilling Contractor	Subsurface Technologies, inc.	Drilling Method	HQ Wire Line	Sampling Methods	SPT / Coring
Auger Data	Tricone / Core Bit	Hammer Data	140 lb hammer/30 in drop	Drilling Equipment	Dietrich D50 Track
Total Depth (ft)	250	Surface Elevation (ft)		Groundwater Level (ft. bgs)	Not Encountered
Vertical Datum		Datum/ System		Easting(x): Northing(y):	

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft^3	OTHER TESTS AND NOTES
0						SC	Red with green, black and gray mottled residual sandy clay with gravel (hard, moist)			
5		6	50/6"	1						
		100				BSLT	Black slightly weathered closely to very closely fractured, very strong basalt, abundant clay filled fractures			
10		83								
						GP	Brown-gray silty gravel with sand			
15		58					With occasional cobbles			
20		80								
						CL	Light brown sandy clay, residual basalt (?) very weak, very closely fractured			
25		82					Brown highly-completely measured volcanic rock, closely fractured, moderately strong			
30		96								
							Light brown-gray highly weathered, moderately strong, closely fractured basalt (?) very closely fractured 31 to 32 feet and 34 to 36 feet			
35										

Note: See Figure D-1 for explanation of symbols.

LOG OF BORING B-7 (Rogue River)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Depth feet	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
35	98					BREC	Grayish-green highly weathered, closely fractured, moderately weak, volcanic breccia in ash matrix			
40	97						Reddish-pink between 41.5 and 49.5 feet			
							Very closely fractured between 43 and 44.3 feet			
							Dark gray to below 44 feet			
45	95						Green, moderately strong and slightly weathered below 45 feet			
							Moderate fracture spacing between 47.2 and 49.4 feet			
50	55						Moderately weathered below 50 feet			
							Moderately weak below 51 feet			
							Highly to completely weathered and weak below 53 feet			
						ASH	Grayish-blue slightly weathered, closely fractured weak volcanic ash			
55	62					BREC	Gray slightly weathered, closely fractured, moderately strong volcanic breccia, very closely fractured 57.5 to 57.8 feet			
						ASH	Grayish-blue slightly weathered to fresh, closely fractured weak volcanic ash			
60	100					BREC	Gray, fresh, very closely fractured, moderately strong volcanic breccia			
							Medium fractured spacing below 61.3 feet			
65	100						Very closely fractured 65.9 to 66.7 feet			
							Closely fractured below 69 feet; dark pink below 69 feet			
70	100						Moderately fractured below 72.5 feet; grayish-blue below 73.4 feet			
75	97									

LOG OF BORING B-7 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
80		100						Widely fractured 80.2 to 83.3 feet			
85		100						Closely fractured below 85 feet			
								Pinkish-red between 87 feet and 89.2 feet			
								Pinkish-red below 89.9 feet			
90		95						Very closely fractured 91.5 to 92 feet			
								Very closely fractured below 94 feet			
95		97						Closely fractured below 97 feet			
								Very closely fractured and highly weathered below 99 feet and moderately weak			
100		95						Closely fractured below 100 feet			
105		100						Grades to fresh and moderately strong below 105.8 fet			
								Very closely fractured between 107.2 and 108.1 feet			
							ASH	Grayish-blue closely fractured fresh weak volcanic ash			
110		97					BREC	Blue-gray closely fractured fresh, moderately weak, moderately strong breccia			
								Very closely fractured and weak between 113.3 and 114 feet			
115		93						Moderately strong below 115 feet			
								Very closely fractured 116 to 117 feet			
120		100									

LOG OF BORING B-7 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Depth feet	SAMPLES: Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
								Very closely fractured 122.8 to 123 feet			
								Very closely fractured 124 to 125 feet			
125		100						Very closely fractured 125 to 125.7 feet			
								Very closely fractured 127.8 to 129 feet			
130		90						Widely spaced fractures 130 to 132 feet			
135		90						Moderately strong to strong below 135 feet			
								Moderately strong below 138 feet			
140		88									
								Widely fractured 141 to 143 feet			
145		87						Very closely fractured below 145 feet			
								Widely fractured below 146.2 feet			
		100									
150		100						Gray medium fractured, fresh, moderately strong breccia			
								Becoming red-pink			
155		100									
160		92						Closely fractured below 160 feet			
		100						Very closely fractured and weak below 164 feet and highly weathered			
165											

LOG OF BORING B-7 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample / Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
								Gray, fresh, closely fractured, strong to very strong andesite			
170		102						Very closely fractured and slightly weathered below 170 feet			
								Closely fractured below 171.7 feet, very strong			
175		100									
								Fresh below 176.5 feet			
180		93									
								Moderately weathered below 183.5 feet			
185		103									
								Very closely fractured 188 to 189 feet			
190		75						Highly weathered 190 to 191 feet (?)			
								Very closely fractured 192 to 192.5 feet			
195		43						Very closely fractured below 195 feet; highly weathered below 197 feet (?)			
200		67						Fresh below 202 feet and closely fractured			
								Fresh, closely fractured, moderately strong, moderately weak breccia			
205		53						Very weak below 204.5 feet			
							ASH	Slightly moderately weathered, closely fractured, weak volcanic ash			

LOG OF BORING B-7 (Rogue River) (continued)

GEOENGINEERS

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

Depth feet	Interval	Recovered (in)	Blows/foot	Sub-Sample Sample Number	Water Level	Graphic Log	Group Symbol	MATERIAL DESCRIPTION	Moisture Content %	Dry Unit Weight, lbs/ft³	OTHER TESTS AND NOTES
210		97					BREC	Blue-gray, fresh, medium fractured, moderately weak to moderately strong breccia			
								Very closely fractured 213.5 to 214 feet			
215		82									
								Moderately strong and widely fractured below 216 feet			
220		103						Medium fractured below 220 feet			
								Closely fractured 221 to 222 feet			
								Very closely fractured 223.5 to 224.5 feet			
225		94									
								Very closely fractured 226.5 to 227.3 feet			
								Moderately weak 228 to 229.5 feet Very closely fractured 228.5 to 229 feet			
230		88									
235											
240											
245											
250								Bottom of hole at 250 feet Groundwater not encountered due to drilling fluid?			

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LOG OF BORING B-7 (Rogue River) (continued)

GeoEngineers

Project: Pacific Connector Gas Pipeline Project
Project Location: Rogue River
Project Number: 8169-021-00

APPENDIX E
Scour Workbooks

Scour Summary Table

Project: Scour Hazards Report
Project Number: 8169-021-06
Watercourse: Various Sites, Oregon
Site: Southern Oregon
Analyst: JGO/GeoEngineers
Latest Revision: 8/24/2007

General Comments:
- This spreadsheet summarizes the cumulative scour depth (Y_s total), in FEET, for the various pipeline crossing / scour locations.
- The two scour types analyzed at all sites include Bend Scour and Contraction Scour.
- Long-term degradation was not estimated for any of the sites.
- Final scour elevations were determined by subtracting the calculated scour depth from the thalweg elevation at the pipeline crossing / scour analysis location. Final elevations were specified and illustrated in Figures by the Bellingham and Seattle Offices. Boise team reported these final scour depths at each of the pipeline crossing Stations (identified in the site-specific HEC-RAS models).
- Final scour depths do not have additional safety factors based on the understanding that the pipeline will be buried (top-of-pipe) at a minimum of 3 feet below the reported scour depth, from the thalweg elevation at the crossing, and at a minimum depth of 5 feet where practicable.

Scour Depths (Y_s) by Recurrence Interval & Scour Type:

Site:	Recurrence Interval (Years)												Comments
	10			25			50			100			
	Bend	Contraction	Total	Bend	Contraction	Total	Bend	Contraction	Total	Bend	Contraction	Total	
North Myrtle Creek	5.0	0.0	**5.0**	6.0	0.0	**6.0**	6.0	0.0	**6.0**	6.5	0.0	**6.5**	Bend scour method 2 selected for scour depth. Live-Bed contraction scour is 0.0 feet.
Middle Creek	5.0	2.0	**7.0**	6.0	3.0	**9.0**	6.0	3.0	**9.0**	7.0	3.5	**10.5**	Bend scour methods averaged and added to calculated Live-Bed contraction scour for each recurrence interval.
South Fork Elk Creek	4.0	0.0	**4.0**	5.0	0.0	**5.0**	5.0	0.0	**5.0**	6.0	0.0	**6.0**	Bend scour methods 1 & 2 averaged for each recurrence interval. Live-Bed & Clear-Water contraction scour calculated to be 0.0-feet.
Olalla Creek	6.0	0.0	**6.0**	7.0	0.0	**7.0**	7.0	0.0	**7.0**	7.5	0.0	**7.5**	Bend scour methods averaged for each recurrence interval. Live-Bed contraction scour calculated to be 0.0 feet.
Rogue River	13.5	0.0	**13.5**	16.5	0.0	**16.5**	18.5	0.0	**18.5**	20.5	0.0	**20.5**	Bend scour methods averaged (except for method 8) for each recurrence interval. Clear-Water contraction scour calculated to be 0.0-feet.
South Umpqua River Crossing No. 1	21.0	0.0	**21.0**	23.5	0.0	**23.5**	25.5	0.0	**25.5**	27.5	0.0	**27.5**	Bend scour methods averaged (except for method 8) for each recurrence interval. Clear-Water contraction scour calculated to be 0.0-feet.
South Umpqua River Crossing No. 2	11.0	0.0	**11.0**	13.2	0.3	**13.5**	14.8	1.2	**16.0**	18.0	0.0	**18.0**	Bend scour methods averaged (except for method 8) and added to calculated Live-Bed contraction scour for each recurrence interval.

Scour Analysis Workbook

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	Middle Creek	**Latest Revision:**	1/10/2007

Workbook Description

- This wookbook contains spreadsheets that facilitate the analysis and/or design of this project.
- This spreadsheet lists the General Project and Workbook Information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.
- Only input data into the SHADED CELLS.
- This workbook is intended for use with ENGLISH UNITS.

Filename: *C:\Documents and Settings\gboyer\Desktop\[Copy of Middle_Ck_Scour_Wbk.xls]Intro*

Sheet Titles:

Scour Analysis Workbook
Discussion/References
General Applicability
Variables
Variable Input Sheet **(User Input Required)**
Figures for Reference
Method 1: Bend Scour, Thorne Equation
Method 2: Bend Scour, Maynord Equation
Method 3: Contraction Scour, Laursen Equation
Method 4: Drop/Weir Scour, USBR Equation for Vertical Drop Structure
Method 5: Drop/Weir Scour, Laursen and Flick Equation for Sloping Sill
Method 6: HEC-23 Scour along Structures
Method 7: USBR Neil Equation
Method 8: USBR Modified Lacey Equation
Method 9: Blench Equation
Results: Bend Scour (User Input Required)
Results: Contraction Scour (**User Input Required**)
Results: Drop/Weir Scour (**User Input Required**)
Results: Scour along Structures (**User Input Required**)
Scour Summary

Variable Input Sheet (User Input Required)

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	Middle Creek	**Latest Revision:**	1/10/2007

- This spreadsheet lists the variables presented in the various scour equations, units, reference information and applicability to the various Methods.
- Refer to previous worksheet for a description of each variable.
- **This spreadsheet REQUIRES YES OR NO ANSWERS to the questions below - PRIOR to entering data.**
- **This spreadsheet is the ONLY SHEET THAT REQUIRES INPUTS for worksheets M1 through M9 to function.**
- **Only input data in the SHADED CELLS.**
- With one exception (fall velocity ω in m/s), this workbook uses ENGLISH units only. All conversions are calculated within the workbook.
- If there is data in this worksheet prior to beginning your scour analysis - CLEAR IT OUT or conditional formatting of cells will not function properly.

Scour Location Information:

Determination of Applicable Scour Type & Method	Yes or No	Applicability
Q1: Is scour location on or near a bend?	yes	**Bend Scour Applies (M1,M2,M7,M8,M9)**
Q2: Is scour location in a contracted area***?	yes	**Contraction Scour Applies (M3)**
Q4: Is scour location downstream of a drop/weir structure?	no	**N/A**
Q5: Is scour location downstream (below) a structure such as a logjam?	no	**N/A**
Q6: Would you like to estimate long-term degradation?	no	**N/A**
Q7: Is the stream sand-bed dominant?	no	**Refer to Discussion Worksheet**

Clear-water/Live-bed Test Results:

***If contraction scour applies, enter Y_1, $D_{50}^{(1)}$, & V_1 for design Q's; then Live-Bed or Clearwater conditions will be calculated here and futher input cells will be highlighted below.

Recurrence Interval (Years)				
10	25	50	100	***Based on the answer to Q2, an intermediate calculation is run to determine input data required. Do not alter these cells!
Live-Bed	Live-Bed	Live-Bed	Live-Bed	

Variable Input Data Requirements:

Scour Type	Variables	Units	Recurrence Interval (Years) 10	25	50	100
Bend	Y_{us}	ft	7.6	8.6	9.2	10.0
	W	ft	131.1	136.1	138.7	143.0
	Rc	ft	940	940	940	940
	Y_{bf}	ft	6.01	6.01	6.01	6.01
	Q	cfs	4348	5470	6120	7225
	q	cfs/ft	54.8	66.1	72.4	82.6
	q_{bf}	cfs/ft	31.2	31.2	31.2	31.2
	D_{50}	ft	0.013	0.013	0.013	0.013
	F_{bo} (See Fig.Ref. for M9)	ft/s^2	5.3	5.3	5.3	5.3
Contraction	Y_1	ft	7.6	8.6	9.2	10.0
	$D_{50}^{(1)}$	ft	0.013	0.013	0.013	0.013
	V_1	ft/s	4.44	4.77	4.94	5.21
	ω (See Fig.Ref. for M3)	m/s	0.3	0.3	0.3	0.3
	Q_1	cfs	4348	5470	6120	7225
	W_1	ft	131.1	136.1	138.7	143.0
	S_1	ft/ft	0.001003	0.000942	0.000916	0.000881
	Y_0	ft	8.17	9.05	9.52	10.25
	Q_2	cfs	4348	5470	6120	7225
	W_2	ft	79.4	82.8	84.6	87.5
	$D_{50}^{(2)}$	ft				
Drop/Weir	q	cfs/ft				
	h (See Fig.Ref. for M4)	ft				
	Y_{tw}	ft				
	Y_c	ft				
	D_{50}	ft				
	R_{50}	ft				
Structures	Fr	----				
	theta	deg				
	Y_1	ft				
Long-term Degradation	Y_s	ft				

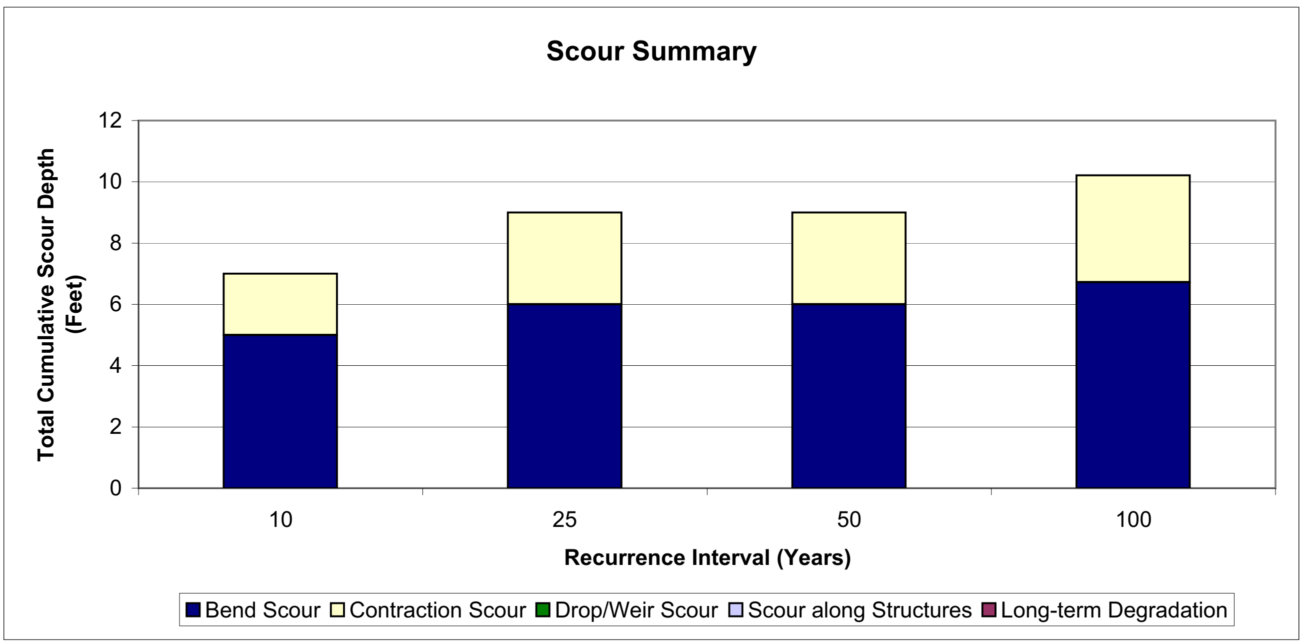
Scour Summary

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	Middle Creek	**Latest Revision:**	1/10/2007

General Comments:
- This worksheet tabulates and plots the final, user-selected scour depths (Ys) in feet from the four previous Scour Results worksheets.
- This worksheet also tabulates and plots Long-term Degradation (Ys) in feet entered on the Variable Inputs Worksheet.
- As noted in the Discussion Worksheet, scour at the site in question is additive. Therefore, cumulative results are plotted by the contribution of each type of scour to the total cumulative scour depth at the site.
- If a Scour Type is not present in the Summary Plot, it was not applicable at this site and automatically removed from the analysis.
- Check final answers against the "Yes or No" questions addressed in the Input Variable Worksheet to verify workbook functionality.

Summary of Scour Depths (Y_s)

Scour Type	Recurrence Interval (Years)			
	10	**25**	**50**	**100**
Bend Scour	5	6	6	7
Contraction Scour	2	3	3	4
Drop/Weir Scour	0	0	0	0
Scour along Structures	0	0	0	0
Long-term Degradation	0	0	0	0
Total Cumulative Scour (ft)	**7**	**9**	**9**	**10**



Discussion of Results and Final Selected Scour Depths:

Scour depth analyzed for the total channel, as modeled in HEC-RAS. Pipeline crossing Station 0+34, approach section Station 1+54.

Final scour depths presented above is the average value of the bend scour methods per recurrence interval; added to the Live-Bed contraction scour estimates per recurrence interval.

Scour Analysis Workbook

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	North Myrtle Creek	**Latest Revision:**	1/11/2007

Workbook Description

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Filename: *P:\8\8169021 TEMP Sea\06\Working\Williams Scour Analysis\Final Scour Workbooks\[N_Myrtle_Ck_Wbk.xls]Intro*

Sheet Titles:

	Scour Analysis Workbook
	Discussion/References
	General Applicability
	Variables
	Variable Input Sheet **(User Input Required)**
	Figures for Reference
	Method 1: Bend Scour, Thorne Equation
	Method 2: Bend Scour, Maynord Equation
	Method 3: Contraction Scour, Laursen Equation
Not Applicable	Method 4: Drop/Weir Scour, USBR Equation for Vertical Drop Structure
Not Applicable	Method 5: Drop/Weir Scour, Laursen and Flick Equation for Sloping Sill
Not Applicable	Method 6: HEC-23 Scour along Structures
	Method 7: USBR Neil Equation
	Method 8: USBR Modified Lacey Equation
	Method 9: Blench Equation
	Results: Bend Scour **(User Input Required)**
	Results: Contraction Scour (**User Input Required**)
	Results: Drop/Weir Scour (**User Input Required**)
	Results: Scour along Structures (**User Input Required**)
	Scour Summary

Variable Input Sheet (User Input Required)

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	North Myrtle Creek	**Latest Revision:**	1/11/2007

- This spreadsheet lists the variables presented in the various scour equations, units, reference information and applicability to the various Methods.
- Refer to previous worksheet for a description of each variable.
- **This spreadsheet REQUIRES YES OR NO ANSWERS to the questions below - PRIOR to entering data.**
- **This spreadsheet is the ONLY SHEET THAT REQUIRES INPUTS for worksheets M1 through M9 to function.**
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- If there is data in this worksheet prior to beginning your scour analysis - CLEAR IT OUT or conditional formatting of cells will not function properly.

Scour Location Information:

Determination of Applicable Scour Type & Method	Yes or No	Applicability
Q1: Is scour location on or near a bend?	yes	**Bend Scour Applies (M1,M2,M7,M8,M9)**
Q2: Is scour location in a contracted area***?	yes	**Contraction Scour Applies (M3)**
Q4: Is scour location downstream of a drop/weir structure?	no	**N/A**
Q5: Is scour location downstream (below) a structure such as a logjam?	no	**N/A**
Q6: Would you like to estimate long-term degradation?	no	**N/A**
Q7: Is the stream sand-bed dominant?	yes	**Refer to Discussion Worksheet**

Clear-water/Live-bed Test Results:

***If contraction scour applies, enter Y_1, $D_{50}^{(1)}$, & V_1 for design Q's; then Live-Bed or Clearwater conditions will be calculated here and futher input cells will be highlighted below.

Recurrence Interval (Years)				
10	25	50	100	***Based on the answer to Q2, an intermediate calculation is run to determine input data required. Do not alter these cells!
Live-Bed	Live-Bed	Live-Bed	Live-Bed	←

Variable Input Data Requirements:

Scour Type	Variables	Units	Recurrence Interval (Years) 10	25	50	100
Bend	Y_{us}	ft	3.8	4.2	4.5	4.7
	W	ft	116.2	116.2	116.2	116.2
	Rc	ft	100	100	100	100
	Y_{bf}	ft	2.24	2.24	2.24	2.24
	Q	cfs	2474	3005	3405	3815
	q	cfs/ft	14.5	17.4	19.5	21.6
	q_{bf}	cfs/ft	8.8	8.8	8.8	8.8
	D_{50}	ft	0.054	0.054	0.054	0.054
	F_{bo} (See Fig.Ref. for M9)	ft/s^2	3.75	3.75	3.75	3.75
Contraction	Y_1	ft	3.8	4.2	4.5	4.7
	$D_{50}^{(1)}$	ft	0.054	0.054	0.054	0.054
	V_1	ft/s	5.56	6.08	6.44	6.78
	ω (See Fig.Ref. for M3)	m/s	0.45	0.45	0.45	0.45
	Q_1	cfs	2459.41	2965.34	3339.04	3713.81
	W_1	ft	116.2	116.2	116.2	116.2
	S_1	ft/ft	0.004731	0.00498	0.005146	0.005278
	Y_0	ft	3.21	3.63	3.94	4.25
	Q_2	cfs	2439.95	2924.99	3283.16	3642.64
	W_2	ft	168.3	168.3	168.3	168.3
	$D_{50}^{(2)}$	ft				
Drop/Weir	q	cfs/ft				
	h (See Fig.Ref. for M4)	ft				
	Y_{tw}	ft				
	Y_c	ft				
	D_{50}	ft				
	R_{50}	ft				
Structures	Fr	----				
	theta	deg				
	Y_1	ft				
Long-term Degradation	Y_s	ft				

Figures for Reference

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	North Myrtle Creek	**Latest Revision:**	1/11/2007

General Comments:
- This worksheet contains Figures necessary for Methods 3, 4 and 9. Data is input back on the "Input Variables" spreadsheet.
- The Figure applicable to Method 4 is for general reference and understanding of the variables. No information is obtained from the schematic.
- **This worksheet requires no direct input.**

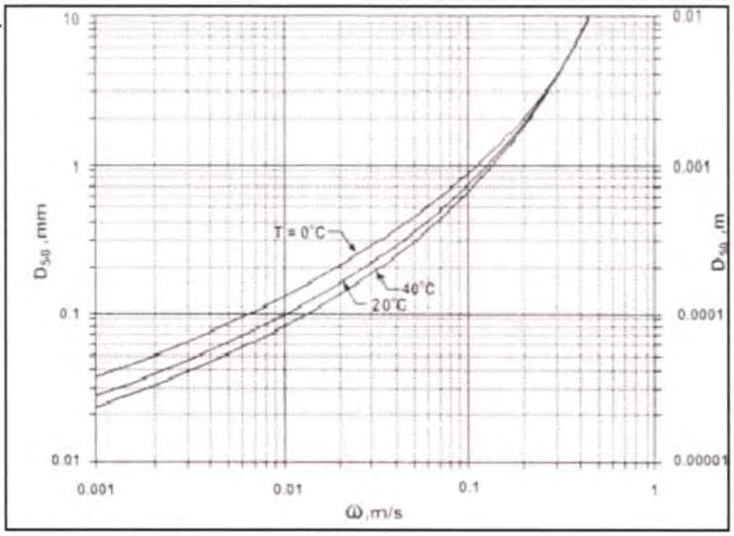
Method 3 Figure Reference:

Figure 5.8 Fall Velocity of sand-sized particles with specific gravity of 2.65 in metric units.

Cells B30,C30,D30,E30 Report D_{50} values in mm. Use these values in Figure to the right.

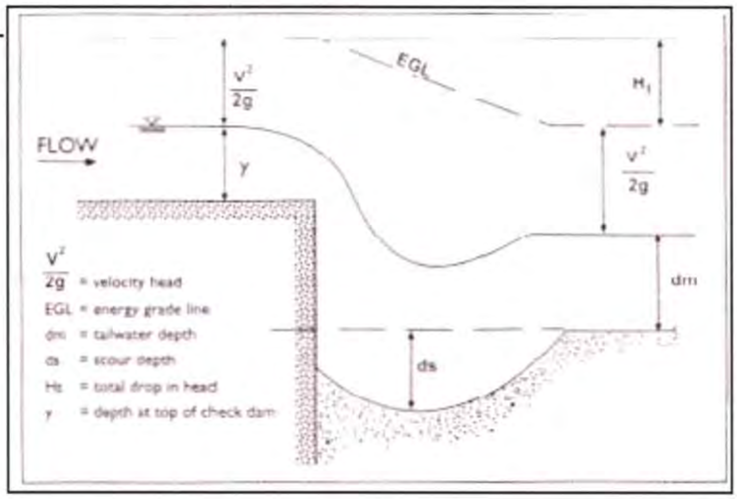
If D_{50} in mm is greater than 10 mm, use 0.45 for ω.

Enter ω **(m/s)** value into input variables spreadsheet if applicable (Live-Bed conditions)



Method 4 Figure Reference:

Schematic of a vertical drop caused by a drop structure.



Method 9 Figure Reference:

Figure: Chart for Estimating Fbo (Blench's Zero Bed Factor).

Cells B22,C22,D22,E22 show D_{50} values. Use these values in Figure to the right.

Enter ft/s^2 value into "Input Variables" spreadsheet in the F_{bo} cells.

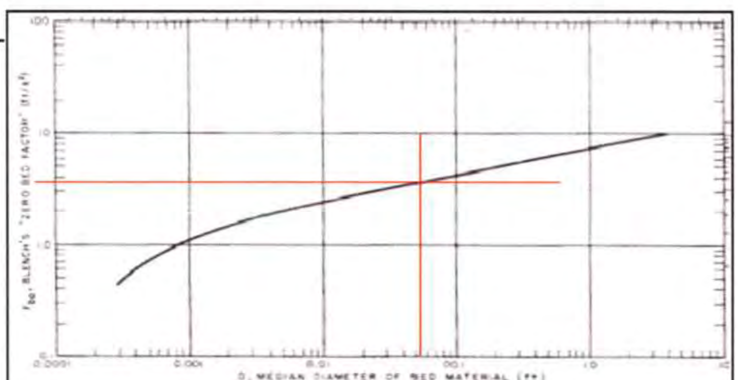


CHART FOR ESTIMATING F_{bo} (AFTER BLENCH)

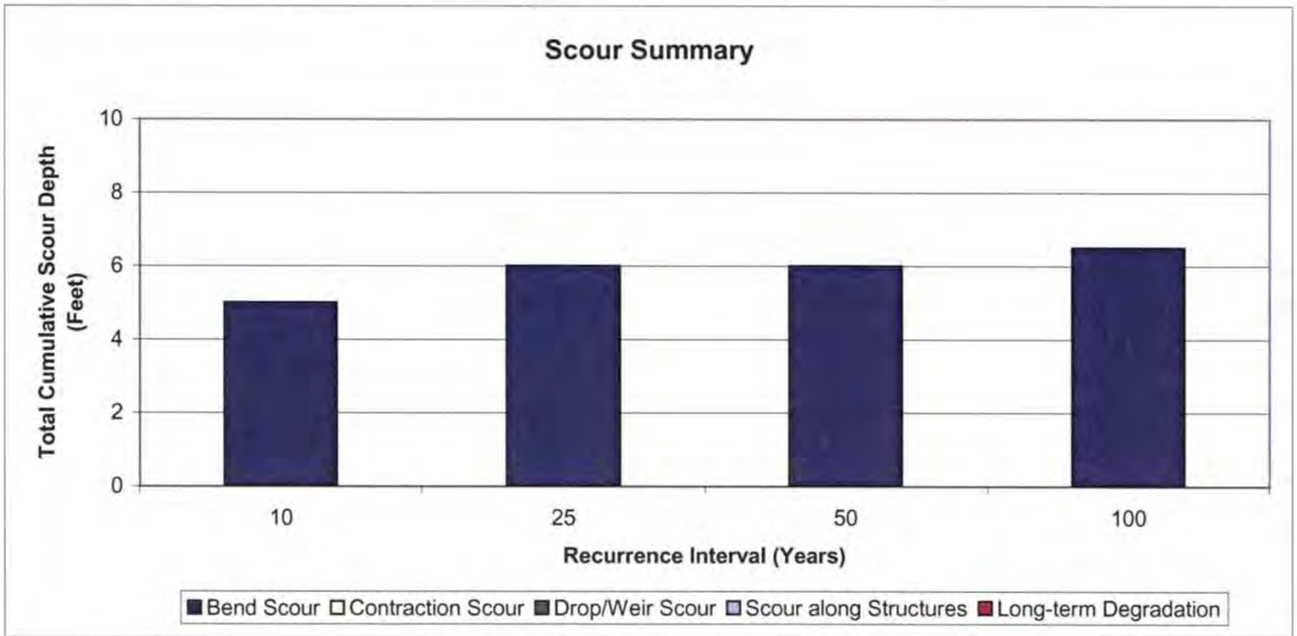
Scour Summary

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	North Myrtle Creek	**Latest Revision:**	1/11/2007

General Comments:
- This worksheet tabulates and plots the final, user-selected scour depths (Ys) in feet from the four previous Scour Results worksheets.
- This worksheet also tabulates and plots Long-term Degradation (Ys) in feet entered on the Variable Inputs Worksheet.
- As noted in the Discussion Worksheet, scour at the site in question is additive. Therefore, cumulative results are plotted by the contribution of each type of scour to the total cumulative scour depth at the site.
- If a Scour Type is not present in the Summary Plot, it was not applicable at this site and automatically removed from the analysis.
- Check final answers against the "Yes or No" questions addressed in the Input Variable Worksheet to verify workbook functionality.

Summary of Scour Depths (Y_s)

Scour Type	Recurrence Interval (Years)			
	10	25	50	100
Bend Scour	5	6	6	6.5
Contraction Scour	0	0	0	0
Drop/Weir Scour	0	0	0	0
Scour along Structures	0	0	0	0
Long-term Degradation	0	0	0	0
Total Cumulative Scour (ft)	**5**	**6**	**6**	**6.5**



Discussion of Results and Final Selected Scour Depths:

Scour was analyzed for the active channel, as modeled in HEC-RAS. Scour analysis location of pipeline crossing: Station 3+15. Upstream approach section used in analysis: Station 5+45.

Final scour depths presented above (for each recurrence interval) is a result of bend scour predictions using Method 2; based on its applicability to bend scour in sand-bed streams.

Live-Bed contraction scour predictions are 0.0 feet for all recurrence intervals at the pipeline crossing location used in this analysis.

Scour Analysis Workbook

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	Olalla Creek	**Latest Revision:**	1/11/2007

Workbook Description

- This wookbook contains spreadsheets that facilitate the analysis and/or design of this project.
- This spreadsheet lists the General Project and Workbook Information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.
- Only input data into the SHADED CELLS.
- This workbook is intended for use with ENGLISH UNITS.

Filename: *P:\8\8169021 TEMP Sea\06\Working\Williams Scour Analysis\Final Scour Workbooks\[Olalla_Scour_Wbk.xls]Intro*

Sheet Titles:

	Scour Analysis Workbook
	Discussion/References
	General Applicability
	Variables
	Variable Input Sheet **(User Input Required)**
	Figures for Reference
	Method 1: Bend Scour, Thorne Equation
	Method 2: Bend Scour, Maynord Equation
	Method 3: Contraction Scour, Laursen Equation
Not Applicable	Method 4: Drop/Weir Scour, USBR Equation for Vertical Drop Structure
Not Applicable	Method 5: Drop/Weir Scour, Laursen and Flick Equation for Sloping Sill
Not Applicable	Method 6: HEC-23 Scour along Structures
	Method 7: USBR Neil Equation
	Method 8: USBR Modified Lacey Equation
	Method 9: Blench Equation
	Results: Bend Scour (User Input Required)
	Results: Contraction Scour (**User Input Required**)
	Results: Drop/Weir Scour (**User Input Required**)
	Results: Scour along Structures (**User Input Required**)
	Scour Summary

Variable Input Sheet (User Input Required)

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	Olalla Creek	**Latest Revision:**	1/11/2007

- This spreadsheet lists the variables presented in the various scour equations, units, reference information and applicability to the various Methods.
- Refer to previous worksheet for a description of each variable.
- **This spreadsheet REQUIRES YES OR NO ANSWERS to the questions below - PRIOR to entering data.**
- **This spreadsheet is the ONLY SHEET THAT REQUIRES INPUTS for worksheets M1 through M9 to function.**
- **Only input data in the SHADED CELLS.**
- With one exception (fall velocity ω in m/s), this workbook uses ENGLISH units only. All conversions are calculated within the workbook.
- If there is data in this worksheet prior to beginning your scour analysis - CLEAR IT OUT or conditional formatting of cells will not function properly.

Scour Location Information:

Determination of Applicable Scour Type & Method	Yes or No	Applicability
Q1: Is scour location on or near a bend?	yes	**Bend Scour Applies (M1,M2,M7,M8,M9)**
Q2: Is scour location in a contracted area***?	yes	**Contraction Scour Applies (M3)**
Q4: Is scour location downstream of a drop/weir structure?	no	**N/A**
Q5: Is scour location downstream (below) a structure such as a logjam?	no	**N/A**
Q6: Would you like to estimate long-term degradation?	no	**N/A**
Q7: Is the stream sand-bed dominant?	no	**Refer to Discussion Worksheet**

Clear-water/Live-bed Test Results:

***If contraction scour applies, enter Y_1, D_{50} (1), & V_1 for design Q's; then Live-Bed or Clearwater conditions will be calculated here and futher input cells will be highlighted below.

Recurrence Interval (Years)				
10	25	50	100	***Based on the answer to Q2, an intermediate calculation is
Live-Bed	Live-Bed	Live-Bed	Live-Bed	run to determine input data required. Do not alter these cells!

Variable Input Data Requirements:

Scour Type	Variables	Units	Recurrence Interval (Years) 10	25	50	100
Bend	Y_{us}	ft	6.09	7.01	7.39	7.78
	W	ft	130.63	130.63	130.63	130.63
	Rc	ft	110	110	110	110
	Y_{bf}	ft	2.01	2.01	2.01	2.01
	Q	cfs	6201	7607	8661	9706
	q	cfs/ft	20.7	25.3	28.6	31.7
	q_{bf}	cfs/ft	11.7	11.7	11.7	11.7
	D_{50}	ft	0.062	0.062	0.062	0.062
	F_{bo} (See Fig.Ref. for M9)	ft/s^2	3.9	3.9	3.9	3.9
Contraction	Y_1	ft	6.09	7.01	7.39	7.78
	D_{50} (1)	ft	0.062	0.062	0.062	0.062
	V_1	ft/s	7.44	7.23	7.42	7.47
	ω (See Fig.Ref. for M3)	m/s	0.45	0.45	0.45	0.45
	Q_1	cfs	5923.07	6614.84	7162.1	7598.42
	W_1	ft	130.63	130.63	130.63	130.63
	S_1	ft/ft	0.004664	0.003658	0.003584	0.003396
	Y_0	ft	3.78	4.55	5.05	5.49
	Q_2	cfs	6171.29	7528.62	8507.23	9443.5
	W_2	ft	297.8	297.8	297.8	297.8
	D_{50} (2)	ft				
Drop/Weir	q	cfs/ft				
	h (See Fig.Ref. for M4)	ft				
	Y_{tw}	ft				
	Y_c	ft				
	D_{50}	ft				
	R_{50}	ft				
Structures	Fr	----				
	theta	deg				
	Y_1	ft				
Long-term Degradation	Y_s	ft				

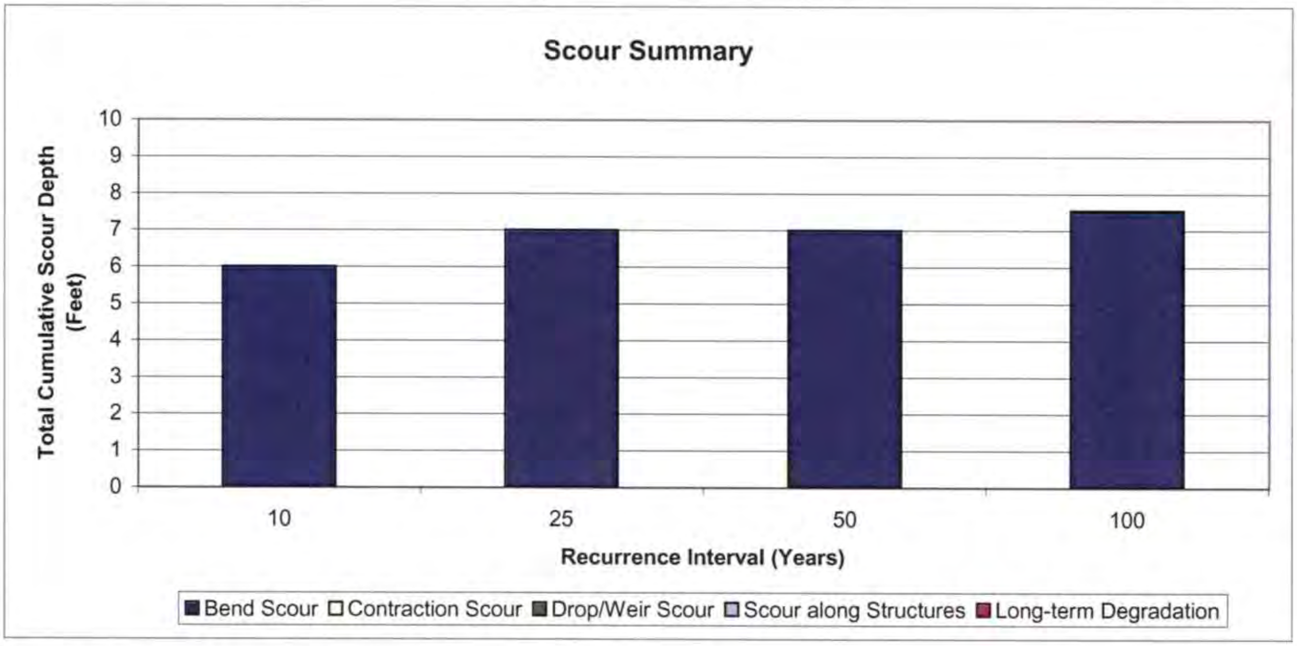
Scour Summary

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	Olalla Creek	**Latest Revision:**	1/11/2007

General Comments:
- This worksheet tabulates and plots the final, user-selected scour depths (Ys) in feet from the four previous Scour Results worksheets.
- This worksheet also tabulates and plots Long-term Degradation (Ys) in feet entered on the Variable Inputs Worksheet.
- As noted in the Discussion Worksheet, scour at the site in question is additive. Therefore, cumulative results are plotted by the contribution of each type of scour to the total cumulative scour depth at the site.
- If a Scour Type is not present in the Summary Plot, it was not applicable at this site and automatically removed from the analysis.
- Check final answers against the "Yes or No" questions addressed in the Input Variable Worksheet to verify workbook functionality.

Summary of Scour Depths (Y_s)

Scour Type	Recurrence Interval (Years)			
	10	**25**	**50**	**100**
Bend Scour	6	7	7	7.5
Contraction Scour	0	0	0	0
Drop/Weir Scour	0	0	0	0
Scour along Structures	0	0	0	0
Long-term Degradation	0	0	0	0
Total Cumulative Scour (ft)	**6**	**7**	**7**	**7.5**



Discussion of Results and Final Selected Scour Depths:

Scour was analyzed for the active channel, as modeled in HEC-RAS. Scour analysis location of pipeline crossing: Station 12+87. Upstream approach section used in analysis: Station 17+32.

Final scour depths presented above are the average value of the bend scour predictions per recurrence interval.

Live-Bed contraction scour predictions are 0.0 feet for all recurrence intervals at the pipeline crossing location used in this analysis.

Scour Analysis Workbook

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	Rogue River	**Latest Revision:**	1/10/2007

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Filename: *P:\8\8169021 TEMP Sea\06\Working\Williams Scour Analysis\Final Scour Workbooks\[Rogue_Scour_Wbk.xls]Intro*

Sheet Titles:

	Scour Analysis Workbook
	Discussion/References
	General Applicability
	Variables
	Variable Input Sheet **(User Input Required)**
	Figures for Reference
	Method 1: Bend Scour, Thorne Equation
	Method 2: Bend Scour, Maynord Equation
	Method 3: Contraction Scour, Laursen Equation
Not Applicable	Method 4: Drop/Weir Scour, USBR Equation for Vertical Drop Structure
Not Applicable	Method 5: Drop/Weir Scour, Laursen and Flick Equation for Sloping Sill
Not Applicable	Method 6: HEC-23 Scour along Structures
	Method 7: USBR Neil Equation
	Method 8: USBR Modified Lacey Equation
	Method 9: Blench Equation
	Results: Bend Scour (User Input Required)
	Results: Contraction Scour (**User Input Required**)
	Results: Drop/Weir Scour (**User Input Required**)
	Results: Scour along Structures (**User Input Required**)
	Scour Summary

Variable Input Sheet (User Input Required)

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	Rogue River	**Latest Revision:**	1/10/2007

- This spreadsheet lists the variables presented in the various scour equations, units, reference information and applicability to the various Methods.
- Refer to previous worksheet for a description of each variable.
- **This spreadsheet REQUIRES YES OR NO ANSWERS to the questions below - PRIOR to entering data.**
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- If there is data in this worksheet prior to beginning your scour analysis - CLEAR IT OUT or conditional formatting of cells will not function properly.

Scour Location Information:

Determination of Applicable Scour Type & Method	Yes or No	Applicability
Q1: Is scour location on or near a bend?	yes	**Bend Scour Applies (M1,M2,M7,M8,M9)**
Q2: Is scour location in a contracted area***?	yes	**Contraction Scour Applies (M3)**
Q4: Is scour location downstream of a drop/weir structure?	no	**N/A**
Q5: Is scour location downstream (below) a structure such as a logjam?	no	**N/A**
Q6: Would you like to estimate long-term degradation?	no	**N/A**
Q7: Is the stream sand-bed dominant?	no	**Refer to Discussion Worksheet**

Clear-water/Live-bed Test Results:

***If contraction scour applies, enter Y_1, $D_{50}^{(1)}$, & V_1 for design Q's; then Live-Bed or Clearwater conditions will be calculated here and futher input cells will be highlighted below.

Recurrence Interval (Years)				
10	25	50	100	***Based on the answer to Q2, an intermediate calculation is
Clear-Water	Clear-Water	Clear-Water	Clear-Water	run to determine input data required. Do not alter these cells!

Variable Input Data Requirements:

Scour Type	Variables	Units	Recurrence Interval (Years) 10	25	50	100
Bend	Y_{us}	ft	10.6	13.0	14.9	16.6
	W	ft	374.7	374.7	374.7	374.7
	Rc	ft	316	316	316	316
	Y_{bf}	ft	6.24	6.24	6.24	6.24
	Q	cfs	35641	47259	56557	66384
	q	cfs/ft	140.3	179.7	208.6	234.5
	q_{bf}	cfs/ft	64.5	64.5	64.5	64.5
	D_{50}	ft	0.295	0.295	0.295	0.295
	F_{bo} (See Fig.Ref. for M9)	ft/s^2	5.4	5.4	5.4	5.4
Contraction	Y_1	ft	10.6	13.0	14.9	16.6
	$D_{50}^{(1)}$	ft	0.295	0.295	0.295	0.295
	V_1	ft/s	8.78	9.3	9.54	9.68
	ω (See Fig.Ref. for M3)	m/s				
	Q_1	cfs				
	W_1	ft				
	S_1	ft/ft				
	Y_0	ft	11.52	14.15	16.02	17.79
	Q_2	cfs	34711.02	44441.51	51593.71	58008.6
	W_2	ft	247.4	247.4	247.4	247.4
	$D_{50}^{(2)}$	ft	0.295	0.295	0.295	0.295
Drop/Weir	q	cfs/ft				
	h (See Fig.Ref. for M4)	ft				
	Y_{tw}	ft				
	Y_c	ft				
	D_{50}	ft				
	R_{50}	ft				
Structures	Fr	----				
	theta	deg				
	Y_1	ft				
Long-term Degradation	Y_s	ft				

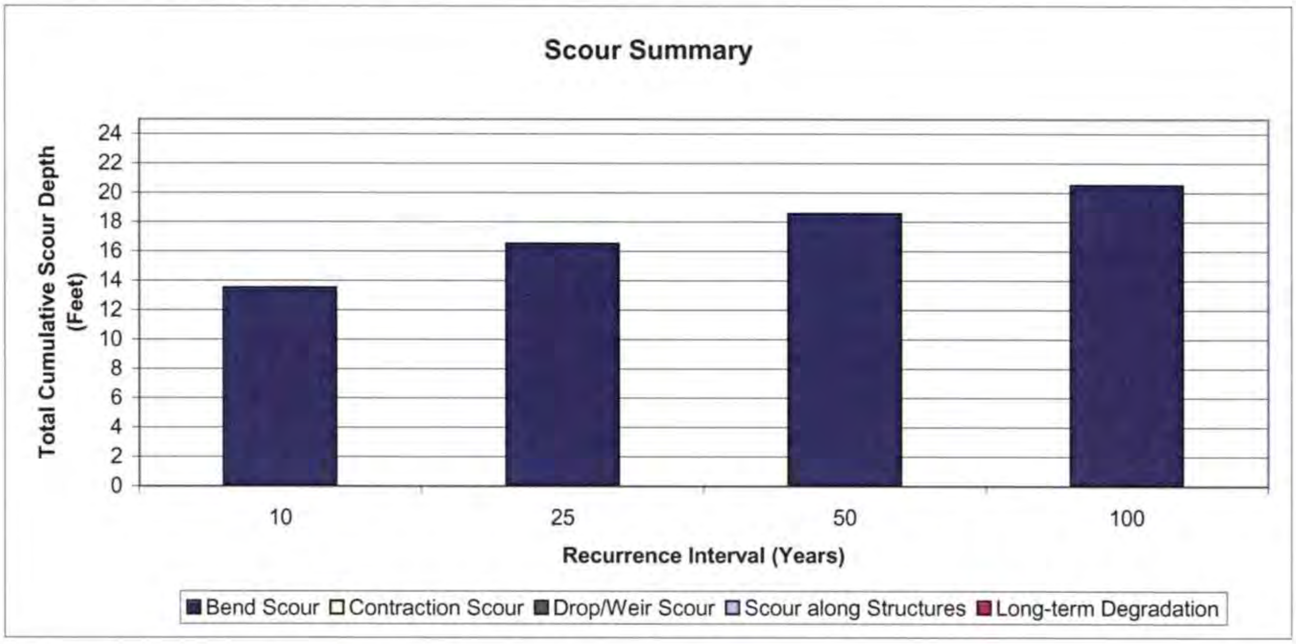
Scour Summary

Project: Scour Hazards Report | **Site:** Southern Oregon
Project Number: 8169-021-06 | **Analyst:** JGO/GeoEngineers
Watercourse: Rogue River | **Latest Revision:** 1/10/2007

General Comments:
- This worksheet tabulates and plots the final, user-selected scour depths (Ys) in feet from the four previous Scour Results worksheets.
- This worksheet also tabulates and plots Long-term Degradation (Ys) in feet entered on the Variable Inputs Worksheet.
- As noted in the Discussion Worksheet, scour at the site in question is additive. Therefore, cumulative results are plotted by the contribution of each type of scour to the total cumulative scour depth at the site.
- If a Scour Type is not present in the Summary Plot, it was not applicable at this site and automatically removed from the analysis.
- Check final answers against the "Yes or No" questions addressed in the Input Variable Worksheet to verify workbook functionality.

Summary of Scour Depths (Y_s)

Scour Type	Recurrence Interval (Years)			
	10	25	50	100
Bend Scour	13.5	16.5	18.5	20.5
Contraction Scour	0	0	0	0
Drop/Weir Scour	0	0	0	0
Scour along Structures	0	0	0	0
Long-term Degradation	0	0	0	0
Total Cumulative Scour (ft)	**13.5**	**16.5**	**18.5**	**20.5**



Discussion of Results and Final Selected Scour Depths:

Scour was analyzed for the active channel, as modeled in HEC-RAS. Scour analysis location of pipeline crossing: Station 2+16. Upstream approach section used in analysis: Station 3+67.

Final scour depths presented above are the average value of bend scour predictions using Methods 1, 2, 7 & 9 per recurrence interval. Method 8 was eliminated for conservatism.

Clear-Water contraction scour predictions are 0.0 feet for all recurrence intervals at the pipeline crossing location used in this analysis.

Scour Analysis Workbook

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	South Umpqua River Crossing No. 1	**Latest Revision:**	1/10/2007

Workbook Description

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Filename: *C:\Documents and Settings\gboyer\Desktop\[Copy of S_Umpqua_1_Wbk.xls]Intro*

Sheet Titles:

Variable Input Sheet (User Input Required)

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	South Umpqua River Crossing No. 1	**Latest Revision:**	1/10/2007

- This spreadsheet lists the variables presented in the various scour equations, units, reference information and applicability to the various Methods.
- Refer to previous worksheet for a description of each variable.
- **This spreadsheet REQUIRES YES OR NO ANSWERS to the questions below - PRIOR to entering data.**
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- If there is data in this worksheet prior to beginning your scour analysis - CLEAR IT OUT or conditional formatting of cells will not function properly.

Scour Location Information:

Determination of Applicable Scour Type & Method	Yes or No	Applicability
Q1: Is scour location on or near a bend?	yes	**Bend Scour Applies (M1,M2,M7,M8,M9)**
Q2: Is scour location in a contracted area***?	yes	**Contraction Scour Applies (M3)**
Q4: Is scour location downstream of a drop/weir structure?	no	**N/A**
Q5: Is scour location downstream (below) a structure such as a logjam?	no	**N/A**
Q6: Would you like to estimate long-term degradation?	no	**N/A**
Q7: Is the stream sand-bed dominant?	no	**Refer to Discussion Worksheet**

Clear-water/Live-bed Test Results:

***If contraction scour applies, enter Y_1, $D_{50}^{(1)}$, & V_1 for design Q's; then Live-Bed or Clearwater conditions will be calculated here and futher input cells will be highlighted below.

Recurrence Interval (Years)			
10	25	50	100
Clear-Water	Clear-Water	Clear-Water	Clear-Water

← ***Based on the answer to Q2, an intermediate calculation is run to determine input data required. Do not alter these cells!

Variable Input Data Requirements:

Scour Type	Variables	Units	Recurrence Interval (Years) 10	25	50	100
Bend	Y_{us}	ft	13.4	15.1	16.4	17.7
	W	ft	631.9	650.5	657.4	664.2
	Rc	ft	885	885	885	885
	Y_{bf}	ft	11.68	11.68	11.68	11.68
	Q	cfs	70162	86736	99251	111912
	q	cfs/ft	117.6	121.8	128.1	132.1
	q_{bf}	cfs/ft	65.8	65.8	65.8	65.8
	D_{50}	ft	0.276	0.276	0.276	0.276
	F_{bo} (See Fig.Ref. for M9)	ft/s^2	5.1	5.1	5.1	5.1
Contraction	Y_1	ft	13.4	15.1	16.4	17.7
	$D_{50}^{(1)}$	ft	0.276	0.276	0.276	0.276
	V_1	ft/s	9.06	9.78	10.26	10.69
	ω (See Fig.Ref. for M3)	m/s				
	Q_1	cfs				
	W_1	ft				
	S_1	ft/ft				
	Y_0	ft	16.2	15.5	15.7	15.7
	Q_2	cfs	70162	86736	99251	111912
	W_2	ft	596.6	712.2	774.5	847.2
	$D_{50}^{(2)}$	ft	0.276	0.276	0.276	0.276
Drop/Weir	q	cfs/ft				
	h (See Fig.Ref. for M4)	ft				
	Y_{tw}	ft				
	Y_c	ft				
	D_{50}	ft				
	R_{50}	ft				
Structures	Fr	----				
	theta	deg				
	Y_1	ft				
Long-term Degradation	Y_s	ft				

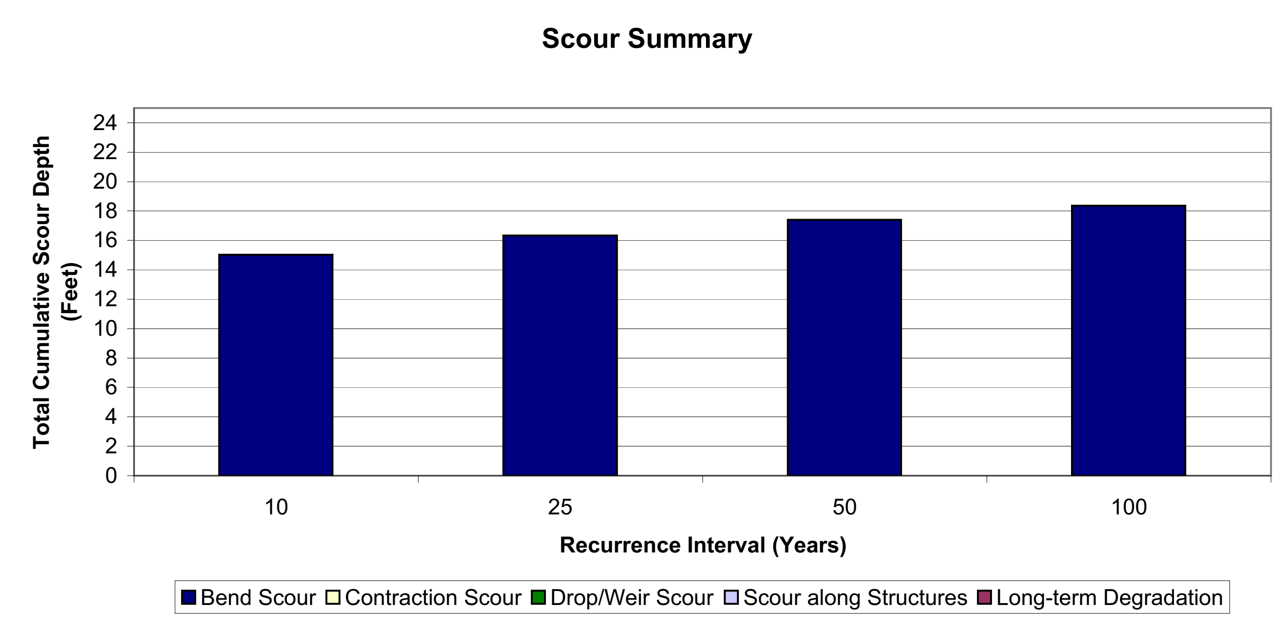
Scour Summary

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	South Umpqua River Crossing No. 1	**Latest Revision:**	1/10/2007

General Comments:
- This worksheet tabulates and plots the final, user-selected scour depths (Ys) in feet from the four previous Scour Results worksheets.
- This worksheet also tabulates and plots Long-term Degradation (Ys) in feet entered on the Variable Inputs Worksheet.
- As noted in the Discussion Worksheet, scour at the site in question is additive. Therefore, cumulative results are plotted by the contribution of each type of scour to the total cumulative scour depth at the site.
- If a Scour Type is not present in the Summary Plot, it was not applicable at this site and automatically removed from the analysis.
- Check final answers against the "Yes or No" questions addressed in the Input Variable Worksheet to verify workbook functionality.

Summary of Scour Depths (Y_s)

Scour Type	Recurrence Interval (Years)			
	10	**25**	**50**	**100**
Bend Scour	15.0	16.3	17.4	18.4
Contraction Scour	0.0	0.0	0.0	0.0
Drop/Weir Scour	0.0	0.0	0.0	0.0
Scour along Structures	0.0	0.0	0.0	0.0
Long-term Degradation	0.0	0.0	0.0	0.0
Total Cumulative Scour (ft)	**15.0**	**16.3**	**17.4**	**18.4**



Discussion of Results and Final Selected Scour Depths:

User Selected Depths for Bend Scour were determined by calculating the average scour for each recurrence interval.

Clear-Water scour calculated to be 0.0-feet at all recurrence intervals.

Recommend adding at least 2-feet due to downstream pool/bend that may potentially migrate upstream into pipeline crossing over time.

Scour Analysis Workbook

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	South Umpqua River Crossing No. 2	**Latest Revision:**	1/10/2007

Workbook Description

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- This workbook is intended for use with ENGLISH UNITS.

Filename: *C:\Documents and Settings\gboyer\Desktop\[Copy of S_Umpqua_2_Wbk.xls]Intro*

Sheet Titles:

Variable Input Sheet (User Input Required)

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	South Umpqua River Crossing No. 2	**Latest Revision:**	1/10/2007

- This spreadsheet lists the variables presented in the various scour equations, units, reference information and applicability to the various Methods.
- Refer to previous worksheet for a description of each variable.
- **This spreadsheet REQUIRES YES OR NO ANSWERS to the questions below - PRIOR to entering data.**
- **This spreadsheet is the ONLY SHEET THAT REQUIRES INPUTS for worksheets M1 through M9 to function.**
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- If there is data in this worksheet prior to beginning your scour analysis - CLEAR IT OUT or conditional formatting of cells will not function properly.

Scour Location Information:

Determination of Applicable Scour Type & Method	Yes or No	Applicability
Q1: Is scour location on or near a bend?	yes	**Bend Scour Applies (M1,M2,M7,M8,M9)**
Q2: Is scour location in a contracted area***?	yes	**Contraction Scour Applies (M3)**
Q4: Is scour location downstream of a drop/weir structure?	no	**N/A**
Q5: Is scour location downstream (below) a structure such as a logjam?	no	**N/A**
Q6: Would you like to estimate long-term degradation?	no	**N/A**
Q7: Is the stream sand-bed dominant?	no	**Refer to Discussion Worksheet**

Clear-water/Live-bed Test Results:

***If contraction scour applies, enter Y_1, $D_{50}^{(1)}$, & V_1 for design Q's; then Live-Bed or Clearwater conditions will be calculated here and futher input cells will be highlighted below.

Recurrence Interval (Years)				
10	**25**	**50**	**100**	***Based on the answer to Q2, an intermediate calculation is run to determine input data required. Do not alter these cells!
Live-Bed	Live-Bed	Live-Bed	Live-Bed	

Variable Input Data Requirements:

Scour Type	Variables	Units	Recurrence Interval (Years) 10	25	50	100
Bend	Y_{us}	ft	11.5	12.3	13.6	14.9
	W	ft	299.1	355.9	374.3	392.8
	Rc	ft	1200	1200	1200	1200
	Y_{bf}	ft	10.44	10.44	10.44	10.44
	Q	cfs	43058	54772	63826	73204
	q	cfs/ft	185.9	225.7	254.2	245.0
	q_{bf}	cfs/ft	109.8	109.8	109.8	109.8
	D_{50}	ft	0.282	0.282	0.282	0.282
	F_{bo} (See Fig.Ref. for M9)	ft/s^2	5.4	5.4	5.4	5.4
Contraction	Y_1	ft	11.5	12.3	13.6	14.9
	$D_{50}^{(1)}$	ft	0.282	0.282	0.282	0.282
	V_1	ft/s	13.25	14.06	14.44	14.8
	ω (See Fig.Ref. for M3)	m/s	0.45	0.45	0.45	0.45
	Q_1	cfs	43058	54772	63826	73204
	W_1	ft	299.1	355.9	374.3	392.8
	S_1	ft/ft	0.003362	0.003055	0.0028	0.0026
	Y_0	ft	13.72	15.34	16.38	15.17
	Q_2	cfs	43058	54772	63826	73204
	W_2	ft	231.7	242.7	251.1	298.8
	$D_{50}^{(2)}$	ft				
Drop/Weir	q	cfs/ft				
	h (See Fig.Ref. for M4)	ft				
	Y_{tw}	ft				
	Y_c	ft				
	D_{50}	ft				
	R_{50}	ft				
Structures	Fr	----				
	theta	deg				
	Y_1	ft				
Long-term Degradation	Y_s	ft				

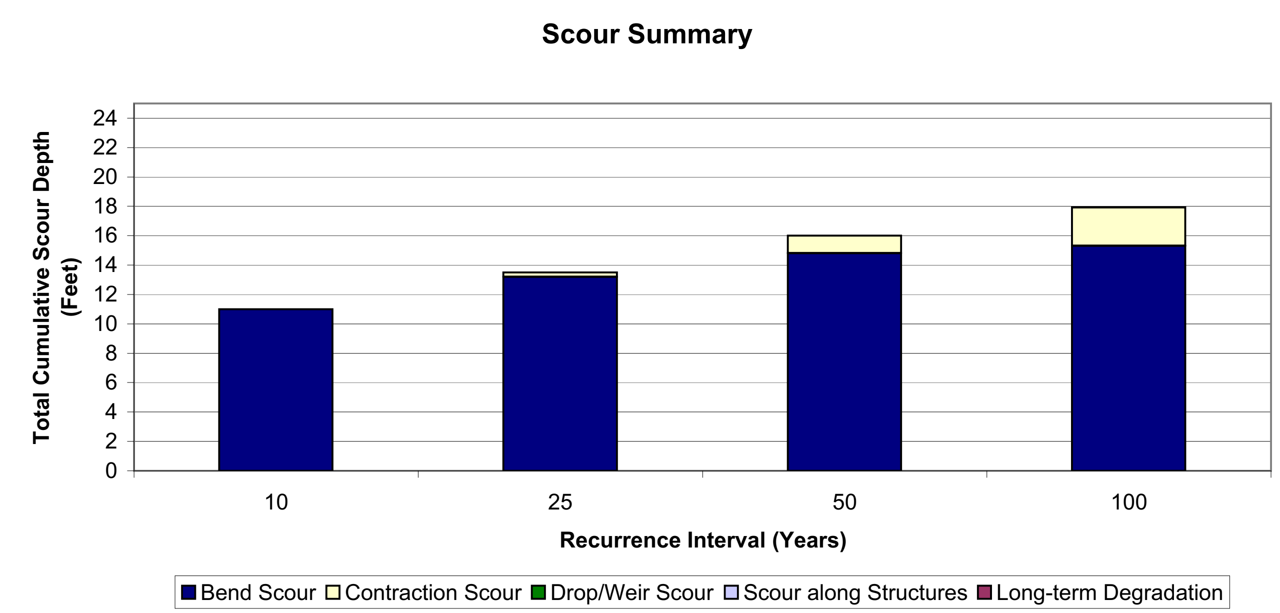
Scour Summary

Project: Scour Hazards Report **Site:** Southern Oregon
Project Number: 8169-021-06 **Analyst:** JGO/GeoEngineers
Watercourse: South Umpqua River Crossing No. 2 **Latest Revision:** 1/10/2007

General Comments:
- This worksheet tabulates and plots the final, user-selected scour depths (Ys) in feet from the four previous Scour Results worksheets.
- This worksheet also tabulates and plots Long-term Degradation (Ys) in feet entered on the Variable Inputs Worksheet.
- As noted in the Discussion Worksheet, scour at the site in question is additive. Therefore, cumulative results are plotted by the contribution of each type of scour to the total cumulative scour depth at the site.
- If a Scour Type is not present in the Summary Plot, it was not applicable at this site and automatically removed from the analysis.
- Check final answers against the "Yes or No" questions addressed in the Input Variable Worksheet to verify workbook functionality.

Summary of Scour Depths (Y_s)

Scour Type	Recurrence Interval (Years)			
	10	25	50	100
Bend Scour	11.0	13.2	14.8	15.3
Contraction Scour	0.0	0.3	1.2	2.6
Drop/Weir Scour	0.0	0.0	0.0	0.0
Scour along Structures	0.0	0.0	0.0	0.0
Long-term Degradation	0.0	0.0	0.0	0.0
Total Cumulative Scour (ft)	**11.0**	**13.5**	**16.0**	**17.9**



Discussion of Results and Final Selected Scour Depths:

Scour depth analyzed for the total channel, as modeled in HEC-RAS. Pipeline crossing / scour analysis location at Station 1+19. Approach cross-section at Station 2+99.

Final scour depths presented above (for each recurrence interval) is the average value of the bend scour methods per recurrence interval; added to the Live-Bed contraction scour estimates per recurrence interval.

Note that bend scour estimates may be low due to the low scour values calculated by Method 8. May consider increasing final bend scour estimate by some percentage for conservatism. Discuss with team.

Scour Analysis Workbook

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	South Fork Elk Creek	**Latest Revision:**	1/11/2007

Workbook Description

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Filename: *P:\8\8169021 TEMP Sea\06\Working\Williams Scour Analysis\Final Scour Workbooks\[S_Fk_Elk_Ck_Wbk.xls]Intro*

Sheet Titles:

	Scour Analysis Workbook
	Discussion/References
	General Applicability
	Variables
	Variable Input Sheet **(User Input Required)**
	Figures for Reference
	Method 1: Bend Scour, Thorne Equation
	Method 2: Bend Scour, Maynord Equation
	Method 3: Contraction Scour, Laursen Equation
Not Applicable	Method 4: Drop/Weir Scour, USBR Equation for Vertical Drop Structure
Not Applicable	Method 5: Drop/Weir Scour, Laursen and Flick Equation for Sloping Sill
Not Applicable	Method 6: HEC-23 Scour along Structures
	Method 7: USBR Neil Equation
	Method 8: USBR Modified Lacey Equation
	Method 9: Blench Equation
	Results: Bend Scour (User Input Required)
	Results: Contraction Scour (**User Input Required**)
	Results: Drop/Weir Scour (**User Input Required**)
	Results: Scour along Structures (**User Input Required**)
	Scour Summary

Variable Input Sheet (User Input Required)

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	South Fork Elk Creek	**Latest Revision:**	1/11/2007

- This spreadsheet lists the variables presented in the various scour equations, units, reference information and applicability to the various Methods.
- Refer to previous worksheet for a description of each variable.
- **This spreadsheet REQUIRES YES OR NO ANSWERS to the questions below - PRIOR to entering data.**
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- If there is data in this worksheet prior to beginning your scour analysis - CLEAR IT OUT or conditional formatting of cells will not function properly.

Scour Location Information:

Determination of Applicable Scour Type & Method	Yes or No	Applicability
Q1: Is scour location on or near a bend?	yes	**Bend Scour Applies (M1,M2,M7,M8,M9)**
Q2: Is scour location in a contracted area***?	yes	**Contraction Scour Applies (M3)**
Q4: Is scour location downstream of a drop/weir structure?	no	**N/A**
Q5: Is scour location downstream (below) a structure such as a logjam?	no	**N/A**
Q6: Would you like to estimate long-term degradation?	no	**N/A**
Q7: Is the stream sand-bed dominant?	no	**Refer to Discussion Worksheet**

Clear-water/Live-bed Test Results:

***If contraction scour applies, enter Y_1, D_{50} (1), & V_1 for design Q's; then Live-Bed or Clearwater conditions will be calculated here and futher input cells will be highlighted below.

Recurrence Interval (Years)				
10	25	50	100	***Based on the answer to Q2, an intermediate calculation is run to determine input data required. Do not alter these cells!
Clear-Water	Clear-Water	Clear-Water	Live-Bed	

Variable Input Data Requirements:

Scour Type	Variables	Units	Recurrence Interval (Years) 10	25	50	100
Bend	Y_{us}	ft	2.4	2.8	3.0	3.1
	W	ft	27.7	27.7	27.7	27.7
	Rc	ft	10	10	10	10
	Y_{bf}	ft	1.3	1.3	1.3	1.3
	Q	cfs	408	511	585	673
	q	cfs/ft	6.6	8.3	9.5	10.9
	q_{bf}	cfs/ft	3.5	3.5	3.5	3.5
	D_{50}	ft	0.150	0.150	0.150	0.150
	F_{bo} (See Fig.Ref. for M9)	ft/s^2	4.6	4.6	4.6	4.6
Contraction	Y_1	ft	2.4	2.8	3.0	3.1
	D_{50} (1)	ft	0.150	0.150	0.150	0.150
	V_1	ft/s	6.01	6.44	6.97	7.53
	ω (See Fig.Ref. for M3)	m/s				0.45
	Q_1	cfs				653.06
	W_1	ft				27.7
	S_1	ft/ft				0.011713
	Y_0	ft	1.85	2.1	2.28	2.46
	Q_2	cfs	407.74	510.17	583.58	670.73
	W_2	ft	61.4	61.4	61.4	61.4
	D_{50} (2)	ft	0.150	0.150	0.150	
Drop/Weir	q	cfs/ft				
	h (See Fig.Ref. for M4)	ft				
	Y_{tw}	ft				
	Y_c	ft				
	D_{50}	ft				
	R_{50}	ft				
Structures	Fr	----				
	theta	deg				
	Y_1	ft				
Long-term Degradation	Y_s	ft				

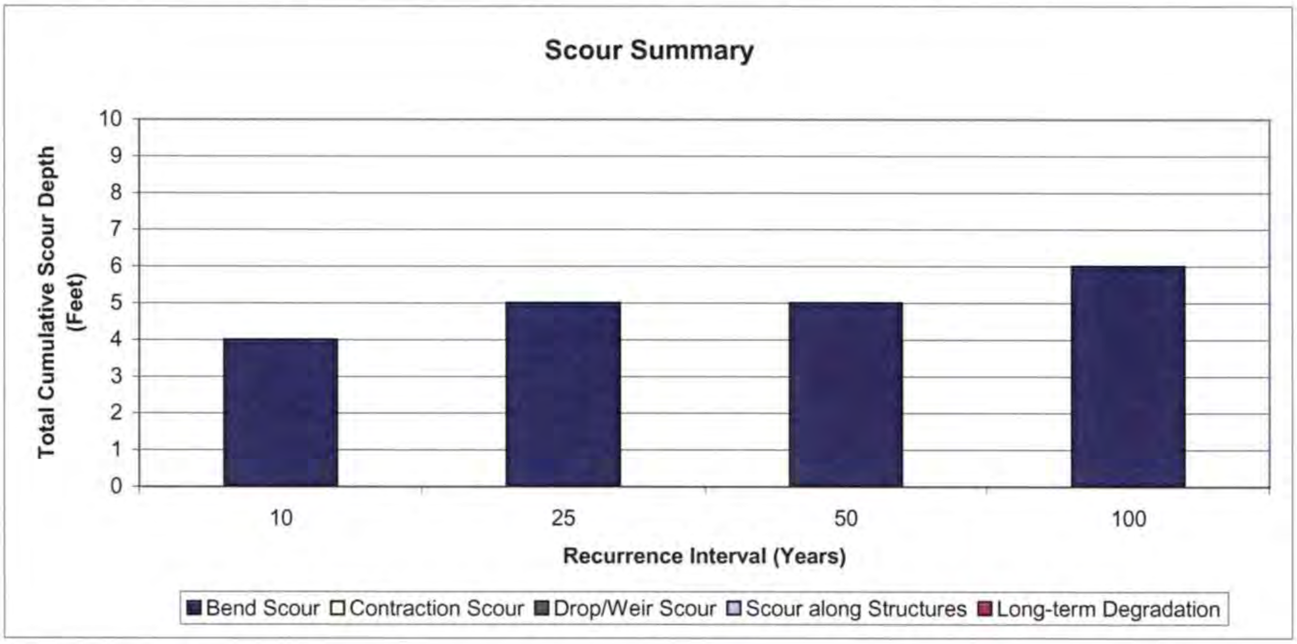
Scour Summary

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	South Fork Elk Creek	**Latest Revision:**	1/11/2007

General Comments:
- This worksheet tabulates and plots the final, user-selected scour depths (Ys) in feet from the four previous Scour Results worksheets.
- This worksheet also tabulates and plots Long-term Degradation (Ys) in feet entered on the Variable Inputs Worksheet.
- As noted in the Discussion Worksheet, scour at the site in question is additive. Therefore, cumulative results are plotted by the contribution of each type of scour to the total cumulative scour depth at the site.
- If a Scour Type is not present in the Summary Plot, it was not applicable at this site and automatically removed from the analysis.
- Check final answers against the "Yes or No" questions addressed in the Input Variable Worksheet to verify workbook functionality.

Summary of Scour Depths (Y_s)

Scour Type	Recurrence Interval (Years)			
	10	25	50	100
Bend Scour	4	5	5	6
Contraction Scour	0	0	0	0
Drop/Weir Scour	0	0	0	0
Scour along Structures	0	0	0	0
Long-term Degradation	0	0	0	0
Total Cumulative Scour (ft)	**4**	**5**	**5**	**6**



Discussion of Results and Final Selected Scour Depths:

Scour was analyzed for the active channel, as modeled in HEC-RAS. Scour analysis location of pipeline crossing: Station 1+92. Upstream approach section used in analysis: Station 3+10.

Final scour depths presented above are the average value of bend scour predictions using Methods 1 & 2 per recurrence interval. Methods 7, 8 and 9 were eliminated for conservatism.

Clear-Water & Live-Bed contraction scour predictions are 0.0 feet at the pipeline crossing location used in this analysis.

Scour Analysis Workbook

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	Spencer Creek	**Latest Revision:**	1/11/2007

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Filename: *P:\8\8169021 TEMP Sea\06\Working\Williams Scour Analysis\Final Scour Workbooks\[Spencer_Ck_Wbk.xls]Intro*

Sheet Titles:

	Scour Analysis Workbook
	Discussion/References
	General Applicability
	Variables
	Variable Input Sheet **(User Input Required)**
	Figures for Reference
	Method 1: Bend Scour, Thorne Equation
	Method 2: Bend Scour, Maynord Equation
	Method 3: Contraction Scour, Laursen Equation
Not Applicable	Method 4: Drop/Weir Scour, USBR Equation for Vertical Drop Structure
Not Applicable	Method 5: Drop/Weir Scour, Laursen and Flick Equation for Sloping Sill
Not Applicable	Method 6: HEC-23 Scour along Structures
	Method 7: USBR Neil Equation
	Method 8: USBR Modified Lacey Equation
	Method 9: Blench Equation
	Results: Bend Scour (User Input Required)
	Results: Contraction Scour (**User Input Required**)
	Results: Drop/Weir Scour (**User Input Required**)
	Results: Scour along Structures (**User Input Required**)
	Scour Summary

Variable Input Sheet (User Input Required)

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	Spencer Creek	**Latest Revision:**	1/11/2007

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Scour Location Information:

Determination of Applicable Scour Type & Method	Yes or No	Applicability
Q1: Is scour location on or near a bend?	yes	Bend Scour Applies (M1,M2,M7,M8,M9)
Q2: Is scour location in a contracted area***?	yes	Contraction Scour Applies (M3)
Q4: Is scour location downstream of a drop/weir structure?	no	N/A
Q5: Is scour location downstream (below) a structure such as a logjam?	no	N/A
Q6: Would you like to estimate long-term degradation?	no	N/A
Q7: Is the stream sand-bed dominant?	no	Refer to Discussion Worksheet

Clear-water/Live-bed Test Results:

***If contraction scour applies, enter Y_1,$D_{50}^{(1)}$,& V_1 for design Q's; then Live-Bed or Clearwater conditions will be calculated here and futher input cells will be highlighted below.

Recurrence Interval (Years)				
10	25	50	100	***Based on the answer to Q2, an intermediate calculation is run to determine input data required. Do not alter these cells!
Clear-Water	Clear-Water	Clear-Water	Clear-Water	

Variable Input Data Requirements:

Scour Type	Variables	Units	Recurrence Interval (Years) 10	25	50	100
Bend	Y_{us}	ft	1.1	1.3	1.4	1.5
	W	ft	106.3	106.3	106.3	106.3
	Rc	ft	100	100	100	100
	Y_{bf}	ft	1.13	1.13	1.13	1.13
	Q	cfs	528	660	753	862
	q	cfs/ft	9.5	11.3	12.3	13.5
	q_{bf}	cfs/ft	6.2	6.2	6.2	6.2
	D_{50}	ft	0.213	0.213	0.213	0.213
	F_{bo} (See Fig.Ref. for M9)	ft/s^2	4.9	4.9	4.9	4.9
Contraction	Y_1	ft	1.1	1.3	1.4	1.5
	$D_{50}^{(1)}$	ft	0.213	0.213	0.213	0.213
	V_1	ft/s	4.2	4.54	4.71	4.89
	ω (See Fig.Ref. for M3)	m/s				
	Q_1	cfs				
	W_1	ft				
	S_1	ft/ft				
	Y_0	ft	1.48	1.61	1.72	1.84
	Q_2	cfs	372.97	441.22	483.42	529.47
	W_2	ft	39.2	39.2	39.2	39.2
	$D_{50}^{(2)}$	ft	0.213	0.213	0.213	0.213
Drop/Weir	q	cfs/ft				
	h (See Fig.Ref. for M4)	ft				
	Y_{tw}	ft				
	Y_c	ft				
	D_{50}	ft				
	R_{50}	ft				
Structures	Fr	----				
	theta	deg				
	Y_1	ft				
Long-term Degradation	Y_s	ft				

Scour Summary

Project:	Scour Hazards Report	**Site:**	Southern Oregon
Project Number:	8169-021-06	**Analyst:**	JGO/GeoEngineers
Watercourse:	Spencer Creek	**Latest Revision:**	1/11/2007

General Comments:
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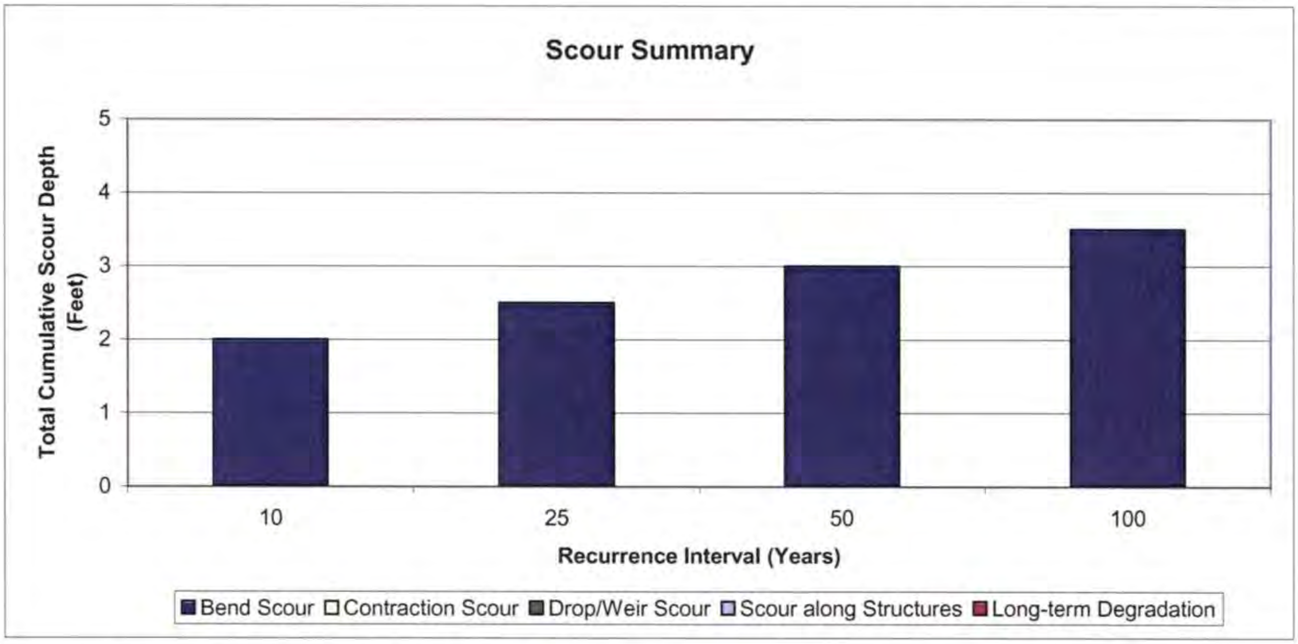
- This worksheet also tabulates and plots Long-term Degradation (Ys) in feet entered on the Variable Inputs Worksheet.
- As noted in the Discussion Worksheet, scour at the site in question is additive. Therefore, cumulative results are plotted by the contribution of each type of scour to the total cumulative scour depth at the site.
- If a Scour Type is not present in the Summary Plot, it was not applicable at this site and automatically removed from the analysis.
- Check final answers against the "Yes or No" questions addressed in the Input Variable Worksheet to verify workbook functionality.

Summary of Scour Depths (Y_s)

Scour Type	Recurrence Interval (Years)			
	10	25	50	100
Bend Scour	2	2.5	3	3.5
Contraction Scour	0	0	0	0
Drop/Weir Scour	0	0	0	0
Scour along Structures	0	0	0	0
Long-term Degradation	0	0	0	0
Total Cumulative Scour (ft)	**2**	**2.5**	**3**	**3.5**



Discussion of Results and Final Selected Scour Depths:

Scour was analyzed for the active channel, as modeled in HEC-RAS. Scour analysis location of pipeline crossing: Station 2+81. Upstream approach section used in analysis: Station 4+40.

Final scour depths presented above are the average value of bend scour predictions using Methods 1 & 2 per recurrence interval. Methods 7, 8 and 9 were eliminated for conservatism.

Clear-Water contraction scour predictions are 0.0 feet for all recurrence intervals at the pipeline crossing location used in this analysis..

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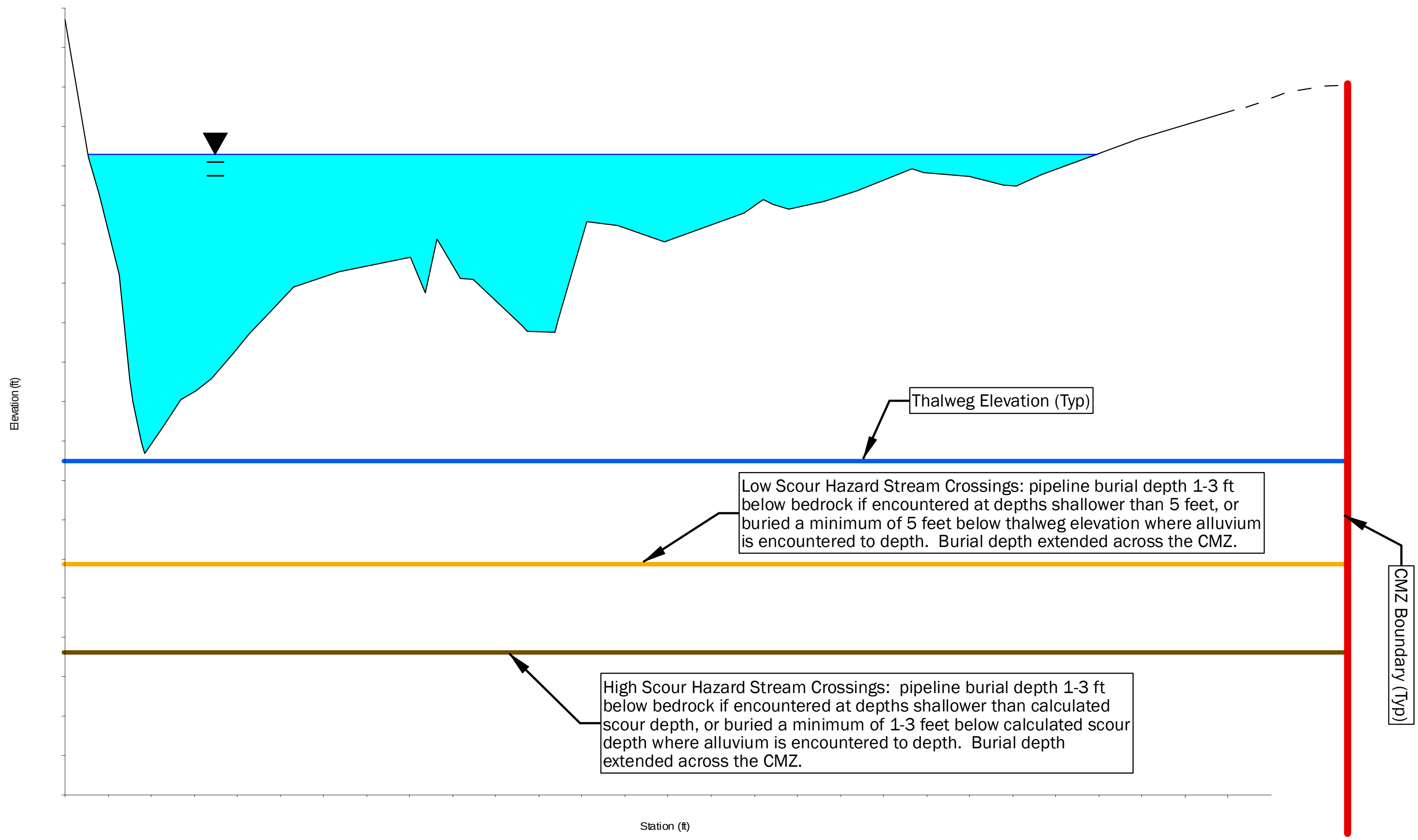

Notes:
1. Figure for conceptual purposes only.
2. Drawing not to scale.

Pacific Connector Gas Pipeline

Typical Crossing Detail
Scour Mitigation

GeoEngineers

Figure 1

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