Wenatchee MP 131 Dry Wash Exposure Evaluation

Chelan County near
Wenatchee, Washington

for
Williams Northwest Pipeline

September 25, 2018

GeoEngineers
Earth Science + Technology

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Chelan County near Wenatchee, Washington

File No. 8169-155-00

September 25, 2018

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INTRODUCTION

The Wenatchee MP 131 Dry Wash Exposure is located on the left bank of an unnamed tributary to Dry Gulch located south of Wenatchee in Chelan County, Washington (Vicinity Map, Figure 1). Williams Northwest Pipeline (Williams) identified an approximate 10-foot-length of exposed 8-inch-diameter pipeline at the crossing location. We understand that that the subject site previously experienced an event that exposed the pipeline in 2014. Williams restored cover over the pipeline that same year. The pipeline was then exposed again after a large flow event in 2016 eroded the northeast (left) bank. GeoEngineers prepared this report to evaluate geologic, hydrologic and hydraulic conditions at the site and to identify conceptual alternatives to provide cover for the pipeline.

SCOPE OF SERVICES

GeoEngineers performed the following services in accordance with Williams Northwest Pipeline Request for Services (RFS) 703387 dated July 5, 2018. The purpose of our services was to provide an assessment of project site conditions and to identify mitigation alternatives to address the exposed 8-inch-diameter Wenatchee Lateral pipeline. Specifically, we completed the following scope of services.

Task 1: Data Collection and Desktop Review

GeoEngineers conducted a desktop study to obtain and review available information for the site. That study included review of aerial photos, geologic mapping, a topographic survey and pipeline profile information, both provided by Williams.

Task 2: Site Reconnaissance

GeoEngineers completed a one-day, focused field reconnaissance to document current geomorphic conditions at the crossing, and approximately 500 feet upstream and downstream of the crossing (1,000 feet total) to understand channel processes and inform conceptual design considerations.

Task 3: Subsurface Exploration and Laboratory Testing Program

GeoEngineers collected three drilled borings along the pipeline alignment. We obtained soil samples at representative intervals from the borings using split spoon samples and standard penetration tests. We classified soils in general accordance with ASTM International Standard Practices Test Method D 2488 and maintained a log of the materials encountered at each boring.

Task 4: Hydrologic Analysis, Hydraulic Model Development and Stream Scour Analysis

GeoEngineers approximated the 2-year and 100-year peak recurrence interval discharge values using regressions-based hydrologic methods. We developed a one-dimensional hydraulic model of the project reach using available LiDAR topographic data. We calculated potential vertical scour using results of the hydraulic model, channel geometry and channel bed material.

Task 5. Channel Migration Zone (CMZ) Analysis

GeoEngineers conducted a CMZ analysis based on historic channel locations, available geologic data and the results of the hydraulic model. We summarized the results of the CMZ analysis and described impacts to project mitigation alternatives.

Task 6. Alternatives Evaluation

GeoEngineers used results of the site evaluation, hydraulic model and CMZ analysis to develop a minimum design burial depth and channel offset. We evaluated the feasibility of accomplishing potential line lowering using direct burial methods. Based on the site assessment, we eliminated the alternative of line lower through horizontal directional drill (HDD) methods from further considerations. We also used the results of the evaluation to inform a mitigation alternative that involved covering the pipe in place.

Task 7. Project Management

GeoEngineers was involved in frequent collaboration with Williams and provided information regarding technical work and anticipated results. We also performed invoicing, scheduling and other managerial tasks.

REPORT OVERVIEW

This report provides a summary of our findings pertaining to the existing conditions of the Wenatchee MP 131 Dry Wash Exposure, and an explanation of the analyses and mitigation alternatives for the exposed 8-inch-diameter pipeline. The report is accompanied by a series of figures and project analysis results in the following appendices:

- Appendix A—Boring Logs
- Appendix B—Hydrologic, Hydraulic and Scour Analysis
- Appendix C—Channel Migration Zone Analysis
- Appendix D—Photograph Log
- Appendix E—Report Limitations and Guidelines for Use

Geological Conditions

Surficial Geology

Surficial mapping (United States Department of Agriculture 2018) indicates that surficial deposits at the MP 131 Dry Wash site consist of three distinct surficial deposits. Near the west side of the crossing near boring B-2, Zen-Rock outcrop complex, 25 to 45 percent slopes is mapped. This unit consists of silt loam overlying unweathered bedrock. Near the dry wash and Boring B-3, Beverly gravelly fine sandy loam is mapped that typically consists of gravelly to extremely gravelly fine sandy loam. East of the crossing near boring B-2, Pogue gravelly fine sandy loam, 25 to 45 percent slopes is mapped. This unit consists of gravelly fine sandy loam and extremely gravelly coarse sand. The mapped surficial geology is generally consistent with our field observations, however the surficial geology encountered along the eastern and western margins of the crossing were sandier, not silty or gravelly as mapped.

Bedrock Geology

Bedrock mapping (Tabor et al. 1982) shows that Tertiary-age (65.5 to 2.5 million years ago) sedimentary rock associated with the Ellensburg Formation underlies the central portion of the crossing alignment near the dry gulch. East and west of the crossing along the pipeline alignment at higher elevations, Tertiary-age basalt is mapped. Generalized mapping of the complex flows in the area could consist of Basalt of Beaver Creek, Basalt of Keane Ranch, Invasive Flow of Duffy Creek, or Basalt of Rocky Point. The basaltic nature of the deposits is consistent with the bedrock conditions encountered in borings B-1 and B-2 advanced at higher elevations along the eastern and western margins of the crossing. However, as described further below, boring B-3 completed near Dry Gulch did not encounter conditions as shown in the geologic mapping.

SITE CONDITIONS

General

The tributary to Dry Gulch is a relatively small ephemeral stream. The pipeline crosses the tributary at a significant meander bend; the most likely location for channel migration. The tributary has a stable planform and had demonstrated limited channel migration. It is confined by valley walls upstream and downstream of the crossing. Based on our observations during site reconnaissance channel scour and bank erosion are more prominent in locations that have been confined by access road construction. Otherwise, channel erosion and near vertical bank conditions are limited to locations with channel confining geologic conditions. The crossing location previously contained significant volumes of fill material that was apparently used to provide vehicular access across the tributary. Evidence of the material exists at the site. We believe this material caused a channel confinement in both horizontal and vertical dimensions and increased the risk of channel instability at the meander. The drainage has recently experienced a fire and a significant peak runoff event. Currently, approximately 10 feet of the pipeline is exposed on the left (northeastern) side the channel along the outside of the meander bend. Refer to Appendix D for a photo log of the project site.

Site Reconnaissance

GeoEngineers performed site reconnaissance on July 17, 2018. We documented geomorphic and streambed conditions and marked proposed boring locations.

During the site reconnaissance, we observed the stream to be predominantly plane bed through the reach, void of any evidence of pools or riffles. At the pipe crossing, severe areas of scour exist with freshly exposed vertical walls ranging from 1 to 7 feet in height. The walls are highly unstable and still sloughing into the stream. The channel width at the crossing was observed to be significantly narrower than observed at other stable locations identified both upstream and downstream of the crossing, see Table 2. Evidence of organics can be seen within the vertical scoured walls on channel right at the crossing, indicating the presence of previously placed fill. We assume the fill was placed for the road crossing and potentially for the original pipeline construction (as well as for the repairs in 2014). Stable channel sections were observed both upstream and downstream of the crossing showing very little evidence of scour or bank erosion. These stable sections contain low angle side slopes, wider bankfull widths and provide floodplain access, see Photo D1 in Photograph Log.

We conducted four pebble counts through the study reach upstream and downstream of the crossing. We averaged the resulting streambed material gradation and listed the results in Table 1. We measured bank full width upstream, downstream and at the pipe crossing location using cross-sectional grade breaks and material size variation as top of bank indicators. We listed each bankfull width measurement in Table 2.

TABLE 1. AVERAGE DISTRIBUTION OF PEBBLE COUNTS

Percent Passing	Particle Diameter (mm)
D15	35
D50	65
D85	120
D95	173

Note:

Boulders between 1 and 3 feet in diameter were observed in the channel and not included in the pebble counts

TABLE 2. BANK FULL WIDTH MEASUREMENTS

Location	Bank Full Width
Up Stream (BFW-1)	34 feet
At Pipe Crossing (BFW-2)	27 feet
Downstream of Crossing (BFW-3)	34 feet
Downstream of Crossing (BFW-4)	30 feet

The dry wash through the study reach has an approximate average longitudinal slope of five percent, a streambed gradation that contains pebbles and cobbles and is highly responsive. Based on our site observations a dominant bedform pattern is not present. Therefore, we considered this reach a plane-bed system (Montgomery Buffington 1993).

SUBSURFACE EXPLORATION

GeoEngineers explored subsurface conditions at the proposed crossing between July 24 and 27, 2018 by drilling three geotechnical soil borings. The borings (B-1, B-2 and B-3) were drilled to depths of 54, 80 and 70 feet below the ground surface (bgs) using a track-mounted drill rig. The boring locations and depths were selected in order to characterize subsurface conditions at the stream crossing for use in scour analysis and along a conceptual HDD alignment to evaluate HDD feasibility.

Soil samples were generally obtained from the borings at 5-foot depth intervals using 1.5-inch inside diameter split spoon samplers. Upon encountering bedrock, continuous rock core was extracted using HQ wireline rock core drilling methods. A GeoEngineers' representative managed the geotechnical explorations and logged the borings on a full-time basis. The GeoEngineers representative visually classified and collected the soil samples and documented other pertinent drilling information. Due to the subsurface conditions encountered related to the design and analysis, laboratory tests were not completed on the samples. A description of the subsurface exploration procedures as well as logs of the borings are presented in Appendix A.

Subsurface Conditions

Boring locations are shown in the Site Plan, Figure 2. In general, borings B-1 and B-2 completed within the slopes to the east and west of the crossing generally consisted of very loose to loose sand with varying amounts of silt overlying basaltic bedrock. Boring B-3 completed close to the channel, encountered interbedded alluvial deposits consisting of very dense gravel and medium stiff hard silt overlying weakly cemented gravel, cobble and boulder conglomerate. Cross Section A-A', Figure 4 presents a geologic profile along the pipeline with plots of the subsurface conditions encountered in borings B-1 through B-3. Cross Section B-B', Figure 5 shows a profile of the conditions at the dry wash crossing. For more detailed information, refer to the boring logs presented in Appendix A.

Boring B-1

B-1 encountered very loose to loose silty fine sand to a depth of approximately 7.5 feet bgs, where medium dense to dense fine to medium sand with varying silt was encountered to 22 feet bgs. Basalt and basalt breccia bedrock was encountered from 22 feet bgs to a depth of 59 feet bgs, the maximum depth explored.

Boring B-2

B-2 encountered about 2.5 feet of very loose silty fine sand overlying loose sand with silt to 22 feet bgs, where Basalt and basalt breccia bedrock was encountered to a depth of 80 feet bgs, the maximum depth explored.

Boring B-3

B-3 encountered about 10 feet of very dense fine to coarse gravel with silt and sand overlying hard silt with fine sand to a depth of approximately 17 feet, where very dense fine to coarse gravel with sand and varying cobbles was encountered to a depth of about 24 feet. Medium stiff sandy silt was encountered to 27.5 feet, where weakly cemented gravel, cobble and boulder conglomerate was encountered to a depth of 70 feet bgs, the maximum depth explored.

Groundwater Conditions

Groundwater was not encountered in borings B-1 and B-2 within the upper soil profiles. Groundwater was encountered at approximately 10 feet bgs in B-3 at the time of drilling. Groundwater levels will often fluctuate seasonally or with water bodies in close proximity. For the design and construction of crossing alternatives, especially for open cut options near the dry wash, the groundwater levels should be considered.

HYDROLOGIC ANALYSIS, HYDRAULIC ANALYSIS AND STREAM SCOUR ANALYSIS

Hydrologic Analysis

There is no available gage data for the dry wash near the pipeline crossing. Therefore, GeoEngineers calculated peak discharges at the project location using the United States Geologic Survey (USGS) StreamStats program (USGS 2018). The StreamStats program calculates peak discharges based on regional regression equations. Table 3 lists the peak discharges.

TABLE 3. PEAK DISCHARGE VALUES

Discharge Event	Discharge (cfs)
2 year	13
100 year	423
500 year	962

Note:

Peak discharges developed through USGS StreamStats Program

Hydraulic Analysis

GeoEngineers developed a one-dimensional (1D) hydraulic model of the project site using the United States Army Corps of Engineers HEC-RAS version 5.0.3 hydraulic modeling program (USACE 2016). The model includes approximately 640 feet of channel, including approximately 385 feet upstream and 255 feet downstream of the pipeline crossing. We ran the model in mixed mode regime, utilizing normal depth as the upstream and downstream boundary conditions. Manning n values for the channel and flood plain were assigned values of .05 and .07, respectively (FHWA 2005). We used an existing LiDAR topographic surface provided by Williams to develop the hydraulic model. Refer to Appendix B for hydraulic model extents and results.

Stream Scour Analysis

GeoEngineers calculated the scour depth at the pipeline crossing and considered three potential scour processes. Those included long-term degradation, general (local) scour and bend scour. We used hydraulic model results from the 100-year peak recurrence discharge to calculate potential scour. Based on the calculations, long term degradation is in equilibrium in the current state of the stream, meaning aggradation is equal to degradation as long as the bedload sediment supply is available. However, if the sediment supply is interrupted through the placement of fill, check dam, or weir structure, significant erosion is predicted to occur below these structures. General scour and bend scour produced a combined scour depth of 3.1 feet from the current stream bed elevation during the 100-year discharge. We recommend a factor of safety of 30 percent be applied to the resulting scour depth. Therefore, the resulting recommended design scour depth is 4.0 feet. Please refer to the scour calculations included in Appendix B.

CHANNEL MIGRATION ZONE (CMZ) ANALYSIS

GeoEngineers evaluated the potential for the tributary to Dry Gulch to migrate laterally into the surrounding terrain near the pipeline crossing. Washington State Department of Ecology provides guidelines for evaluating channel migration which we attempted to employ. However, after review of historical imagery and LiDAR, it is clear the stream at the crossing has not experienced measurable past channel migration and no CMZ exists along the subject tributary. Therefore, professional fluvial geomorphic and hydraulic engineering judgement takes precedent. Some concepts of a typical CMZ analysis were applied to suggest a setback for potential erosion but no formal CMZ was delineated.

Interpretation of Historical Aerial Photographs and LiDAR Hillshade

GeoEngineers reviewed historical aerial photographs available in Google Earth software and a LiDAR generated hillshade model of the site. Williams retained a firm to complete a LiDAR survey and take high resolution imagery of the site in 2018. A site plan with the high-resolution imagery and LiDAR hillshade base are presented in Figures 2 and 3, respectively.

Review of historic aerial photographs suggest a stationary channel, as the channel throughout the reach has not visibly moved over the historical record. Although not georeferenced, a 1962 aerial photograph has a similar plan view configuration as the current channel. Several terraces are visible in the LiDAR hillshade downstream of the crossing indicating different pre-historic channel positions but there is no indication of previous channel locations near the pipeline visible in the LiDAR. Additionally, vegetation growing in and adjacent the channel remains consistent in observed photographs from 1990 to 2013.

The channel during this time was typically vegetated reflecting an historically low activity channel. In the vicinity of the pipeline in the 1990-2013 photographs, we are unable to see the channel bottom to assess channel width, but up and downstream of the pipeline the channel is in the range of 20 to 30 feet wide.

An unpaved road crosses the channel approximately 30 feet upstream of the pipeline crossing. Based on our site observations, and interpretations of aerial photographs, we suspect that the road crossing was constructed as a ford crossing by raising the channel bed with fill. We estimate that the channel bed was raised approximately 3 to 4 feet extending up and downstream approximately 100 feet. The road encroaching into the channel appears to have effectively narrowed the channel at this location relative to up and downstream observations. Flow over the road was directed straight at the outside of the meander bend at the pipeline crossing.

The 2014 aerial photograph shows significant local channel response albeit an unchanged channel position. A large flood event occurred sometime after the July 2013 aerial photograph and before the July 2014 aerial. The 2013/2014 flood eroded the vegetation that once dominated the channel bottom and deposited clean gravel visible throughout the watershed in the 2014 aerial. It did not appear, however, to substantially alter the channel position here or elsewhere in the watershed. We understand that it was this flood event that initially exposed the pipeline in the outside meander bend and washed out the road crossing.

The July 2014 aerial shows evidence of repairs having been recently made to restore cover over the pipeline. Although the 2014 photograph resolution and quality were not sufficiently clear to observe the details of the repairs, it appears that fill was placed along the left bank outside meander bend where the pipeline was exposed.

We have no as-built information regarding the repair at the pipeline that occurred after the 2013/2014 flood event but large boulders observed in the current channel suggest riprap may have been placed for stream bank protection by Williams. The channel appears to have been re-constructed from the road crossing downstream approximately 90 feet. The 2014 aerial shows the channel width up and downstream generally in the range of 20 to 30 feet wide. However, just upstream of the road, the active channel width is closer to 50 feet. Water that spreads out at that location must converge again at, and funnel through, the road crossing. The channel downstream of the road appears to have been narrowed during construction to approximately 12 feet throughout the constructed section.

Review of 2015 and 2017 aerials suggest the stream near the pipeline maintained the re-constructed configuration through 2017, until another large flood occurred in 2018. The flood was exacerbated due to increased runoff resulting from hydrophobic soils following wildfires in the area. This event again eroded the outside of the meander bend eroding the previous bank protection and possibly more. Bank erosion occurred at both the upstream and downstream ends of the meander. Erosion is observed just upstream of the road on the right bank and downstream just before the stream straightens out again. Similar to the erosion after the 2014 event, we believe this erosion is isolated to this location due to a similar set of factors. In this case, the road crossing was rebuilt and brought up to grade with armoring material without a culvert after 2014 and the channel remained narrowed at this location directing flow to the outside bend at the pipeline crossing. The channel from the crossing downstream about 90 feet was narrowed to approximately two-thirds of the width indicated up and downstream of the channel in 2014. Refer to Appendix C, Figure C-2 for the approximate locations of the channels in 2013, 2015 and 2018.

Currently, the channel through the subject meander bend is somewhat confined and considerably incised with little to no floodplain. Incision is active as a head cut has recently moved upstream beyond the crossing, and we believe it will continue to travel further upstream of the pipeline as the stream readjusts the channel gradient. Channel incision, which limits the channel's ability to spread large peak recurrence discharges over the floodplain, has caused approximately 2 to 4 feet of recent degradation. This is illustrated in the LiDAR hillshade as a tributary enters just upstream of the pipeline, adjacent to the road crossing (Figure C-1). It is also illustrated upstream of the road crossing where the head cut has eroded the downstream end of the large bar and side channel on the left side of the channel where a more gradual transition in topography would be expected. Downstream of the crossing, the gradient appears to be stabilizing, although we cannot completely rule out additional headcutting.

FLUVIAL PROCESS CONCLUSIONS

General

Based on our evaluation, Dry Gulch and its tributaries have been historically stable except where man made modifications have created locally unstable conditions such as those observed at the subject crossing. The contributing factors at the site include a narrowed channel at the road crossing location, channel fill, and bank disturbance associated with pipeline construction. During the extreme flow events, increased shear from confinement eroded the channel fill and contributed to undermining the downstream banks. Flow was directed at the undermined and marginally stable banks along the outside meander bend at the pipeline crossing causing the exposure.

Erosion Potential

Because the tributary has been fairly inactive historically, we assume the 2018 event represents the maximum potential erosion for a single flood event. Some locations of undisturbed banks (Figure C-2) experienced up to approximately 8 feet of erosion measured from the Google Earth 2015 to Williams 2018 aerial (Figure C-2). If left unchanged, there is potential for further erosion into the left (northeast) bank as a result of scour during large flow events and as a result of slope failure due to its currently oversteepened condition undercutting the adjacent hillside. Because there are no natural rates of migration from which we can reference, we must estimate the magnitude of potential future bank erosion using our professional judgement. We expect that further regression of the left meander bend could be on the order of 4 to 6 feet from a single event. However, slope failure due to the oversteepened bank condition could result in additional mass wasting extending upslope from the base of the bank at a gradient of approximately 1.5H:1V, the approximate angle of repose of the sandy soil material. Figure C-3 illustrates the area of potential erosion that might be expected if left unchanged.

Further erosion may occur upstream of the meander bend on the right bank. However, as with the outside meander at the exposure, we expect that potential future erosion is unlikely to exceed 4 to 6 feet over the design life of the pipeline. If applied to the base of the slope at the thalweg elevation, and with an angle of repose setback, the pipeline is currently outside of this erosion potential area on the west side of the crossing. However, the distance from edge of channel to the pipeline is approximately 25 feet. It may be prudent to consider preventative mitigation at this location during final design.

Avulsion Hazard

We evaluated the risk of avulsion at this location relative to the southwest bank. Often the inside of a meander bend poses a potential path for avulsion. No relict channels that might act as an avulsion path are observed in aerials or LiDAR. Incision has prevented the 100-year flow from overtopping the bank upstream of and on the inside of the meander, thereby limiting the potential for avulsion. It is our opinion that no avulsion hazards exist at this site that would jeopardize the pipeline.

Mitigation Alternative Evaluation

Line Lowering by Horizontal Directional Drilling

GeoEngineers evaluated the potential to lower the pipeline below of and outside the potential erosion hazard zone of the subject drywash crossing by means of HDD methods. The subsurface conditions encountered by boring B-3 at the dry wash crossing are not conducive to the HDD method of construction. Specifically, gravelly alluvium overlying gravel, cobble and boulder conglomerate was encountered to the full boring depth of 70 feet. Gravelly soils pose a high risk of hole collapse during HDD operations. Moreover, the drilling fluid is generally unable to effectively remove gravel cuttings from the hole. These two factors render it nearly impossible to maintain a sufficiently cleaned and open hole to accomplish a successful pullback.

Line Lowering by Open Cut Methods

We developed a conceptual open cut line lowering alternative as shown in Conceptual Line Lowering Alternative, Figure 6. Based on the design scour depth of 4 feet, the conceptual proposed pipeline alignment was established at a depth of 5 feet below the thalweg. This elevation maintained outward a distance of 5 feet beyond the base of the existing banks to account for future erosion and raveling of the banks to their natural angle of repose. However, this offset is not sufficient to account for the potential mass wasting from the oversteepened left outside meander bend if left unprotected and without additional support. Therefore, the line lowering concept also includes a rock rip rap revetment along the outside meander bend as shown in Figure 6. The rip rap revetment would consist of an embankment inclined at a maximum gradient of 1H:1V and keyed into the underlying channel bed to the design scour depth of 4 feet.

Leave Pipeline In-Place and Restore Cover

Because of the lack of a channel migration zone and the relative stability of the channel through the project reach, it is our opinion that the man-made factors that contributed to localized instability at the subject site may be mitigated such that pipeline cover can be restored and reliably maintained through appropriate design and construction without having to relocate the pipeline. Conceptual In-Place Alternative, Figure 7, presents a conceptual profile showing the fundamental measures for bed and bank control at the site. For channel bed control, we propose to place 6 to 18 inches of structural bed material which will serve to add cover over the pipeline and to serve as a foundation for articulated concrete grid mattresses to armor the channel bed from future scour events.

As described in the open cut line lowering alternative, a revetment will be necessary to stabilize the outside meander bend and to restore cover over the pipeline. In order to prevent mobilization during the extreme flow events, such a revetment will require large rip rap sized material that is generally not considered acceptable to be placed on or around the pipe zone. Therefore, we propose to reconstruct the bank to its pre-erosion condition and protecting/supporting it with a modular concrete block or gabion basket wall in lieu of rip rap because a modular block wall can be constructed with a gap to accommodate the pipeline. The wall would need to be approximately 7.5 feet in exposed height as shown in Figure 6.

LIMITATIONS

We have prepared this report for Williams Pipeline Northwest for the Scour and Migration Zone Analysis for the pipeline crossing of the unnamed dry gulch located south of Wenatchee in Chelan County, Washington.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the disciplines of hydrologic modeling, hydraulic modeling, scour analysis, channel migration estimation and feasibility evaluation in this area at the time this report was prepared. The conclusions, recommendations and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty, express or implied, applies to our services and this report.

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FIGURES

N
W E
S

2,000 0 2,000
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, 2016

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Vicinity Map

Dry Gulch Pipeline Exposure-Mitigation
Alternatives Evaluation
Chelan County, Washington

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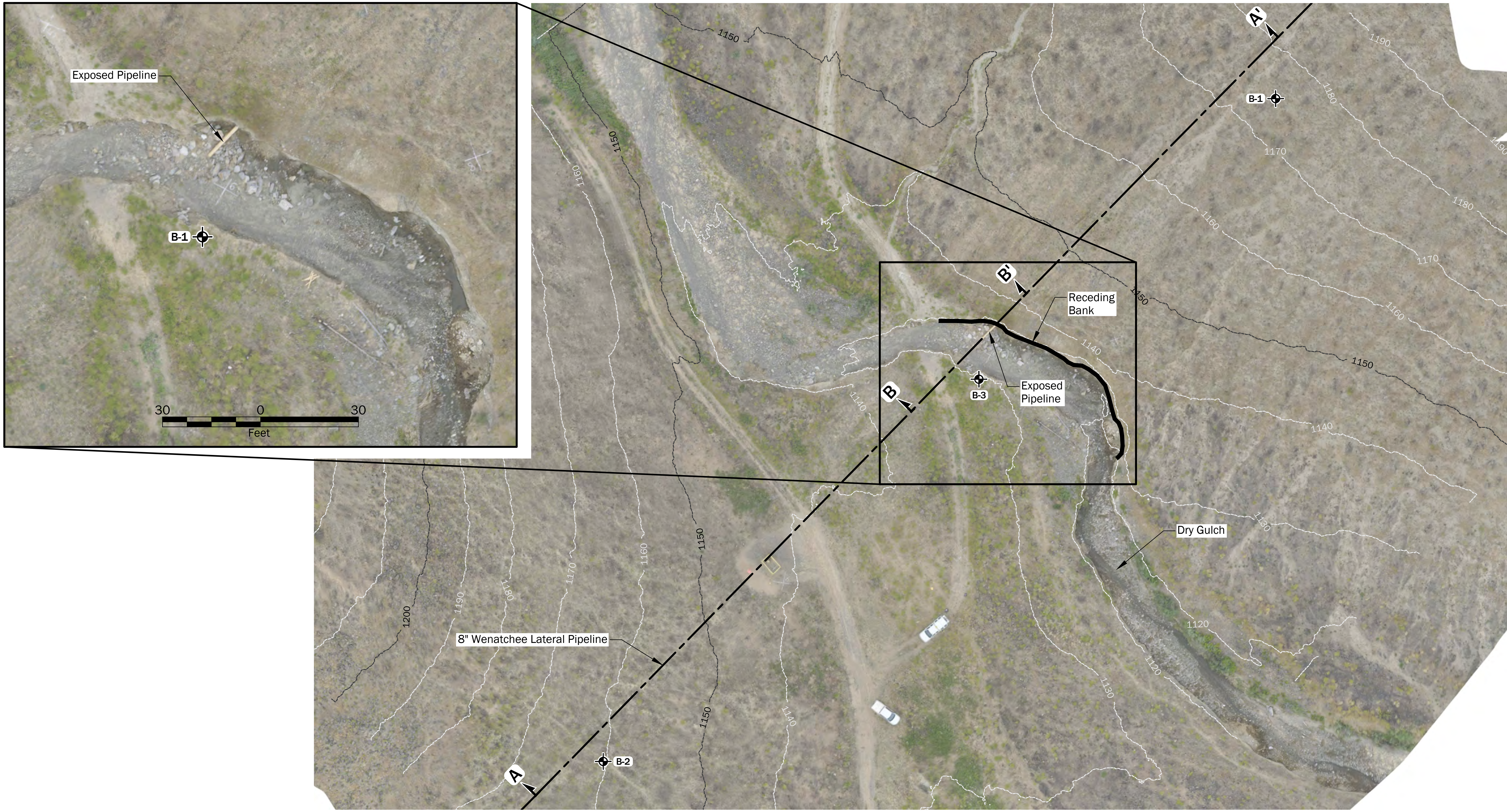
Figure 1



Notes:
1. The locations of all features shown are approximate.
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Data Source: Ground surface and Pipeline profile provided by Williams NWP.

Projection: WA State Plane, N Zone, NAD83, US Foot

Legend

B-1 Boring by GeoEngineers, 2018

-------- 1150 -------- Ground Elevation Contour (Feet)

A A' Cross-Section Location

N W E S

60 0 60
Feet

Site Plan

Dry Gulch Pipeline Exposure -
Mitigation Alternatives Evaluation
Chelan County, Washington

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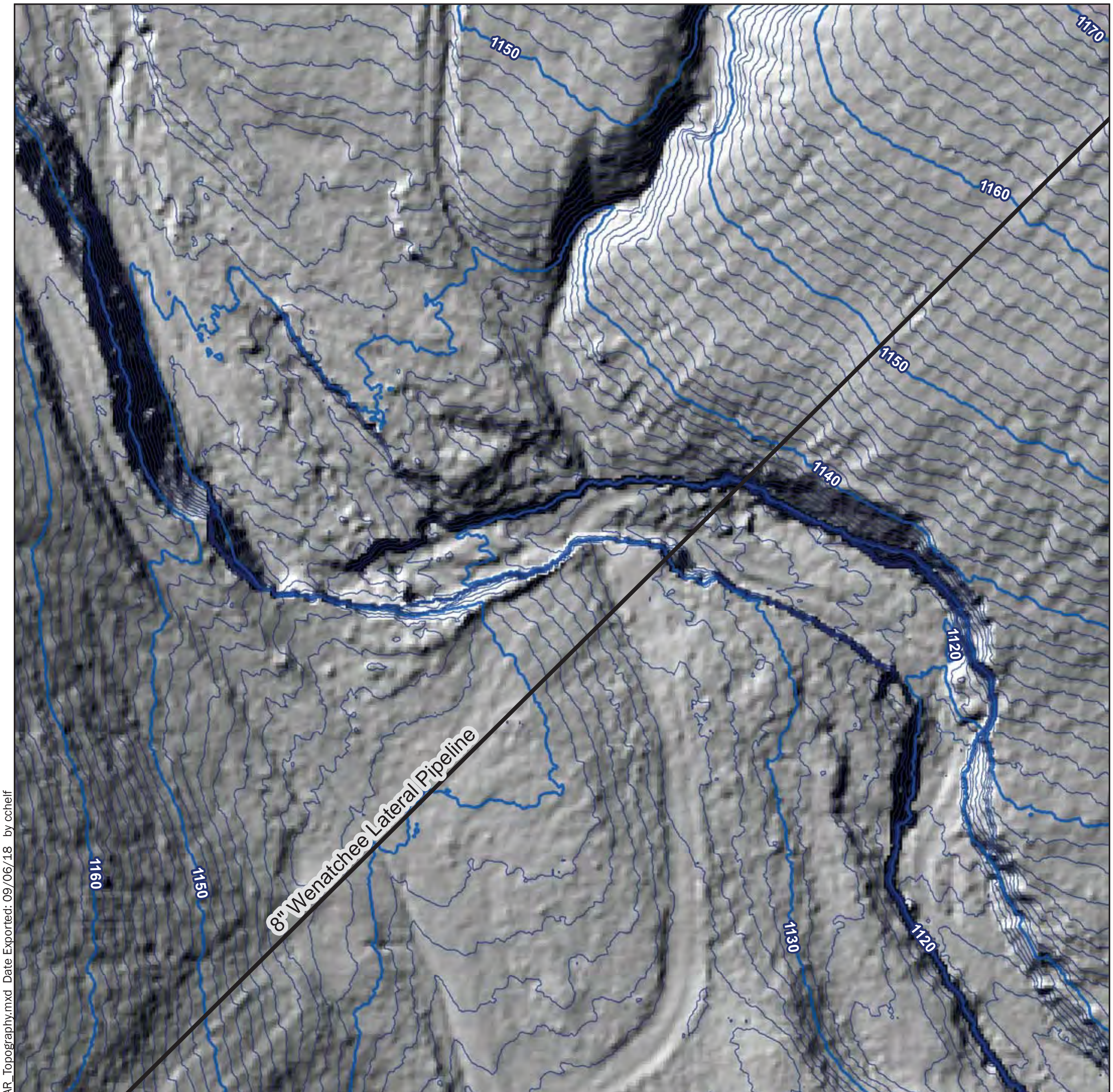
Figure 2

P:\8\8169155\CAD\00\Geotechnical\816915500_F02-F06 Site Plan and Cross-Sections.dwg TAB:F02 Plan View Date Exported: 09/05/18 - 13:07 by tmichaud



Legend

Major Contours 10ft

Minor Contours 1ft

50 0 50

Feet

N
W E
S

Notes:

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Data Source: LiDAR- Williams Pipeline Co.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Topography

Dry Gulch Pipeline Exposure - Mitigation Alternatives Evaluation Chelan County, Washington

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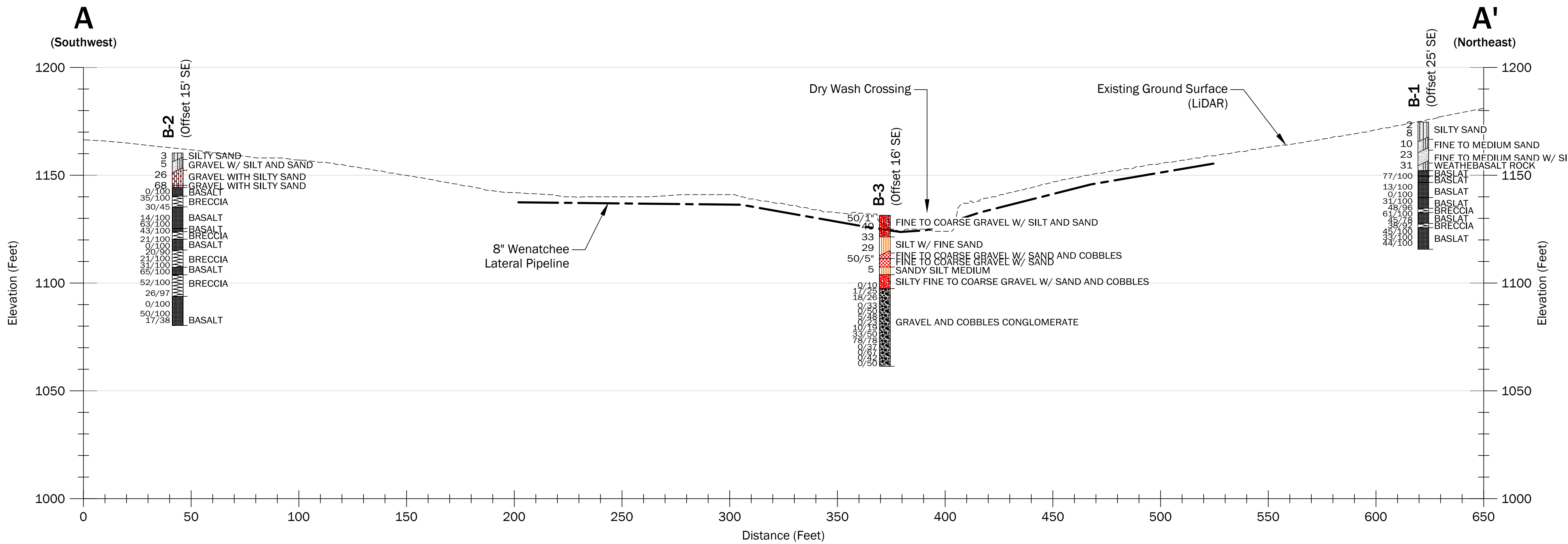
Figure 3

\\geoengineers.com\wan\Projects\8\8169155\GIS\MXD\816915500_F03_LiDAR_Topography.mxd Date Exported: 09/06/18 by cchelf



Notes:
1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
3. Ground surface and Pipeline profile provided by Williams NWP.

Datum: NAVD 88, unless otherwise noted.

Legend:

SPT (N) | Type of Soil
Type of Rock | RQD/REC%

50 0 50
Horizontal Scale in Feet
50 0 50
Vertical Scale in Feet
Vertical Exaggeration: 1X

Cross-Section A-A'

Dry Gulch Pipeline Exposure -
Mitigation Alternatives Evaluation
Chelan County, Washington

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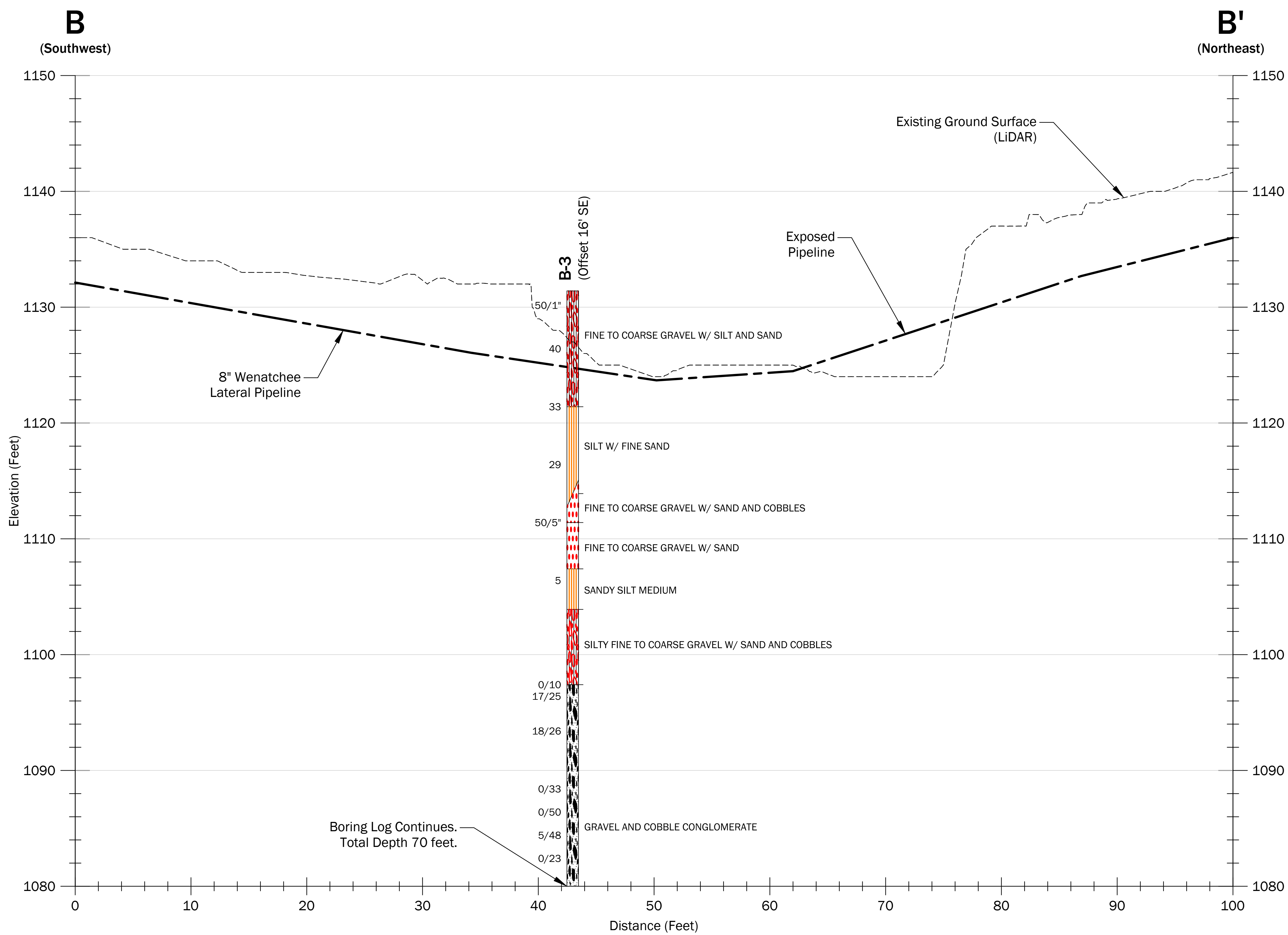
Figure 4



Notes:
1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
3. Ground surface and Pipeline profile provided by Williams NWP.

Datum: NAVD 88, unless otherwise noted.

Legend:

SPT (N) | Type of Soil
Type of Rock | RQD/REC%

10 0 10
Horizontal Scale in Feet
10 0 10
Vertical Scale in Feet
Vertical Exaggeration: 1X

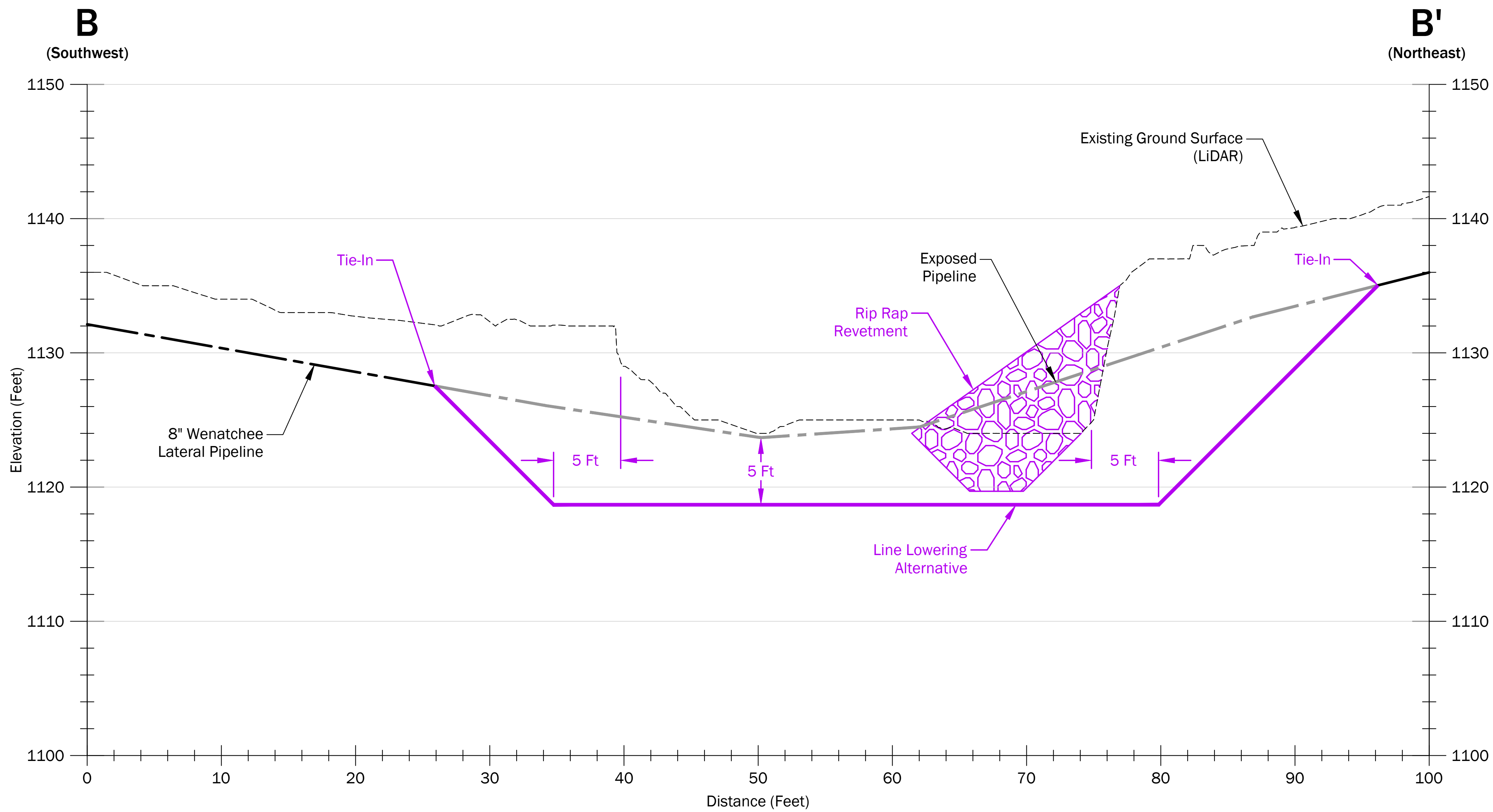
Cross-Section B-B'

Dry Gulch Pipeline Exposure -
Mitigation Alternatives Evaluation
Chelan County, Washington

GeoEngineers

Figure 5

P:\8\8169155\CAD\00\Geotechnical\816915500_F02-F06 Site Plan and Cross-Sections.dwg TAB:F05 Cross-Section BB Date Exported: 09/07/18 - 10:57 by tmichaud



P:\8\8169155\CAD\00\Geotechnical\816915500_F02-F06 Site Plan and Cross-Sections.dwg TAB:F06 Cross-Section Mitigation Alternatives (2) Date Exported: 09/07/18 - 10:55 by tmichaud

Notes:
1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
3. Ground surface and Pipeline profile provided by Williams NWP.

Datum: NAVD 88, unless otherwise noted.

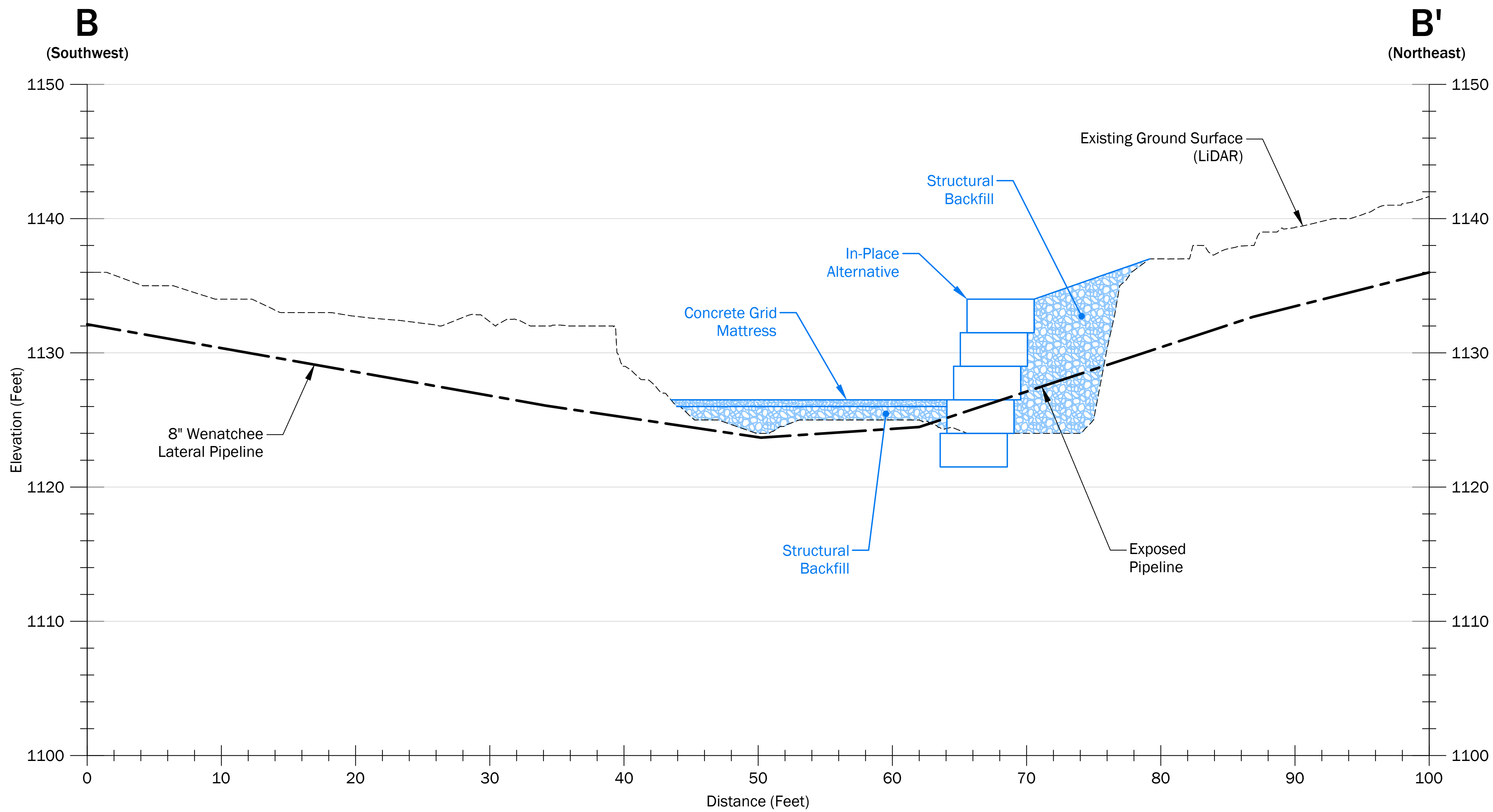
10 0 10
Horizontal Scale in Feet
10 0 10
Vertical Scale in Feet
Vertical Exaggeration: 1X

Conceptual Line Lowering Alternative

Dry Gulch Pipeline Exposure -
Mitigation Alternatives Evaluation
Chelan County, Washington

GeoEngineers

Figure 6



Notes:
1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
3. Ground surface and Pipeline profile provided by Williams NWP.

Datum: NAVD 88, unless otherwise noted.

10 0 10
Horizontal Scale in Feet

10 0 10
Vertical Scale in Feet
Vertical Exaggeration: 1X

Conceptual In-Place Alternative

Dry Gulch Pipeline Exposure -
Mitigation Alternatives Evaluation
Chelan County, Washington

GeoEngineers

Figure 7

APPENDICES

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APPENDIX A
Boring 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 ON 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
	SOD	Sod/Forest Duff
	TS	Topsoil

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

Approximate contact between soil strata

Material Description Contact

Contact between geologic units

Contact between soil of the same geologic unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Continuous Coring

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.

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

"WOH" indicates sampler pushed using the weight of the hammer.

Laboratory / Field Tests

%F	Percent fines
%G	Percent gravel
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DD	Dry density
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
Mohs	Mohs hardness scale
OC	Organic content
PM	Permeability or hydraulic conductivity
PI	Plasticity index
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

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

UNIFIED ROCK CLASSIFICATION SYSTEM (URCS)*

BASIC ELEMENTS

DEGREE OF WEATHERING				
WEATHERED		ALTERED	REPRESENTATIVE	
SAND SIZE COMPLETELY DECOMPOSED STATE (CDS) E	GRAVEL SIZE PARTLY DECOMPOSED STATE (PDS) D	STAINED STATE (STS) C	VISUALLY FRESH STATE (VFS) B	MICRO FRESH STATE (HAND LENSE) (MFS) A
PLASTIC NON-PLASTIC	PLASTIC NON-PLASTIC	COMPARE TO FRESH STATE	UNIT WEIGHT, RELATIVE ABSORPTION	

ESTIMATED STRENGTH				
REMOLDING		REACTION TO IMPACT OF 1 LB. BALLPEEN HAMMER		
"MOLDABLE" (FRIABLE) (MBL) E	"CRATERS" (SHEARS) (CQ) D	"DENTS" (COMPRESSIVE) (DQ) C	"PITS" (TENSIONAL) (PQ) B	"REBOUNDS" (ELASTIC) (RQ) A
<1,000 PSI (<7 MPa)	1,000 to 3,000 PSI (7 to 21 Ma)	3,000 to 8,000 PSI (21 to 55 MPa)	3,000 to 15,000 PSI (55 to 103 MPA)	>15,000 PSI (>103 MPa)

DISCONTINUITIES						
TRANSMITS WATER				LATENT PLANES OF SEPARATION (LPS) C	SOLID-PREFERRED BREAKAGE (SPB) B	SOLID-RANDOM BREAKAGE (SRB) A
YES	NO	YES	NO			
3-DIMENSIONAL PLANES OF SEPARATION (3D) E		2-DIMENSIONAL PLANES OF SEPARATION (2D) D				
INTERLOCK		ATTITUDE				

UNIT WEIGHT				
LESS THAN 130 LBS/CU FT (2.10 Mg/CU M) (<130) E	130 TO 140 LBS/CU FT (2.10 TO 2.25 Mg/CU M) (130) D	140 TO 150 LBS/CU FT (2.25 TO 2.40 Mg/CU M) (140) C	150 TO 160 LBS/CU FT (2.40 TO 2.55 Mg/CU M) (150) B	GREATER THAN 160 LBS/CU FT (2.55 Mg/CU M) (>160) A

DESIGN NOTATION			
WEATHERING	STRENGTH	DISCONTINUITY	WEIGHT
A-E	A-E	A-E	A-E

* Williamson, Douglas A., 1984, Unified Rock Classification System: Association of Engineering Geologists Bulletin, Vol. XXI, No. 3, pp. 345-354

ROCK CLASSIFICATION SYSTEM

GeoEngineers

FIGURE A-2

Drilled	Start 7/26/2018	End 7/26/2018	Total Depth (ft)	59	Logged By SJW Checked By RSC	Driller Haz-Tech Drilling, Inc.	Drilling Method	Hollow-stem Auger/HQ wireline rock core

Surface Elevation (ft) Vertical Datum	Undetermined	Hammer Data	Autohammer 140 (lbs) / 30 (in) Drop	Drilling Equipment	CME 850 track-mount
Latitude Longitude	47.315123 -120.117282	System Datum	Decimal Degrees WGS84	Groundwater not observed at time of exploration	

Notes:

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Sample/Run Testing	RQD %	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0		13	2	1			SM	Brown silty fine to medium sand (very loose, moist) (native)			
	5		12	8	2				Becomes loose			
								SP-SM	Gray fine to medium sand with silt (medium dense, moist)			
	10		13	10	3							
								SP	Gray fine to medium sand (medium dense, moist)			
	15		13	23	4							
								SP-SM	Gray fine to medium sand with silt (dense, moist)			
	20		16	31	5							
								BSLT	Weathered basalt rock			Significant drill chatter at 22½ feet below ground surface, weathered bedrock
	25		100		Run 1	77		BSLT	Basalt; gray, slightly weathered, soft, closely fractured, vesicular, open 3-D planes of separation with clay infilling Becomes brecciated from 27 to 28 feet			
								BSLT	Basalt; gray, slightly weathered, soft, closely fractured, slightly vesicular, open 3-D planes of separation with occasional clay infilling Becomes medium hard, very closely fractured Becomes brecciated from 30 to 30.3 feet			Lost ½ drilling fluid return circulation
	30		100		Run 2	13						
			100		Run 3	0						
	35				Run 4							
								BSLT	Basalt; gray, slightly weathered, medium hard, very closely fractured, slightly vesicular, open 3-D planes of separation with occasional clay infilling			
			100		Run 5	31						
			96		Run 6	48						
	40											

Note: See Figure A-1 for explanation of symbols; Figure A-2 for ASTM Rock Classification System.
Coordinates Data Source: Horizontal approximated based on . Vertical approximated based on .

Date:9/6/18 Path:P:\8\8169155\GINT\816915500.GPJ DBLibrary/Library:GEOENGINEERS_DF_STD_US_JUNE_2017.GLB/GEI8_GEOTECH_SOIL_ROCK_%F_NO_GW

Log of Rock Core Boring B-1

GEOENGINEERS

Project: Wenatchee MP 131 Dry Wash Exposure Project
Project Location: Wenatchee, Washington
Project Number: 8169-155-00

Figure A-3
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Sample/Run Testing	RQD %	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	40							BREC	Basalt breccia; gray and brown, weathered, very soft, closely fractured			
								BSLT	Basalt; gray, slightly weathered, medium hard, very closely fractured, very slight clay infilling			
			100		Run 7	61			Becomes closely fractured			
	45		78		Run 8	45			Becomes very closely fractured			
								BREC	Basalt breccia; gray and brown, very weathered, very soft, very closely fractured			
			92		Run 9	38						
								BSLT	Basalt; gray, slightly weathered, medium hard, slightly vesicular, very closely fractured, open 3-D planes of separation			
	50		100		Run 10	45						
			100		Run 11	33						
	55		100		Run 12	44						
									Becomes closely fractured			
									Becomes very closely fractured			

Boring backfilled with bentonite chips from 20 to 59 feet below ground surface and cement-bentonite grout from 0 to 20 feet below ground surface

Date:9/6/18 Path:P:\8\8169155\GINT\816915500.GPJ DBLibrary/Library:GEOENGINEERS_DF_STD_US_JUNE_2017.GLB/GEI8_GEOTECH_SOIL_ROCK_%F_NO_GW

Log of Rock Core Boring B-1 (continued)

GeoEngineers

Project: Wenatchee MP 131 Dry Wash Exposure Project

Project Location: Wenatchee, Washington

Project Number: 8169-155-00

Drilled	Start 7/24/2018	End 7/25/2018	Total Depth (ft)	80	Logged By SJW / Checked By RSC	Driller Haz-Tech Drilling, Inc.	Drilling Method	Hollow-stem Auger/HQ wireline rock core

Surface Elevation (ft) / Vertical Datum	Undetermined	Hammer Data	Autohammer 140 (lbs) / 30 (in) Drop	Drilling Equipment	CME 850 track-mount
Latitude / Longitude	47.31402 / -120.11896	System / Datum	Decimal Degrees / WGS84	Groundwater not observed at time of exploration	

Notes:

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Sample/Run Testing	RQD %	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0		12	3	1			SM	Brown silty fine to medium sand (very loose, moist) (native)			
								SP-SM	Brown fine to medium sand with silt (loose, moist)			
	5		13	5	2							
								GP-GM	Brown fine to medium gravel with silt and sand (medium dense, moist)			Drill chatter 8 to 11 feet below ground surface
	10		13	26	3							
												Drill chatter 14 to 16½ feet below ground surface
	15		13	68	4			GP-GM	Brown silty fine to coarse sand (dense, moist)			
			100		Run 1	0		BSLT	Basalt; gray, highly weathered, very soft, very closely fractured, vesicular, open 3-D planes of separation with clay infilling Becomes soft			Grinding, auger refusal drilling conditions at 17 feet below ground surface, switch to HQ coring
	20		100		Run 2	35		BREC	Basalt breccia; gray and brown, slightly weathered, soft, very closely fractured Becomes closely fractured Becomes very closely fractured			
	25		45		Run 3	30		BSLT	Basalt; gray, slightly weathered, soft, vesicular, very closely fractured, open 3-D planes of separation with clay infilling Becomes closely fractured Becomes very closely fractured			
	30		100		Run 4	14						
			100		Run 5	63			Becomes closely fractured			
	35		100		Run 6	43		BSLT	Basalt; gray, slightly weathered, soft, vesicular, very closely fractured, open 3-D planes of separation with clay infilling			
								BREC	Basalt breccia; brown and gray, weathered, soft, closely fractured			
	40											

Note: See Figure A-1 for explanation of symbols; Figure A-2 for ASTM Rock Classification System.
Coordinates Data Source: Horizontal approximated based on . Vertical approximated based on .

Date:9/6/18 Path:P:\8\8169155\GINT\816915500.GPJ DBLibrary/Library:GEOENGINEERS_DF_STD_US_JUNE_2017.GLB/GEI8_GEOTECH_SOIL_ROCK_%F_NO_GW

Log of Rock Core Boring B-2

GeoEngineers

Project: Wenatchee MP 131 Dry Wash Exposure Project
Project Location: Wenatchee, Washington
Project Number: 8169-155-00

Figure A-4
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Recovered (in)	Blows/foot	Sample/Run Testing	RQD %	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	40	100		Run 7	21	BSLT	Basalt; gray, slightly weathered, medium hard, very closely fractured, open 3-D planes with slight clay infilling Rubble zone from 41.8 to 42.2 feet			
		100		Run 8	0					
	45	90		Run 9	20	BREC	Basalt breccia; gray and brown, weathered, soft, very closely fractured			
	50	100		Run 10	21					
		100		Run 11	31					
						BSLT	Basalt; gray, slightly weathered, very closely fractured, open 3-D planes with no infilling			
	55	100		Run 12	65					
						BREC	Basalt breccia; gray and tan, soft, slightly weathered, closely fractured			
	60	100		Run 13	52		Becomes gray and very closely fractured			
							Becomes closely fractured			
	65	97		Run 14	26					
						BSLT	Basalt; gray, slightly weathered, medium hard, very closely fractured, open 3-D planes of separation with very little clay infilling			
	70	100		Run 15	0					
	75	100		Run 16	50					
		38		Run 17	17					
	80									

Boring backfilled with bentonite chips from 20 to 80 feet below ground surface and cement-bentonite grout from 0 to 20 feet below ground surface

Log of Rock Core Boring B-2 (continued)

GEOENGINEERS

Project: Wenatchee MP 131 Dry Wash Exposure Project
Project Location: Wenatchee, Washington
Project Number: 8169-155-00

Figure A-4
Sheet 2 of 2

Drilled	Start 7/27/2018	End 7/27/2018	Total Depth (ft)	70	Logged By SJW	Checked By RSC	Driller	Haz-Tech Drilling, Inc.	Drilling Method	Hollow-stem Auger/HQ wireline rock core

Surface Elevation (ft) Vertical Datum	Undetermined	Hammer Data	Autohammer 140 (lbs) / 30 (in) Drop	Drilling Equipment	CME 850 track-mount
Latitude Longitude	47.314656 -120.118021	System Datum	Decimal Degrees WGS84	See "Remarks" section for groundwater observed	

Notes:

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Sample/Run Testing	RQD %	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0		0	50/1"	1			GW-GM	Brown fine to coarse gravel with silt and sand (very dense, moist) (native)			
	5		10	40	2				Becomes dense			
	10		13	33	3			ML	Brown silt with fine sand (hard, wet)			Groundwater observed at approximately 10 feet below ground surface at time of drilling Material appears softer than blow counts indicate
	15		12	29	4							
								GP	Gray fine to coarse gravel with sand and cobbles (very dense, wet)			Drill chatter at 17 feet below ground surface
	20		11	50/5"	5			GP	Gray fine to coarse gravel with sand (very dense, wet)			Chattery drilling 20 to 24 feet below ground surface
								ML	Brown sandy silt (medium stiff, wet)			
	25		13	5	6							Smooth drilling Chattery drilling
								GM	Brown silty fine to coarse gravel with sand and cobbles (very dense, moist)			
	30		12	49	7							Rounded gravel; chattery, slow auger drilling 30 to 34 feet below ground surface
			10		Run 1	0		CONG	Conglomerate; brown, slightly weathered, subrounded basalt gravel, cobbles and boulders in claset supported matrix of weakly cemented silty sand (possible debris flow deposit)			Auger refusal at 34 feet; switch to HQ coring; poor recovery and washout
	35		25		Run 2	17						
			26		Run 3	18						
	40											

Note: See Figure A-1 for explanation of symbols; Figure A-2 for ASTM Rock Classification System.
Coordinates Data Source: Horizontal approximated based on . Vertical approximated based on .

Log of Rock Core Boring B-3

GeoEngineers

Project: Wenatchee MP 131 Dry Wash Exposure Project
Project Location: Wenatchee, Washington
Project Number: 8169-155-00

Figure A-5
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Sample/Run Testing	RQD %	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	40							CONG	Conglomerate; brown, slightly weathered, subrounded basalt gravel, cobbles and boulders in claset supported matrix of weakly cemented silty sand (possible debris flow deposit)			Conglomerate and not uncemented alluvium based on drilling "hardness"
			33		Run 4	0						Rounded gravel
	45		50		Run 5	0						Rounded gravel
			48		Run 6	5			Becomes with fine to coarse basalt gravels			
			23		Run 7	0						
	50											
			19		Run 8	10						
	55		50		Run 9	33						
			78		Run 10	78			Becomes with basalt cobbles			
	60											Rounded gravel and cobbles
			37		Run 11	0						Rounded gravel
			67		Run 12	0						
	65		42		Run 13	0						
			50		Run 14	0						
			42		Run 15	17						
	70								Boring backfilled with bentonite chips			

Log of Rock Core Boring B-3 (continued)

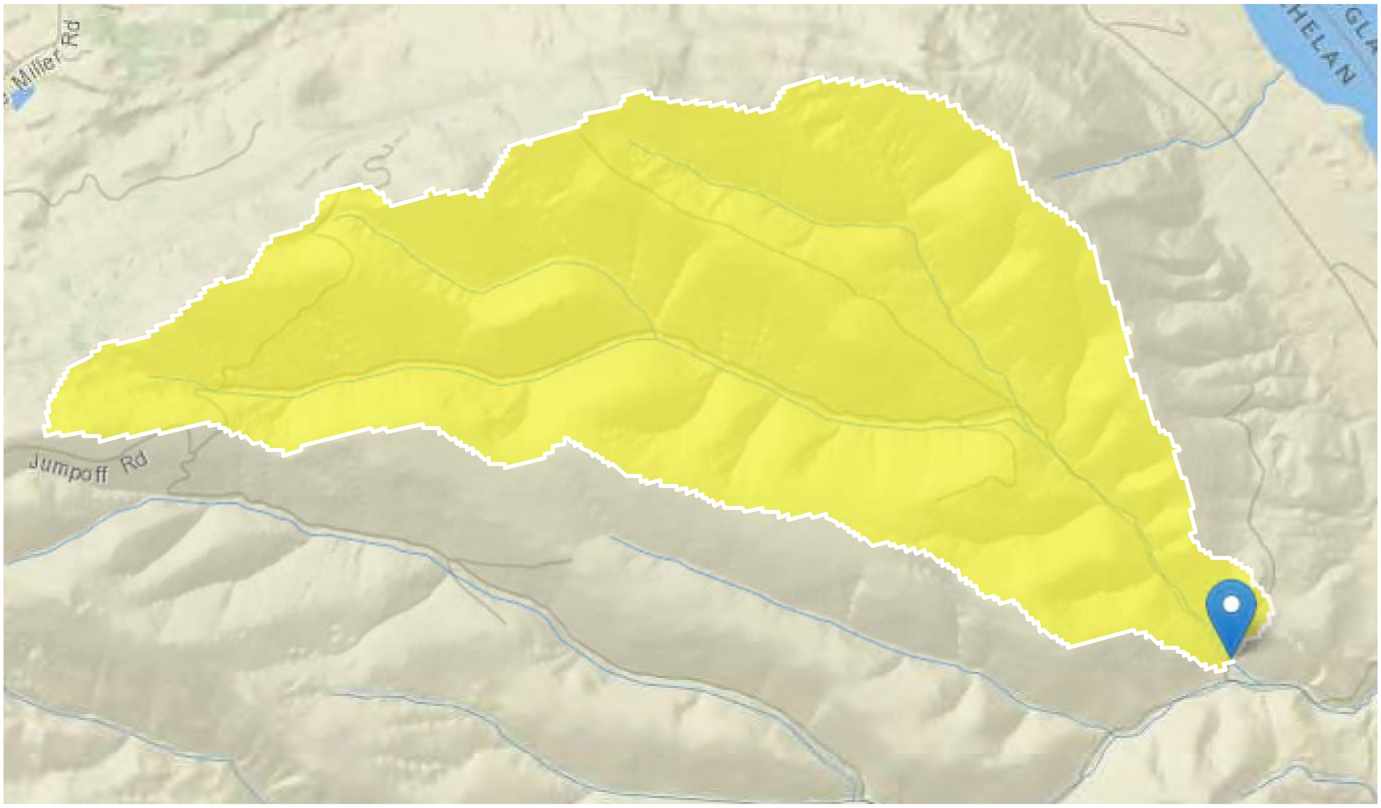
GeoEngineers

Project: Wenatchee MP 131 Dry Wash Exposure Project
Project Location: Wenatchee, Washington
Project Number: 8169-155-00

APPENDIX B
Hydrologic, Hydraulic and Scour Analysis

MP 131 Crossing

Region ID: WA
Workspace ID: WA20180817165755031000
Clicked Point (Latitude, Longitude): 47.31434, -120.11788
Time: 2018-08-17 10:58:09 -0600



Streamstats Peak flows and basin characteristics

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	5.76	square miles
PRECPRIS10	Basin average mean annual precipitation for 1981 to 2010 from PRISM	11.4	inches
CANOPY_PCT	Percentage of drainage area covered by canopy as described in OK SIR 2009_5267	0.028	percent
BSLDEM30M	Mean basin slope computed from 30 m DEM	21.5	percent

Parameter Code	Parameter Description	Value	Unit
ELEV	Mean Basin Elevation	2180	feet
ELEVMAX	Maximum basin elevation	3420	feet
MINBELEV	Minimum basin elevation	1130	feet
PRECIP	Mean Annual Precipitation	11.9	inches

Peak-Flow Statistics Parameters [Peak Region 2 2016 5118]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	5.76	square miles	0.42	1330
PRECPRIS10	Mean Annual Precip PRISM 1981 2010	11.4	inches	8.86	84.2
CANOPY_PCT	Percent Area Under Canopy	0.028	percent	0	81.8

Peak-Flow Statistics Flow Report [Peak Region 2 2016 5118]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	SEp
2 Year Peak Flood	13	ft^3/s	4.05	42	77.2
5 Year Peak Flood	45.6	ft^3/s	15.6	133	69.1
10 Year Peak Flood	88.7	ft^3/s	29.1	271	72.2
25 Year Peak Flood	180	ft^3/s	52.7	612	81.2
50 Year Peak Flood	283	ft^3/s	75.7	1060	89.2
100 Year Peak Flood	423	ft^3/s	104	1730	96.9
200 Year Peak Flood	614	ft^3/s	137	2750	106
500 Year Peak Flood	962	ft^3/s	190	4870	120

Peak-Flow Statistics Citations

Mastin, M.C., Konrad, C.P., Veilleux, A.G., and Tecca, A.E.,2016, Magnitude, frequency, and trends of floods at gaged and ungaged sites in Washington, based on data through water

year 2014 (ver 1.1, October 2016): U.S. Geological Survey Scientific Investigations Report 2016–5118, 70 p. (http://dx.doi.org/10.3133/sir20165118)

Application Version: 4.2.1

N
W
E
S

Not to Scale

XXXX-XXX-XX Date Exported: 04/09/15

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.

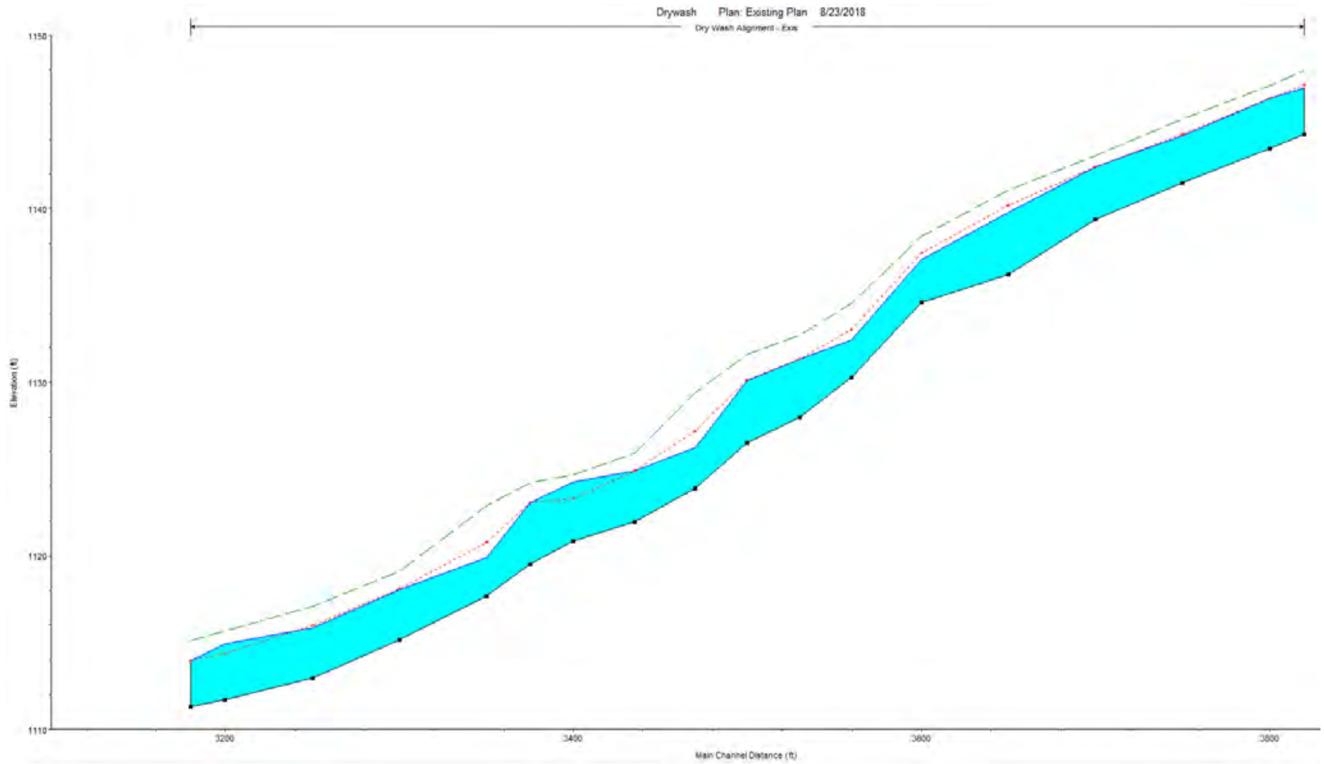
Data Source:

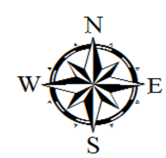
HECRAS - Plan

Williams NWP –MP 131 Dry Wash
Wenatchee, Washington

GEOENGINEERS

Figure B1





Not to Scale

HECRAS - Profile

Williams NWP – MP 131 Dry Wash
Wenatchee, Washington

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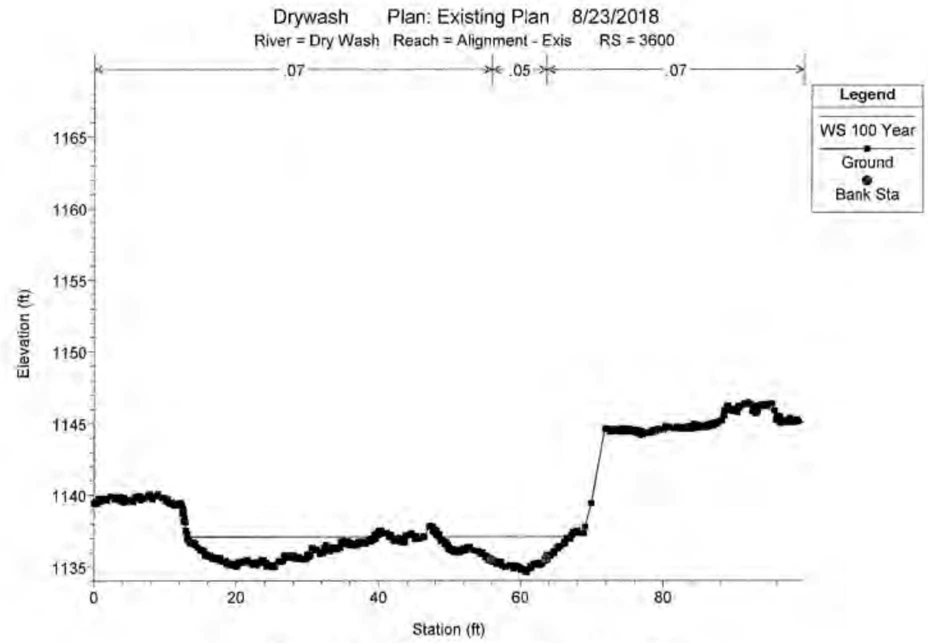
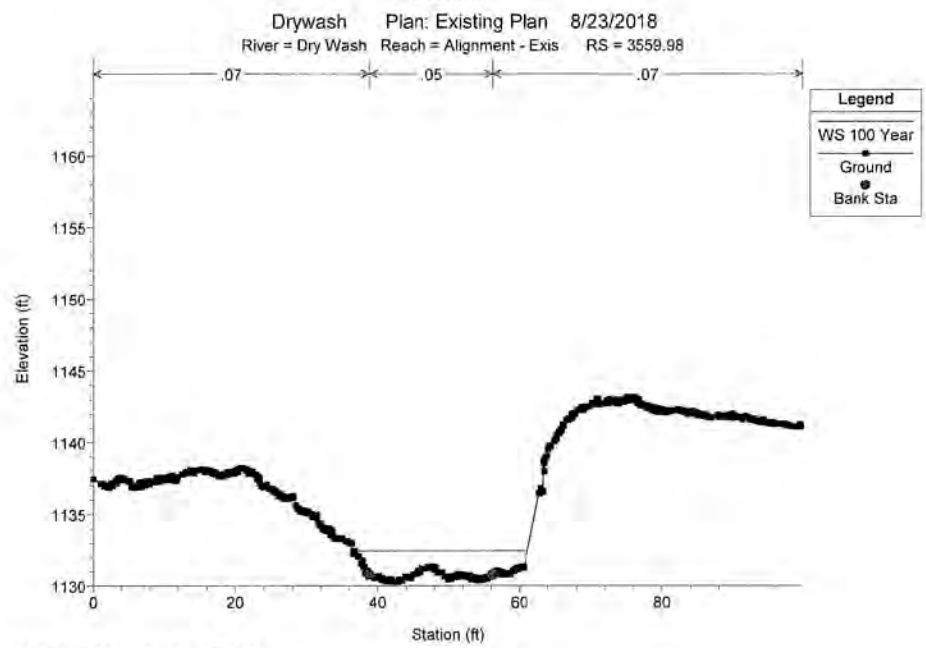
Figure B2

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:

XXXXX-XXX-XX Date Exported: 04/09/15





XXXXX-XXX-XX Date Exported: 04/09/15

Notes:
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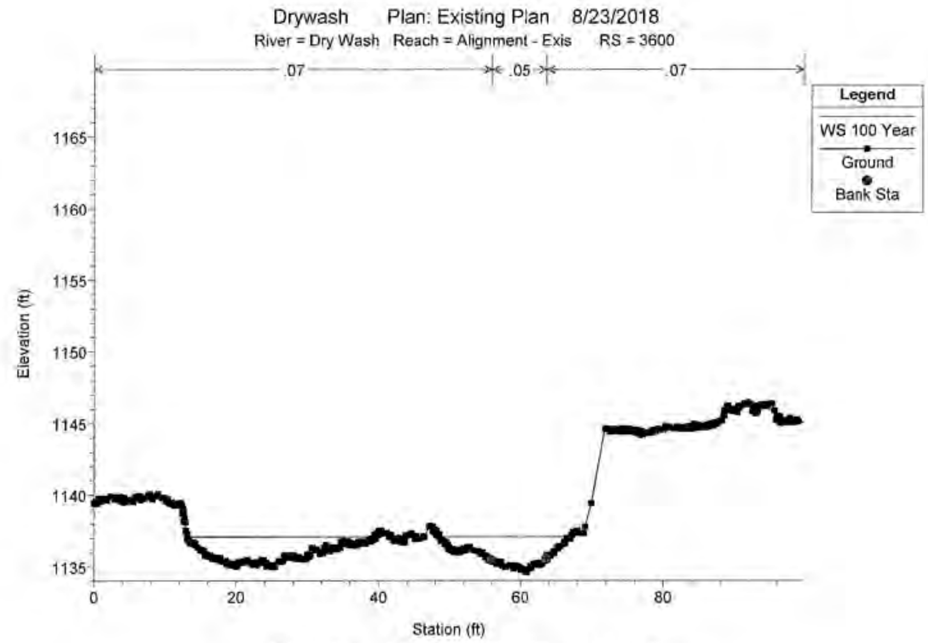
Data Source:

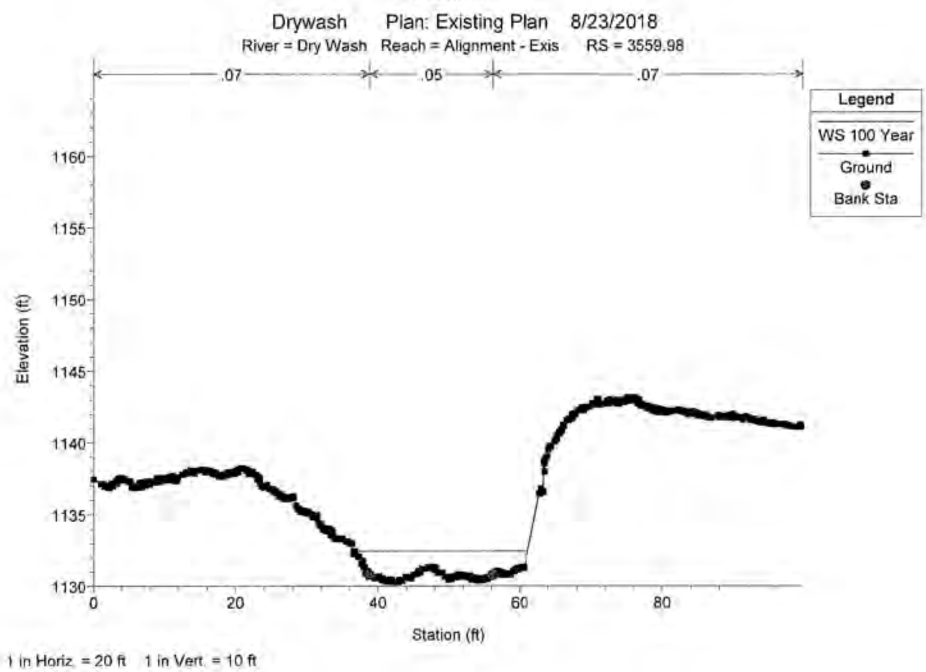
HECRAS – Cross Sections

Williams NWP – MP 131 Dry Wash
Wenatchee, Washington

GEOENGINEERS

Figure B3





HECRAS – Cross Sections

Williams NWP – MP 131 Dry Wash
Wenatchee, Washington

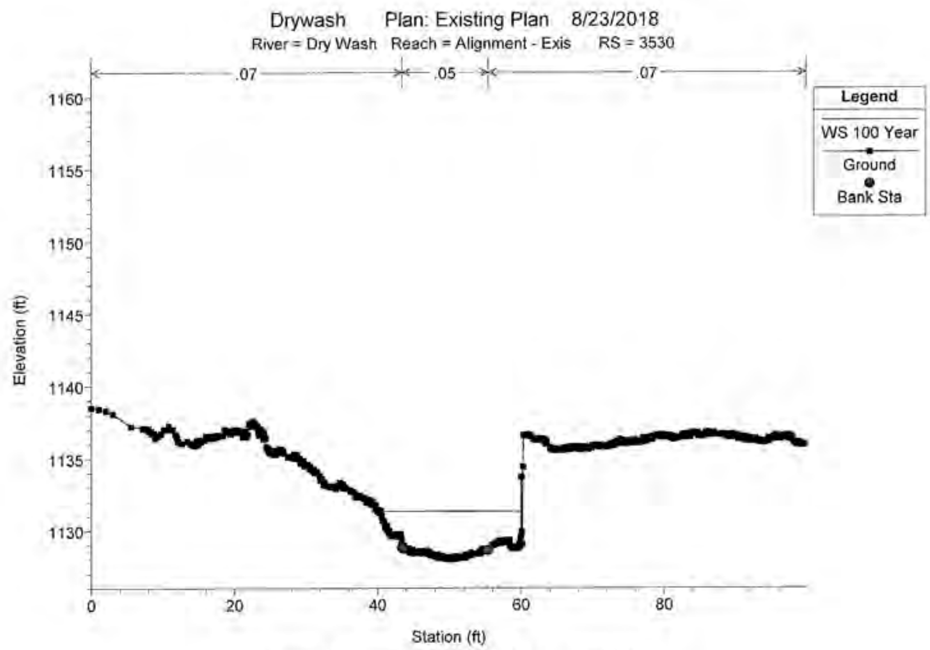
GEOENGINEERS

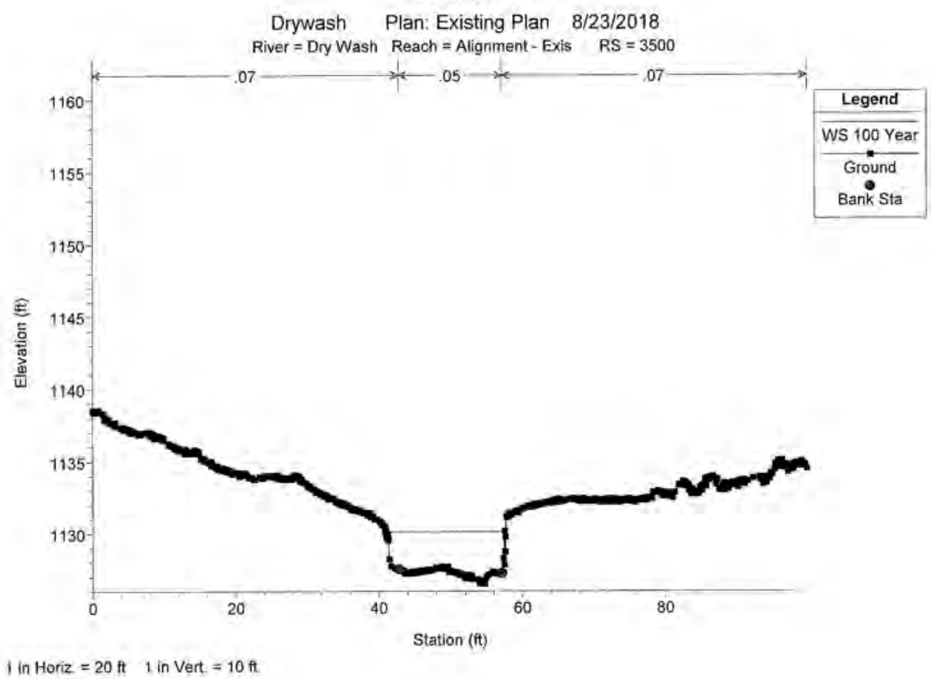
Figure B3

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:

XXXXX-XXX-XX Date Exported: 04/09/15





XXXXX-XXX-XX Date Exported: 04/09/15

Notes:

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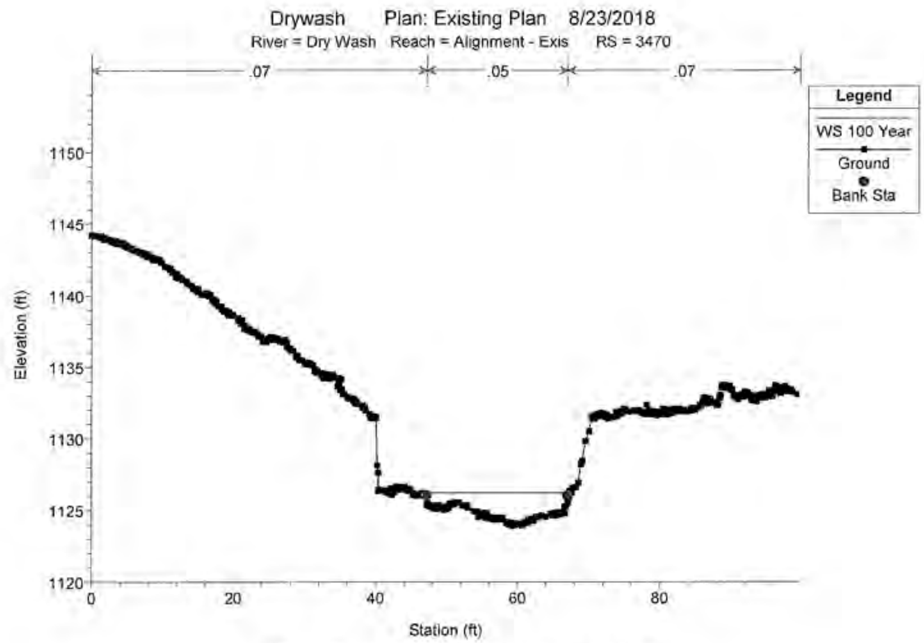
Data Source:

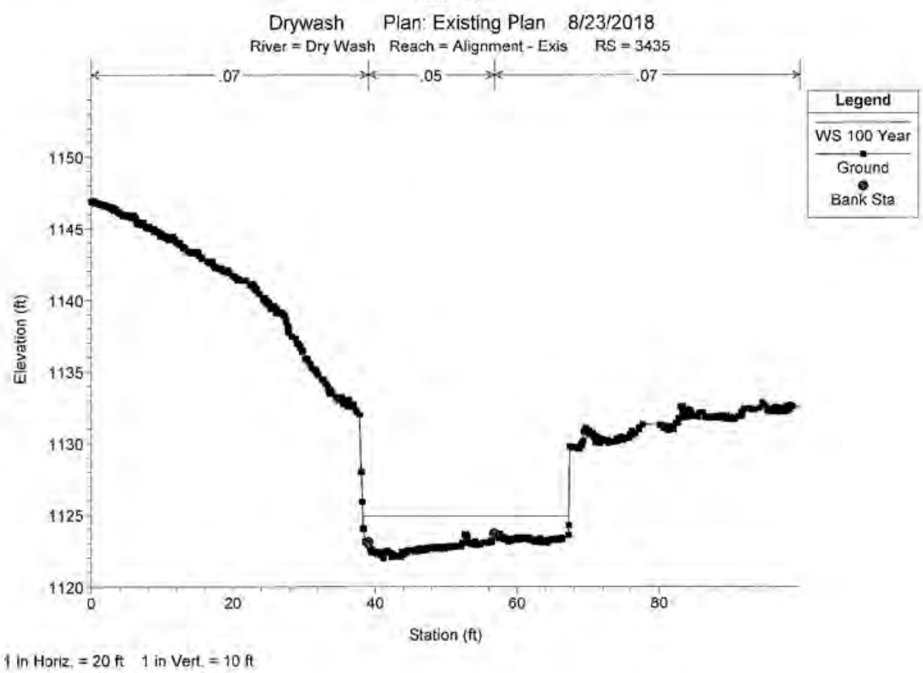
HECRAS – Cross Sections

Williams NWP – MP 131 Dry Wash
Wenatchee, Washington

GeoEngineers

Figure B4





XXXXX-XXX-XX Date Exported: 04/09/15

Notes:
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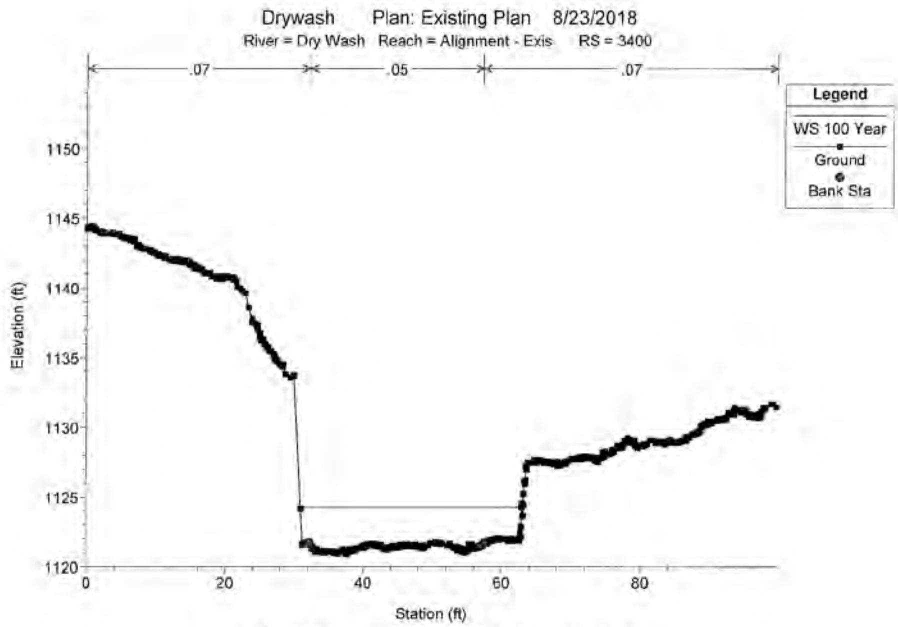
Data Source:

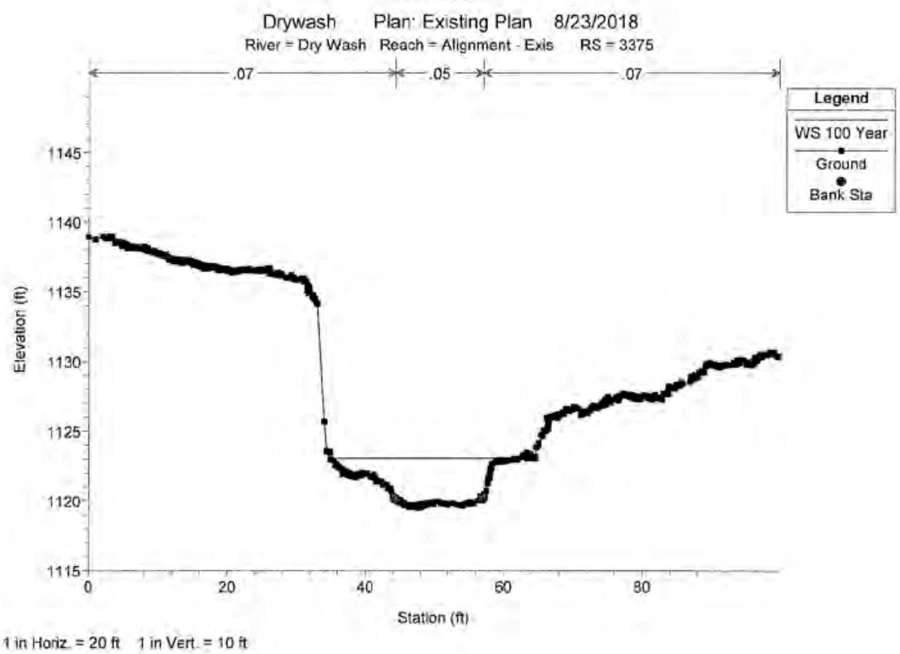
HECRAS – Cross Sections

Williams NWP – MP 131 Dry Wash
Wenatchee, Washington

GeoEngineers

Figure B5





XXXXX-XXX-XX Date Exported: 04/09/15

Notes:
1. The locations of all features shown are approximate.
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Data Source:

HECRAS – Cross Sections

Williams NWP – MP 131 Dry Wash
Wenatchee, Washington

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Figure B6

Channel Scour Analysis - Cover Sheet

Project:	Wenatchee MP 131	Site:	MP 131
Watercourse:	Effemeral Stream	Analyst:	ESM
Checked By:	RSC	Latest Revision:	9/6/2018

Description:

- This workbook contains spreadsheets that facilitate the analysis of channel scour for the design of this project.
- This spreadsheet lists the general project information that is consistent throughout this workbook.
- This spreadsheet lists the titles of spreadsheets contained in this workbook.
- Only input data into the orange shaded cells.
- This workbook is intended for use with English Units.

Sheet Titles:

Legend:

General	- General Text And Information
Input	- Cells That Require Input
Output	- Cells That Calculate Output

Channel Scour Analysis - Discussion

Project:	Wenatchee MP 131	Site:	MP 131
Watercourse:	Effemeral Stream	Analyst:	ESM
Checked By:	RSC	Latest Revision:	9/6/2018

Description:

- This workbook contains general discussion information on the use and background of this spreadsheet.

General Reference:

This workbook addresses five types of scour: Long Term Scour, Bend Scour, Contraction Scour, Bedform Scour, and Structure Scour associated with drops/weirs, lateral structures, and mid-channel structures.

The primary references are listed below, and scour equations are presented following the format, applicability and guidelines in these specific documents.

Reference (1): 5th Edition Hydraulic Engineering Circular No. 18 (HEC-18), "Evaluating Scour At Bridges". Published by the U.S. Department of Transportation Federal Highway Administration, April 2012.
Reference (2): 3rd Edition Hydraulic Engineering Circular No. 23 (HEC-23), "Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance". Published by the U.S. Department of Transportation Federal Highway Administration, September 2009.
Reference (3): Integrated Stream Protection Guidelines (ISPG). PUblished by the Washington State Aquatic Habitat Guidelines Program, 2002.
Reference (4): National Engineering Handbook 210-VI, Part 654, Technical Supplement 14B: Scour Calculations. Published by the U.S. Army Corps of Engineers, August 2007.
Reference (5): Design Manual for Engineering Analysis of Fluvial Systems, Prepared for Arizona Department of Water Resources by Simons Li and Associates, 1985.

Scour Analysis Overview:

Most of the scour equations presented in this workbook were developed to predict hydraulic processes associated with man-made structures, such as bridges, located within relatively large, often sandbed, streams. There are no widely used scour equations developed specifically for use on gravelbed streams, so the equations developed for sand-bed streams are presented along with methods of modification and interpretation that allow their application to gravel-bed streams with larger bed material.

Scour Depth Calculation Overview:

Determining the maximum depth of scour in this workbook is accomplished by:
1. Identifying the type(s) of scour expected by answering a series of yes or no questions regarding the site in question;
2. Entering the required input data into the shaded cells on the "Input" Worksheet and selecting final scour depths on the "Summary" Worksheet;
3. Reviewing the calculated scour depth for accuracy based on experience from similar streams, conditions noted during field visits and an understanding of the calculations.

Note:

Channel Scour Analysis - Discussion

Project:	Wenatchee MP 131	Site:	MP 131
Watercourse:	Effemeral Stream	Analyst:	ESM
Checked By:	RSC	Latest Revision:	9/6/2018

1. A hydraulic model of the stream or river is required to generate the input variables;
2. This workbook should only be used by someone knowledgeable with hydraulics, hydraulic modeling and scour. Caution and engineering judgement is required;
3. The cumulative effects of each type of scour (if more than one type of scour is present) are accounted for automatically on the "Summary" worksheet.

Scour Equation Discussion

Long-Term Degradation

• **Armoring Equation** is based on a relationship to compute scour depth downstream of a dam in a channel with a well-mixed bed comprised of particles with the same specific gravity. This relationship utilized the Shields curve for the initiation of motion to estimate the smallest particle size armoring the channel.

• **Manning and Shields Relationship** is for bed material courser than sand for D50 > 6mm where the equilibrium slope is calculated and compared to the original bed slope. The difference in elevation is estimated based on the distance downstream to the next channel bed control.

• **Meyer-Peter Muller Relationship** is based on the Meyer-Peter Muller sediment transport equation for material coarser than sand to calculate an equilibrium slope. The difference in elevation is estimated based on the distance downstream to the next channel bed control.

• **Schoklitsch Equation** is for coarse sand or gravel and calculates and equilibrium slope. The difference in elevation is estimated based on the distance downstream to the next channel bed control.

• **Henderson Formula** is also for bed materials greater than 6 mm and calculates and equilibrium slope. The difference in elevation is estimated based on the distance downstream to the next channel bed control.

Contraction Scour

• **Laursen Live-Bed and Clear-Water Scour Equations** were developed primarily from flume tests with contraction resulting from bridge abutments. However, these equations apply equally well to natural contractions or contractions caused by installation of instream structures such as groins. Contraction equations are based on either live-bed or clear-water conditions. Live-bed conditions occur when the bed material upstream of the contraction is in motion, and clear-water conditions occur when the bed material is not in motion (ISPG, 2002). Contraction equations on the contraction worksheet are calculated in accordance with Reference 1. Note: In extreme cases, backwater can decrease velocity, shear stress, and sediment transport in the upstream cross-section. This will increase scour at the contracted section. The backwater can, by storing sediment in the upstream section, change live-bed conditions to clear-water conditions. Use caution!

Channel Scour Analysis - Discussion

Project:	Wenatchee MP 131	Site:	MP 131
Watercourse:	Effemeral Stream	Analyst:	ESM
Checked By:	RSC	Latest Revision:	9/6/2018

Bend Scour

• **Thorne Equation** is based on flume and large-river experiments where the mean bed-particle size varied from 0.3 to 63mm. This equation is applicable to gravel-bed streams and therefore should be used with caution on sand-bed streams (particle size is not incorporated into the calculation). There are no restrictions or limitations built into this workbook for this Method, use engineering judgement based on site characteristics.

• **Maynord Equation** is based on regression analysis of 215 sand-bed channel data points. The scour data were measured at high discharges that were within the channel banks and had return intervals of 1-5 years. Although his studies are restricted to sand-bed streams, the method agrees reasonably well with the limited number of gravel-bed data points obtained in a separate study. A safety factor of 2 is used (HEC-23, 2001). Limits to this equation are specified and incorporated within the worksheet, however must still be used with caution and engineering judgement.

• **National Engineering Handbook Equation** is a conservative scour estimate based on a collection of field data. This equation is an asymptotic relationship with a theoretical minimum ymax/ymean of 1.5 representing pool scour depths expected in a straight channel with a pool-riffle bed topography.

• **Zeller Equation**

Bedform Scour

• **National Engineering Handbook Equation** estimates bedform scour related to bedform type and assumes that half the amplitude of a dune bedform is contributable to scour.

Grade Control/Vertical Drop Scour

• **USBR Equation** looks at drop structures such as check dams, log weirs, exposed pipes and tightly constructed rock can create hydraulic conditions associated with vertical drop structures. This equation is recommended for predicting scour depth immediately downstream of a vertical drop structure and for determining a conservative estimate of scour depth for sloping sills (ISPG, 2002).

• **Mason and Arumugam Equation** is a modification of the USBR Equation to take into account the erodibility of the channel bed and is based upon a free falling jet which might be conservative in the calculation of a sloping sill or other non vertical drop.

• **Laursen and Flick Slopiing Sill Equation** specifically addresses sloping sills constructed of rock.

• **D'Agostino and Ferro Equation** was developed as a dimensionless function using dimensional analysis based on their review of previous work dealing with prediction of scour downstream from grade control structures.

Lateral Structure Scour

• **Kuhnle Formula** is based on a series of clear-water, steady-flow, movable-bed flume studies using various spur dike geometries.

• **Karaki and Richardson Equation** estimates scour along an abutment or lateral structure where the transverse structure length projecting into the flow is small in comparison to flow depth (a/y < 25) which fits most cases of large wood and channel groins.

• **Froehlich Equation** was developed as a regression from the analysis of 170 live-bed scour measurements in laboratory flumes. This equation removes the addition of an extra average flow depth typically added for design calculations, but tends to overestimate scour.

• **Vertical Wall Scour Equation** presented in this workbook calculates the scour realized along structures (wingwalls, abutments, spurs, dikes, logjams, etc...) that are either parallel or perpendicular to the flow (Theta = zero degrees for parallel flow and 90 degrees for perpendicular flow). This analysis is presented in accordance with Reference 2.

Channel Scour Analysis - Discussion

Project:	**Wenatchee MP 131**	Site:	**MP 131**
Watercourse:	**Effemeral Stream**	Analyst:	**ESM**
Checked By:	**RSC**	Latest Revision:	**9/6/2018**

Mid Channel Structure Scour

• **HEC-18 Pier Scour Equation** is based on the CSU equation and is recommended for both clear and live-bed scour depths for riverine flow situations in an alluvial sand-bed complex. The 5th Edition of HEC-18 removed an armoring K4 factor. We have left this K4 factor in to better represent gravel bed streams.

Channel Scour Analysis - Abbreviations

Project:	Wenatchee MP 131	Site:	MP 131
Watercourse:	Effemeral Stream	Analyst:	ESM
Checked By:	RSC	Latest Revision:	9/6/2018

Description:

- This workbook contains general information on the symbols used, their description and units associated with them.

-There is no input on this sheet.

Input Questions

Do you want to calculate long-term degradation?	yes
Is the site located at a contraction?	no
Is the site located along a channel bend?	yes
Do you want to look at bedform scour?	No
Does your site contain a channel spanning grade control structure?	no
Does your site contain a structure along a bank (partial spanning)?	no
Does your site contain a mid-channel structure?	no

Scour Type		Variables	Units	Variable Description	Variable Used
Long-Term Degradation	Long-Term Degradation	y	feet	Average flow depth	Yes
		S_o	ft/ft	Existing channel Slope	Yes
		D_{90}	feet	Size of material that 90% is finer than	Yes
		D_{84}	feet	Size of material that 84% is finer than	Yes
		D_{50}	feet	Size of material that 50% is finer than	Yes
		D_{16}	feet	Size of material that 16% is finer than	Yes
		SG_b	unitless	Bouyant specific gravity of bed material (SG-1)	Yes
		NSSUS	unitless	No Sediment Supply from Upstream (Yes or No Answer)	Yes
		L	feet	Distance from site to downstream grade control	Yes
		n	unitless	Manning's roughness coefficient	Yes
		Q_{BF}	cfs	Bankfull discharge (Channel Forming Discharge)	Yes
		TW_{BF}	feet	Bankfull width (Channel Forming Channel Width)	Yes
General Scour	Blodgett	D_{50}	feet	Size of material that 50% is finer than	Yes
	Blench + Lacey	Q_d	ft^3/sec	Design discharge	Yes
		W_f	feet	Flow width at design discharge	Yes
		D_{50}	mm	Size of material that 50% is finer than	Yes
	Bend Scour	Y_{us}	feet	Average flow depth upstream of the bend	Yes
		TW_{us}	feet	Top width of the channel through the bend	Yes
		RC	feet	Radius of curvature of the bend	Yes
		$Y_{h\ us}$	feet	Hydraulic depth upstream of bend	Yes
		$Y_{us\ max}$	feet	Max depth upstream of bend	Yes
		S_o	ft/ft	Existing channel Slope	Yes
		V_{us}	ft/sec	Average velocity upstream of bend	Yes

Channel Scour Analysis - Data Input

Project:	Wenatchee MP 131	Site:	MP 131
Watercourse:	Effemeral Stream	Analyst:	ESM
Checked By:	RSC	Latest Revision:	9/6/2018

Description:

- This workbook contains general information on the input of what type of scour is applicable to the site, and the input variables.
- Answer the seven yes or no questions for each site and/or return flow period and input cells will highlight for you to fill in to ensure all cells are active.
- Only enter values into the orange shaded cells.

Input Questions

Hydraulic Scenario	2 Year	100 Year	500 Year	
Do you want to calculate long-term degradation?	Yes	Yes	yes	
Is the site located at a contraction?	No	No	no	
Is the site located along a channel bend?	Yes	Yes	yes	
Do you want to look at bedform scour?	no	no	no	
Does your site contain a channel spanning grade control structure?	No	no	no	
Does your site contain a structure along a bank (partial spanning)?	No	No	no	
Does your site contain a mid-channel structure?	No	No	no	
Do you want to calculate general scour?	Yes	Yes	yes	

Input Variables

Scour Type		Variables	Hydraulic Scenario			
			2 Year	100 Year	500 Year	
Long-Term Degradation	Long-Term Degradation	Y_s (ft)	0.37	2.92	3.9	
		S_o (ft/ft)	0.051	0.051	0.051	
		D_{90} (ft)	0.570	0.570	0.570	
		D_{84} (ft)	0.390	0.390	0.390	
		D_{50} (ft)	0.210	0.210	0.210	
		D_{16} (ft)	0.120	0.120	0.120	
		SG_b	1.75	1.75	1.75	
		NSSUS	No	No	No	
		L (ft)	1650	1650	1650	
		n	0.05	0.05	0.05	
		Q_{BF} (cfs)	13	423	962	
		TW_{BF} (ft)	14	32	40	
General Scour	Blodgett	D_{50} (ft)	0.21	0.21	0.21	
	Blench + Lacey	Q_d (ft^3/s)	13	423	962	
		W_f (ft)	14	32	40	
		D_{50} (mm)	65	65	65	
		Reach Type	Moderate Reach	Moderate Reach	Moderate Reach	
	Bend Scour	Y_{us} (ft)	0.37	2.9	3.89	
		TW_{us} (ft)	14	32	40	
		RC (ft)	97	97	97	
		$Y_{h\ us}$ (ft)	0.37	2.5	3.89	
		$Y_{us\ max}$ (ft)	1	3.6	5.7	
		S_o (ft/ft)	0.051	0.051	0.051	
		V_{us} (ft/s)	3	10.1	13.3	

Channel Scour Analysis - Long Term Degradation

Project:	Wenatchee MP 131	Site:	MP 131
Watercourse:	Effemeral Stream	Analyst:	ESM
Checked By:	RSC	Latest Revision:	9/6/2018

Description:

- This workbook contains calculations to estimate the formation of an armor layer, the max scour depth to an armor layer formation, and long-term degradation based on a lack of sediment supply from upstream (sand and gravel systems) and the distance to a downstream grade control.
- If there is no lack of sediment supply shortage the long-term aggradation is solely based on the max scour depth to an armor layer
- If an armor layer does not form and sediment is adequate long term degradation is estimated to be zero.
- All equations for long term degradation come from Reference 4 listed on the Discussion worksheet.

Smallest Armor Particle Size

Input

	Hydraulic Scenario			
	2 Year	100 Year	500 Year	
Y_s (ft)	0.4	2.9	3.9	
S_o (ft/ft)	0.05100	0.05100	0.05100	
D_{90} (ft)	0.57000	0.57000	0.57000	
D_{84} (ft)	0.39000	0.39000	0.39000	
D_{50} (ft)	0.21000	0.21000	0.21000	
D_{16} (ft)	0.12000	0.12000	0.12000	
SG_b	1.750	1.750	1.750	

Calculations

U_* (ft/sec)	0.78	2.19	2.53	
Particle Re	15590	43796	50615	
D_x (ft)	0.1833	1.4467	1.9322	
e	0.304	0.304	0.304	

Validation

Is $D_x < D_{100}$	YES	NO	NO	

Maximum Scour Depth Limited by Armoring

Calculations

P_x	0.60	-0.19	-0.35	
T (ft)	0.4	-10.8	-7.8	
z_x (ft)	0.3	NO ARMORING	NO ARMORING	

Long-Term Degradation

Input

NSSUS	No	No	No	
L	1650	1650	1650	
n	0.05	0.05	0.05	
Q_{BF} (cfs)	13	423	962	
TW_{BF} (ft)	14	32	40	

Channel Scour Analysis - Long Term Degradation

Project:	Wenatchee MP 131	Site:	MP 131
Watercourse:	Effemeral Stream	Analyst:	ESM
Checked By:	RSC	Latest Revision:	9/6/2018

Calculations

Manning and Shields Relation				
S_{eq} (ft/ft)	0.07533	0.00773	0.00463	
z_d (ft)	0.0	71.4	76.5	
Meyer-Peter Muller Relationship				
S_{eq} (ft/ft)	0.17891	0.01837	0.01100	
z_d (ft)	0.0	53.8	66.0	
Schoklitsch Equation				
S_{eq} (ft/ft)	0.04163	0.00568	0.00363	
z_d (ft)	15.5	74.8	78.2	
Henderson Formula				
S_{eq} (ft/ft)	0.02247	0.00453	0.00310	
z_d (ft)	47.1	76.7	79.0	

Summary of Long-Term Degradation

Armoring Depth (ft)	0.3	NO ARMORING	NO ARMORING	
No Sediment Supply Upstream	No	No	No	
Average Long Term Degradation (ft)	15.6	69.2	74.9	

Average Long-Term Degradation

Long-Term Degradation (ft)	0.3	0.0	0.0	

Note: Long-term degradation is based on depth to armor layer formation, and long-term degradation calculations. If there is an equilibrium of sediment transport the long-term degradation is set to armoring depth. If there is an upstream sediment supply shortage the long-term degradation is equal to the lesser of the armoring depth or the average long-term degradation based off of equilibrium slope equations.

Channel Scour Analysis - General Scour

Project:	Wenatchee MP 131	Site:	MP 131
Watercourse:	Effemeral Stream	Analyst:	ESM
Checked By:	RSC	Latest Revision:	9/6/2018

Description:

- This workbook contains calculations to estimate the general scour depth predicted by Blodgett (1986), and Blench (1970) + Lacey (1931) methodologies, as presented in the NRCS Technical Supplement 14B, Scour Calculations. D50 for the bed materials is shown as a clayey sand, thus was approximated as a medium sand, equal to D50=2 mm from ASTM Standards.
- Add note for straigh reach

$$Z_t(Mean) = KD_{50}^{-0.115}$$

$$Z_t(Max) = KD_{50}^{-0.115}$$

Blodgett 1986

Input

Hydraulic Scenario

	2 Year	100 Year	500 Year	
K	1.42_{mean}, 6.5_{max}	1.42_{mean}, 6.5_{max}	1.42_{mean}, 6.5_{max}	
D_{50} (ft)	0.21000	0.21000	0.21000	

Calculations

Z_t (Mean)	1.70	1.70	1.70	
Z_t (Max)	8	8	8	

Blench 1970 + Lacey 1931

$$Z_t = KQ_d^a W_f^b D_{50}^c$$

Input

Hydraulic Scenario

	2 Year	100 Year	500 Year	
Q_d	13.0	423.0	962.0	
Wf	14.000	32.000	40.000	
D_{50} (mm)	65.000	65.000	65.000	
Reach Condition	Moderate Reach	Moderate Reach	Moderate Reach	
K_{Lacey}	0.195	0.195	0.195	
a_{Lacey}	0.333	0.333	0.333	
b_{Lacey}	0.000	0.000	0.000	
c_{Lacey}	-0.167	-0.167	-0.167	
K_{Blench}	0.530	0.530	0.530	
a_{Blench}	0.667	0.667	0.667	
b_{Blench}	-0.667	-0.667	-0.667	
c_{Blench}	-0.109	-0.109	-0.109	

Calculations

Z_t (Lacey)	0.23	0.73	0.96	
Z_t (Blench)	0.32	1.88	3	

Summary of General Scour Depths

	2 Year	100 Year	500 Year	
Blodgett Mean	1.70	1.70	1.70	
Blodgett Max	7.78	7.78	7.78	
Lacey	0.23	0.73	0.96	

Channel Scour Analysis - General Scour

Project:	Wenatchee MP 131		Site:	MP 131
Watercourse:	Effemeral Stream		Analyst:	ESM
Checked By:	RSC		Latest Revision:	9/6/2018

Blench	0.32	1.88	2.80	

Channel Scour Analysis - Bend Scour

Project:	Wenatchee MP 131	Site:	MP 131
Watercourse:	Effemeral Stream	Analyst:	ESM
Checked By:	RSC	Latest Revision:	43349

Description:

- This workbook contains calculations to estimate the amount of scour associated with the bend in a channel.
- The Thorne Equation is taken from Reference 3, the Maynord equation is taken from Reference 3, the NEH equation is taken from Reference 4, the Zeller equation is taken from Reference

Bend Scour - Thorne Equation

Input

Hydraulic Scenario

	2 Year	100 Year	500 Year	
Y_{us} (ft)	0.4	2.9	3.9	
TW_{us} (ft)	14.0	32.0	40.0	
RC (ft)	97.0	97.0	97.0	

Calculations

RC/TW_{us}	6.9	3.0	2.4	
Check Range	6.9	3.0	2.4	
z_b (ft)	0.3	3.1	4.4	

Bend Scour - Maynord Equation

Input

Hydraulic Scenario

	2 Year	100 Year	500 Year	
Y_{us} (ft)	0.37	2.9	3.89	
TW_{us} (ft)	14	32	40	
RC (ft)	97	97	97	

Calculations

RC/TW_{us}	6.9	3.0	2.4	
Check Range	6.9	3.0	2.4	
TW_{us}/y_{us}	37.8	11.0	10.3	
Check Range	37.8	20.0	20.0	
z_b (ft)	0.3	2.4	3.3	

Bend Scour - National Engineering Handbook

Input

Hydraulic Scenario

	2 Year	100 Year	500 Year	
Y_{us} (ft)	0.37	2.9	3.89	
TW_{us} (ft)	14	32	40	
RC (ft)	97	97	97	

Calculations

TW_{us}/RC	0.1	0.3	0.4	
z_b (ft)	0.6	7.2	11.1	

Channel Scour Analysis - Bend Scour

Project:	Wenatchee MP 131		Site:	MP 131
Watercourse:	Effemeral Stream		Analyst:	ESM
Checked By:	RSC		Latest Revision:	43349

Bend Scour - Zeller Equation

Input

	Hydraulic Scenario			
	2 Year	100 Year	500 Year	
TW_{us} (ft)	14	32	40	
RC (ft)	97	97	97	
$Y_{h\ us}$ (ft)	0.37	2.9	3.89	
$Y_{max\ us}$ (ft)	1.0	3.6	5.7	
S_o (ft/ft)	0.05100	0.05100	0.05100	
V_{us} (ft/s)	3.0	10.1	13.3	

Calculations

TW_{us}/RC	0.14	0.33	0.41	
z_b (ft)	0.0	0.7	1.5	

Summary of Bend Scour

	Hydraulic Scenario			
	2 Year	100 Year	500 Year	
Thorne	0.3	3.1	4.4	
Maynord	0.3	2.4	3.3	
Zeller	0.0	0.7	1.5	
NEH-Max	0.6	7.2	11.1	

Average Bend Scour

Bend Scour	0.3	3.1	4.4	

Channel Scour Analysis - Scour Summary

Project:	Wenatchee MP 131	Site:	MP 131
Watercourse:	Effemeral Stream	Analyst:	ESM
Checked By:	RSC	Latest Revision:	43349

Description:

- This workbook contains summary information from the previous scour workbooks.

Scour Summary

Scour Calculations

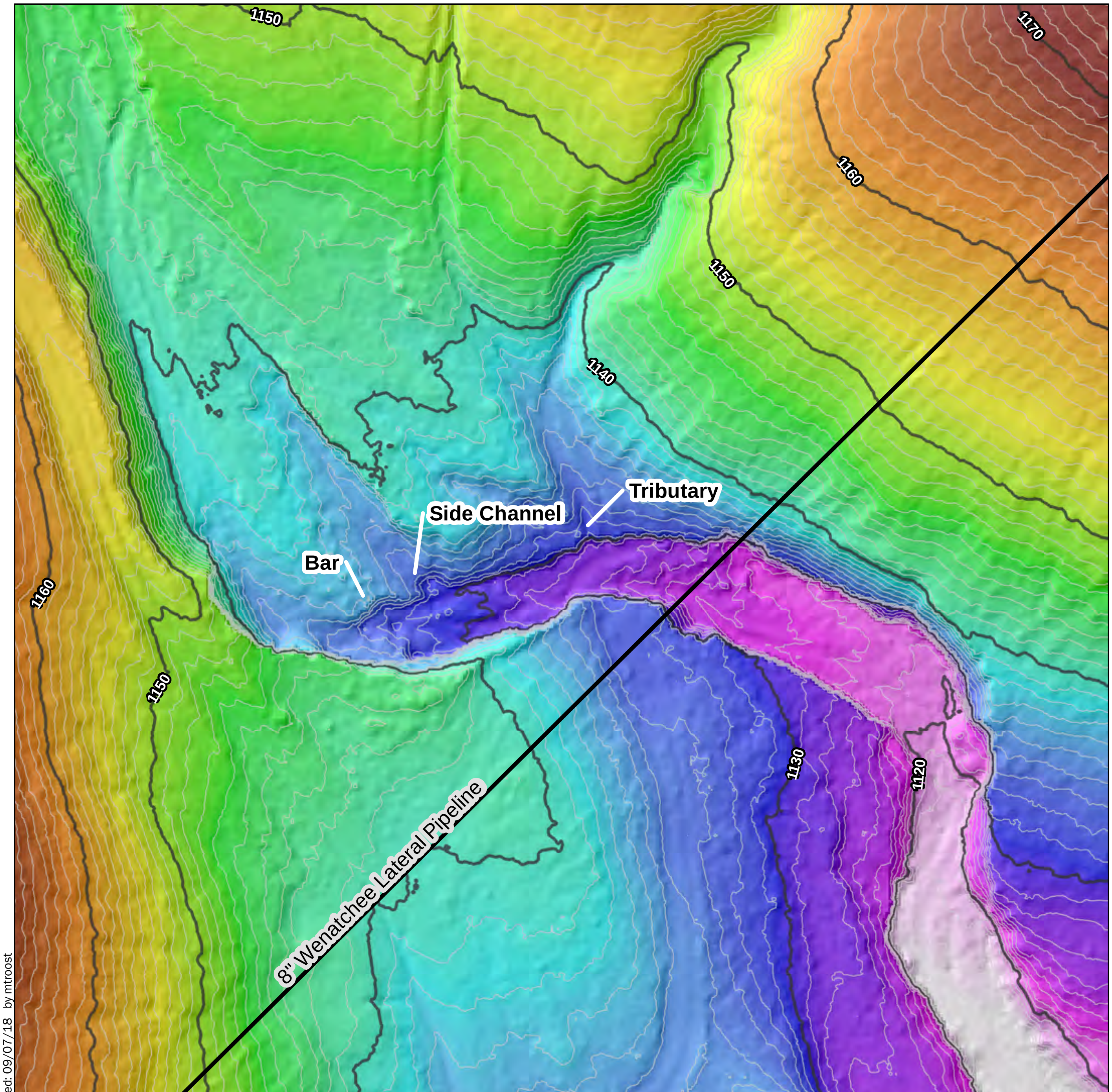
	Hydraulic Scenario			
Scour Type	2 Year	100 Year	500 Year	NA
Long-Term Degradation Range (ft)	0 - 47.1	53.8 - 76.7	66 - 79	0.0
Armor Layer	Armored Bed	No Armor Layer	No Armor Layer	0.0
Average Long-Term Degradation (ft)	0.3	0.0	0.0	0.0
Blodgett - Mean Scour (ft)	1.7			
Blodgett - Max Scour (ft)	7.8			
Lacey - Scour (ft)	0.2	0.7	1.0	0.0
Blench - Scour (ft)	0.3	1.9	2.8	0.0
Bend Scour Range (ft)	0 - 0.6	0.7 - 7.2	1.5 - 11.1	0.0
Average Bend Scour (ft)	0.3	3.1	4.4	0.0

Total Estimated Scour

	2 Year	100 Year	500 Year	NA
Total Estimated Scour (ft)	0.6	3.1	4.4	0.0
Factor of safety	1.3	1.3	1.3	1.3
Design Estimated Scour (ft)	0.8	4.0	5.8	0.0

Justification Notes:

APPENDIX C
Channel Migration Zone Analysis



Legend

Major Contours 10ft

Minor Contours 1ft

50 0 50

Feet

N W E S

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: LiDAR- Williams Pipeline Co.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Topography

Dry Gulch Pipeline Exposure -
Mitigation Alternatives Evaluation
Chelan County, Washington

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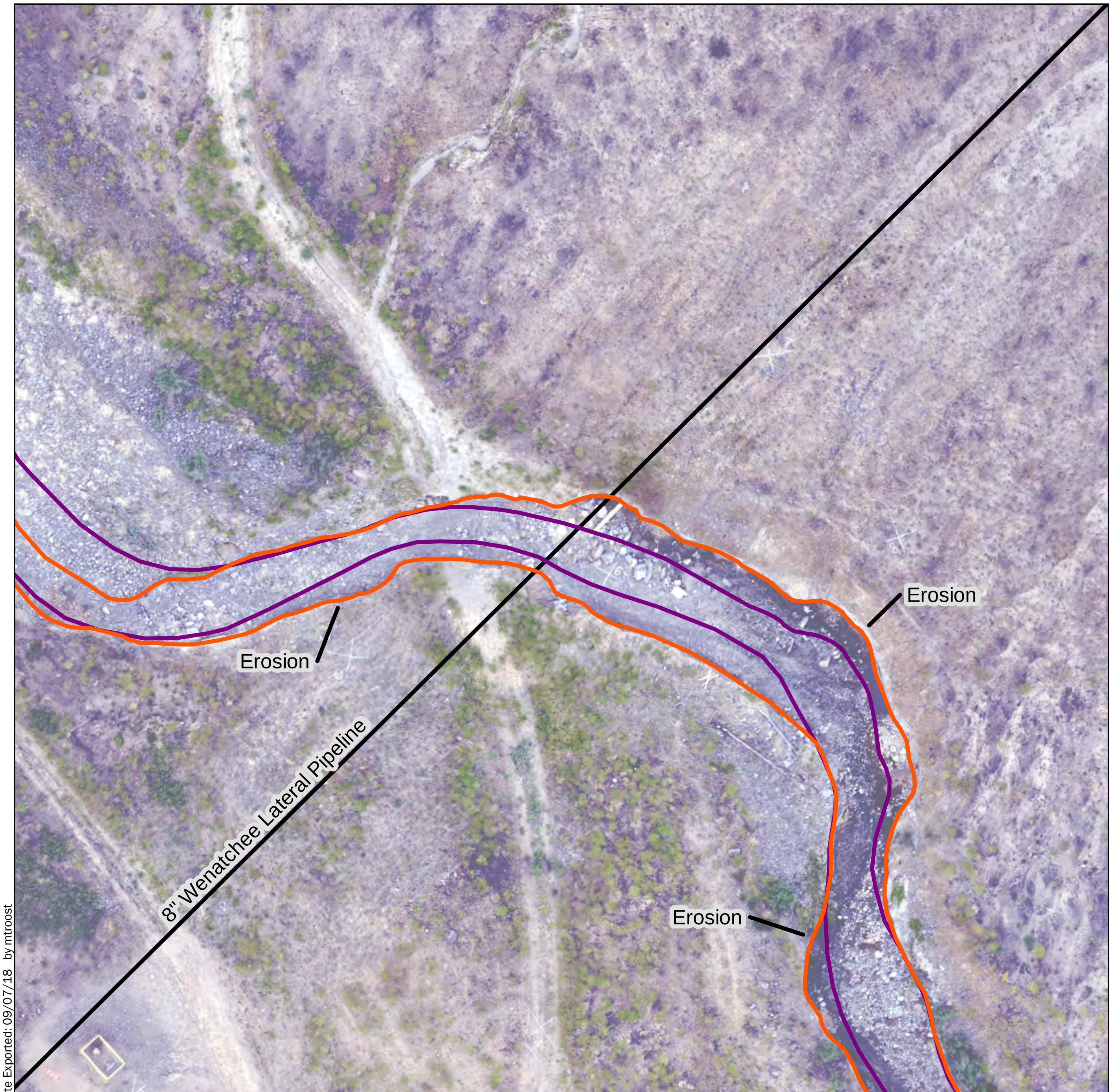
Figure C-1

P:\8\8169155\GIS\MXD\816915500_FC1_LiDAR_Topography.mxd Date Exported: 09/07/18 by mtroost



Legend

2018 Channel

2015 Channel

2013 Channel

40 0 40

Feet

N
W E
S

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: 2018 Aerial - Williams Pipeline Co.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Channel Positions

Dry Gulch Pipeline Exposure -
Mitigation Alternatives Evaluation
Chelan County, Washington

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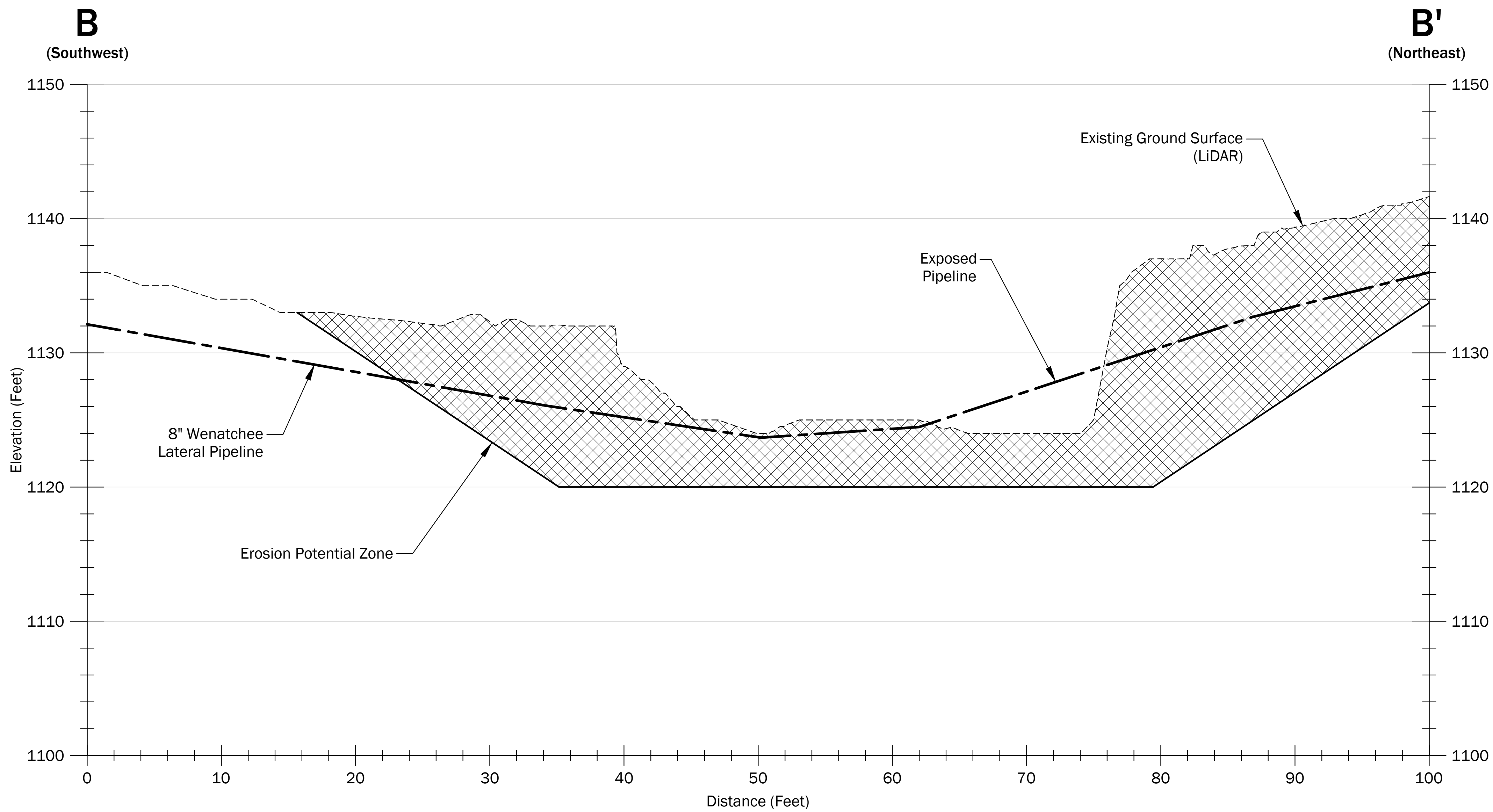
Figure C-2

P:\8\8169155\GIS\MXD\816915500_FC2_Stream_Channel_Locations.mxd Date Exported: 09/07/18 by mtroost



P:\8\8169155\CAD\00\Geotechnical\816915500_F02-F06 Site Plan and Cross-Sections.dwg TAB:FC-3 Date Exported: 09/07/18 - 10:48 by tmichaud

Notes:
1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
3. Ground surface and Pipeline profile provided by Williams NWP.

Datum: NAVD 88, unless otherwise noted.

10 0 10
Horizontal Scale in Feet

10 0 10
Vertical Scale in Feet
Vertical Exaggeration: 1X

Erosion Potential Zone

Dry Gulch Pipeline Exposure -
Mitigation Alternatives Evaluation
Chelan County, Washington

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Figure C-3

APPENDIX D
Photograph Log

Notes:

Photograph of bankfull width measurement approximately 720 feet upstream of the pipeline crossing. Photograph facing downstream

Data Source:

XXXXX-XXX-XX Date Exported: 04/09/15

Reference Channel Condition Upstream of Crossing

Williams NWP –MP 131 Dry Wash
Wenatchee, Washington

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Figure D-1

Notes:

Photograph of near vertical bank upstream of crossing and of crossing (background). Photograph facing downstream.

Data Source:

Vertical Bank – Upstream of Crossing

Williams NWP –MP 131 Dry Wash
Wenatchee, Washington

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Figure D-2

XXXXX-XXX-XX Date Exported: 04/09/15

Notes:

Photograph of near vertical bank upstream of crossing. Photograph facing upstream.

Data Source:

Vertical Bank – Upstream of Crossing

Williams NWP –MP 131 Dry Wash
Wenatchee, Washington

GEOENGINEERS

Figure D-3

XXXXX-XXX-XX Date Exported: 04/09/15

Notes:

Photograph of failed roadway crossing. Photograph taken facing across the channel generally facing east.

Data Source:

Failed Access

Williams NWP –MP 131 Dry Wash
Wenatchee, Washington

GeoEngineers

Figure D-4

XXXXX-XXX-XX Date Exported: 04/09/15

Notes:

Photograph of exposed gas pipeline and failed roadway crossing. Photograph taken facing downstream.

Data Source:

Pipe Exposure at Crossing and Failed Access

Williams NWP –MP 131 Dry Wash
Wenatchee, Washington

GeoEngineers

Figure D-5

XXXXX-XXX-XX Date Exported: 04/09/15

Notes:

Photograph of exposed 8-inch diameter pipeline at MP 131. Photograph taken facing upstream.

Data Source:

Exposed Pipeline Looking Upstream

Williams NWP –MP 131 Dry Wash
Wenatchee, Washington

GeoEngineers

Figure D-6

Notes:

Photograph of near vertical bank downstream of pipeline crossing. Photograph taken facing downstream.

Data Source:

Near Vertical Bank Downstream of Crossing

Williams NWP –MP 131 Dry Wash
Wenatchee, Washington

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Figure D-7

XXXXX-XXX-XX Date Exported: 04/09/15

Notes:

Photograph of near vertical bank downstream of pipeline crossing. Photograph taken facing downstream.

Data Source:

Near Vertical Bank Downstream of Crossing

Williams NWP –MP 131 Dry Wash
Wenatchee, Washington

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Figure D-8

Notes:

Photograph of reference channel condition approximately 700 feet downstream of the crossing. Photograph taken facing downstream.

Data Source:

Reference Channel Downstream of Crossing

Williams NWP –MP 131 Dry Wash
Wenatchee, Washington

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Figure D-9

APPENDIX E
Report Limitations and Guidelines for Use

APPENDIX E
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.

READ THESE PROVISIONS CLOSELY

Some clients, design professionals and contractors may not recognize that stream and river engineering analysis and design practices are less exact than other engineering and natural science disciplines. Such misunderstanding can create unrealistic expectations, sometimes leading 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.

STREAM AND RIVER DESIGN ENGINEERING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES, PERSONS AND PROJECTS

This report has been prepared for Williams Pipeline Northwest and their authorized agents and regulatory agencies for use on the Project(s) specifically identified in the report. The information contained herein is not applicable to other sites or projects.

GeoEngineers structures its services to meet the specific needs of its clients. No party other than Williams Northwest Pipeline may rely on the product of our services unless we agree to such reliance in advance and in writing. Within the limitations of the agreed scope of services for the Project(s), and its (their) schedule and budget, our services have been executed in accordance with our Agreement with Williams Pipeline Northwest dated and executed on July 5, 2018 and generally accepted practices in this area at the time this report was prepared. We do not authorize and will not be responsible for, the use of this report for any purposes or projects other than those identified in the report.

A SCOUR AND CHANNEL MIGRATION ANALYSIS REPORT IS BASED ON A UNIQUE SET OF PROJECT-SPECIFIC FACTORS

This report has been prepared for the Wenatchee MP 131 Dry Wash Evaluation, located near Wenatchee, Washington. 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, it is important not to rely on this report if it was:

- Not prepared for you,
- Not prepared for your project,
- Not prepared for the specific site, or
- Completed before project changes were made.

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

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

- Subsurface geologic conditions;
- Changes to channel geomorphology;
- Changes in drainage basin characteristics; or
- Project ownership.

If changes occur after the date of this report, GeoEngineers cannot be responsible for any consequences of such changes in relation to this report unless we have been given the opportunity to review our interpretations and recommendations in the context of such changes. Based on that review, we can provide written modifications or confirmation, as appropriate.

CONDITIONS CAN CHANGE

This report is based on conditions that existed at the time the study/design 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, new information or technology that becomes available subsequent to the report date, or by natural events such as floods, earthquakes, slope instability, stream flow fluctuations or stream channel fluctuations. If more than a few months have passed since issuance of our report or work product, or if any of the described events may have occurred, please contact GeoEngineers before applying this report for its intended purpose so that we may evaluate whether changed conditions affect the continued reliability or applicability of our conclusions and recommendations.

REPORT RECOMMENDATIONS AND DESIGNS ARE NOT FINAL

The recommendations included in this report are preliminary and should not be considered final. The designs depicted herein are approximate and are intended to express the overall design intent of the Project and need to be adjusted in the field during construction in order to meet the specific-site conditions and intended function. GeoEngineers' recommendations can be finalized only by observing actual site-specific conditions revealed during construction.

REPORT COULD BE SUBJECT TO MISINTERPRETATION

Misinterpretation of this report by members of the design team or by contractors can result in costly problems. GeoEngineers can help reduce the risks of misinterpretation by conferring with appropriate members of the design team after submitting the report, reviewing pertinent elements of the design team's plans and specifications, participating in pre-bid and preconstruction conferences, and providing construction observation.

HAZARDS OF INSTREAM HABITAT STRUCTURES

Instream habitat structures ("Structures") create potential hazards, including, but not limited to:

- Persons falling from the Structures and associated injury or death;
- Collisions of recreational users' and their watercraft with the Structures, and associated risk of injury, and damage of the watercraft;

- Mobilization of a portion or all of the Structures during high water flow conditions and related damage to downstream persons and property;
- Flooding;
- Erosion; and
- Channel avulsion.

In some cases, channel stabilization structures are only intended to be temporary, providing temporary stabilization while stream/river processes stabilize. This gradual deterioration with age and vulnerability to major flood events make the risks with temporary Structures inherently greater with their increasing age.

GeoEngineers strongly recommends that the Client appropriately address safety concerns, including but not limited to warning construction workers of hazards associated with working in or near deep and fast-moving water and on steep, slippery and unstable slopes. In addition, signs should be placed along the enhanced stream reaches in prominent locations to warn third parties, such as nearby residents and recreational users, of the potential hazards noted above.

INCREASED FLOOD ELEVATIONS AND WETLAND EXPANSION ARE POSSIBLE

The proposed stream enhancements may result in increased flood elevations and expansion of wetlands. These impacts are generally considered advantageous for aquatic and riparian habitat in the project locations of these stream systems, but the analysis, consideration and quantification of these impacts is beyond the scope of this report, unless expressly included within GeoEngineers' scope of services.

CHANNEL EROSION AND MIGRATION ARE POSSIBLE

In general, river and stream enhancements result in more stable streambeds, banks and floodplains. In some cases, stream enhancement and channel stability include reestablishing the natural balance of sediment erosion, distribution and deposition, which in some cases may induce channel meandering and migration. Therefore, channel erosion, channel migration and/or avulsions can occur over time.

GeoEngineers