Report of Engineering Geologic Services

Upper Peshastin Migration Barrier Design 14-1739

Chelan County, Washington

Prepared for

Waterfall Engineering, LLC
and
Chelan County NRD

August 13, 2015
Hart Crowser No. 154-025-001

HARTCROWSER

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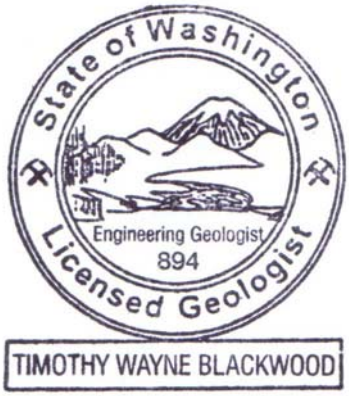

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Report of Engineering Geologic Services

Upper Peshastin Migration Barrier Design 14-1739

Chelan County, Washington

INTRODUCTION

Hart Crowser, Inc (Hart Crowser) is pleased to submit our engineering geologic evaluation of a landslide (often referred to as the Ruby Slide) adjacent to Peshastin Creek, just upstream of the Ruby Creek confluence in Chelan County, Washington. The location of the site is shown on Figure 1. Our work was completed in general accordance with our proposal dated April 21, 2015.

The project site is an area of steep slopes, adjacent to the west side of Peshastin Creek from river mile (RM) 10.2 to 10.6. Within this section of the creek, a large historic landslide abuts the stream. The landslide is believed to be depositing material into the creek, impinging upon this section of the stream. Through this same reach, road building and repair have severely restricted and armored the stream on the opposite side from the landslide. This report supports the conceptual design of measures to address adult fish migration on Peshastin Creek at RM 10.2 to 10.6. Due to technical concerns about the risk of the slide destroying proposed fish passage improvements, a geotechnical evaluation was added to the fish migration project. Waterfall Engineering, LLC requested an evaluation of the effect(s) of the landslide on the stream in order to determine whether mitigation to improve fish passage conditions is feasible. This information will be submitted to the Salmon Recovery Funding Board Review Panel. The following report provides the results of our assessment, including our findings, evaluation, and conclusions related to the above project elements.

Scope of Services

The purpose of our work was to evaluate the landslide and the likely effect(s) it will have on the stream. Our complete scope of work was described in our April 21, 2015 proposal and included the following primary elements.

- Reviewed existing available reports, geologic maps, and other information pertinent to the site.
- Attended a meeting with stakeholders to gather additional anecdotal and other information related to the landslide and previous road and other alterations in the area.
- Conducted a site reconnaissance to evaluate current conditions, which included observations of geologic conditions and completing field developed cross sections.
- Conducted a qualitative evaluation of the site, based on our field work, focused on the stability of the landslide and the likelihood for future movement to occur.
- Prepared this report outlining our findings, evaluation, and conclusions.

BACKGROUND INFORMATION

Site Description

The project site is an area of Peshastin Creek that has been affected by historic landsliding, near mile post (MP) 176 on Highway 97, approximately 450 feet south of the junction with Ruby Creek. The channel through this reach is restricted on the east by riprap armoring for Highway 97 and on the west by the toe of a deep-seated landslide that abuts Peshastin Creek for approximately 730 feet. The slide extends uphill approximately 1,200 feet from the creek, incorporating approximately 16 acres of ground. The landslide has two distinct segments: 1) a moderately steep northern section and 2) a steeper southern section. Each segment has a headscarp area that exhibits exposed soils. Hummocky ground uphill of the exposed soil headscarps is vegetated.

The northern section of the landslide consists of moderate slopes with gradients of approximately 55 percent overall. The uphill portion of this section is approximately 600 feet high and contains an upper segment that appears relatively stable, with moderately weathered surface geomorphology and mature trees. Below this, a long, relatively flat bench extends laterally for approximately 400 feet before dropping off to Peshastin creek at a gradient of approximately 70 percent. Vegetation consists of scattered native shrubs and large pockets of mixed conifer and hardwood trees. Elevations in the northern segment range from approximately 2,700 feet MSL at the top to 2,050 feet above mean sea level (MSL) near the toe.

The southern section of the landslide consists of steeper slopes with gradients of approximately 65 percent overall. The uphill portion of this segment is a predominantly bare scree slope, void of vegetation, which is approximately 700 feet long. At the base of this scree slope, the slope morphology transitions to a complex set of landforms, including back-tilted blocks, grabens, hummocky topography, and tilted and jack-strawed conifer. At the downhill edge of this complex block, a steep slope abruptly drops off to Peshastin Creek at a gradient greater than 100 percent. Exposed soil scarps adjacent to the creek are over-steepened and indicate ongoing sloughing in this area. The creek is actively eroding here, entrenching into the landslide toe and creating steep bare slopes adjacent to the stream. Vegetation consists of scattered native shrubs and occasional mixed conifer and hardwood trees. Elevations in the southern section range from approximately 2,680 feet above MSL at the top to 2,080 feet MSL near the toe.

Site Geology

The geology of the site is mapped in the Geologic Map of the Wenatchee 1:100,000 Quadrangle, Central Washington, by the US Geological Survey (USGS). The geologic mapping shows that the project site is underlain by the Ingalls Tectonic Complex, which includes rocks previously mapped as Peshastin formation by Smith in 1904. The complex consists of argillite, phyllite, sandstone, metasandstone, metamorphosed flows, and breccias. The rocks are predominately described as black hackly argillite to slaty argillite with subordinate very fine grained, angular, lithic subquartzose sandstone. It also contains radiolarian chert and metachert (Tabor and others 1982). A report by Pilz in 1960 further describes the site geology as containing irregular peridotite intrusions into the

Paleozoic sedimentary series of the Peshastin formation (Pilz 1960). These intrusions have been subject to hydrothermal alteration and serpentization. The serpentinite is described as lying below the Peshastin formation, which consists in the project area of weak phyllites and slates (Pilz 1960). A large vertical basalt dike cuts both the serpentine and the Peshastin formation within the slide area (Pilz 1960). Rocks described as foliated and massive serpentine, serpentinized peridotite and metaserpentinite are mapped at the head of the landslide area (Tabor and others 1982).

Geologic hazards at the site are mapped as Quaternary landslide deposits and described as "poorly sorted deposits ranging from muddy boulder gravel to boulder mud; clasts are angular… most slides have hummocky surfaces, bulbous toes… smaller slides generally head at theater-shaped scars" (Tabor and others 1982). Based on our observations, the site geology is generally consistent with the mapping. Our field observations are described later in this report.

Summary of Background Information and History of Movement

We reviewed background documents provided by the Chelan County Natural Resources Department (NRD). The documents we reviewed included the following:

1. The Peshastin Creek Landslide Geology, H. A. Pilz, 1960
2. Peshastin Ck. Landslide Memo, WSDOT, January 1996
3. Blewett Pass Flood Repair, series of copied emails, WSDOT, February 1996
4. US 97 Blewett Pass Emergency Flood Repair, construction drawings, WSDOT, 2009

Our review found that the Peshastin Creek landslide has been active for at least the past 95 years (Pilz 1960). In the last 55 years, four episodes of significant landslide movement have been documented. Two of these episodes occurred in the consecutive years of 1959 and 1960 and then two more episodes in the consecutive years of 1995 and 1996. The specific details of these events, based on the documents, are detailed below.

Prior to 1959, Highway 97 traversed midslope across the slide, approximately 200 feet above the stream on the west side of the valley. However, the highway in this location was reportedly affected by episodes of landslide activity since at least the 1920s (Pilz 1960). Continued movement of the landslide and resulting highway problems prompted relocation of the highway to the creek bed on the east side of the valley in 1959, and re-channelization of Peshastin Creek through the toe of the slide (Badger and Allen 1996; Pilz 1960). Although detailed construction documents are not available, Pilz's 1960 report states "relatively little mass was removed from the toe area of the portion of the slide which became active," which implies that some landslide material was removed at the toe of the slide coincident with the highway relocation, although not a great deal.

The year following highway relocation, the landslide failed in April 1960. The relocation of the highway was thought to have accelerated an already active portion of the slide (Piltz 1960). The failure resulted in the damming and shifting of the creek channel to its original location and destruction of 600 feet of newly constructed roadway embankment (Pilz 1960; Badger and Allen 1996). Pilz's 1960 report stated that "replacement of a portion of the original excavated mass by raising the grade, is perhaps the only practical way to deal with this problem." We understand that the road was constructed on an elevated embankment that was intended to help stabilize the slide. After reconstruction was complete, no significant landslide problems were reported in the area until 1995, 35 years later.

In the winter of 1995, reactivation of the landslide was reported due to heavy November rainfall. The site was visited a few weeks later by the Washington State Department of Transportation (WSDOT), which described site conditions in a January 29, 1996 memorandum (Badger and Allen 1996). An estimated flow of 1,600 cubic feet per second (cfs) was reported by WSDOT, greater than the 100-year flood estimate of 1,050 for this location (Powers 2015). At that time the observed limits of landslide movement were equivalent to the historical limits of the failure. It was interpreted that the entire slide mass had remobilized with the possible exception of a several hundred foot section of the upstream portion of the toe, equivalent to the Southern Section, shown on Figure 2. The observed width of the active toe area was estimated to be 200 to 300 feet and represented approximately half the estimated width of the total slide mass. The slide mass partially constricted the flow of the creek, resulting in ponding of the creek behind the constriction. At that time it was believed that a total blockage of the creek would not likely occur due to the steep stream gradient and rapid erosion of the recently deposited fine-grained material that was expected to occur. The WSDOT (1996) memorandum implies that no roadway work or repair was done at that time.

Just 3 months later, in February of 1996, a large storm impacted the area near the Peshastin Creek landslide causing flooding and partial reactivation of the landslide. WSDOT again visited the site and reported that severe flooding eroded the roadway embankment toe resulting in almost total failure of the south bound shoulder and truck climbing lane. WSDOT also noted that the "Ruby Creek slide was also being impacted by the flooding" (WSDOT 1996). At our site visit on June 4, 2015, a WSDOT representative indicated that the slide had filled and dammed up the creek, causing the water to flow down the highway. As a result of this activity, a retaining wall was proposed to support the roadway section opposite the slide in order to protect the highway. 2007 as-builts provided by WSDOT indicate that roadway repairs were made adjacent to the "Ruby Creek slide;" however, no specific indication that landslide reactivation had occurred was noted.

The Peshastin Creek landslide has been stable enough to maintain a channel for the last 19 years, and WSDOT indicted they have no plans to do more work on the roadway. Ongoing shallow sloughing of material continues at the location of the "Ruby Creek slide" but no significant or catastrophic movement of the landslide mass has been documented since 1996.

FIELD RECONNAISSANCE

We completed a surface reconnaissance of the landslide area on June 4 and 5, 2015. Based on our reconnaissance, we divided the landslide into the two distinct sections mentioned previously (the Northern Section and the Southern Section as shown on Figure 2). We traversed on foot and used a laser range finder to create two cross sections, one through the moderate slopes in the Northern Section of the landslide and one through the steeper slopes in the Southern Section. We also traversed along the toe of the slope and streambed to assess geomorphic conditions there. These areas and the features within them are shown on Figure 2 and described in detail in the following sections.

Northern Section

The Northern Section is dominated by a long, mostly moderate slope that gives way to a gentler shelf. The topography consists of large, planar, treed benches on the upper slopes (Photograph A-1) and hummocky deposits on the lower slopes (Photograph A-2). Extending down from the headscarp, the upper slopes have an average gradient of approximately 70 percent. The lower slopes are identified by a slope break where the gradient shallows to approximately 20 percent, and then steepens to approximately a 70-percent gradient down to Peshastin Creek at the toe of the slide. Vegetation is variable and consists mainly of conifer and low shrubs. We constructed a field-developed cross section of the area labeled A - A' on Figure 2.

At the top of the active slide area, near station T-1, the headscarp is approximately 160 feet across, with a depth well below the rooting depth of trees within the slide. Within the headscarp and along the sidewall, exposed soil is visible with active sloughing observed. The ground above the active headscarp has a disrupted texture with scree and rock slopes intermixed. The trees both above and below the active headscarp show signs of past movement, including bent and bowed trunks and strong crooks in the upper portions of tree trunks (Photograph A-3). Trees above the headscarp, near station T-2, were estimated to be more than 80 years old.

Below the active headscarp, just south of station T-3, a long planar intact bench with mature trees extends down the slope for approximately 350 feet. Some trees were tilted and are estimated to be approximately 30 to 40 years old. Moving to the south, the main body of the slide consists of large rubble and gravel piles (Photograph A-4), which become coarser as you move into the Southern Section of the landslide.

The lower slopes of the Northern Section, near station T-4, contain rounded hummocks and swales. No ponded water or springs were observed at the time of our site visit. At the northern edge of the slide, near station T-5, hummocks gently give way to more stable ground outside of the recent landslide boundary. Talus debris in the Northern Section of the landslide consists of fine to coarse angular gravel.

Southern Section

The Southern Section consists of a shorter, steeper overall slope than the northern section. Geomorphic features in this area include a combination of scree slopes, largely un-vegetated hummocky gravel and talus piles, and a partially vegetated back-tilted block. We constructed a field-developed cross section of the area labeled B - B' on Figure 2. Slopes in the Southern Section have an overall gradient of approximately 65 percent.

At the top of the headscarp, near station T-6, fresh exposed soil was observed in the headscarp and sidewalls. Tilted and bowed trees were observed above the headscarp and soil, and rock above the active scarp appeared loose and disturbed (Photograph A-5). The upper headscarp in the Southern Section is approximately 130 feet across, with a depth well below the rooting depth of trees within the slide.

Near station T-7, in the center of the slide, largely unvegetated small slide benches were observed to have a gentle, rounded morphology (Photograph A-6). These benches were observed to collect debris and boulders with some debris tracks visible across the slope. Material in this area consists of coarse gravel to boulder sized talus and rubble. The rock is weak, fissile, splits easily, and appears to have been pulverized as it moved downhill. No seeps or springs were observed in this area. From Station T-7 the width across the main body of the slide is approximately 550 feet.

At the base of the slope an over-steepened and back-tilted block abuts Peshastin Creek. A fresh slide scar is apparent on the face of this block (Station T-8), contributing active sloughing of debris and landslide material into the creek. Rock trenches, ground cracks, and areas of poorly developed internal drainage were observed within and adjacent to the back-tilted block at the base of the slope (Photograph A-7). No springs or standing water were observed at the time of our visit; however, grass was observed growing in the small flatter depressions. The area was hummocky and partially vegetated by trees and shrubs (Photograph A-8). The trees were approximately 20 to 40 years old. In the upper 15 to 20 feet of the trees, near the top, a strong crook was noticed in several trees. Secondary scarps (Photograph A-9) were also observed along with lateral ground mounding and ridges formed parallel to the fresh scarp face. A small, straight tree was observed near the edge of the scarp face with an estimated age of 10 years.

Landslide Toe

At the toe of the slide along Peshastin Creek, the length of the entire landslide is approximately 730 feet. The creek has a gradient of approximately 11 percent through the reach of the slide (Photograph A-10). Boulders within the creek are on average between 6 and 11 feet in diameter (Photograph A-11). Finer material observed in the stream is typically large gravel to cobble sized. Adjacent slopes showed evidence of sloughing of silt and sand sized material; however, these finer materials were not observed to comprise the stream bed in this location. The northern section of the slide occupies approximately 350 feet in the downstream direction, while the southern section of the slide takes up the remaining 380 feet in the upstream direction.

EVALUATION

We evaluated the potential for future landsliding to occur, estimated the magnitude and frequency for such movement, and considered factors likely to affect these parameters. Our evaluations for each are discussed separately below and are based on the above document review and field reconnaissance.

Landslide Potential

The Peshastin Creek landslide is a predominantly natural feature that is being actively eroded by Peshastin Creek and also affected by anthropogenic factors, such as road building, road repair, and armoring of the opposite stream bank. Within the period of record (since about the 1920s) it has been subject to multiple episodes of landsliding, with variations in magnitude and extent. Based on our evaluation we have identified three primary modes of potential future failure. These include a catastrophic failure of the pre-historic landslide, a moderate failure of a portion of the active landslide, and shallow sliding/raveling of the steep toe slopes. The following paragraphs describe the potential of each of these failure modes separately.

Failure of the Pre-Historic Landslide

Failure of the pre-historic landslide would involve reactivation of the entire landslide body, including the Northern and Southern Sections, the hummocky ground upslope of the headscarps, and possibly even extending laterally past the historic limits of the landslide. Hummocky ground upslope and outside of the active landslide area have not been involved in historic landsliding. However, physical features, such as consistent bends in the trunks of conifer trees and hummocky morphology, suggest these areas have been part of larger prehistoric landsliding. Although failure of this large feature is possible, the historic record of movement and these physical features document that the Ruby Creek Landslide has not moved as a large single event, but rather discrete areas have moved individually or in tandem at different times. Additionally, there is an overall, although not necessarily local, increasingly stable configuration to the landslide from displacement and subsequent weathering. Based on these factors, it is our opinion that the likelihood of catastrophic movement of the prehistoric landslide is low.

Failure of a Portion of the Active Landslide

Failure of a portion of the active landslide would involve movement of moderate to large areas, such as has occurred within the Northern and Southern Sections, historically. The Northern Section, Southern Section, upslope hummocky ground, and other specific areas of the landslide appear to have undergone separate episodes of displacement. Variations of landforms and vegetation within the Northern Section and Southern Section document the relative ages and apparent stability for different portions of the landslide. The mature trees on the long, intact planar bench within the Northern Section indicate this morphologic feature has been relatively stable since the 1960s. The back-tilted block in the Southern Section was involved in movement in 1959/1960, did not move in the 1996/1997 landsliding, but currently exhibits indications of instability. Strong bends in the upper trunks of trees, closed depressions, secondary scarps, ground cracks, and lateral ground ridges are relatively fresh, indicating that the block is experiencing continued movement. Based on this history of episodic

movement of sections of the landslide, it is our opinion that this pattern is most likely to continue. We consider the likelihood of movement of a portion of the active landslide to be moderate to high, and, in particular, the likelihood of failure of the unstable block in the Southern Section to be high.

Shallow Sliding/Raveling of the Steep Toe Slopes

Shallow landsliding and raveling of steep toe slopes generally consists of movement of the upper few feet or less of soil within the steepest stream-adjacent slopes. These types of failures have been ongoing to varying degrees in magnitude and extent since the 1996 movement. Fresh scarp faces were observed adjacent to the stream at the toe of the slide indicating current and ongoing sloughing. Cobble to large boulder-size debris littered the stream channel at the toe of the landslide, while coarse gravel to moderate cobble sized material is characteristic of material in the stream outside of the landslide-impacted reach. It is our opinion that there is a high likelihood for the continuance of shallow slides and raveling of material along the toe of the slide, causing frequent sediment delivery to the stream channel.

Landslide Magnitude and Frequency

Our review of background information and our field evaluation indicate that the landslide experiences movement of the types noted (the pre-historic landslide, portions of the active landslide, and shallow landsliding/raveling) at various intervals. The volumes of such material delivered to the stream by such events would also vary. These are summarized below:

- Since the 1920s no recorded episodes of reactivation of the larger prehistoric landslide have occurred. Based on these data, reactivation of the complete landslide would occur with a frequency of greater than approximately 100 years. If movement of the entire slide were to occur, it would involve a very large volume of material and likely dam the creek with coarse and fine sediments.

- Since the 1920s, four specific instances of movement within the active landslide were recorded. Between the 1920s and 1959, the slide conditions were described as active; however, there is no specific information on the extent or magnitude of the movement. In 1959 a significant portion of the landslide moved and then again in 1960. Similarly two episodes of significant movement occurred in 1995 and 1996. This record gives an average recurrence interval of 14 years. Rather than considering these episodes as four, they may actually be two events. The movement in 1960 was likely a result of the construction activities undertaken in 1959 to relocate the highway. Similarly, the movements in 1995/1996 were related to winter flooding at greater than 100-year flood event levels. The 1996 activity could be considered a continuation of the 1995 reactivation. If these episodes are considered two events rather than four, the recurrence interval for such landslides decreases to approximately every 28 years. Given this range of 14 to 28 years, the active landslide experiences episodic movement with recurrence intervals at a decadal scale, likely varying from a decade to a few decades. The volume of sediment reaching the stream from such landslides would be significant. We have not completed volume calculations; however, it would be on the order of thousands of cubic yards of material into the stream. The material would probably be deposited rapidly, temporarily blocking the stream, as occurred in the previous events, until the stream were able to erode through it.

- Shallow landslides and raveling are not specifically documented in the background information we reviewed; however, their frequency and volume can be estimated by physical features at the site. Based on the steep slopes, erosive nature of soils present, and the extent of fresh soil scars, such displacement occurs each year during the wet season or from high stream flows. The volume of shallow movement is variable, but will generally be on the order of a few cubic feet to a few cubic yards at a time. Less frequently, larger slumps of a few tens of yards could occur. This soil will mostly, rapidly erode away, except for large boulders that are incorporated within the slide mass. This process can be illustrated by Photograph A-12, provided by Waterfall Engineering Services. This photograph shows evidence of fresh raveling from the southern toe, as a result of 2009 high winter stream flows of around 88 cfs (Powers 2015).

FACTORS AFFECTING LANDSLIDE MOVEMENT

Landslide movement can be attributed to three main factors: 1) weather, 2) unweighting the toe-slope, and 3) toe erosion.

- Precipitation (both rain and snow) can create saturated conditions within the slide body that adversely contribute to slope movement. We would expect significant landslide occurrence to be associated with periods of high precipitation in the future.

- Unweighting the toe-slope removes support at the toe and decreases resisting forces. Removal of material at the toe-slope, such as from previous excavation for roadway construction, increases the likelihood of landslide movement.

- Erosion of soil at the toe of the landslide by flooding or normal stream flow also removes resisting forces, increasing the likelihood of landslide movement. Factors that increase flows, such as large storms, will increase erosion and likewise increase the potential for landslide movement.

The most likely periods for reactivation of the landslide are during large scale storm events that generate high erosive floodwaters. The combination of high water eroding at the toe of the slide and saturated soils negatively affects the stability of this slide.

LIMITATIONS

We have prepared this report for the exclusive use of Waterfall Engineering LLC and their authorized agents for the Peshastin Creek Landslide Evaluation project in Chelan County, Washington, in accordance with our April 21, 2015 proposal. Our report is intended to provide our opinion of geologic hazards for the project based on our field reconnaissance and observed conditions. However, conditions can vary significantly across a site, particularly during extreme conditions, such as seismic events and major storms. Therefore, our conclusions should not be construed as a warranty or guarantee of subsurface conditions or future site performance.

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

Any electronic form, facsimile, or hard copy of the original document (email, text, table, and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by Hart Crowser and will serve as the official document of record.

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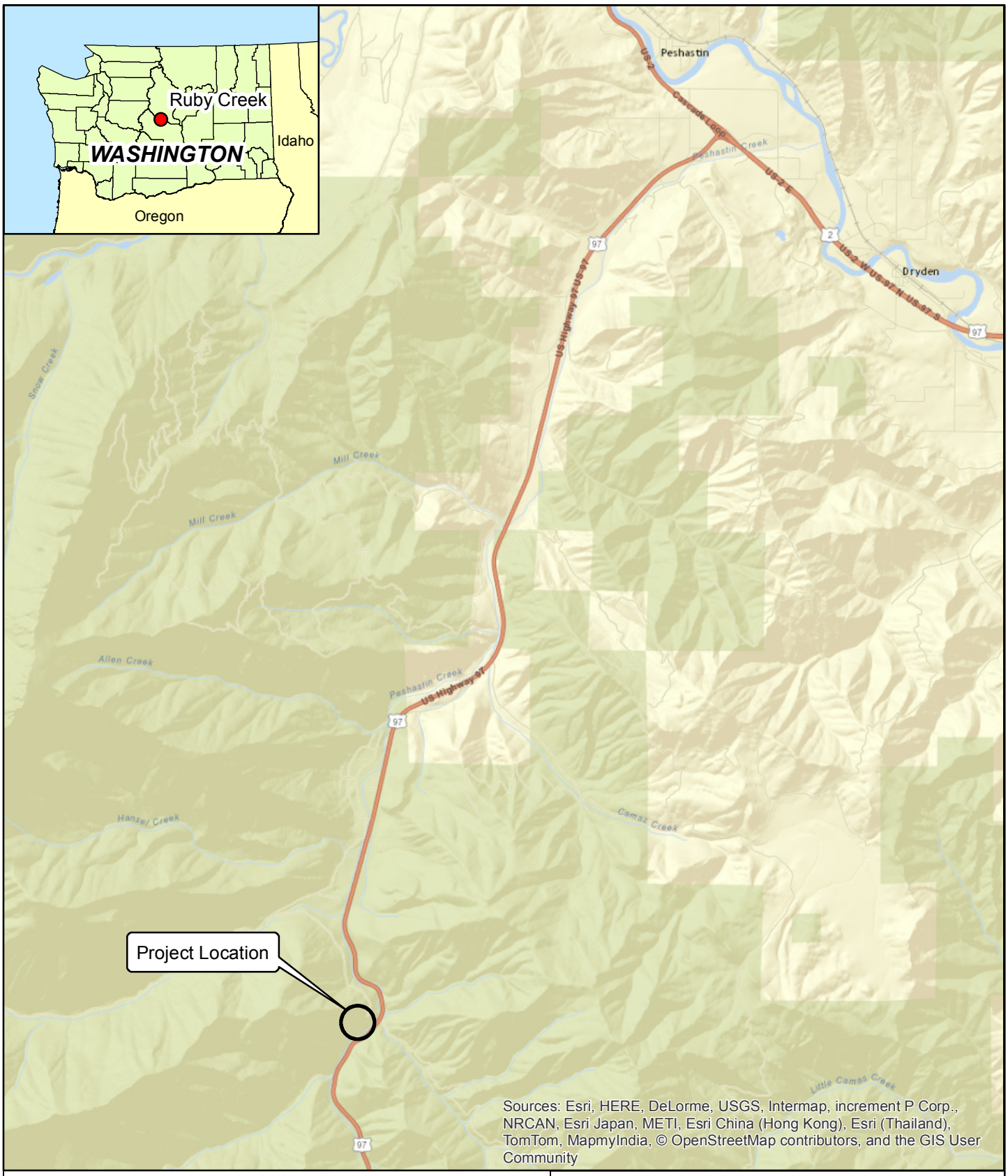

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Upper Peshastin Migration Barrier Design 14-1739
Chelan County, Washington

Vicinity Map

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Figure 1

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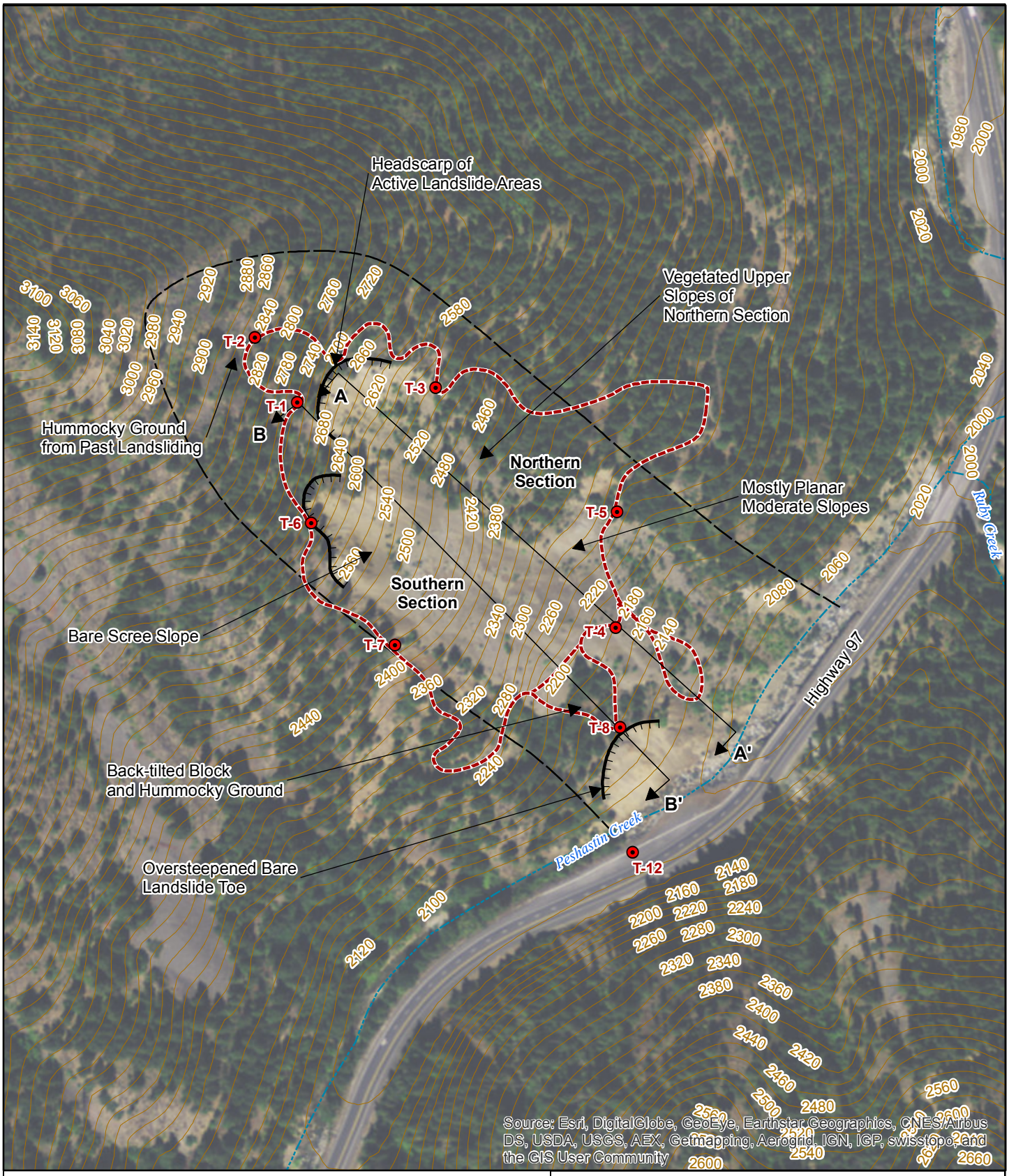

LEGEND

- Traverse Point
- Cross Section
- Traverse Route
- Scarp
- Lanslide Limits
- Streams
- Elevation Contours

Note: Feature locations are approximate.

0 150 300 600 Feet

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Upper Peshastin Migration Barrier Design 14-1739
Chelan County, Washington

Site Plan

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Figure
2

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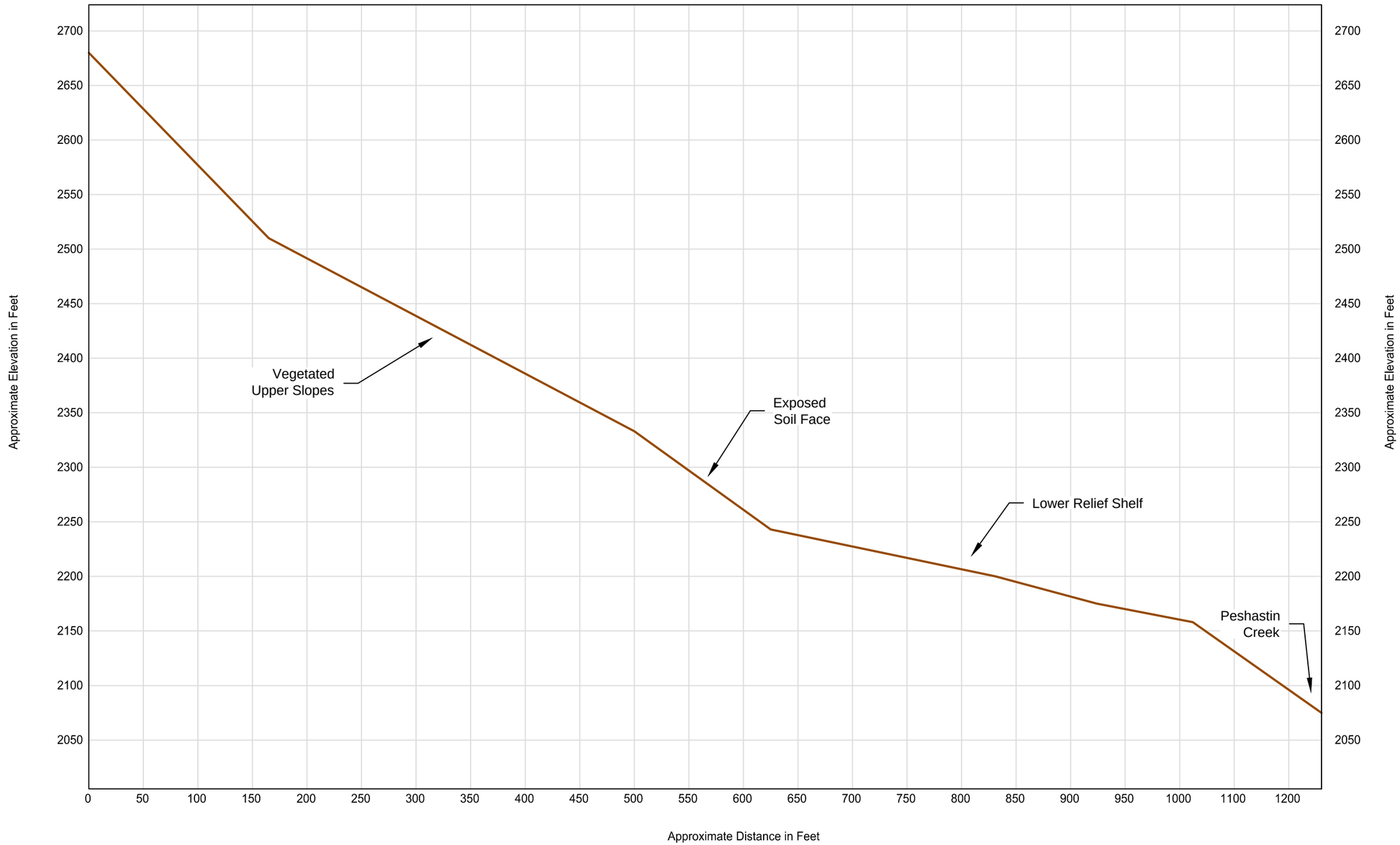

Source: Base map prepared from field sketch dated June 5, 2015.

0 100 200
Horizontal and Verical Scale in Feet

Upper Peshastin Migration Barrier Design 14-1739
Chelan County, Washington

Cross Section A-A'

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Figure
3

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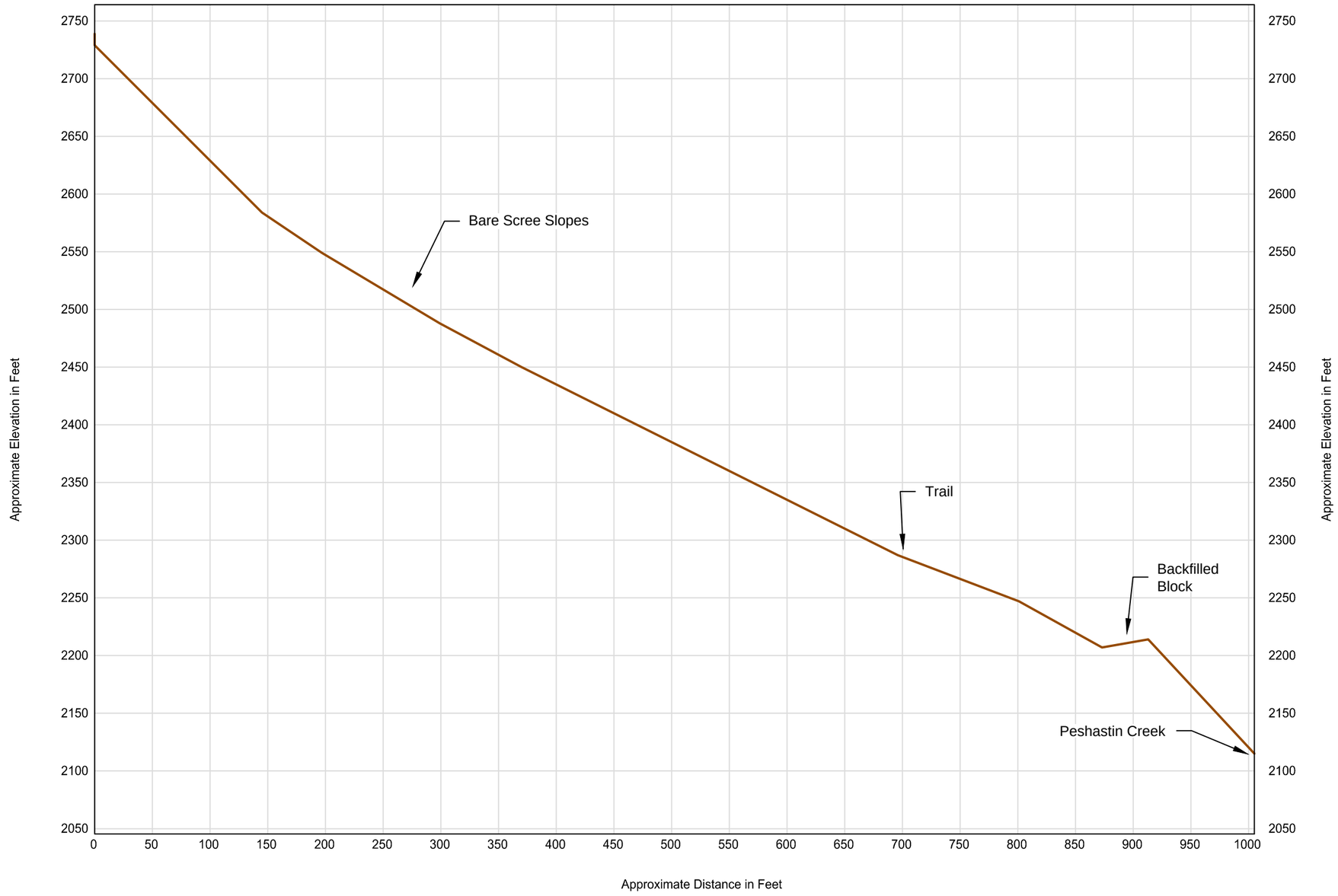

Source: Base map prepared from field sketch dated June 5, 2015.

0 100 200
Horizontal and Verical Scale in Feet

Upper Peshastin Migration Barrier Design 14-1739
Chelan County, Washington

Cross Section B-B'

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Figure
4

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APPENDIX A
Site Photographs

Photograph A-1

Photograph A-2

Photograph A-3

Photograph A-4

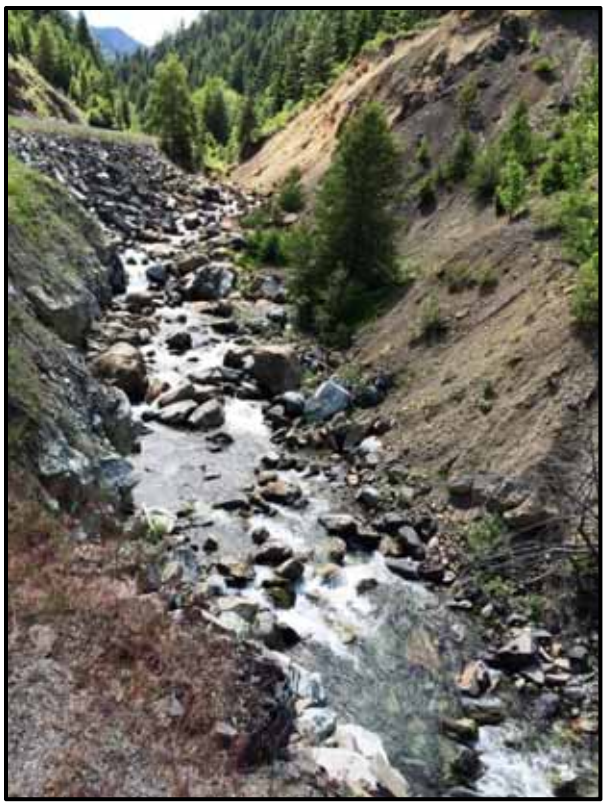
Photograph A-5

Photograph A-6

Photograph A-7

Photograph A-8

Photograph A-9



Photograph A-10

Photograph A-11

Photograph A-12