UPPER PESHASTIN BARRIER CONCEPTUAL DESIGN
PROJECT # 14-1739

FINAL PROJECT REPORT

Prepared for

CCNRD

Prepared by

Waterfall Engineering

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1 INTRODUCTION

Peshastin Creek, from RM 10.4 to 10.6 is believed to be limiting upstream fish passage success to spawning habitat. Spawning distribution and timing data, as well as field observations, suggest that landslide activity in combination with a confined channel created by SR 97 above the Ruby Creek confluence may be contributing to channel conditions which create poor fish passage at low flows, thus inhibiting access to high quality spawning areas and delaying the run timing of fish. The slide has been stable enough the last 20 years to maintain a channel but aggradation of the channel in the form or large boulders has resulted in a slowly steepening of the channel slope, increased turbulence and a lack of pools for fish to hold.

Upper Peshastin Creek and tributaries above this reach provide diverse habitat types and substantial low gradient spawning habitat. The creek channel in this reach is on land owned by the USFS and WSDOT (SR 97 right of way). Chelan County parcel maps show the existing creek centerline as the approximate boundary. Road building, in particular the construction of US 97 in 1956 has altered the river corridor through channel straightening, levee construction, bank armoring, vegetation clearing and large wood removal. Road construction throughout the watershed has contributed to a 70% potential increase in drainage network resulting in increased peak flows and reduced summer low flows (Peshastin Watershed Assessment, 1999). These problems have been exacerbated in this reach by the failure of the slope above the reach on USFS road 7312 (The Ruby Slide), and Washington State Department of Transportation repairs to this stretch of US 97. The resulting channel is confined between vertical wire walls and riprap.

Spawning surveys conducted by WDFW throughout the Wenatchee basin from 2004 to 2010 shows that steelhead spawning in Peshastin Creek contributes significantly to the basin as a whole. In 2010 Peshastin Creek had 12.2% of all the steelhead redds located in the Wenatchee sub basin (Hillman et al. 2011). The majority of the spawning is distributed in the lower Peshastin between RM 3 to 6.5. In the upper Peshastin steelhead show a pattern of concentrated spawning between Ingalls and Ruby Creek with dispersed spawning beyond the project site and in Tronsen Creek (see Figure 1).

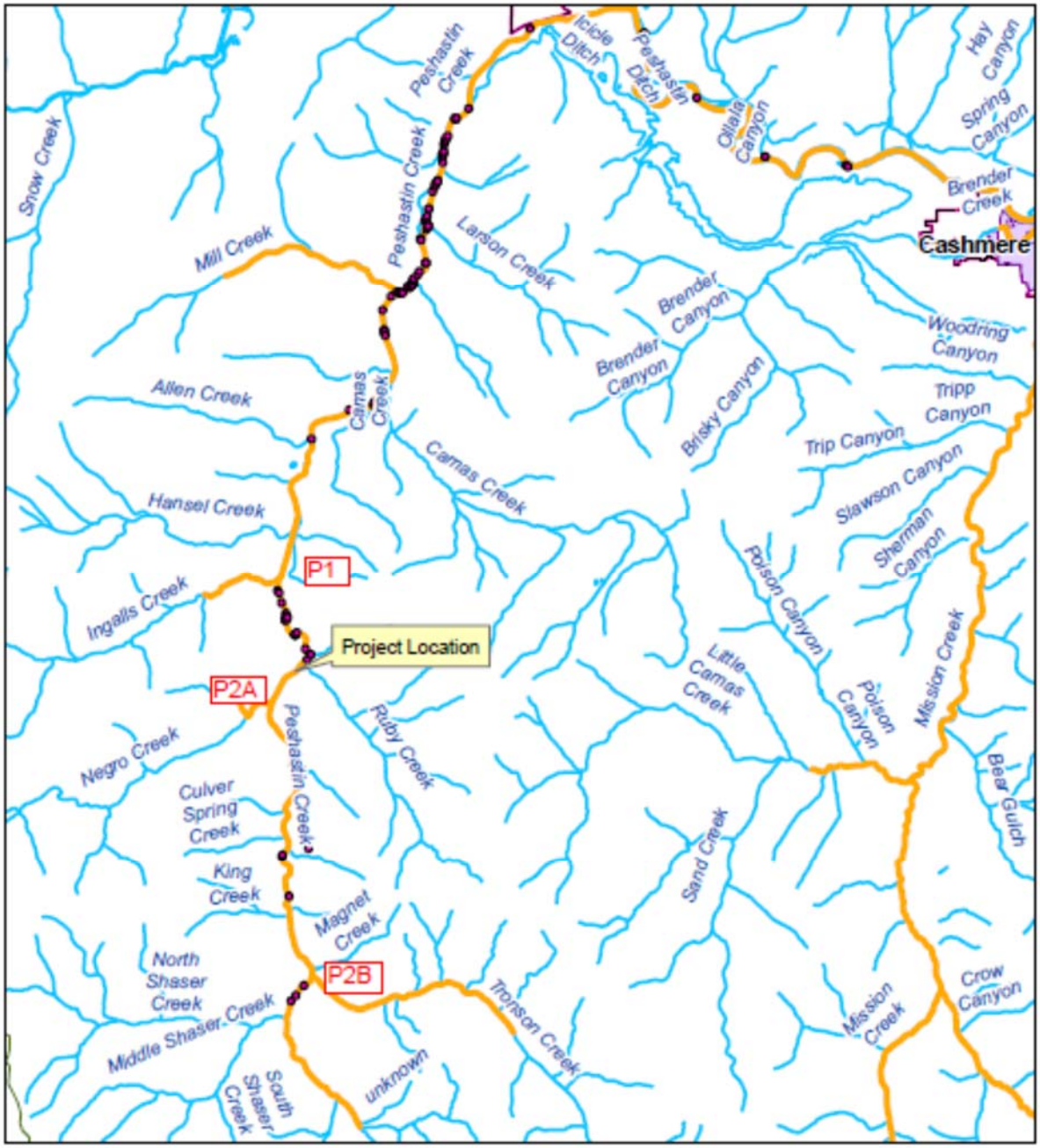

Figure 1 – Steelhead Distribution and Spawning Redds (2005 – 2012). Red dots denote redds, yellow line is distribution, Cram, 2014.

This is Phase One of a proposed three phase project. Phase 2 will be the development of preliminary and final designs and Phase 3 construction. The goal of the overall project is to improve steelhead access to the upper reaches of Peshastin Creek. Project objectives for Phase One include, identifying species of fish, size range and migration timing, collect data including, topographical survey, water surface elevations, geomorphic conditions and velocities, develop a

hydraulic model which can provide velocities and depths, calculate fish passability, develop conceptual designs and cost estimates based on the passage assessment and geomorphic assessment and stakeholder input and select a preferred alternative.

2 SITE DATA COLLECTION AND SURVEY

Two topographic surveys were conducted. The horizontal and vertical datum was assumed (Northing 6000, Easting 4000 and Vertical 1000). The first survey was done on November 2, 2015 at a flow of 60 cfs. Some of the deep pools were difficult to reach and the intent was to return in summer 2016 to complete detailed low flow portions of the survey. On November 17, 2015 and December 9, 2015 the site experienced floods at approximately the 15 year peak flood event. Based on observations from a March 2, 2016 field trip comparing photos it became apparent the bed has shifted as much as 4 feet vertically in some areas. Several major boulders used as reference points had moved and the drop/turbulence in some areas was very different. A second survey was completed on July 15, 2016. The flow was only 15 cfs. The focus of the survey was to redo the changed portions and extend the survey further downstream.

3 FISH MIGRATION TIMING

Fish migration timing in Peshastin Creek has been reported by Andonaegui, 2001. For steelhead the spawning life stage is from March to May. For Bull Trout the spawning life stage is September and October. Data was provided by the Washington Department of Fish and Wildlife (WDFW, Cram, 2014), to assess actual movement and passage success. An assessment of data was completed to determine the likley migration timing. During the process, WDFW installed a pit-tag detector just upstream of the Upper Reach (see Photo 1). From March 25 to May 2, 2016; 17 Steelhead were detected moving upstream. Flows ranged from 150 to 313 cfs (at Ruby Slide based on correlation with Greenbridge Figure 4), during this time period. Photo 10 shows the three reaches at flows of 280 cfs.

Redd counts provided by WDFW (Cram, 2014) is summarized in Figure 2. Redd counts in Figure 2, are for all the steelhead in Peshastin Creek. The intent was to get a big picture of upstream fish movement. Redd counts in Peshastin Creek were recorded based on four reaches (see Table 1). It is difficult to decifer distinct dates and flows when fish could not pass, but the general concensus by regional fisheries biologists is passage is very poor at low flow. Reach P2B is above the Ruby Slide area. Redds observed in this reach were plotted relative to flow in

an attemp to understand if there was a preference or flow which provided pasage (see Figure 3). The flow used was calculated as the average of flows for the previous seven days from the observation at the Greenbridge gaging site, then modified based on the correlation dipected in Figure 4. The plot in Figure 3, lacks a significant trend without removing outlier data points.

Reach	Description
P1	Mouth to Ingalls Creek
P2A	Ingalls Creek to Etienne Creek
P2B	Etienne Creek to Scotty and Tronson Creeks
P2C	?

Table 1 – Reach descriptions and locations for Steelhead Redd counts, from Cram (2014).

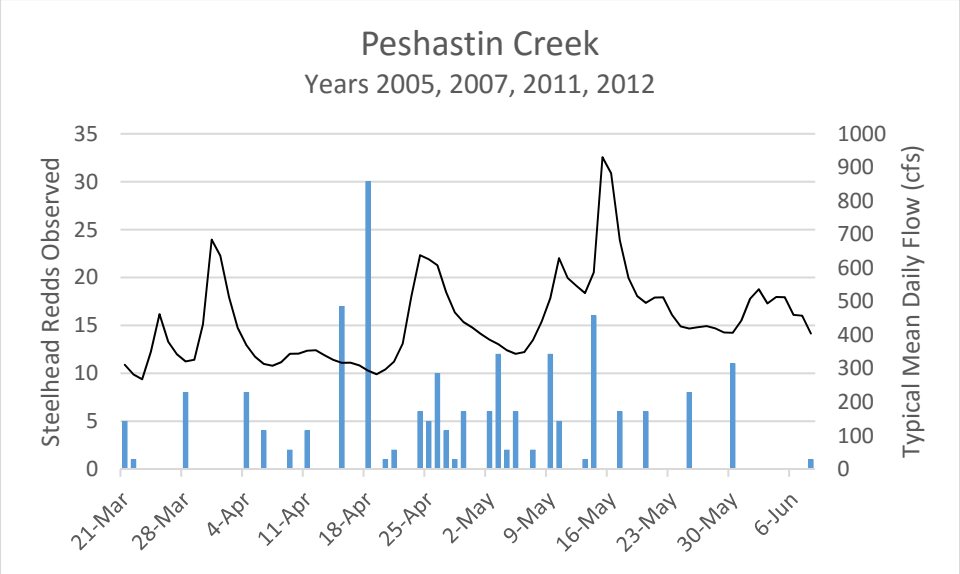

Figure 2 – Summary of observed Steelhead Redds from data provided by Cram, 2014. Plot of mean daily flows at Greenbridge is for the same years just for reference.

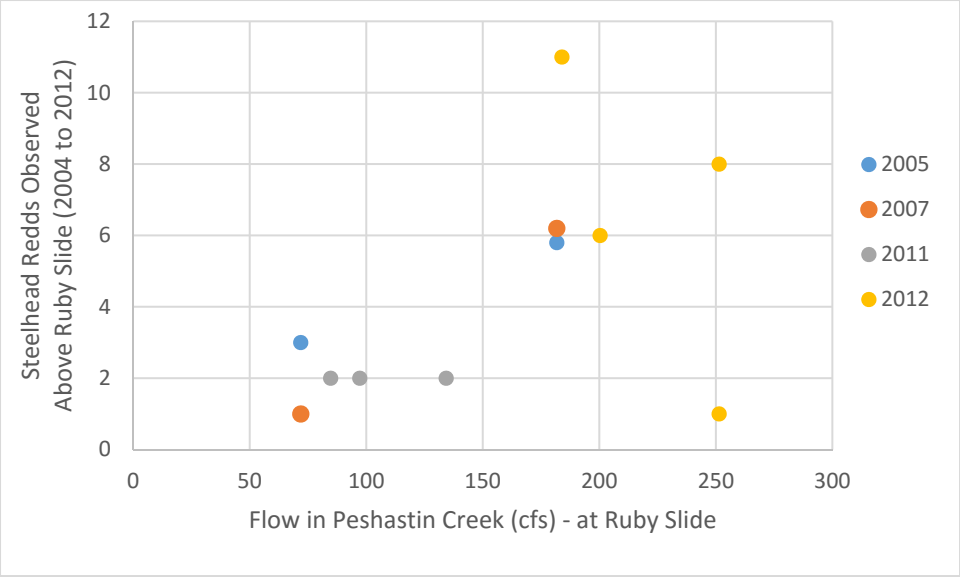

Figure 3 – Steelhead Redds Observed in Reach P2B, above the Ruby Slide versus flow. The flow was calculated by averaging the seven days prior to redd observation.

4 HYDROLOGY

The hydrology of Peshastin Creek was analyzed to determine which flows to assess fish passage and channel stability. The Washington State Department of Ecology has been operating a stream gage at RM 2.5 on Peshastin Creek since 2002 (14 years). The basin area above this gage is 130.5 square miles. Flows vary annually as shown in Figure 5. March, April and May are the most consistent months of flow as the upper basin is driven by snow melt. The US EPA has reported from (USGS, 2016) that in the Pacific Northwest low flows have generally decreased in parts of the Southeast and the Pacific Northwest (that is, streams are carrying less water than before), and in parts of the country with substantial snowmelt, winter-spring runoff is happening at least five days earlier than in the mid-20th century at most gauges, and that the largest changes have occurred in the Pacific Northwest and Northeast. Peak flows can occur anytime of the year. They are rainfall driven in the fall months and snow melt driven in the spring. Summer flows get very low due to irrigation diversions in the lower river.

To develop flows above Ruby Creek, a stream gaging device was established at the culvert outlet, just above Ruby Creek. Data was collected from 2/25/2015 to 11/12/2015. Six flow measurements were made from 6 to 206 cfs, and a rating curve was developed. The data was then compared to flows at the Greenbridge site. The resulting comparison is shown in Figure 4.

A third order polynomial equation was developed to best fit the data. Flows correlated well during the late fall, winter and spring runoff events, but not in the summer when irrigation diversions modify the natural hydrology downstream.

To assess fish passage mean daily flows from 2004 to 2014 were analyzed and monthly flow duration curves developed (see Figure 6). Flows were then selected to assess fish passage during the months of March through May at the 90, 50 and 10 percent exceedance flow (30, 100 and 210 cfs, respectively). The percent exceedance numbers used are based on similar values used in past fish passage assessment projects by the author (Powers, 2009).

In addition, for an assessment of the overall channel hydraulics, peak flood flows were analyzed. The calculated 10 year and 100 year peak flood flows from the Greenbridge data are 3611 cfs and 6441 cfs respectively. Using the stream correlation information from the Rudy Slide site the respective 10 year and 100 year peak flood flows for Peshastin Creek at the Ruby Slide are 801 and 1367 cfs.

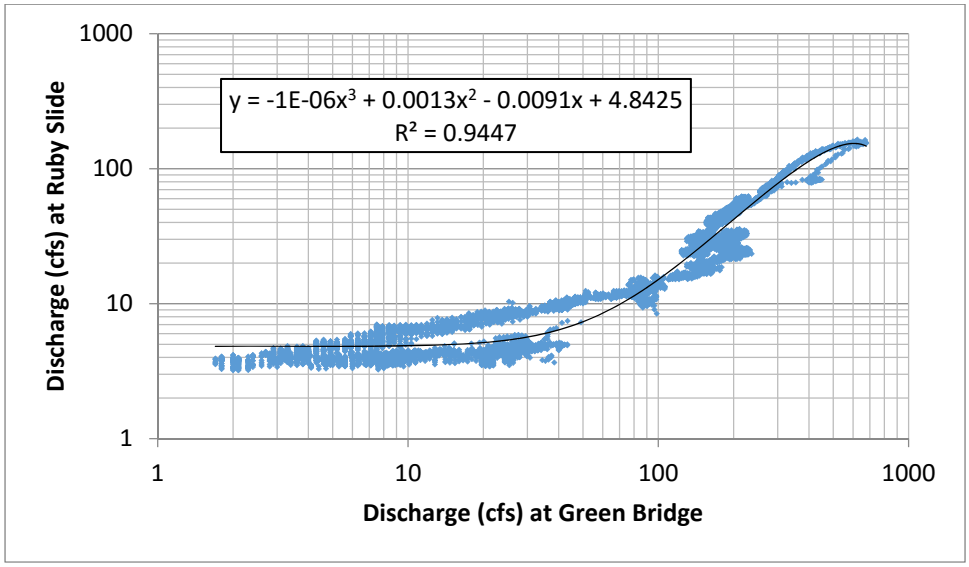

Figure 4 – Mean Daily flows gaged at the Ruby Slide site compared to flows at the Greenbridge.

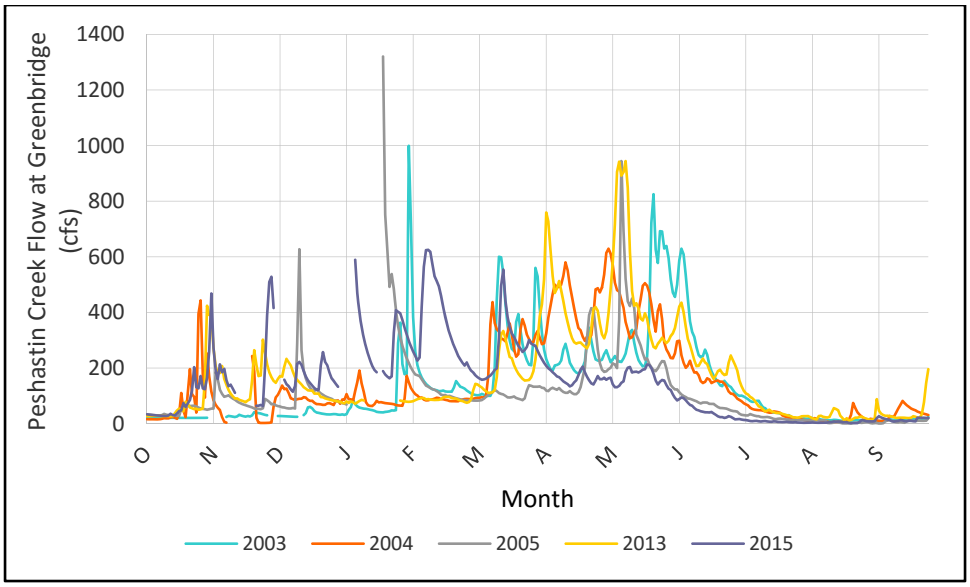

Figure 5 – Peshastin Creek mean daily flows for a random selection of years.

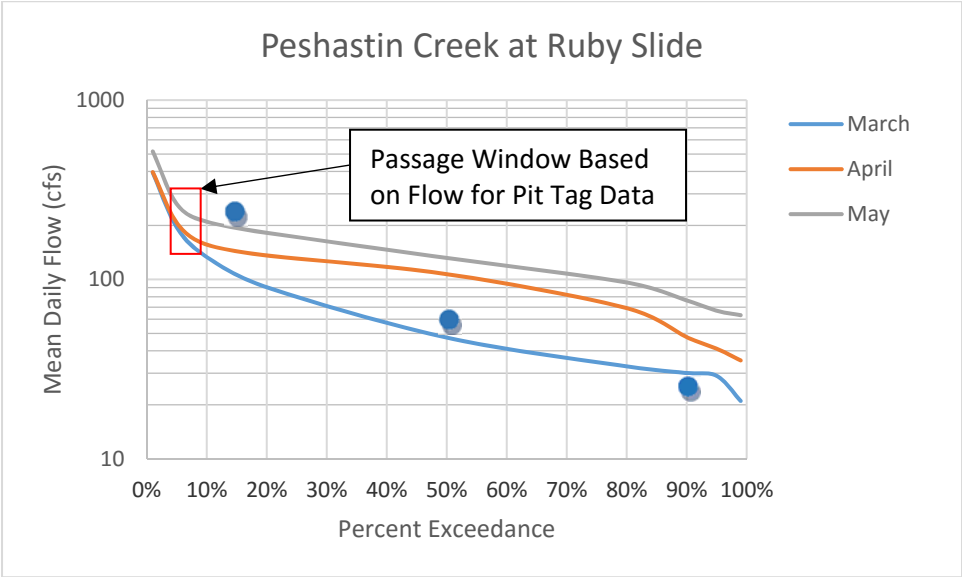

Figure 6 – Monthly flow duration curves based on mean daily flows for March, April and May. Stream flows were calculated per the regression equation from Figure 4.

5 SITE DESCRIPTION

The lower nine miles of Peshastin Creek is generally wide and unconfined, but at RM 9.2 the creek enters a narrow floodplain defined by canyon walls and State Route 97. At RM 10.4 (just upstream of Ruby Creek) there is a large slide on the left canyon wall (Figure 7). A detailed geologic report of the site history and current conditions in provided in Appendix B. The report documents that the landslide has been active for the last 95 years, and a series of highway

relocation and channelization projects have occurred. The most recent work was in 1996. Since that time the overall landslide has been stable but slope and toe erosion has occurred (see Photo 2).

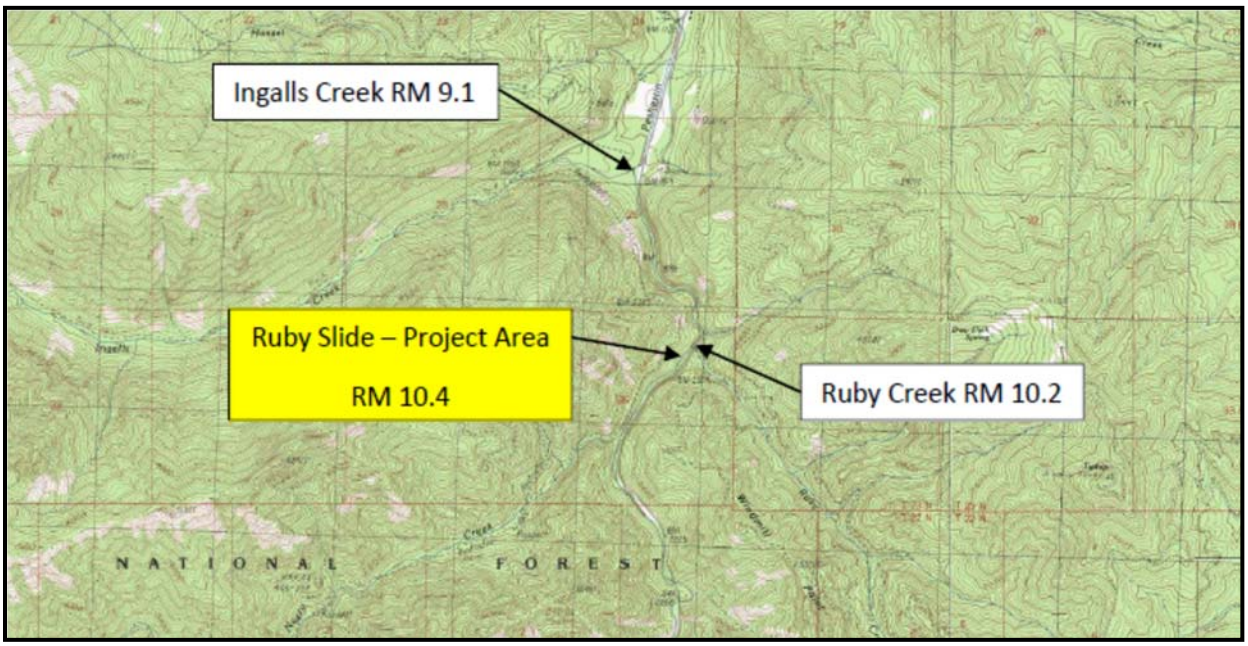

Figure 7 – USGS Topo Map of Peshastin Creek Project Area.

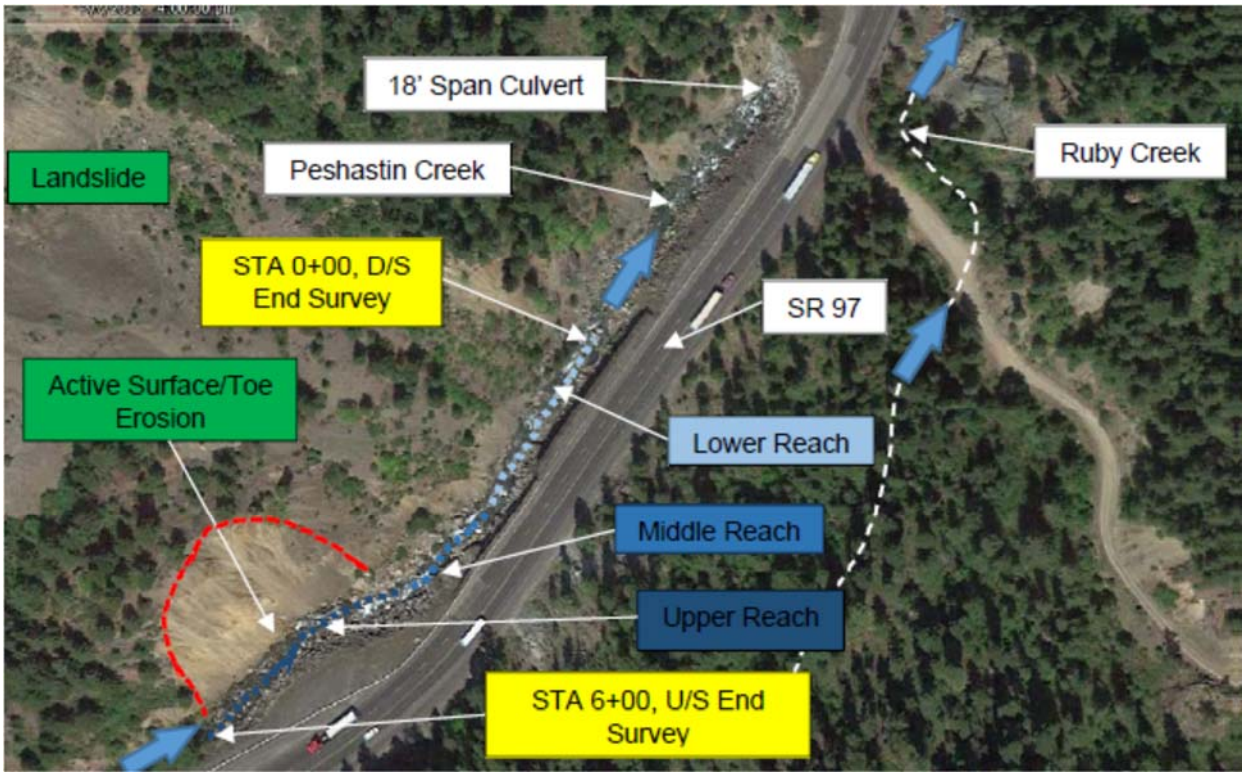

Figure 8 – Description of project site.

The study site is shown in Figure 8. Initially the extent of the site in terms of the actual location of fish passage problems was identified as above the SR 97 culvert to just above the slide. To verify the site location Peshastin Creek was surveyed for a length of 3000 feet from upstream of the slide and through three culverts under SR 97 (see Photo 4 to Photo 5). Upstream of the slide area, the channel is confined but the gradient is much less. Through the slide area the gradient increases and there are two locations with drops in the 4 to 5 feet range (Falls 1 and 2, see Photo 6). Falls 1 is more distinct as the location is formed by a bedrock outcropping on the right bank. Downstream of Falls 1 there is a short high gradient section and then the channel widens and the gradient is reduced all the way to the culvert under SR 97 (see Figure 9). This culvert is 18 feet wide and 185 feet long. Velocities are very low with good depth inside the culvert. This seems like ideal resting habitat for fish migrating upstream (deep pools, low velocity). Ruby Creek discharges into the tailout of this culvert. Downstream of this culvert the channel gradient, width and substrate appears suitable for fish passage at medium to high flows. Extreme low flow fish passage may always be a problem in this reach due to a lack of depth. The channel confinement and substrate size does not allow deep pools to develop. Based on this assessment it was decided to focus the survey and passage assessment work on a 600 foot

reach (see Figure 8). For purposes of describing the site three reaches were identified, the Upper, Middle and Lower Reach.

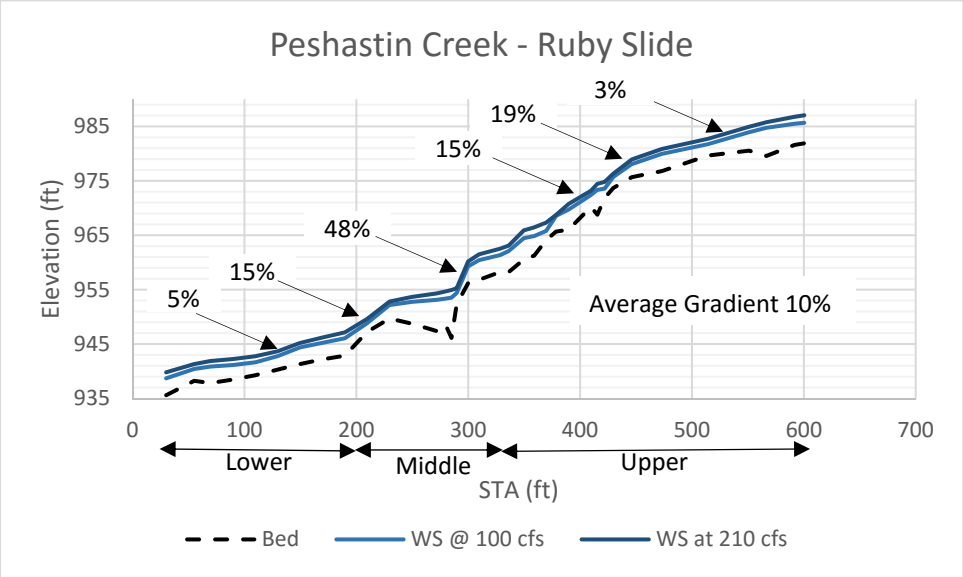

Figure 9 – Stream profile through project site.

Lower Reach

The lower reach starts 400 feet upstream of the SR 97 culvert and extends for a length of 190 feet. The gradient averages 4 percent. This section of channel is very similar to creek segments further downstream between the culverts. The channel width averages 25 feet. The channel is confined on the left bank by the toe of the slide and the right bank by the retaining wall of SR 97 (see Photo 7).

Middle Reach

This section starts at the upstream end of the lower reach and extends 100 feet upstream. The downstream portion is a 15 percent channel, transitions into a 7 foot deep plunge pool and then a falls with a 6.1 foot drop. The left bank of the channel is the toe of the slide and the right bank is a bedrock outcropping and 1:1 riprap slope. Channel width is 15 to 20 feet (see Photo 8).

Upper Reach

The upper reach is a steep 15 percent slope for 100 feet than steepens to 19 percent before leveling out at 3 percent. The upper portion of this reach is the most active in terms of boulders

entering the channel from the slide. A combination of heavy rain and high water create surface erosion and toe erosion. As boulders are exposed they fall into the channel. The channel width is 25 feet (see Photo 9).

6 HYDRAULIC MODELING RESULTS

A one-dimensional hydraulic model was developed for the site using HEC RAS Version 5.0.3. The reach length modeled was 600 feet. Flows were modeled from 30 to 1367 cfs. The model was calibrated at measured site flows and water surface elevations of 250 and 920 cfs. A Manning's n of 0.2 was used to match the measured water surface elevations. Detailed output is provided in Appendix D.

At 250 cfs, the maximum water depth varies 2 to 5 feet, with velocities ranging from 3 to 8 fps. At the 10-year estimated peak flood event (801 cfs), the maximum channel depth varies from 5 to 11 feet with average channel velocities ranging from 5 to 10 fps. At the estimated 100-year peak flood event velocities average 6 to 11 fps. Channel shear stress values are shown in Figure 10. The combination of slope and water depth drive the high shear stress values. These can be reduced by 1) decreasing the hydraulic gradient and 2) decreasing the water depth by widening the channel. Hydraulic gradients for the site is shown in Figure 11.

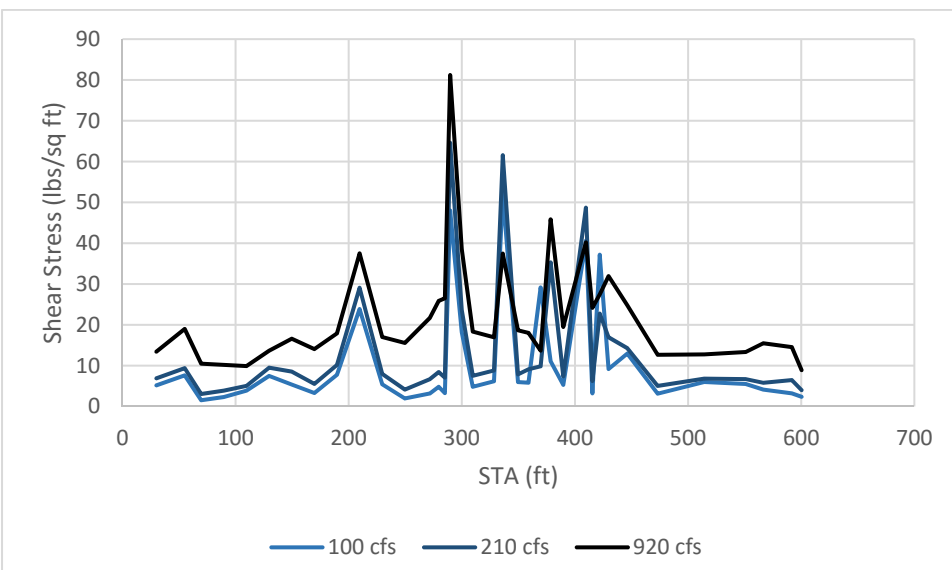

Figure 10 – Channel shear stress values from HEC RAS Model.

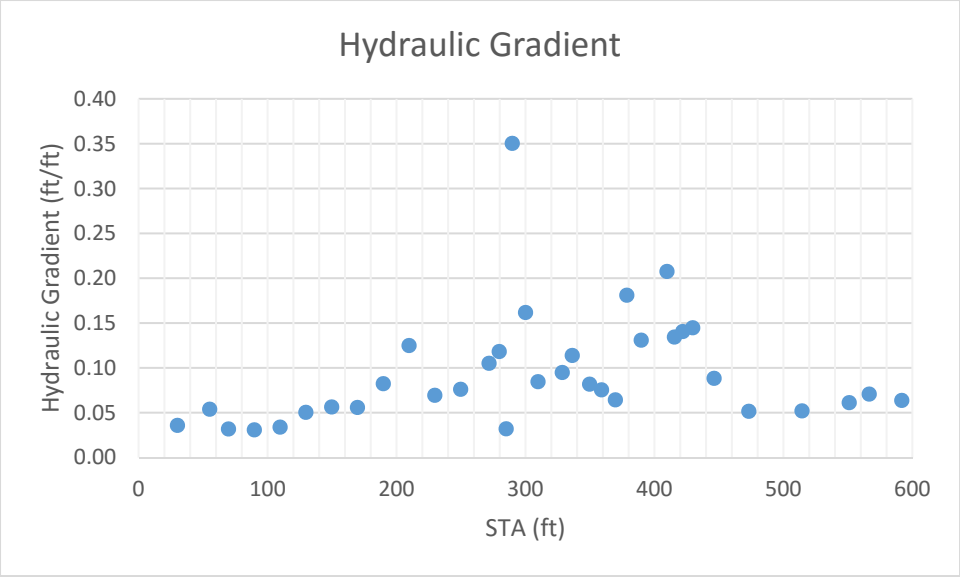

Figure 11 – Hydraulic gradient for the assessment reach. Values from STA 0 to 200 are typical for this reach of Peshastin Creek.

7 FISH PASSAGE ASSESSMENT

Fish passage through natural and disturbed channels should be based on an assessment of the stream and watershed condition, comparing drop, velocity and turbulence to fish jumping and swimming abilities and local knowledge and actual documentation of fish passage from red counts and tagging studies. For this site, since redds have been counted upstream and fish have been detected moving upstream, the intent of the passage assessment is not to look at whether the site is a barrier, but more a degree of difficulty rating based on site conditions. From the hydrology section it was determined to assess fish passage at flows of 30, 100 and 210 cfs. A summary of the fish passage assessment is shown in Figure 14. The following is an explanation for the passage rating.

<u>Low Flow - 30 cfs</u>

At 30 cfs passage was assessed as good in the lower reach. There is a good step/pool profile and the reach seems stable enough in terms of slope, sediment size and water depth to provide passage routes for adult fish. Channel conditions for fish passage in the lower reach are similar to downstream sections of Peshastin Creek. In the middle reach a combination of gradient increase and sediment size increase (boulders) creates fair to poor fish passage conditions. There is a good plunge pool downstream of the 6 foot drop, but the crest of the falls consists of

unstable boulders and has poor landing/resting conditions for fish and very shallow depths (see Photo 11). During the one year of monitoring this site for passage conditions it appeared much worse after some of the boulders had moved due to a lack of pools, passage routes and turbulence. In the Upper Reach the downstream section passage is rated as poor, again due to a lack or water depth, pools and an undefined thalweg for fish to move upstream. The slope varies 15 to 19 percent. For fish to pass they would have to swim through a shallow path between boulders, turning 90 degrees on top of a boulder, change direction and burst back into another slot. After 100 feet the gradient drops back to 3 percent and passage appears good, similar to downstream.

Medium Flow – 100 cfs

At 100 cfs, conditions for passage are similar to 30 cfs, with the exception that more water creates more depth and alternative fish passage routes. Velocities through the lower and upper reaches range from 2 to 4 fps, and 2 to 6 fps in the middle reach. Velocity does not appear to be a problem at this flow at first glance due to the roughness created by the large boulders. It was calculated that a 26 inch long steelhead could pass (see Figure 12). But, due to the size of the boulders and slope, turbulence becomes a problem in confined areas and areas with drops.

Turbulence was assessed in terms of drop (spill into a plunge pool) and velocity relative to slope. Two equations have been used to assess turbulence for fish passage. In a pool, where fish leap to pass the following equation has been used:

$$4xPVF = \gamma xQxH$$ (Bates, 1991 and NOAA 2008)

Where, PVF = Pool Volume Factor, γ = unit weight of water, Q = discharge (cfs) and H = hydraulic drop (ft). A PVF of 4 is appropriate for a pool and weir fishway with concrete walls. Based on recent work by Powers (2009), for a pool in a natural waterfall a PVF of 8 may indicate good passage whereas a PVF of 16 or higher may indicate poor passage. For Falls 1 at STA 2+79, the PVF was calculated at 9, 16 and 24 respectively for flows of 30, 100 and 210 cfs. The high values at 210 cfs are created by the narrow and steep channel downstream where the pool volume does not increase significantly (see Photo 12).

To assess turbulence in a steep channel where fish are attempting to pass by swimming (versus leaping), the following equation has been used:

$$\boldsymbol{EDF = SxVx\gamma}$$

Where, EDF = Energy Dissipation Factor, S = channel slope (ft/ft), V is velocity (fps) and γ = unit weight of water. WDFW recently developed guidance for EDF relative to steep roughened channel designs (Barnard, 2013). Figure 13 is a plot of EDF at 100 and 210 cfs showing stations above the design curve which exceed the maximum design recommendation. It should be pointed out that these calculations are somewhat subjective and good data points on actual roughened channels which are barriers based on turbulence is not well documented. Fish size is also an important factor when considering the effect of turbulence on fish passage success.

<u>High Flow – 210 cfs</u>

At high flow fish passage is rated as poor in the middle and upper reaches due to velocity and turbulence. Velocities through the lower and upper reaches range from 3 to 5 fps, and 3 to 8 fps in the middle reach. Velocity does appear to be a problem, it was calculated that a 26 inch long steelhead could not pass (see Figure 12). But again, turbulence is a concern for passage. This is somewhat contrary to recent data from pit tag studies where 17 Steelhead were found moving upstream at an average flow of 219 cfs during the time period from March 25 to May 2, 2016. Flows actually ranged from 160 to 270 cfs during this time period. It is likely there are pockets of low velocity water and low turbulence along the right bank riprap wall. This wall and the channel toe appear to be much more stable compared to the left channel toe.

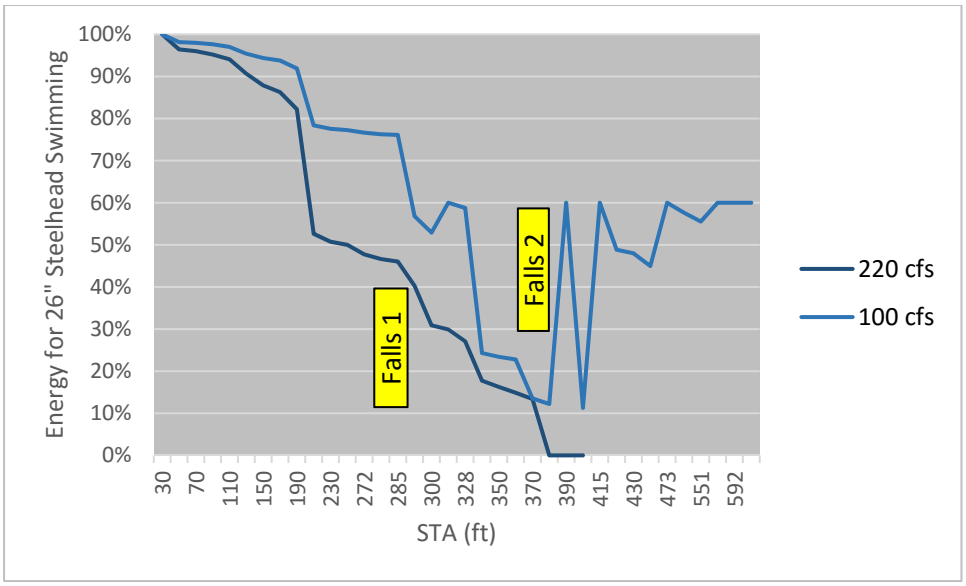

Figure 12 – Energy calculations for a 26 inch long Steelhead attempting to pass the reach. At 100 cfs a fish successfully passes with 60 percent energy left. At 220 cfs the fish runs out of energy just upstream of falls 2.

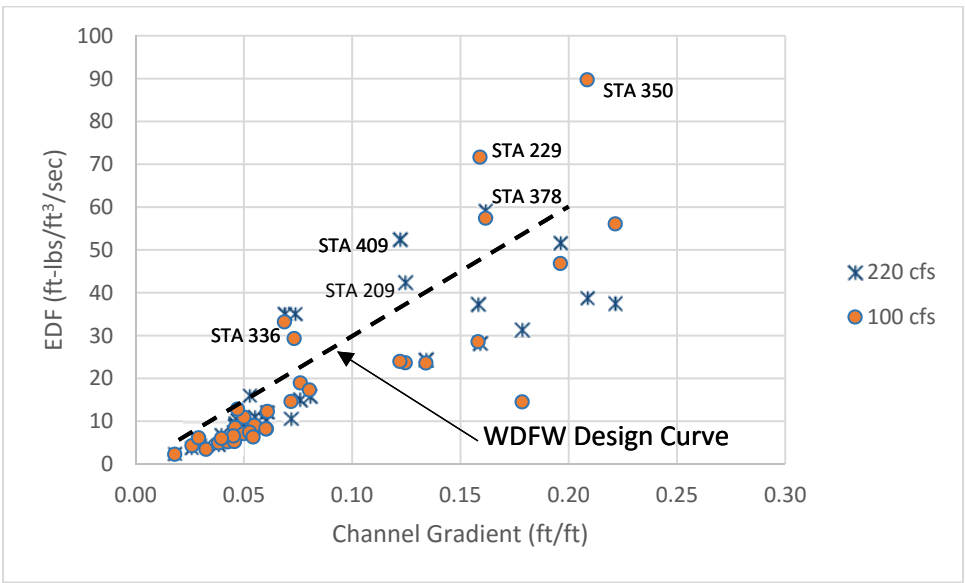

Figure 13 – EDF as a function of channel gradient per WDFW Water Crossing Guidelines. Points above the dashed line with STA locations indicate high levels of turbulence beyond the recommended maximum design range.

	Channel Distance (ft)	Description
Entire Reach	600	
Lower Reach	190	Starting 400' US Culvert Under SR 97, Slope Average 4%
Middle Reach	100	Section of 15% Slope, then plunge pool and falls and 8' Drop
Upper Reach	170	Steep 15% slope increasing to 19% before leveling out at 3%

Peshastin Creek - Ruby Slide

Flow at Ruby Creek Slide (cfs)	Percent of Time Flow is Exceeded	Lower Reach 190 ft	Middle Reach 100 ft		Upper Reach 170 ft	
30	90	G	F	P	P	G
100	50	G	F		F	
210	10	F	P		P	

RATINGS
Good = G
Fair = F
Poor = P
Barrier = B

Figure 14 – Summary of Fish Passage Assessment. For 30 cfs, the assessment is split in the Middle and Upper Reaches. For the Middle Reach the Fair rating is for the 15% slope downstream and the poor is for Falls 1. Similar for the Upper Reach, the Poor rating is for the steep 15 to 19% section and the Good is for the 3% section upstream.

8 CONCEPTUAL DESIGN OPTIONS

Developing conceptual design options for this reach of Peshastin Creek in very challenging due the slope stability issues, confined channel and the gradient. The overall geomorphic and anthropogenic processes creating the passage problem can be boiled down to two items, 1) channel aggradation from the frequent input of sediment/large boulders from the active slide area due to the confinement between the riprap revetment constructed to protect the highway, and 2) the bedrock knob downstream which has confined the channel vertically and horizontally and reduces the potential for regrade. These two items create increased slope downstream, resulting in decreased pool depth at low flow and increased turbulence at higher flows. The channel cannot create scour/pools due to the size and number of boulders in the channel which have accumulated over time. Comparing photo points at STA 3+50 (Falls 2) the right side of the channel appears more stable than the left. Fish Passage work along the right toe to remove boulders and create pools would have more longevity than work along the left bank.

Based on the fish passage assessment the following options were developed. Options 2 through 5 are all based on a concept of either raising or lowering the channel to achieve a gradient where a roughened channel can be constructed for fish passage. Design guidance for the roughened channels are taken from experience of the design team and from the WDFW Water Crossings Manual section on Roughened Channels. The basic channel proposed would be 30 to 35 feet wide with a slope ranging from 8 to 10 percent. The largest material size would be 4 to 5 foot diameter rocks, with a medium rock size of 18 to 24 inches. A subgrade cutoff wall with sheet pile/concrete or grouted rock may be needed in some areas to seal the channel for low flow. Voids would be filled with 12 inch minus gravel material. Construction access and flood risk issues will need to be discussed if any design options move forward to a preliminary design.

Option 0

Option 0 would be status quo. Some fish do currently pass upstream. The overall gradient through the study reach is 8 percent, but local areas greater than 15 percent create passage problems at low and high flow. The steeper slope sections have developed due to channel aggradation upstream with large boulders from the landslide and constrictions, and bedrock outcroppings which create down cutting and scour. These problems have been developing since 1996. The problems with fish passage have developed due to re-channelization of the creek once the highway was moved in 1960. The condition will continue to affect fish passage and likely get worse over time in the form of increased channel slope dominated by large boulders which creates low flow passage problems and excessive turbulence at high flow.

Option 1

Option 1 would create a low flow fish passage channel along the right toe of the existing rock revetment in the upper and middle reaches. The basic concept of this design is that the right toe of the channel appears stable and the left toe is aggrading from slope and toe erosion. Large boulders would be removed and other boulders broken to create pools. The material would be deposited on top and within a log revetment toe wall. Development of the channel should occur over a three to four year period to monitor changes in the bed and make adjustments as needed. A design sketch and cost estimate is provided in Appendix E. The main cost for this

option is the construction of an access road down the face of the riprap revetment. This is needed for rock removal and repositioning.

Option 2 and 3

Option 2 and 3 would address fish passage mainly in the middle reach (Falls 1). An 8 or 10 percent sloped roughened channel would be constructed. The channel length would vary from 150 to 260 feet. The channel width in some areas would be increased from 15 to 25 feet. The falls and plunge pool would be eliminated. The local elevation of the 100-year flood would increase. This option would not address the passage issues in the upper reach, but would provide good passage past Falls 1 and reduce the distance fish have to swim to pass through Falls 2. Either of these Options would work well also with Option 1. Construction access issues need to be discussed with the USFS and WSDOT. As the bed of the channel is raised, the designs need to consider bank erosion and scour along both banks (slide and revetment of west shoulder of SR 97). A channel profile is provided in Appendix E.

Option 4

This option would raise the entire channel for a length of 390 feet. The channel slope would be 10 percent. As the bed of the channel is raised, the designs need to consider bank erosion and scour along both banks (slide and revetment of west shoulder of SR 97). Filling and raising the channel has the effect of widening which will reduce depth and shear stress. A rock riprap revetment along the left toe 6 to 8 feet high may be needed for the 100 year flood. The channel would be wider and allow some deposition of slope material without (directly impacting the channel in the short term.

Option 5

This option would move (cut) the material from the upper reach and (fill) down into the lower reach, regrade the channel to form an 8 percent step/pool roughened channel for a length of 590 feet. Since lowering the upper reach would result in increased risk to toe erosion in the active slide area a log revetment wall is proposed. The wall would consist of logs bolted together and backfilled with excavated material from the channel. The concept would be that the wall given the height and width would catch material unraveling from the slope for 15 to 20 years before it

filled up and started to enter the creek again. Then, over another 15 to 20 years the material entering the channel would reduce the effectiveness of the design.

Preferred Option

To select a preferred Option more discussion with project stakeholders is needed. At this time the USFS (one of the land owners does not support doing any work due to the risk and project longevity associated with the Options). They have not reviewed Option 1. It is the authors Opinion that a combination of Option 1 and Option 3 would be the approach which is least cost and provides the highest benefit to fish. Option 3 could be reduced in scope depending on the design of Option 1. Cost estimates were developed for each Option and provided in Appendix E and summarized in Table 2. These costs should be used only for comparative purposes and actual construction costs may vary. Two items which are of biggest concern for the design are 1) construction access which needs to be reviewed and discussed with WSDOT, and 2) the final bank conditions of the new channel and the relation to potential areas of concern for further slope instability. The next phase of this project should be a preliminary design working closely in coordination with the USFS and WSDOT. There may be too many significant design issues to resolve to proceed directly to construction.

Design Option	Estimated Cost
1	$105,000
2	$203,000
3	$159,000
4	$358,000
5	$618,000

Table 2 – Conceptual level construction costs for comparison purposes.

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APPENDIX A – SITE PHOTOS

Photo 1 – WDFW Pit Tag Detector location upstream of the slide area.

Photo 2 – Panoramic view of 350 feet of most active portion of slide from May 4, 2016 at 280 cfs.

Photo 4 – SR 97 Culvert downstream of landslide. The culvert is backwatered by a constructed roughened channel downstream.

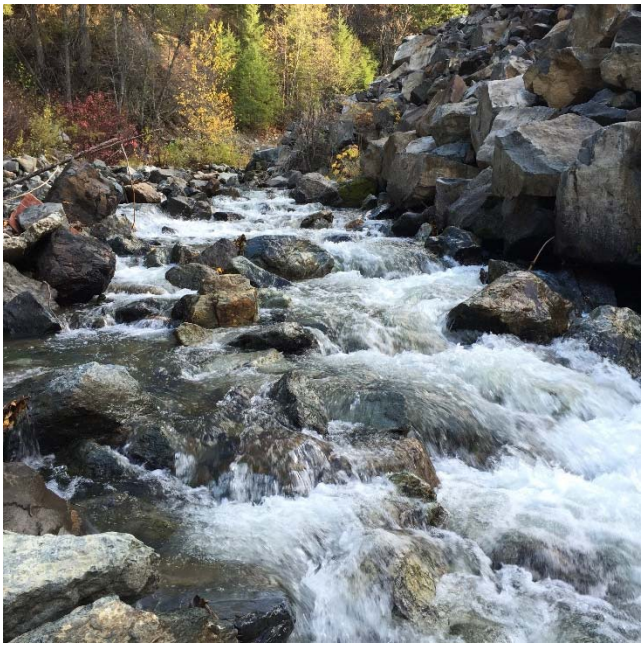


Photo 3 – Roughened Channel downstream of SR 97 Culvert and Ruby Creek.

Photo 5 – Second SR 97 culvert downstream of Ruby Creek.

Photo 6 – View upstream Falls 1 (left) and Falls 2 (right). The drop at the time of survey November 2, 2015 was 4.3' and 4.5' respectively.

Photo 7 – Lower Reach view downstream at 13 cfs. Right bank is confined by wire retaining wall which supports the South Bound lanes of SR 97.

Photo 8 – Falls 1 in Middle Reach. Left photo is 60 cfs from 11/2/2015, right photo is 15 cfs from July 2016. The left photo has painted lines (one foot spacing) on a rock. This rock could not be identified in the right photo.

Photo 9 – Upper Reach: Left photo is 60 cfs from November 2015, right photo is 15 cfs from July 2016.

Photo 10 – From left to right, Lower, Middle and Upper Reaches at 280 cfs (May 4, 2016).

Photo 11 – From left to right, Falls 1 (Middle Reach) and Falls 2 (Upper Reach) at 15 cfs. Shallow depths, a lack of pools and turbulence create poor passage conditions.

Photo 12 – View upstream of Falls 1 (Middle Reach) at 250 cfs showing turbulence in pool from drop.

APPENDIX B – REPORT OF ENGINEERING GEOLOGIC SERVICES – UPPER PESHASTIN MIGRATION BARRIER DESIGN – HART CROWSER, INC. 2015.

APPENDIX C – STAKHOLDER COMMENTS

A stakeholder meeting was on January 17, 2017 at the CCNRD office in Wenatchee. The meeting was attended by Pete Cruickshank and Adrienne Roumasset of the CCNRD, Pat Powers of Waterfall Engineering and Jeremy Cram and Ben Truscott of WDFW. Other stakeholders (WSDOT and USFS) were invited but did not attend. Waterfall Engineering presented the draft report and a discussion pursued to the overall approach and plan for the next steps. There was general agreement to the approach and results of the fish passage analysis. WDFW suggested adding a lower cost design option (now Option 1), to address specific areas within the project site. Given the history of the site and the potential issues with modifying the existing channel it was agreed that communication with WSDOT and the USFS was needed. The CCNRD reached out by email to solicit comments.

The following comments were provided by William Gould of WSDOT by email on 1/23/2017:

We don't have a preferred option however, we are interested in ensuring the roadway prism does not become impacted. Below are the questions and comments concerning these alternatives from our hydraulic and material's offices.

Overall, our concerns are with the long term stability of the highway embankment along with no increase in maintenance. As for the different options, any of them are suitable if it meets these concerns.

An increase in water height would most likely require bank protection per FHWA/WSDOT standards. This would be riprap with freeboard designed to match our rain-on-snow design flow or better.

Here are some questions we request you provide answers to once you are further into the design:

- *The profiles have stationing that I cannot relate that to our culvert. It appears to be about 700' downstream of the falls. So the stationing of the culvert inlet is at -5+50? Do you have inlet elevation of culvert?*
- *The falls are not called out in the profile. Is this at 2+85 to 3+05 and 1+85 to 2+30?*
- *The options do not show bank protection on the highway side. Will there be any? If so, what design flow is this designed for? What type of protection and how high is it designed for?*
- *What are the reductions in velocities and shear stresses for different sized flows for the preferred option? How about the water height increases?*
- *Do you have a sheet that shows the stationing on a plan sheet? This attachment showed the profile, but no plan sheet showing the stationing. My concerns are about option NO 3 where you are proposing using sheet piles/concrete cutoff wall in conjunction with a grouted boulder cutoff wall all along the slide side of the stream and how these will this impact the road prism during certain flows or slope movement.*

Eventually, we would like to review the hydraulic model and/or calculations and also keep for our records for future work that may be needed to be done by WSDOT.

The following are answers to the above questions:
The culvert is 450 feet downstream of the end of the survey. The culvert invert was not surveyed. Falls 1 and 2 are now shown on the profiles. The roughened channel material would extend up the slopes on both sides. The current estimated 100 year flood depth is about 8 to 9 feet. This would likely be reduced as the channel width increases. The design flow for fish passage would likely be 210 cfs, but 100 year for channel stability. At this conceptual level the channel width would increase, depth and shear stress decrease. Water would flow against the bank higher than currently but as noted above these areas will be part of the roughened channel design. STA has been added to the plan set. The boulder cutoff wall is just a concept at this point in the design. At a maximum the height of the cutoff wall would be 4 to 6 feet.

Comments from the USFS Jeffrey Rivera, District Ranger:

USDA United States Department of Agriculture
Forest Service
Okanogan-Wenatchee National Forest
Wenatchee River Ranger District
22976 State Highway 207
Leavenworth, WA 98826
509-548-2550
Fax: 509-548-5817

File Code: 2600; 2500
Date: February 14, 2017

Pete Cruickshank
Natural Resources Specialist
Chelan County Natural Resources Department
411 Washington Ave, Office #201
Wenatchee, Wa 98801

Dear Mr. Cruickshank,

Thank You for sharing the Peshastin Migration Barrier Conceptual Design Draft Report (Waterfall Engineering 2017) and diagrams with the Forest Service, the earlier report Upper Peshastin Migration Barrier Design 14-1739 (HartCrowser, 2015), and the opportunity to inform you of our preferred alternative and provide comments.

As mentioned in our earlier correspondence (Aug 21, 2015), the Forest Service is concerned about the stability of the adjacent slope and the potential lifespan/efficacy of any instream work.

After reviewing the most recent documentation, our concerns and interpretation of the site conditions have not changed.

Accordingly, the only option the Forest Service supports is Option 1 (status quo, no action).

As noted in the HartCrowser report, the likelihood of failure of the unstable block in the Southern Section of the landslide is interpreted to be high. The report also notes that the most recent instances of movement were associated with either construction activities, or flooding events. The recurrence interval was estimated to be at the decadal scale (14-28 yrs). Their assessment of effects of another failure event would be significant sediment delivery to the stream (on the order of thousands of cubic yards).

Given that the proposed alternatives would involve raising bed elevations, while perhaps decreasing velocity and turbulence in the reach, our interpretation is that such actions would also increase the chance of a modified channel impinging on the active slide, potentially leading to continued ravel or re-activation of the slide block. The Forest Service notes that in the Upper Peshastin Barrier Conceptual Design report, observations indicate an actively shifting channel, with several very large boulders moving in the channel. These recent observations enforce our earlier concerns about the lifespan/efficacy of such actions.

One proposed option (option 5) considers log revetment to prevent toe erosion, however, our assessment is that any excavation required to construct such a structure carries a significant risk to further undermine the active slide. Further, it seems that such structures would be of insufficient size, design to prevent movement of the larger unstable block which raises questions about the purpose and efficacy of such structures.

Again, given that there is currently fish passage through the project site (although limited) and the potential risk involved with any instream work, the Forest Service does not support any of the proposed alternatives other than Option 1 (status quo).

Feel free to contact me if you have any questions at:

Jeffrey A. Rivera
District Ranger, Wenatchee River Ranger District
600 Sherbourne,
Leavenworth, WA 98826
(509) 548-2553

Sincerely,

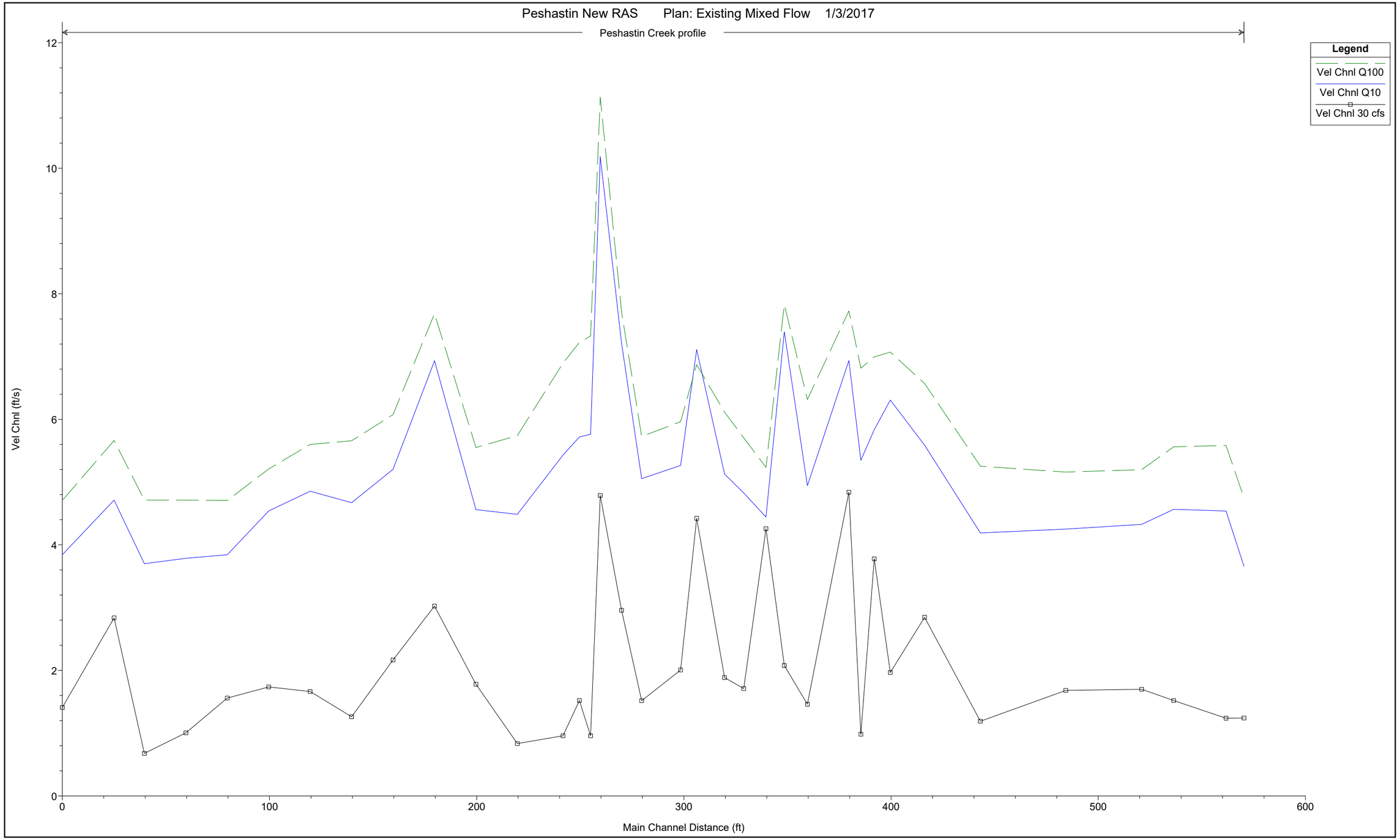
Kathy A McMillan (ADR) for

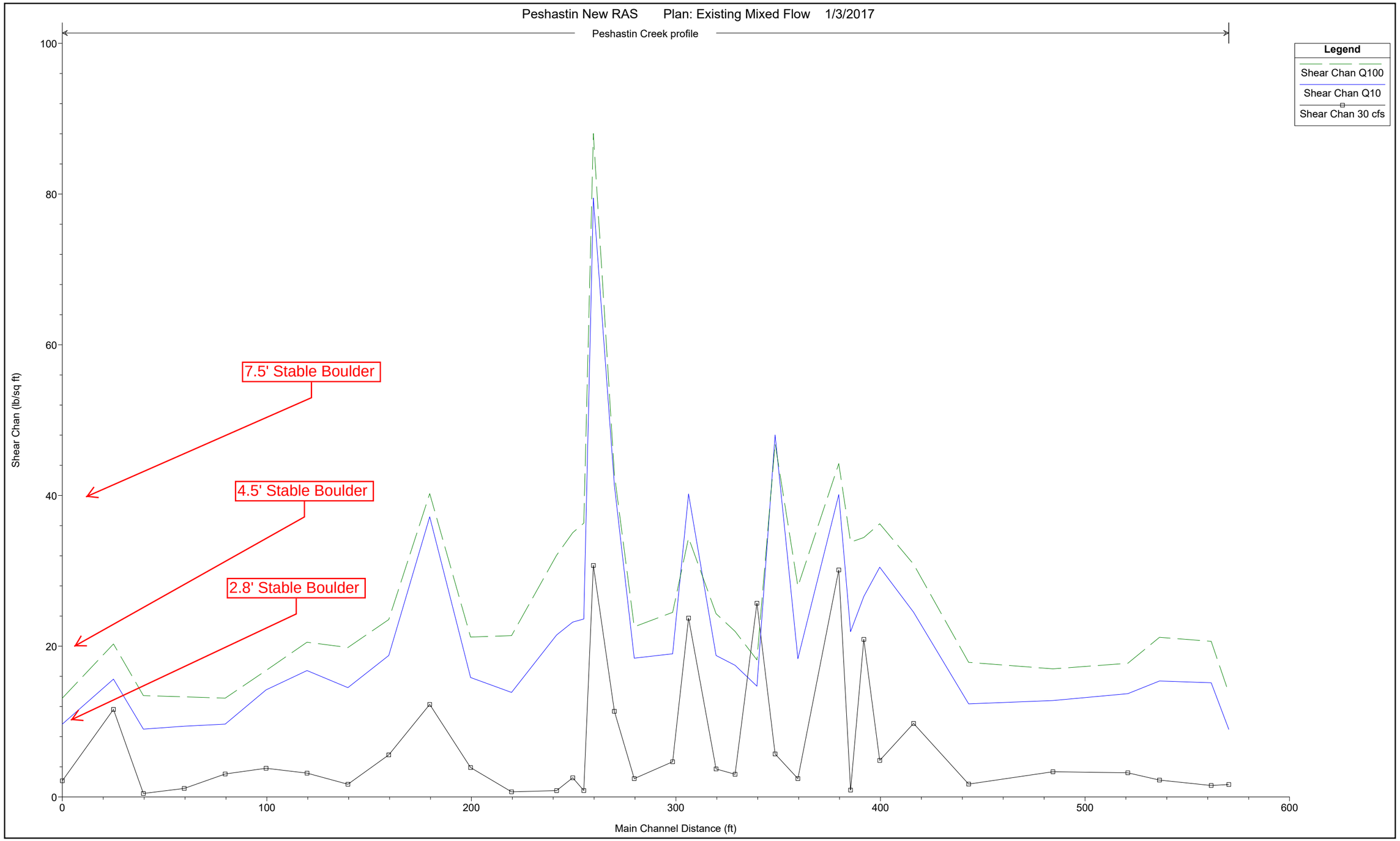
JEFFREY RIVERA
District Ranger

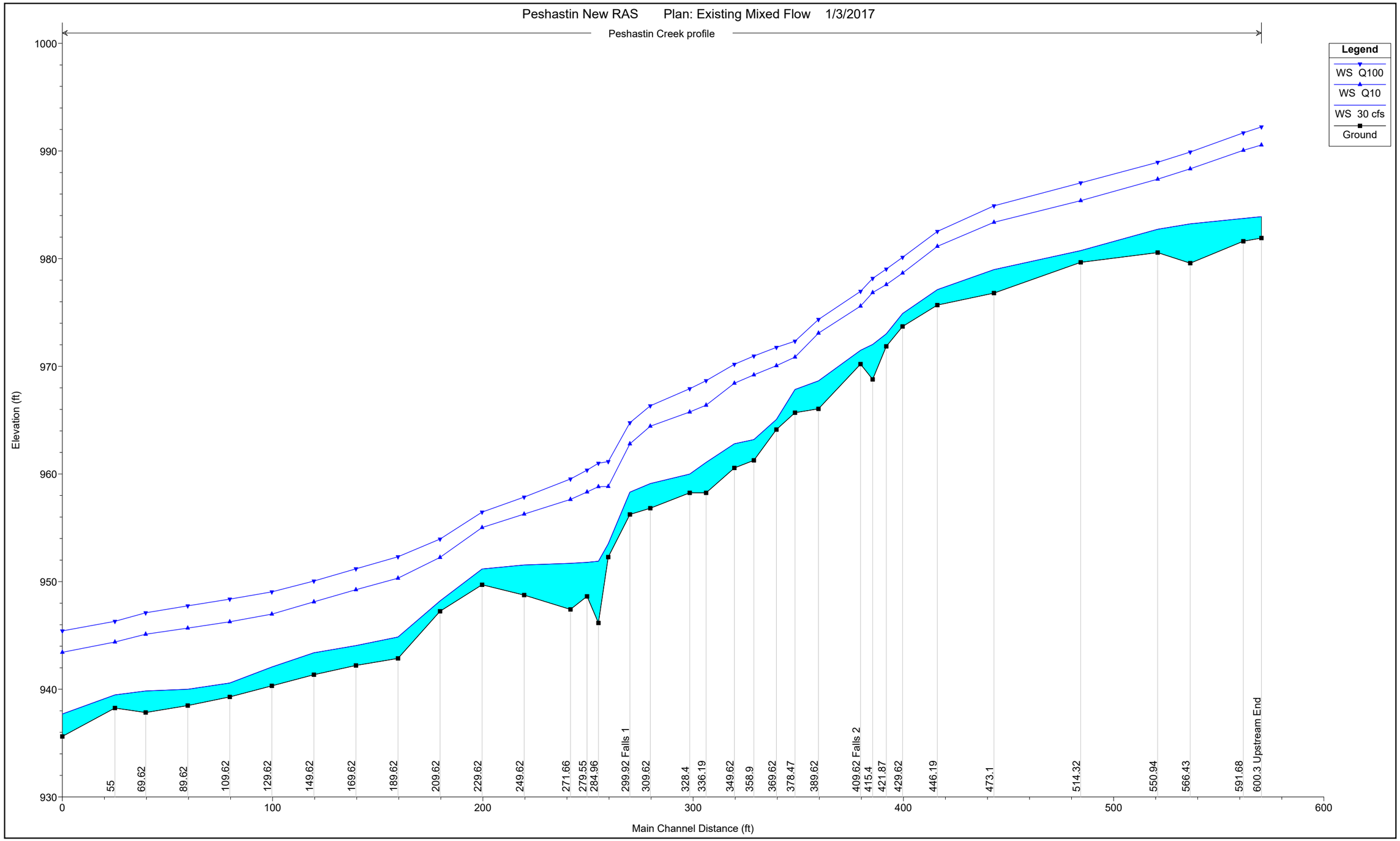
Response to USFS Comments:

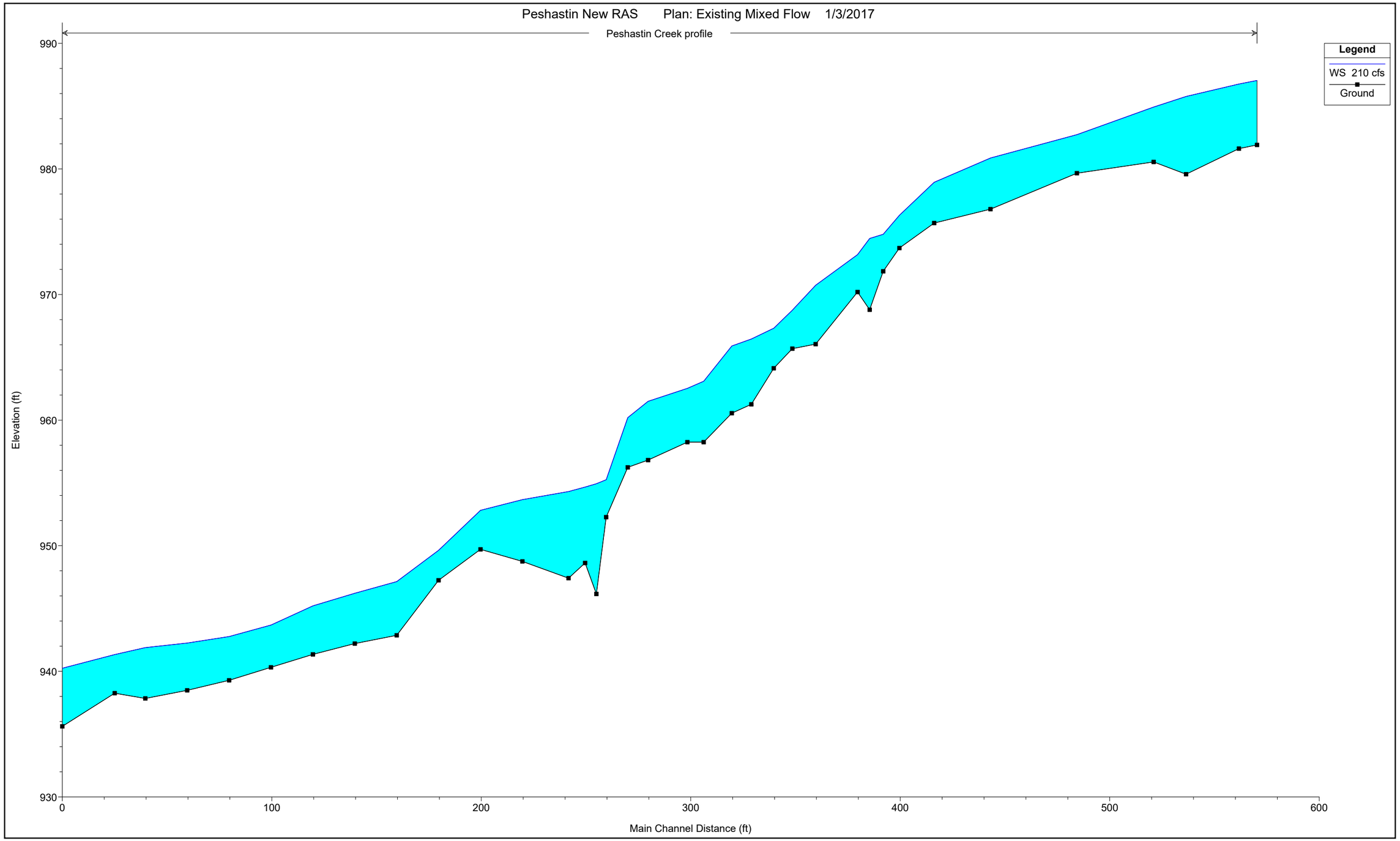
The proposed roughened channel design would extend up the slope to prevent any erosion at the max design flood. The channel section for Option 4 was modified to show this concept. It is anticipated that this bank slope protection will only be needed on about one third to one half of the project site. The intent with the log revetment was to not excavate the slope, maybe 5 or 10 feet out and then backfill. This is not intended to stabilize the slope, but to prevent toe erosion. The finished channel width may be less after this work is complete. Over time the slope will build back up to the top of the LWD and continue to deliver material into the creek, but this may take 20 years. The point being the toe is protected from erosion. Material being delivered from this slope was identified as the single most important issue affecting fish passage and the overall assessment is fish passage will continue to get worse as this material aggrades in the channel and increases the downstream slope. Again, this is just a concept and design details would be needed to address all concerns. The option numbers were modified, the previous Option 1 is now Option 0. Option 1 is now proposed doing minor work to specific areas, by boulder busting, and pool creation.

APPENDIX D – HEC RAS OUTPUT

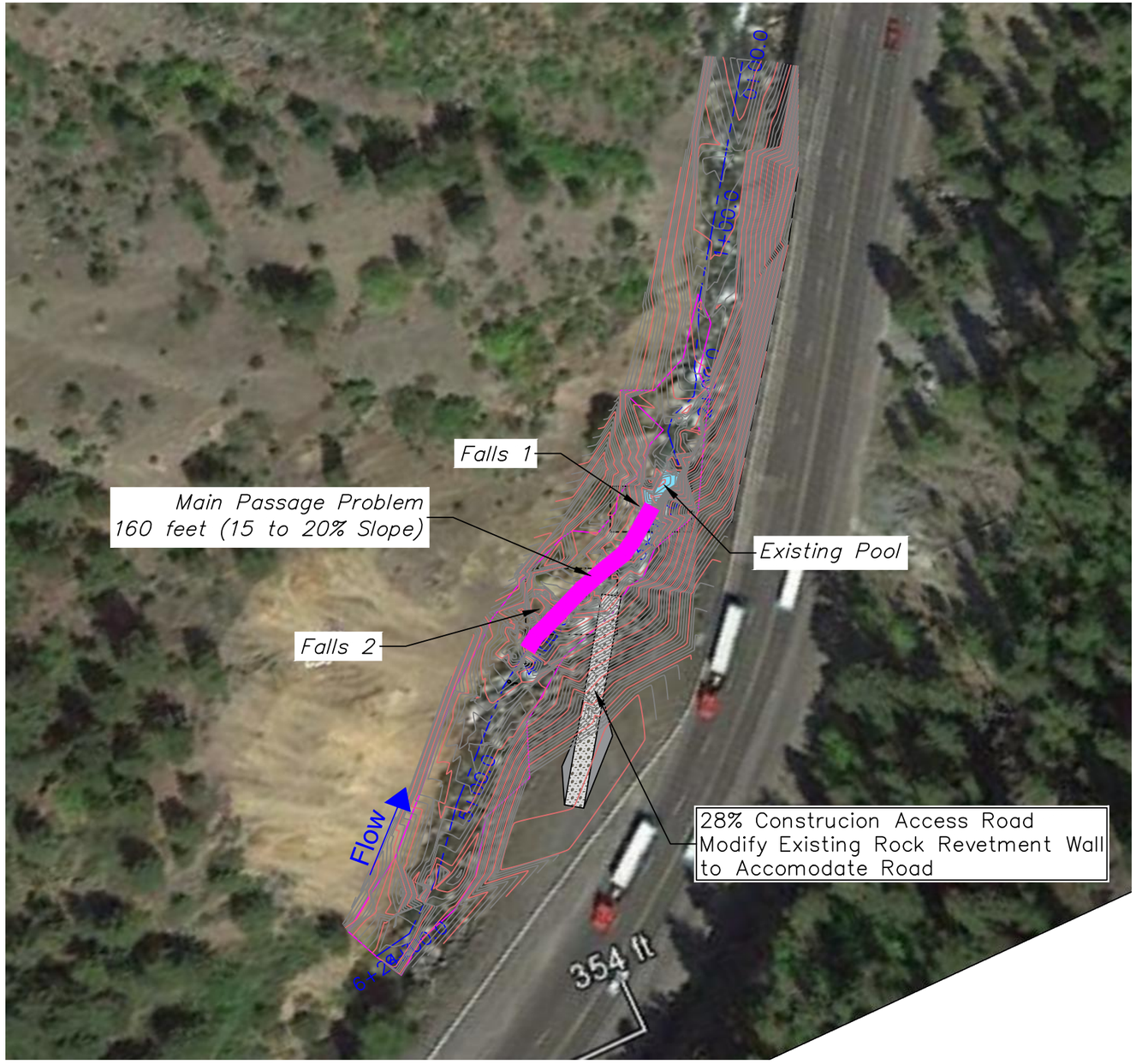

Peshastin New RAS Plan: Existing Mixed Flow 1/3/2017
Peshastin Creek profile
Legend
Vel Chnl Q100
Vel Chnl Q10
Vel Chnl 30 cfs
Vel Chnl (ft/s)
0
2
4
6
8
10
12
0
100
200
300
400
500
600
Main Channel Distance (ft)


Peshastin New RAS Plan: Existing Mixed Flow 1/3/2017
Peshastin Creek profile
Legend
Shear Chan Q100
Shear Chan Q10
Shear Chan 30 cfs
7.5' Stable Boulder
4.5' Stable Boulder
2.8' Stable Boulder
Shear Chan (lb/sq ft)
Main Channel Distance (ft)
0
20
40
60
80
100
0
100
200
300
400
500
600


Peshastin New RAS Plan: Existing Mixed Flow 1/3/2017
Peshastin Creek profile
Legend
WS Q100
WS Q10
WS 30 cfs
Ground
Elevation (ft)
1000
990
980
970
960
950
940
930
0
100
200
300
400
500
600
Main Channel Distance (ft)
55
69.62
89.62
109.62
129.62
149.62
169.62
189.62
209.62
229.62
249.62
271.66
279.55
284.96
299.92 Falls 1
309.62
328.4
336.19
349.62
358.9
369.62
378.47
389.62
409.62 Falls 2
415.4
421.87
429.62
446.19
473.1
514.32
550.94
566.43
591.68
600.3 Upstream End


Peshastin New RAS Plan: Existing Mixed Flow 1/3/2017
Peshastin Creek profile
Legend
WS 210 cfs
Ground
Elevation (ft)
990
980
970
960
950
940
930
0
100
200
300
400
500
600
Main Channel Distance (ft)

APPENDIX E – CONCEPTUAL DESIGN DRAWINGS AND COST ESTIMATES



May 2015 Aerial Photo

DRAWING INDEX:

1. Construction Access
2. Option 1
3. Extent Option 2 and 3
4. Extent Option 4 and 5
5. Option 2 Profile
6. Option 3 Profile and Roughened Channel Detail
7. Option 4 Profile
8. Option 5 Profile/Detail

Site Plan
SCALE: 1"= 50'

0 50
SCALE

Upper Peshastin Barrier Assessment Conceptual Design

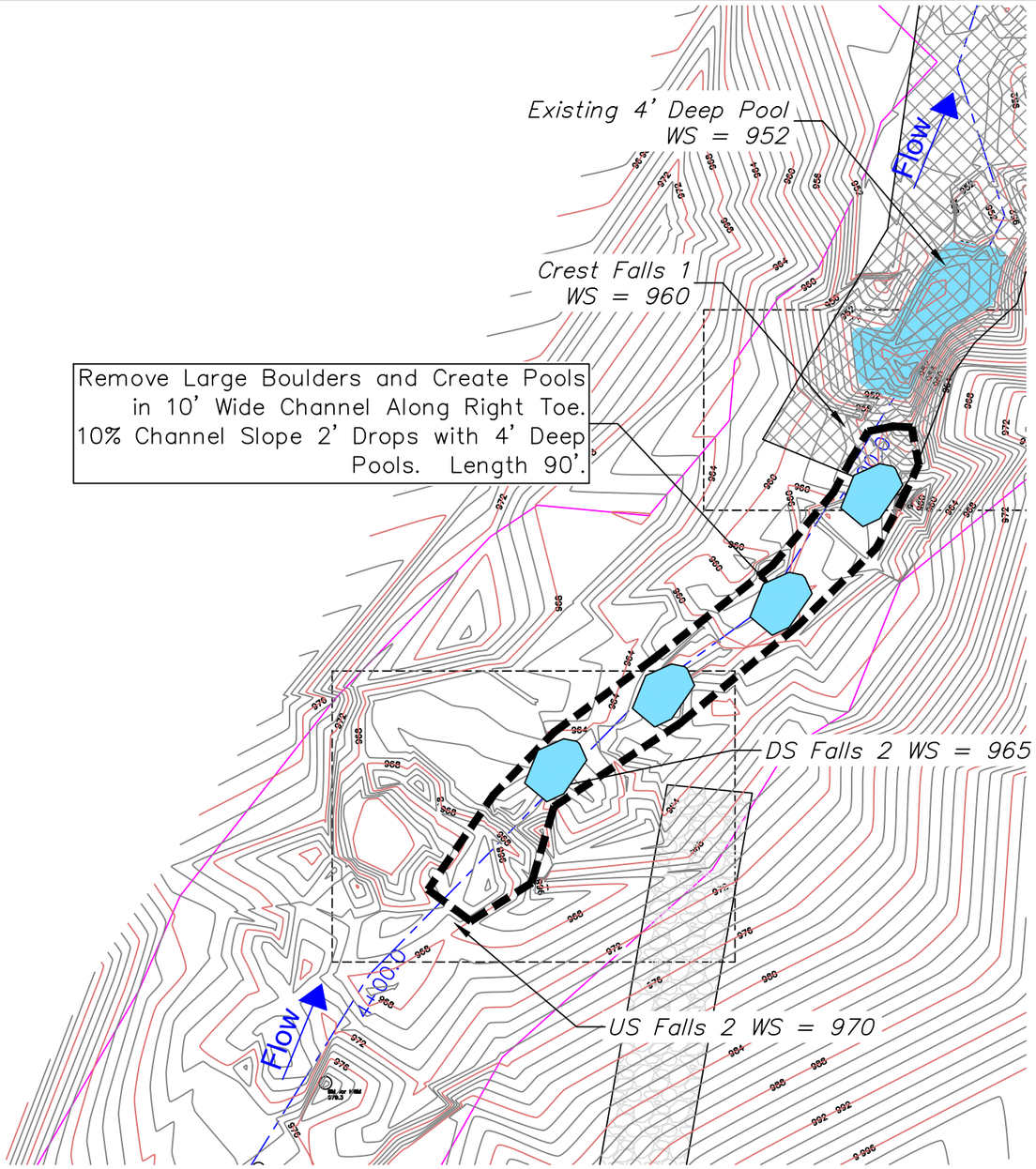
REV	DATE	BY	APP'D	DESCRIPTION

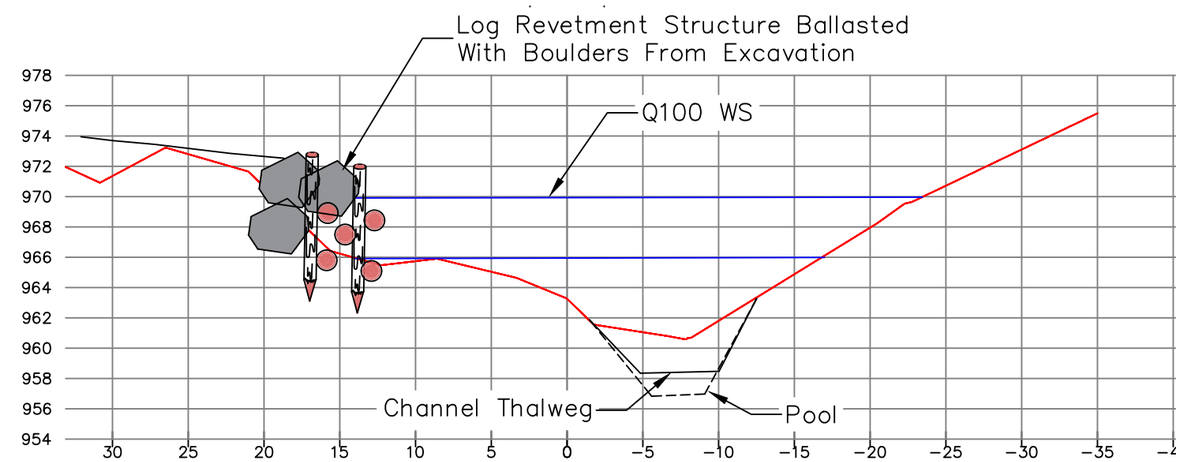
BAR IS ONE INCH ON ORIGINAL DRAWING. SCALE VERIFICATION 0 1" IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DESIGN BY: Waterfall Engineering
DRAWN BY: RiverSide Drafting and Design
DATE: 3/30/2017

Construction Access

1 SHEET OF 8





STA 3+50 View Downstream

SCALE: 1"= 10'

Plan

SCALE: 1"= 20'

0 50

SCALE

Upper Peshastin Barrier Assessment Conceptual Design

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SCALE VERIFICATION

0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

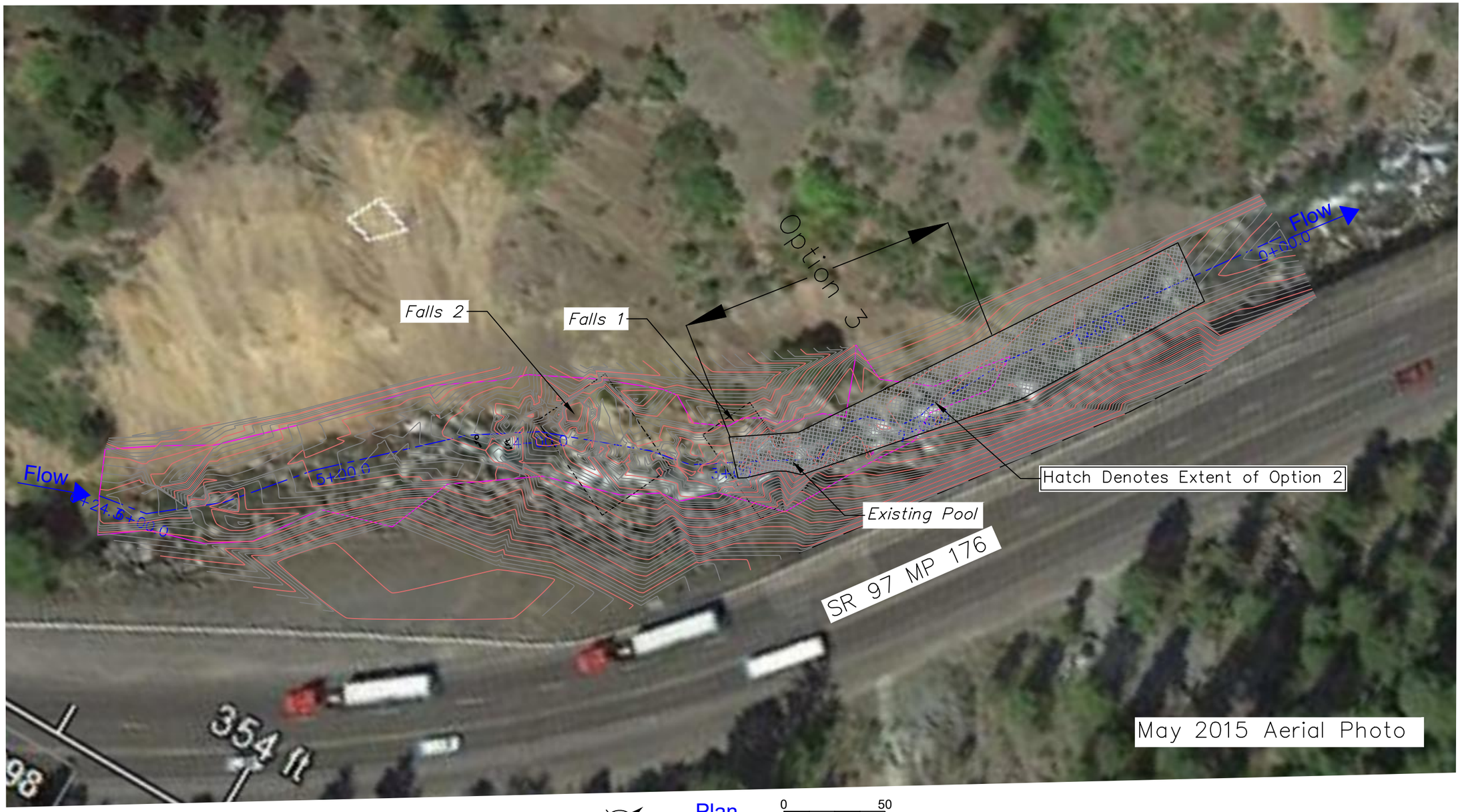
DESIGN BY: Waterfall Engineering

DRAWN BY: RiverSide Drafting and Design

DATE: 3/30/2017

Option 1

SHEET 2 OF 8



Plan
SCALE: 1"= 50'

0 50
SCALE

Upper Peshastin Barrier Assessment Conceptual Design

REV	DATE	BY	APP'D	DESCRIPTION

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SCALE VERIFICATION
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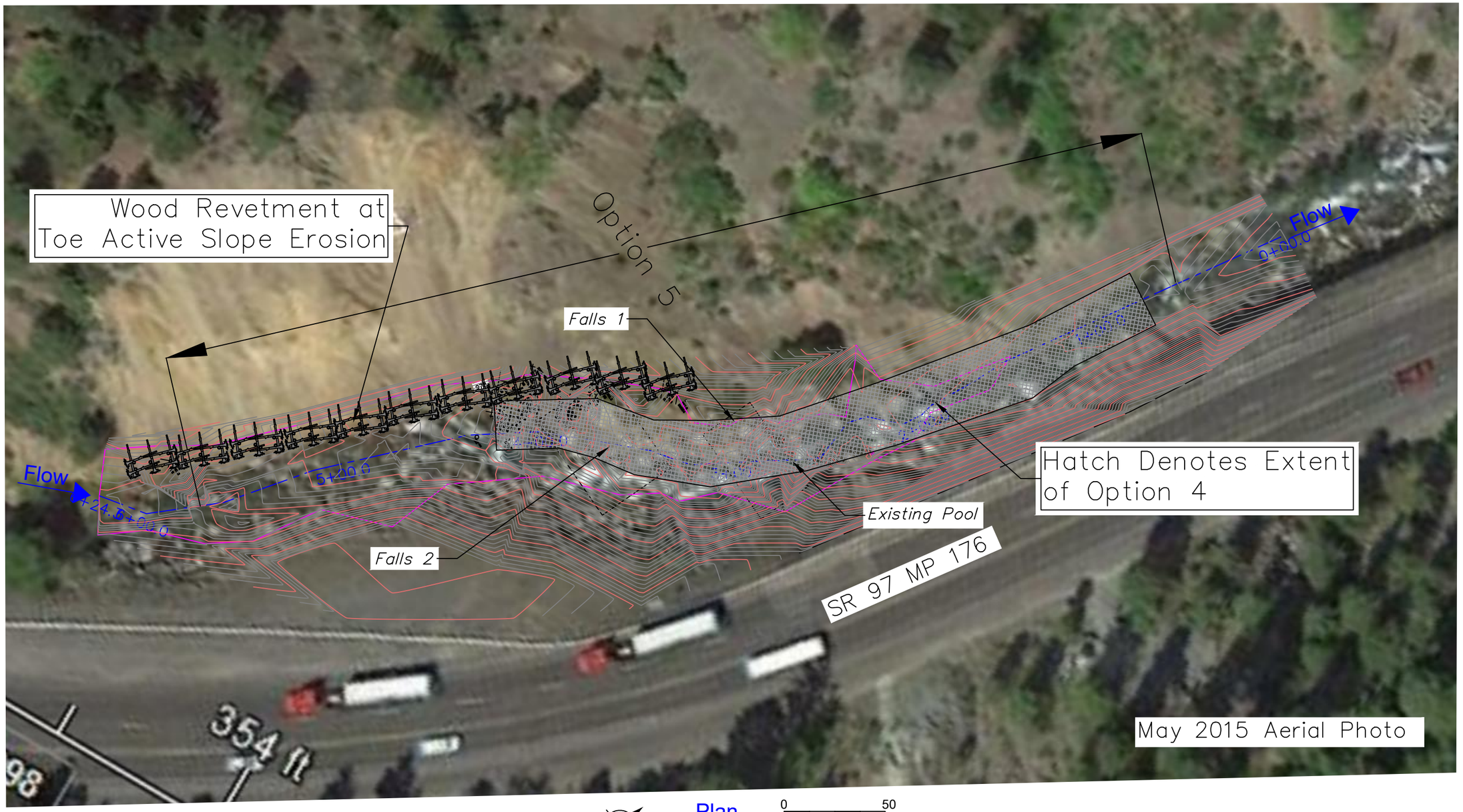
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DESIGN BY: Waterfall Engineering
DRAWN BY: RiverSide Drafting and Design
DATE: 3/30/2017

Option 2 and 3 Extent

SHEET 3 OF 8



Plan
SCALE: 1"= 50'

0 50
SCALE

Upper Peshastin Barrier Assessment
Conceptual Design

REV	DATE	BY	APP'D	DESCRIPTION

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SCALE VERIFICATION
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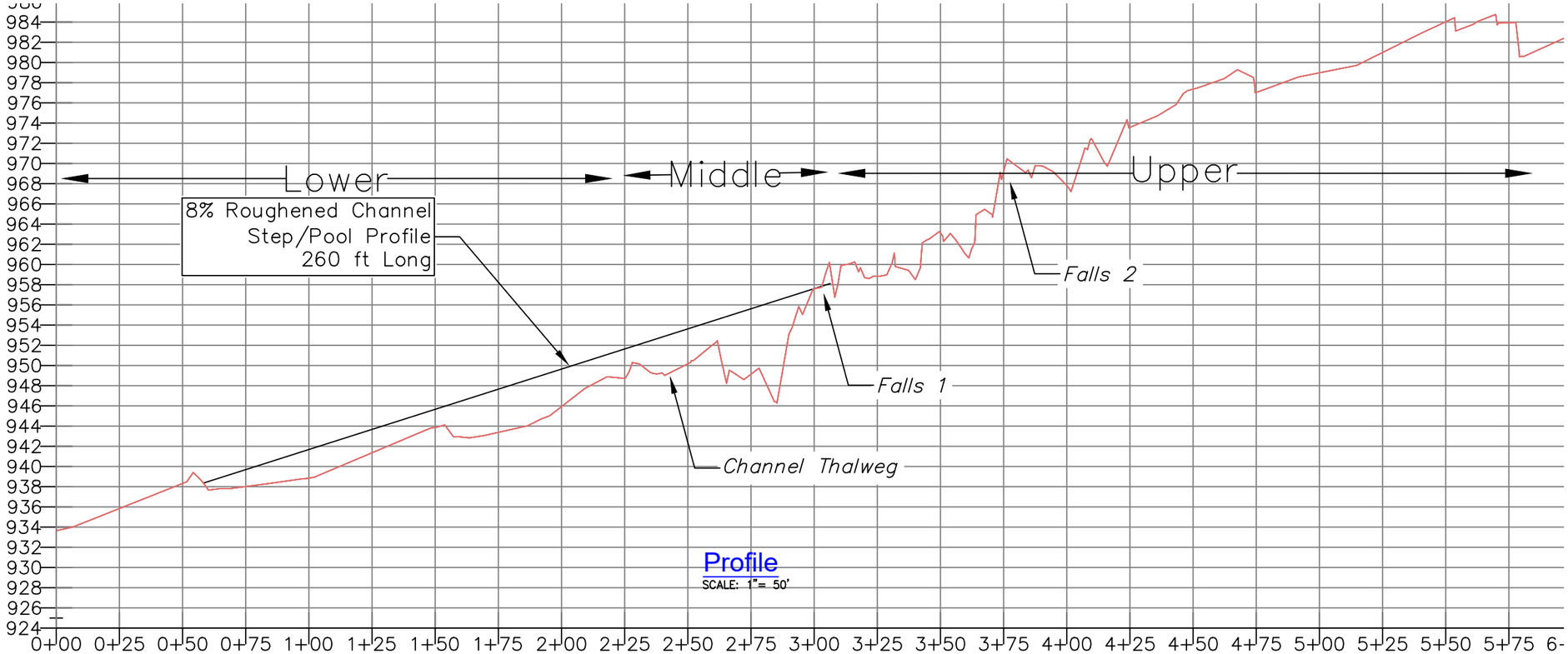
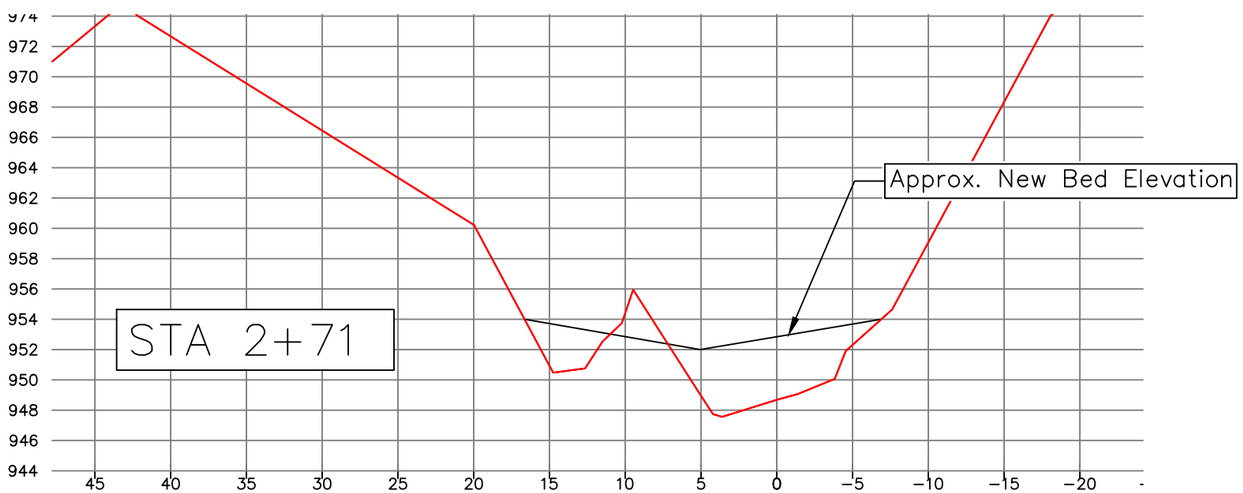
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DESIGN BY: Waterfall Engineering
DRAWN BY: RiverSide Drafting and Design
DATE: 3/30/2017

Option 2 and 3 Extent

SHEET 4 OF 8





Upper Peshastin Barrier Assessment
Conceptual Design

REV	DATE	BY	APP'D	DESCRIPTION

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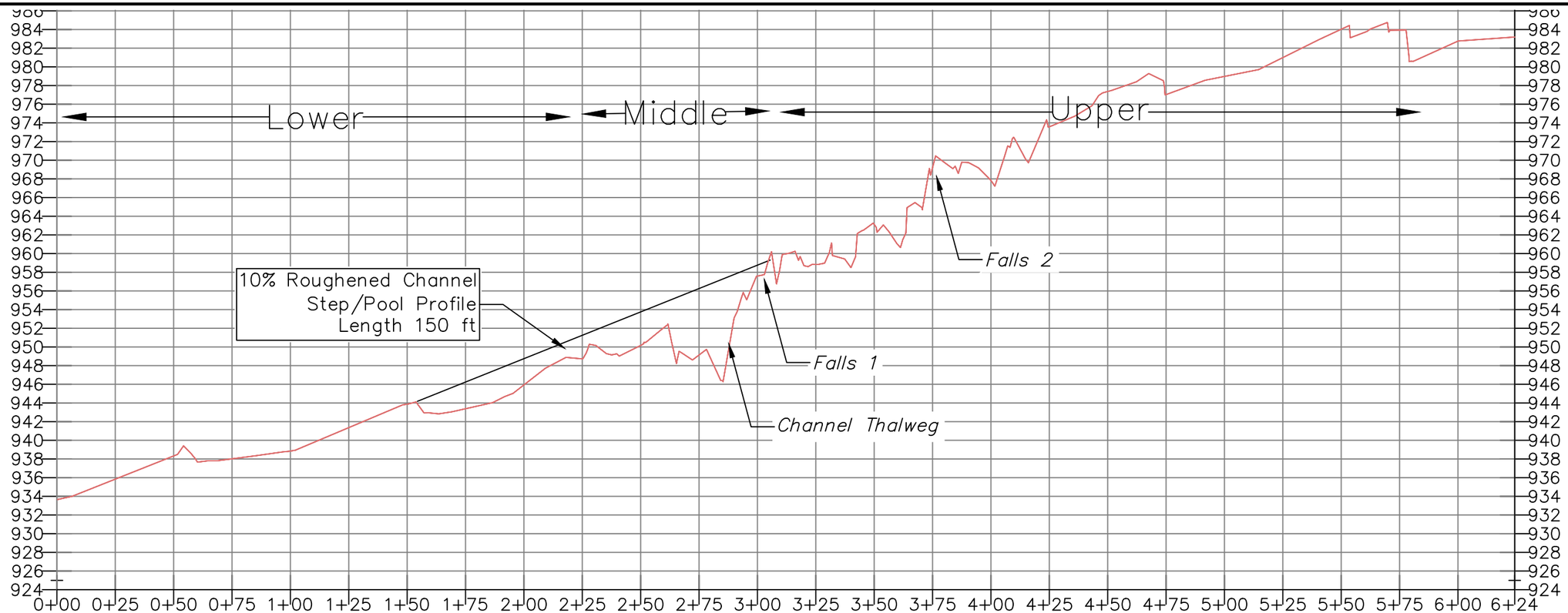
DRAWN BY: RiverSide Drafting and Design
DATE: 3/30/2017

Conceptual Design
Option 2

SHEET 5 OF 8



Profile
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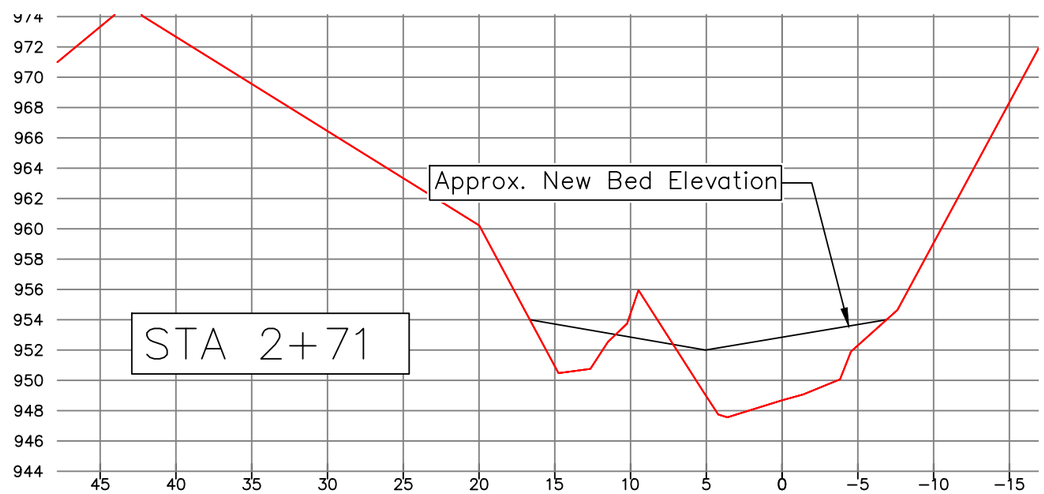
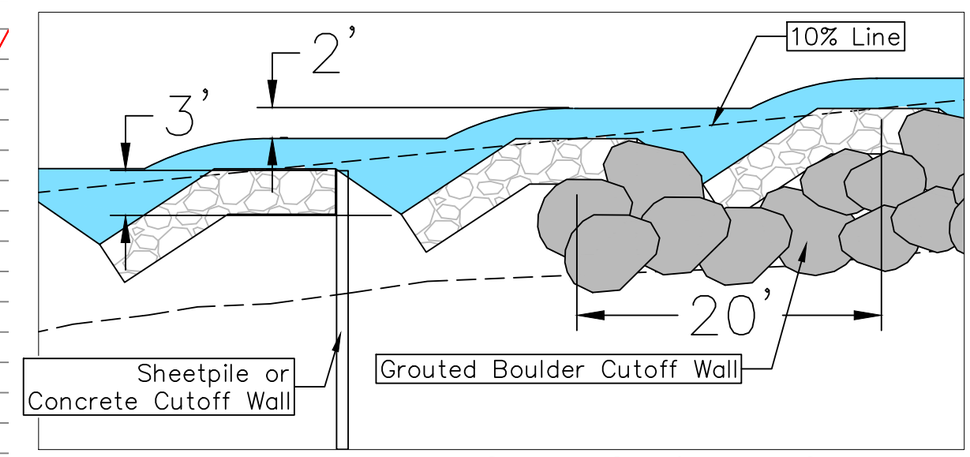




Typical Roughened Channel Step/Pool Profile

Upper Peshastin Barrier Assessment
Conceptual Design

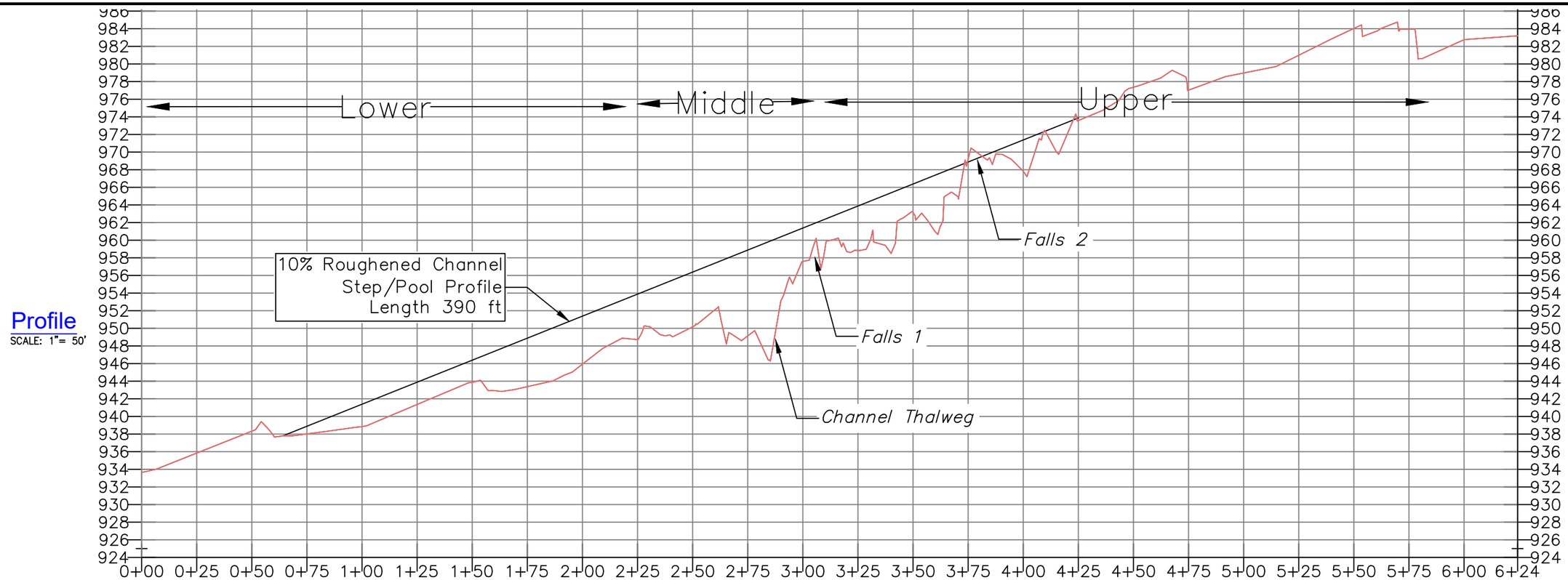
REV	DATE	BY	APP'D	DESCRIPTION

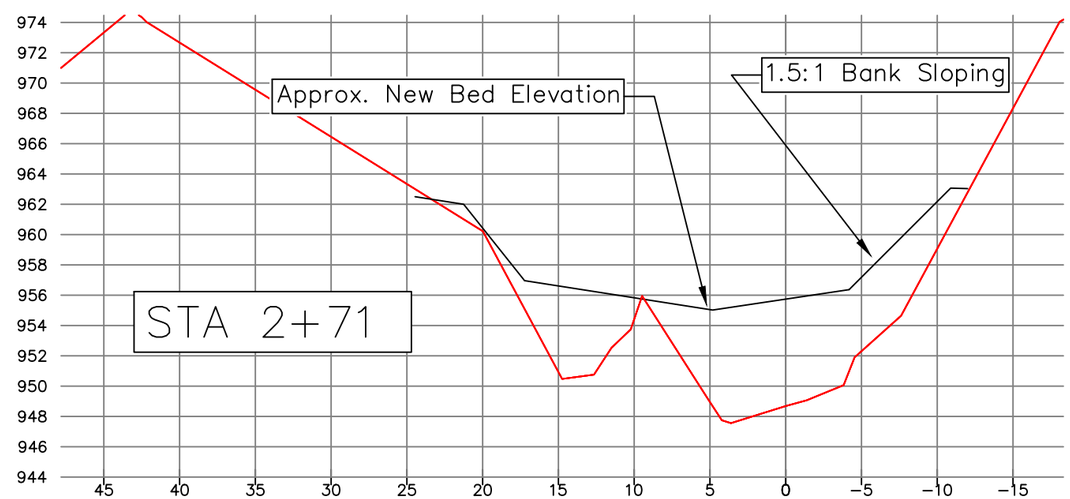
BAR IS ONE INCH ON ORIGINAL DRAWING. SCALE VERIFICATION 0 1" IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

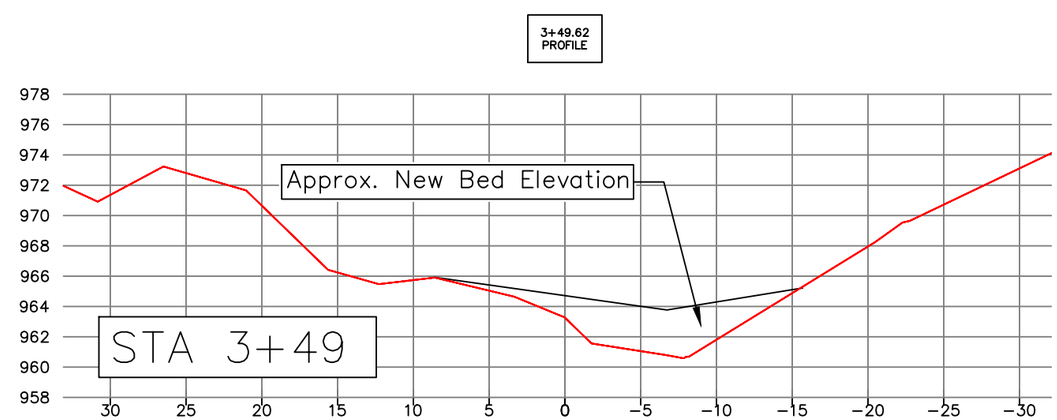
DESIGN BY: Waterfall Engineering
DRAWN BY: RiverSide Drafting and Design
DATE: 3/30/2017

Conceptual Design
Option 3

SHEET 6 OF 8







Upper Peshastin Barrier Assessment
Conceptual Design

REV	DATE	BY	APP'D	DESCRIPTION

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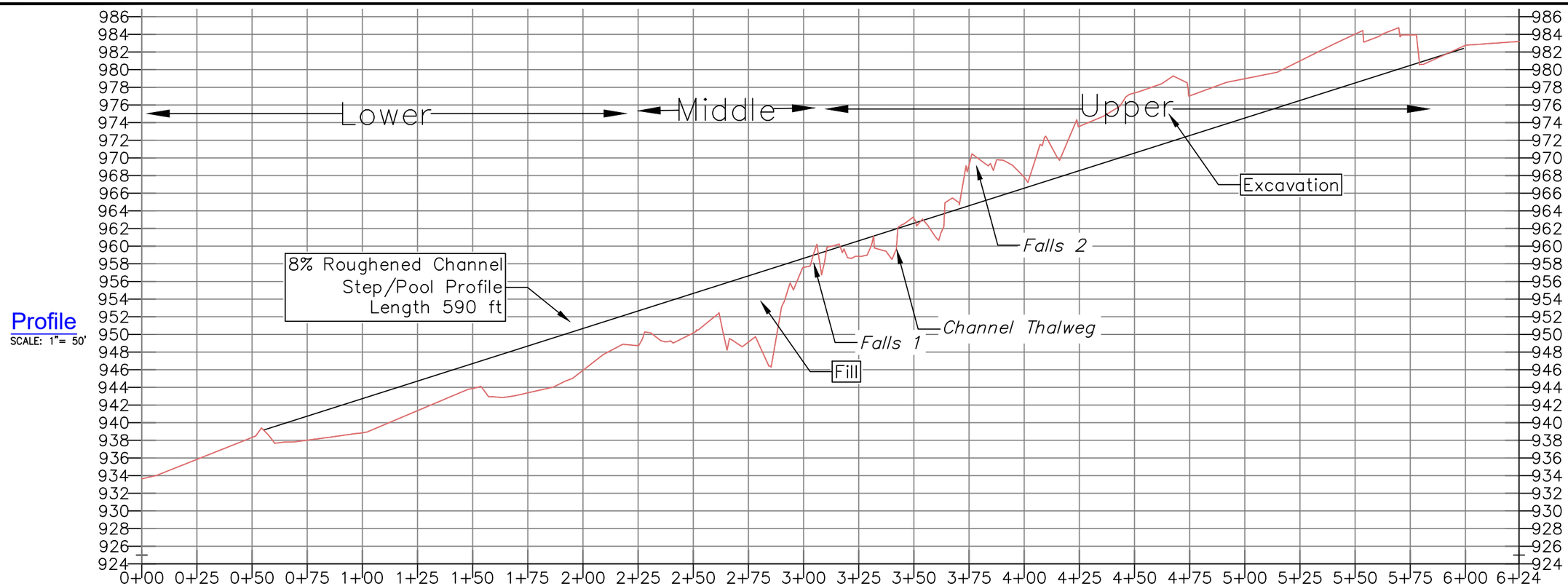
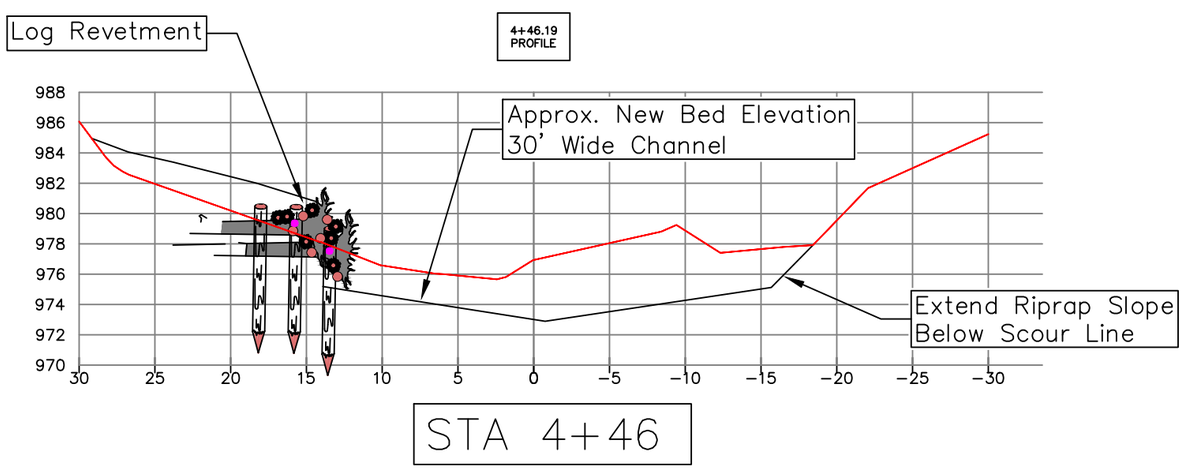
DESIGN BY: Waterfall Engineering
DRAWN BY: RiverSide Drafting and Design
DATE: 3/30/2017

Conceptual Design
Option 4

SHEET 7 OF 8





Upper Peshastin Barrier Assessment
Conceptual Design

REV	DATE	BY	APP'D	DESCRIPTION

BAR IS ONE INCH ON ORIGINAL DRAWING. SCALE VERIFICATION 0 1" IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DESIGN BY: Waterfall Engineering
DRAWN BY: RiverSide Drafting and Design
DATE: 3/30/2017

Conceptual Design
Option 5

SHEET 8 OF 8

Upper Peshastin Barrier Assessment - Option 1

Date: 3/30/17
Design Level: 10% Conceptual
Assumed Construction Time: 2019

Build 120' Access Road, Remove Select Boulders From Channel and Create Pools

Description	Unit	CAD Qty	Mult	Actual Qty	Cost	Amount	Sub Total	*Comments*
Mobilization Erosion Control							**$14,400**	
Mobilization	L.S.	1			$6,400.00	$6,400		*Typically 10% of construction costs*
Water Management	L.S.	1			$3,000.00	$3,000		*Work During Low Flow/Some Pumping*
Staging Along Highway	L.S.	1			$5,000.00	$5,000		*Staging Along Highway*
Access Road							**$26,256**	
Excavation	C.Y.	240	1.2	288	$25.00	$7,200		*Spoil on site*
Disposal	C.Y.	240	1.2	288	$12.00	$3,456		
Quarry Spalls	C.Y.	110	1.2	132	$65.00	$8,580		
Riprap Replacement	C.Y.	90	1.2	108	$65.00	$7,020		
Boulder Busting and Pool Creation							**$10,880**	
Boulder Busting	ea.	10			$800.00	$8,000		
Rock Excavation/Pools	C.Y.	36			$80.00	$2,880		
Log Revetment								
Logs Placed and Bolted	ft.	90			$250.00	$22,500	**$23,400**	
Rock Placement	C.Y.	36			$25.00	$900		
Sub Total							**$74,936**	
Contingency	30%						$22,481	
Sales Tax	8.0%						$7,800	
Construction Total							**$105,200**	

Opinions of Probable Construction Cost

In providing opinions of probable construction cost, the Client understands that the Consultant (Waterfall Engineering, L.L.C.) has no control over the cost or availability of labor, equipment or materials, or over market condition or the Contractor's method of pricing, and the consultant's opinions of probable construction costs are made on the basis of the Consultant's professional judgment and experience. The Consultant makes no warranty, express of implied that the bids or the negotiated cost of the Work will not vary from the Consultant's opinion of probable construction cost.

Upper Peshastin Barrier Assessment - Option 2

Date: 3/30/17
Design Level: 10% Conceptual
Assumed Construction Time: 2019

Construct 260 Long Roughened Channel, 8% Slope to Backwater Falls 1

Description	Unit	CAD Qty	Mult	Actual Qty	Cost	Amount	Sub Total	*Comments*
Mobilization Erosion Control							**$34,000**	
Mobilization	L.S.	1			$20,000.00	$20,000		*Typically 10% of construction costs*
Water Management	L.S.	1			$6,000.00	$6,000		*Pipe Diversion Around Work Area*
Staging Along Highway	L.S.	1			$8,000.00	$8,000		*Staging Along Highway*
Access Road							**$26,256**	
Excavation	C.Y.	240	1.2	288	$25.00	$7,200		*Spoil on site*
Disposal	C.Y.	240	1.2	288	$12.00	$3,456		
Quarry Spalls	C.Y.	110	1.2	132	$65.00	$8,580		
Riprap Replacement	C.Y.	90	1.2	108	$65.00	$7,020		
Roughened Channel Creation							**$84,600**	
Import Roughened Channel Mix	C.Y.	740	1.2	888	$75.00	$66,600		
Boulder Cut Off Wall	ea.	3			$5,000.00	$15,000		
Restoration	ea.	1			$3,000.00	$3,000		
Sub Total							**$144,856**	
Contingency	30%						$43,457	
Sales Tax	8.0%						$15,100	
Construction Total							**$203,400**	

Opinions of Probable Construction Cost

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Upper Peshastin Barrier Assessment - Option 3

Date: 3/30/17
Design Level: 10% Conceptual
Assumed Construction Time: 2019

Construct 150 Long Roughened Channel,10% Slope to Backwater Falls 1

Description	Unit	CAD Qty	Mult	Actual Qty	Cost	Amount	Sub Total	*Comments*
Mobilization Erosion Control							**$29,000**	
Mobilization	L.S.	1			$15,000.00	$15,000		*Typically 10% of construction costs*
Water Management	L.S.	1			$6,000.00	$6,000		*Pipe Diversion Around Work Area*
Staging Along Highway	L.S.	1			$8,000.00	$8,000		*Staging Along Highway*
Access Road							**$26,256**	
Excavation	C.Y.	240	1.2	288	$25.00	$7,200		*Spoil on site*
Disposal	C.Y.	240	1.2	288	$12.00	$3,456		
Quarry Spalls	C.Y.	110	1.2	132	$65.00	$8,580		
Riprap Replacement	C.Y.	90	1.2	108	$65.00	$7,020		
Roughened Channel Creation							**$58,000**	
Import Roughened Channel Mix	C.Y.	500	1.2	600	$75.00	$45,000		
Boulder Cut Off Wall	ea.	2			$5,000.00	$10,000		
Restoration	ea.	1			$3,000.00	$3,000		
Sub Total							**$113,256**	
Contingency	30%						$33,977	
Sales Tax	8.0%						$11,800	
Construction Total							**$159,000**	

Opinions of Probable Construction Cost

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Upper Peshastin Barrier Assessment - Option 4

Date: 3/30/17
Design Level: 10% Conceptual
Assumed Construction Time: 2019

Construct 390' Long Roughened Channel,10% Slope to Backwater Falls 1 and Extend Through Falls 2

Description	Unit	CAD Qty	Mult	Actual Qty	Cost	Amount	Sub Total	*Comments*
Mobilization Erosion Control							**$55,000**	
Mobilization	L.S.	1			$35,000.00	$35,000		*Typically 10% of construction costs*
Water Management	L.S.	1			$12,000.00	$12,000		*Pipe Diversion Around Work Area*
Staging Along Highway	L.S.	1			$8,000.00	$8,000		*Staging Along Highway*
Access Road							**$46,256**	
Excavation	C.Y.	240	1.2	288	$25.00	$7,200		*Spoil on site*
Disposal	C.Y.	240	1.2	288	$12.00	$3,456		
Quarry Spalls	C.Y.	110	1.2	132	$65.00	$8,580		
Riprap Replacement	C.Y.	90	1.2	108	$65.00	$7,020		
Additonal DS Access Road Creation	L.S.	1			$20,000.00	$20,000		
Roughened Channel Creation							**$154,000**	
Import Roughened Channel Mix	C.Y.	1400	1.2	1680	$75.00	$126,000		
Boulder Cut Off Wall	ea.	5			$5,000.00	$25,000		
Restoration	ea.	1			$3,000.00	$3,000		
Sub Total							**$255,256**	
Contingency	30%						$76,577	
Sales Tax	8.0%						$26,500	
Construction Total							**$358,300**	

Opinions of Probable Construction Cost

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Upper Peshastin Barrier Assessment - Option 5

Date: 3/30/17
Design Level: 10% Conceptual
Assumed Construction Time: 2019

Regrade Falls 2 Area Down to Falls 1, Construct 590' Long Roughened Channel with Log Toe Revetment (250') Along Left Bank Upper Portion

Description	Unit	CAD Qty	Mult	Actual Qty	Cost	Amount	Sub Total	*Comments*
Mobilization Erosion Control							**$73,000**	
Mobilization	L.S.	1			$50,000.00	$50,000		*Typically 10% of construction costs*
Water Management	L.S.	1			$15,000.00	$15,000		*Pipe Diversion Around Work Area*
Staging Along Highway	L.S.	1			$8,000.00	$8,000		*Staging Along Highway*
Access Road							**$56,256**	
Excavation	C.Y.	240	1.2	288	$25.00	$7,200		*Spoil on site*
Disposal	C.Y.	240	1.2	288	$12.00	$3,456		
Quarry Spalls	C.Y.	110	1.2	132	$65.00	$8,580		
Riprap Replacement	C.Y.	90	1.2	108	$65.00	$7,020		
Additonal DS Access Road Creation	L.S.	1			$30,000.00	$30,000		
Roughened Channel Creation							**$311,200**	
Upper Channel Excavation	C.Y.	750	1.2	900	$75.00	$67,500		
Spoil Material Downstream	C.Y.	750	1.2	900	$55.00	$49,500		
Creation of Step/Pool Design	C.Y.	1200	1.2	1440	$55.00	$79,200		
Boulder Cut Off Wall	ea.	7			$5,000.00	$35,000		
LWD Revetment	ea.	15			$5,000.00	$75,000		*Wood Piles and Bolted Connections with Backfill*
Restoration	ea.	1			$5,000.00	$5,000		
Sub Total							**$440,456**	
Contingency	30%						$132,137	
Sales Tax	8.0%						$45,800	
Construction Total							**$618,400**	

Opinions of Probable Construction Cost

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