

**Reach Assessment
Clay Creek at SR 410 MP 35.76**



**Rob Schanz, Hydrologist
Jim Park, Senior Hydrologist
WSDOT Environmental Services
Hydrology Program**

December 2009



Washington State Department of Transportation
Environmental and Engineering Service Center
Environmental Services Office

Table of Contents

Figures.....	iii
Tables	iii
Introduction.....	4
Site History and Problem Description	5
Hydrology and Watershed Conditions	7
Stream Geomorphology.....	10
Fish Utilization and Habitat.....	15
Mechanisms and Causes of Problems at the Site	16
Treatment Alternatives	17
Recommendations	21
References	22

Reach Assessment, Clay Creek at SR 410 MP 35.76

Figures

Figure 1. Photo of the Culvert Inlet after the 2009 Repair.	5
Figure 2. Channel Incision at the Culvert Outlet.....	6
Figure 3. Watershed Boundaries and Surficial Geology.	8
Figure 4. Recent Logging Activity in the Clay Creek Watershed.	9
Figure 5. Profile of the Clay Creek Streambed.....	10
Figure 6. Cascade Channel and Step-Pools about 850 feet upstream of SR 410.	11
Figure 7. Channel Flow Paths Near SR 410	12
Figure 8. Falls Created by Logjams downstream of SR 410.....	13
Figure 9. Failing Banks in the Gully Downstream of SR 410.	14
Figure 10. Conceptual Cross Section of the Recommended Bridge Opening.	20

Tables

Table 1. Peak Flow Estimates for Clay Creek at SR 410.	7
Table 2. Physical Characteristics of Clay Creek Alternatives.....	18
Table 3. Comparison of Clay Creek Bridge and Regrading Alternatives.	19

Introduction

This reach assessment examines channel instability and culvert blockage problems at the Clay Creek culvert on SR 410 near Milepost (MP) 35.76. The report uses GIS map analysis, site surveys, and literature review to describe site history, watershed conditions, stream geomorphology, and existing fish habitat. We then synthesize this information to identify the mechanisms and causes of problems at the culvert, and to evaluate alternatives for culvert replacement and channel stabilization.

The purpose of this report is to identify one or more long-term solutions that can enhance the natural movement of water, sediment, and aquatic organisms through Clay Creek as it crosses under SR 410. Solutions are described at a conceptual level to allow stakeholders to compare alternatives and develop an appropriate funding package. The report does not address short term measures WSDOT may pursue to stabilize the existing culvert.

Reach Assessment, Clay Creek at SR 410 MP 35.76

Site History and Problem Description

Clay Creek crosses under SR 410 through a 6- by 6-foot concrete box culvert. The culvert is about 125 feet long, and slopes at 14% (WDFW and WSDOT, 2009).

Clay Creek periodically delivers large pulses of sediment, rock, and woody debris that clog the culvert inlet. The creek then spills over SR 410 and splits into several incised gullies that lie east of the main channel. This covers the road with debris, and erodes the downstream road embankment at each gully. This occurred most recently during the January 2009 flood. Following this event WSDOT excavated debris from the channel bed to clear the culvert inlet, installed two boulder drop structures upstream of the inlet, and placed riprap on the banks adjacent to the upstream wingwalls (Figure 1). WSDOT also placed riprap at the heads of the east gullies to repair eroded sections of the downstream road embankment.



Figure 1. Photo of the Culvert Inlet after the 2009 Repair.

The steep and undersized culvert has also caused massive channel incision at the outlet (Figure 2). This incision has undermined the outlet apron and wingwalls, causing large sections to drop off into the channel bed. Water now spills 15 vertical feet off of the outlet apron onto a pile of rubble, riprap, and concrete debris. The flow drops another 12 vertical feet over this debris before meeting the scoured channel bed about 30 feet downstream. The culvert is a complete barrier to fish passage (WDFW and WSDOT, 2009).

Reach Assessment, Clay Creek at SR 410 MP 35.76

The remaining sections of outlet apron and wingwalls are severely undermined, and continue to fail. This will eventually threaten the integrity of the road embankment.



Figure 2. Channel Incision at the Culvert Outlet.

Reach Assessment, Clay Creek at SR 410 MP 35.76

Hydrology and Watershed Conditions

Clay Creek drains 1.61 square miles upstream of SR 410, and flows into the White River about 1400 feet downstream of SR 410. Table 1 shows peak flows estimated using the USGS Streamstats program (USGS, 2009).

Table 1. Peak Flow Estimates for Clay Creek at SR 410.

Flow Statistic	Peak Flow (cfs)
2-year	104
10-year	193
25-year	241
50-year	286
100-year	323
500-year	431

Figure 3 shows the surficial geology of the Clay Creek watershed. The parent material in most of the watershed is volcanic rock, primarily andesite flows and volcanoclastic rocks. The steep valley walls are highly susceptible to mass wasting and landslides, and almost the entire western half of the watershed is covered by historical landslide deposits. These slide deposits continue across the SR 410 right of way and transition onto alluvial terraces and floodplains associated with the White River. The creek channel and east gullies on the downstream side of the road split around large hummocks that are likely derived from this slide material.

Land use in the watershed is devoted primarily to timber harvest and forestry. Aerial photos from 1955, 2000, 2003, and 2006 were examined for major changes in the watershed, then contrasted with the 2006 full basin image. The 1955 photo shows only limited clear-cutting, but by 2006 recent clear-cuts covered about sixty percent of the watershed area. This high level of recent land disturbance increases the risk of landslides and debris flows to Clay Creek.

Reach Assessment, Clay Creek at SR 410 MP 35.76

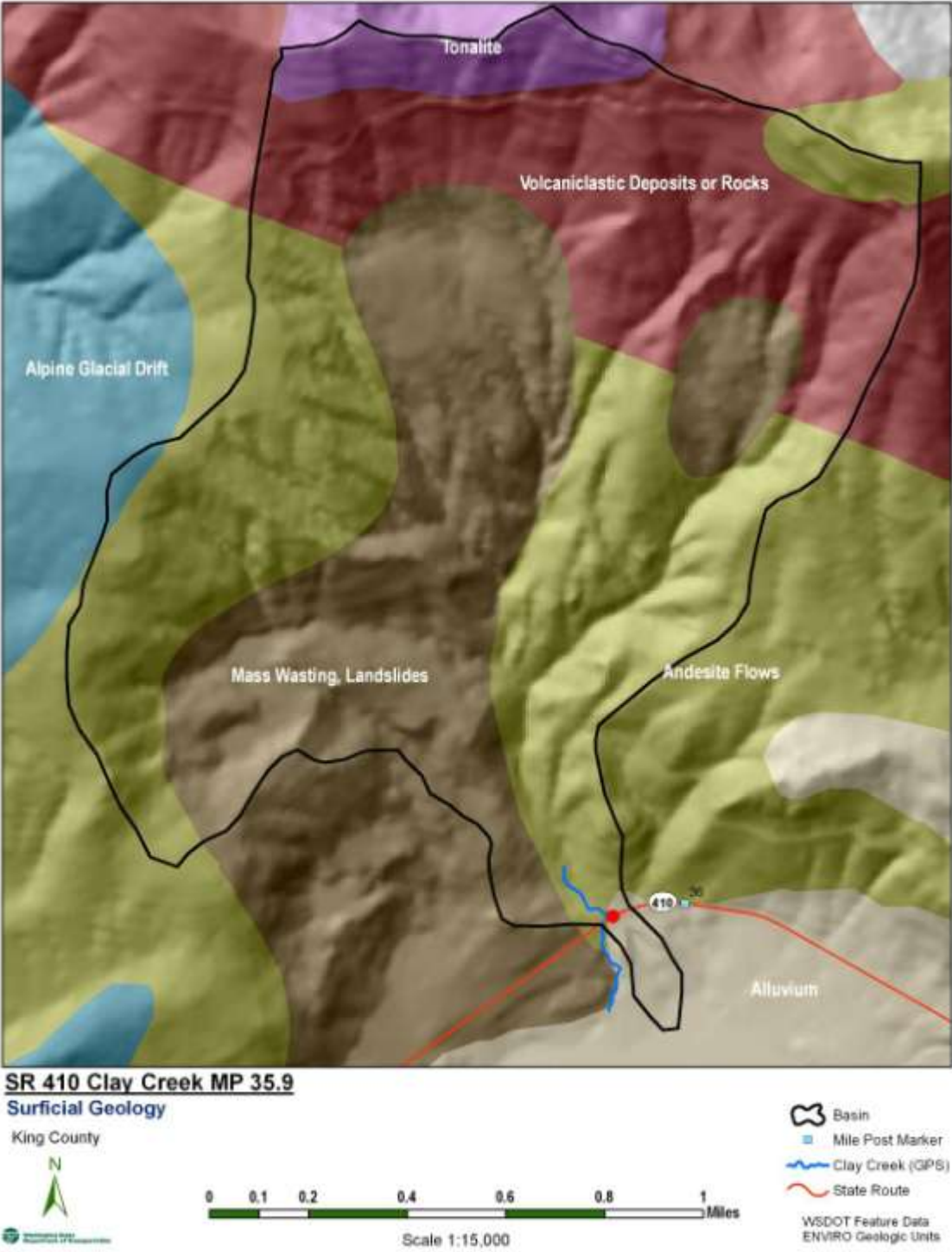


Figure 3. Watershed Boundaries and Surficial Geology.

Reach Assessment, Clay Creek at SR 410 MP 35.76

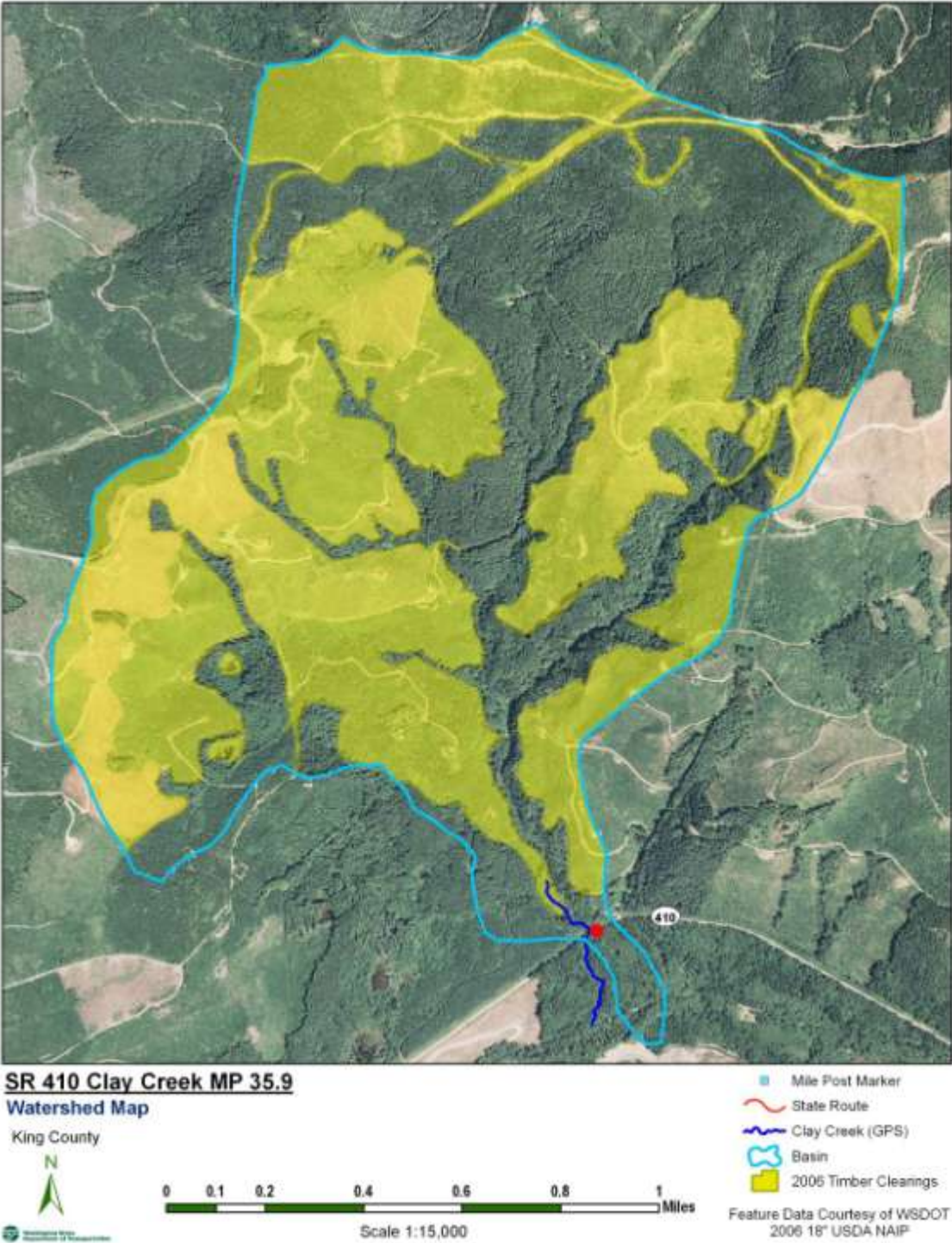


Figure 4. Recent Logging Activity in the Clay Creek Watershed.

Reach Assessment, Clay Creek at SR 410 MP 35.76

Stream Geomorphology

Clay Creek is a steep mountain channel shaped by frequent landslide debris flows of volcanic rock and sediment. Under natural conditions this creates a steep cascade channel with a gradient of about 10 to 15 percent. These steep gradients are maintained by coarse material (boulders and cobbles) delivered by debris flows. The culvert at SR 410 is too small to pass debris, and therefore starves downstream reaches of the coarse material needed to maintain a stable bed.

Figure 5 shows the profile of the streambed upstream and downstream of SR 410, as surveyed by WSDOT in June 2009. The headwater channels begin as steep chutes (>20 percent gradient) scoured down to bedrock. The mainstem chute discharges onto boulder-covered falls about 2000 feet upstream of SR 410. These falls eventually transition into a cobble- and boulder-lined channel that slopes at between 7 and 12 percent. At these gradients the bed usually consists of a cascade channel with random pools spaced less than one channel width apart (Montgomery and Buffington, 1997). Large boulders and woody debris occasionally create short segments of step pool morphology (Figure 6).

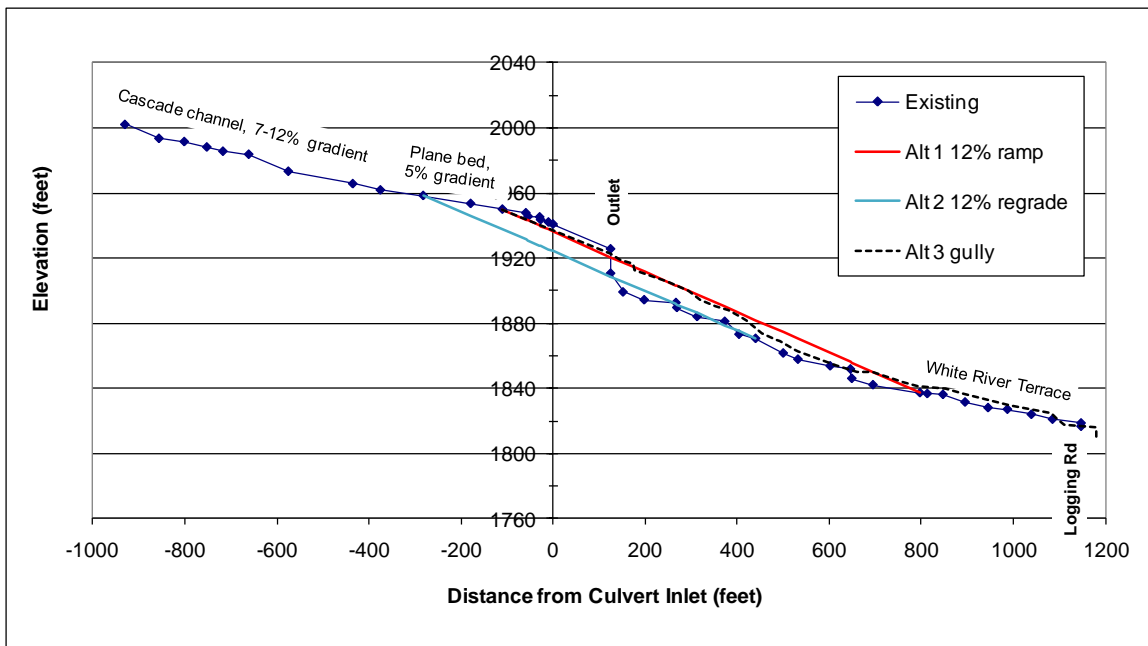


Figure 5. Profile of the Clay Creek Streambed.

Reach Assessment, Clay Creek at SR 410 MP 35.76



Figure 6. Cascade Channel and Step-Pools about 850 feet upstream of SR 410.

About 700 feet upstream of SR 410 the channel shifts to the edge of a fan of boulder and cobble landslide deposits. The remaining vegetation on this fan consists of young alders that indicate frequent disturbance by debris flows.

The creek leaves this recent slide deposit and cuts through a vegetated terrace before dropping into the SR 410 culvert. The gradient near the culvert decreases to about five percent, creating a plane-bed channel lined with cobbles, gravel, and sand. This drop in gradient is created by sediment deposition and aggradation at the culvert inlet.

At the time the culvert was constructed the outlet channel would have sloped at 12 to 15 percent to meet the White River terrace about 700 feet downstream. The channel bed would have consisted of a chaotic cascade over cobbles and boulders, with occasional falls and pools created by woody debris. The SR 410 culvert starved this reach of the sediment and debris needed to maintain this gradient. As a result, the outlet channel has downcut by more than 15 feet since the culvert was constructed.

The existing outlet channel is heavily incised at the outlet, with numerous piles of woody debris and sediment from adjacent undercut banks. The bed slopes at about 10 percent before transitioning onto a White River floodplain terrace about 700 feet downstream of the culvert (Figure 7). Three major logjams create distinct steps in the profile with falls of three feet or more (Figure 8). As the creek transitions onto the terrace the gradient drops to about six percent. The channel on the terrace consists of a cobble-lined plane-bed that enters a 7-foot CMP logging road culvert 960 feet downstream of SR 410 (Figure 7). This culvert has a two-foot water surface drop at the outlet that is likely a fish passage barrier. The creek enters the White River about 350 feet downstream of the logging road.

Reach Assessment, Clay Creek at SR 410 MP 35.76

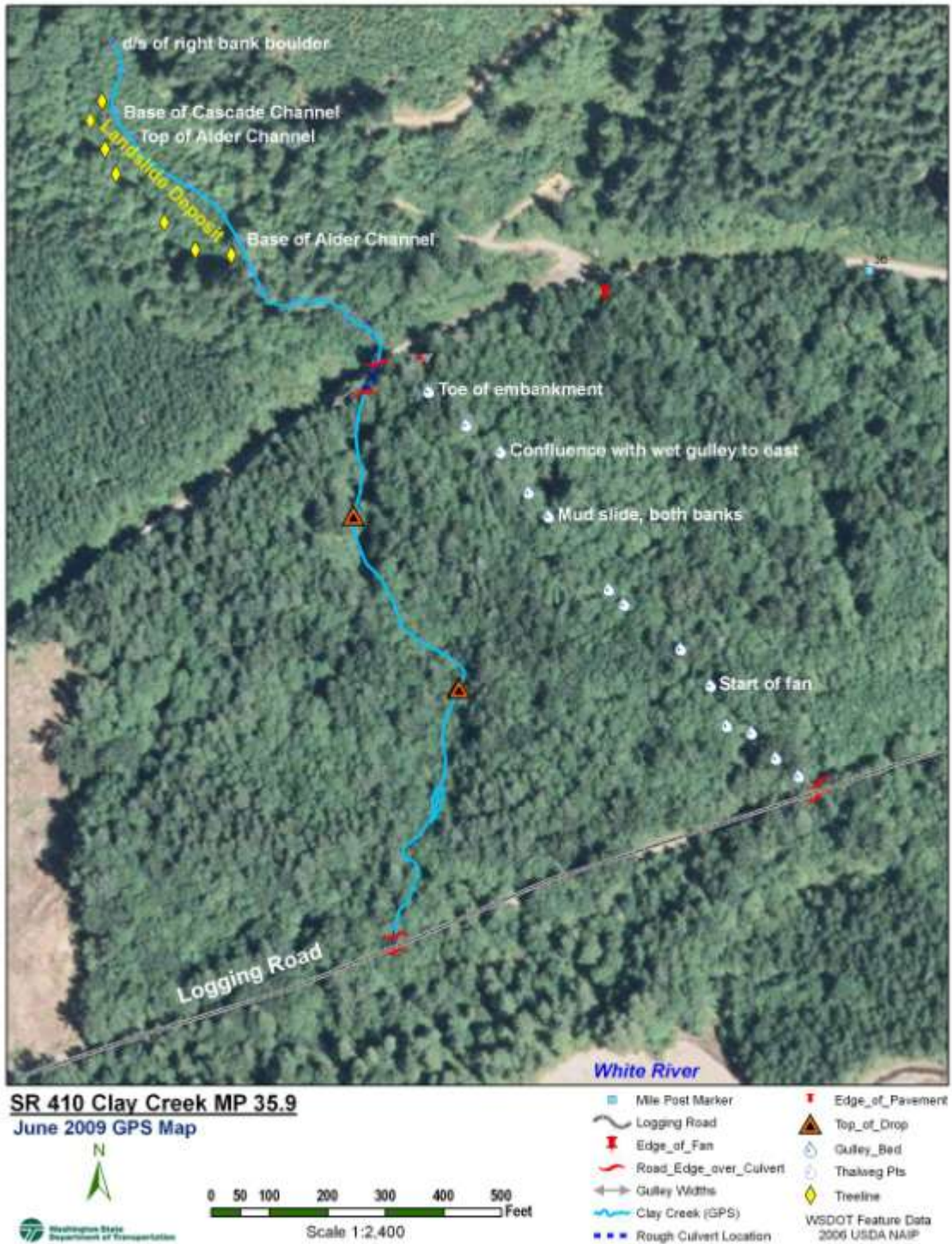


Figure 7. Channel Flow Paths Near SR 410

Reach Assessment, Clay Creek at SR 410 MP 35.76



Figure 8. Falls Created by Logjams downstream of SR 410

Gullies east of the existing channel periodically carry water and debris that spills over SR 410 when the culvert clogs. The first east gully has an alignment that provides a more direct crossing of the SR 410 right-of-way. This gully has a bed slope similar to what likely existed in the Clay Creek channel prior to incision, and is typically eight to 20 feet wide at the bottom. The bed consists of scattered boulders and cobbles embedded in volcanic silt and clay. The unvegetated banks frequently slump into the gully, and consist of angular cobbles embedded in sandy silt volcanic soil (Figure 9).

This gully joins with the next east one about 170 feet downstream of SR 410. After passing a series of bank failures it then transitions and fans out onto the White River terrace. The dry channel eventually joins Packard Creek at the inlet of a four-foot CMP logging road culvert 1050 feet downstream of SR 410. This culvert has a 3.7-foot water surface drop at the outlet. Packard Creek enters a side channel of the White River about 150 feet downstream of the logging road.

Reach Assessment, Clay Creek at SR 410 MP 35.76



Figure 9. Failing Banks in the Gully Downstream of SR 410.

Reach Assessment, Clay Creek at SR 410 MP 35.76

Fish Utilization and Habitat

Clay Creek does not appear in WDFW GIS coverages for resident fish or salmonids (WSDOT, 2009). The Department of Natural Resources classifies Clay Creek near SR 410 as Type F (fish-bearing). The White River at the Clay Creek confluence supports a diverse array of resident and anadromous fish, including spring Chinook (rearing), fall chum (presence/migration), coho (rearing), Dolly Varden/bull (presence/migration), pink salmon (presence/migration), sockeye (presence/migration), and winter steelhead (rearing).

WDFW has classified the Clay Creek SR 410 culvert as a complete barrier to fish passage (WDFW and WSDOT, 2009). The culvert inventory identifies 2200 linear feet of stream habitat that would be gained by removing this barrier. The downstream logging road culverts on Clay Creek and Packard Creek are also barriers to fish passage, with outlet water surface drops of 2.0 and 3.7 feet respectively.

Reach Assessment, Clay Creek at SR 410 MP 35.76

Mechanisms and Causes of Problems at the Site

The mechanisms of failure are debris deposition at the culvert inlet and scour/channel incision at the outlet. These are caused by high debris loads from a steep, heavily-logged watershed with numerous landslides. The SR 410 culvert cannot pass this debris, and confines the creek to a single channel as it flows through landslide deposits towards the White River. This starves downstream reaches of the coarse debris needed to maintain a steep gradient. The channel has responded to this by cutting downward, creating a massive drop at the culvert outlet that undermines the culvert apron and wingwalls and prevents fish passage.

Reach Assessment, Clay Creek at SR 410 MP 35.76

Treatment Alternatives

We identified three treatment alternatives that could restore fish and debris passage across SR 410 and accommodate a dynamically-stable channel gradient:

- Alternative 1 – Construct new bridge and fill downstream to eliminate the drop at SR 410.
- Alternative 2 – Construct new bridge and excavate upstream to eliminate the drop at SR 410.
- Alternative 3 – Construct new bridge and reroute Clay Creek into the east gully downstream of SR 410.

Table 2 summarizes physical characteristics of the alternatives, and Table 3 compares advantages and disadvantages. The alternatives reflect different combinations of the following design variables:

Channel Location: Alternatives 1 and 2 leave the creek in its existing downstream alignment, while Alternative 3 shifts the creek into the next gully to the east.

Channel Gradient and Bedform: Each alternative re-grades the channel to eliminate the vertical drop below SR 410 and tie in at a linear gradient to stable channel segments upstream and downstream (Figure 5). Alternative 1 does this by filling downstream of SR 410 to raise the bed to meet the existing outlet elevation. The depth of fill would range from about 18 feet at the outlet to 4 feet near the end of the filled bed 700 feet downstream of SR 410.

Alternative 2 eliminates the drop by excavating through aggraded segments above the inlet to tie in to the slide channel about 280 feet upstream of SR 410. The existing bed would have to be lowered by about 17 feet for the first 60 feet of upstream of SR 410. About 75 linear feet of channel at the SR 410 outlet would also have to be filled in to eliminate a scour hole and create a sloping bed.

Alternative 3 uses the existing grade of the east gully. The gully channel is currently undersized, and would have to be widened and stabilized for at least 500 feet downstream of SR 410.

Figure 5 compares the streambed profiles for each alternative. In all cases the terrain dictates a steep 12 to 14 percent channel with a coarse boulder and cobble bed to resist scour. This will create a cascade channel with chaotic flow through fields of randomly-strewn boulders, similar to natural segments upstream of SR 410. The channel would be constructed with a 20-foot bed width. Channel banks in excavated segments would slope at 2:1. Rootwads could be installed along the channel margins to provide roughness and habitat diversity. Engineered log or boulder sills would not be installed in the steep channel bed, since these would not be stable and would create drops that do not meet fish passage criteria. However, log sills and step pools may develop naturally over time as debris flows deliver large wood to the creek bed.

Reach Assessment, Clay Creek at SR 410 MP 35.76

Table 2. Physical Characteristics of Clay Creek Alternatives.

Alternative	Stream Gradient	Height of abutment slope (feet)	Total Bridge Length (Feet)	
			2:1 abutments	1.5:1 abutments
1 – Fill Downstream	12.4%	29	156	127
2 – Excavate Upstream	12.0%	41	204	163
3 – Route to East Gully	13.5%	27	148	121

Bridge Opening Width/Length: Stream crossing structures are normally sized for flood conveyance and WDFW stream simulation fish passage criteria. In this case the stream is steeper than normally applicable for stream simulation, and is shaped more by debris flows than flooding. There are no widely-accepted methods for sizing stream structures for landslide debris conveyance, so as a first cut we assume that the 75-foot top width of the Clay Creek gully downstream of SR 410 evolved in response to the driving geomorphic processes, and therefore reflects the needed conveyance width. The bottom of the opening would be 40 feet wide, to accommodate a 20-foot active channel bed and sufficient overbank area for debris deposition. Figure 10 illustrates the recommended cross-section of the bridge opening.

The total bridge length will also need to account for abutment slopes. This additional length will depend on the elevation drop from the bridge to the streambed (which varies by alternative) and the design slope of the abutments. Table 2 and Figure 10 illustrate how bridge lengths will vary depending on the proposed stream grading alternative and abutment slopes. These lengths are provided only for comparison of conceptual alternatives, since the actual configuration of the bridge spans and abutments will depend on much more detailed site data and bridge engineering analysis that will be developed during project design.

Reach Assessment, Clay Creek at SR 410 MP 35.76

Table 3. Comparison of Clay Creek Bridge and Regrading Alternatives.

Alternative	Advantages	Disadvantages/Impacts
1 – Fill Downstream	<p>Minimizes disturbance of upstream fish habitat</p> <p>Maintains the existing connection to the White River</p>	<p>Places extensive fill on 700 feet of streambed habitat downstream of SR 410</p> <p>Higher risk of channel scour or dewatering in bed materials placed on fill.</p> <p>Aggraded channel upstream of SR 410 limits debris passage at the inlet</p> <p>Provides less vertical clearance for debris passage under SR 410</p>
2 – Excavate Upstream	<p>Minimizes disturbance of all but 75 feet of streambed habitat downstream of SR 410.</p> <p>Maintains the existing connection to the White River</p> <p>Lower risk of scour or dewatering since bed material can be embedded in native landslide deposits and clays.</p> <p>Eliminates aggradation upstream of SR 410 and provides more vertical clearance for debris passage under SR 410.</p>	<p>Disturbs 280 feet of existing plane-bed channel habitat upstream of SR 410</p> <p>Requires longer bridge to accommodate higher abutment slopes</p> <p>Excavation costs for 280 feet of stream re-grading upstream of SR 410.</p>
3 – Route to East Gully	<p>Minimizes disturbance of upstream fish habitat.</p> <p>Provides a more direct (less skewed) alignment across SR 410.</p> <p>Provides an existing bed slope that requires little cut or fill to create a stable gradient.</p>	<p>Diverts flow from 1400 feet of existing stream habitat</p> <p>Changes connection of Clay Creek to the White River</p> <p>Requires extensive work to widen and stabilize the downstream gully banks, risk of high fine sediment load to the White River as the channel widens and stabilizes</p> <p>Aggraded channel upstream of SR 410 limits debris passage</p>

Reach Assessment, Clay Creek at SR 410 MP 35.76

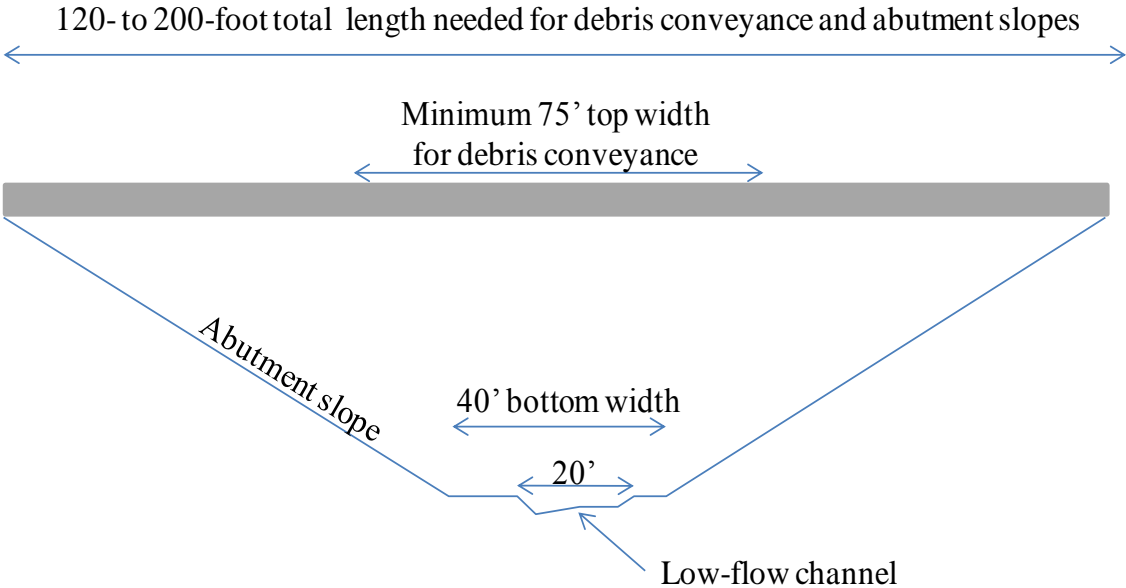


Figure 10. Conceptual Cross Section of the Recommended Bridge Opening.

Reach Assessment, Clay Creek at SR 410 MP 35.76

Recommendations

Restoring fish passage and debris conveyance in Clay Creek will require a significantly larger bridge, as well as extensive stream grading to re-establish a stable streambed profile. Table 3 summarizes the advantages and disadvantages of the three alternatives. We recommend Alternative 2 (Excavate Upstream) because this alternative has the least impact on existing downstream aquatic habitat, establishes the most stable streambed profile, and provides the highest clearance for debris conveyance under the bridge. This is also the alternative that will require the largest bridge and highest construction cost, but we believe the lower risks of failure and aquatic habitat impacts justify the additional costs. Alternative 1 (Filling Downstream) impacts over 700 feet of habitat downstream, and has a much higher risk of streambed erosion and dewatering. Rerouting the creek to the east gully (Alternative 3) would abandon all existing habitat downstream of SR 410, and would require significant work to widen and stabilize the gully.

Reach Assessment, Clay Creek at SR 410 MP 35.76

References

Montgomery, D.R. and J.M. Buffington, 1997. Channel-Reach Morphology in Mountain Drainage Basins. Geological Society of America Bulletin Volume 105 No. 9, p. 596-611, May 1997.

U.S. Geologic Survey. 2009. StreamStats in Washington.
<http://water.usgs.gov/osw/streamstats/Washington.html>. Accessed February 2009.

Washington State Conservation Commission, 1999. Salmon Limiting Factors Analysis for the Puyallup River basin (WRIA 10).

Washington State Department of Fish and Wildlife, 2003. Design of Road Culverts for Fish Passage.

Washington State Department of Fish and Wildlife and Washington State Department of Transportation, 2009. WSDOT Fish Passage Inventory, Progress Performance Report, July 2009.

Washington State Department of Transportation, 2009. Geodata Catalog, GIS Coverages of Fish Species of Interest, Resident Fish, and Endangered Species Listings.