

APPENDIX A

Emergency Memorandum

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Herrera Environmental Consultants, Inc.

Memorandum

To Jim Park, Washington State Department of Transportation

CC Mike Golden, Ed Burnside, Pat Moylan, and Mark Cornwall, Washington State Department of Transportation; and Paul Kennard, Mount Rainier National Park

From Tim Abbe, PhD, LEG; Jennifer Goldsmith; Ian Mostrenko, PE; and Chris Brummer, PE, Herrera Environmental Consultants

Date Draft submitted December 24, 2004
Final submitted January 18, 2005

Subject **Flood risk assessment and emergency response measures for State Route 410 near Crystal Mountain Boulevard, MP 57-60**

Introduction

The Washington State Department of Transportation (WSDOT) requested that Herrera Environmental Consultants, Inc. (Herrera) prepare a memorandum to identify sections of State Route (SR) 410 in Pierce County between Mile Post (MP) 57-60 at eminent risk of flooding or erosion and recommend appropriate emergency actions for the Winter of 2004-2005 (Figure 1). Flooding and erosion in October 2003 resulted in temporary closure of this section of SR 410 that prevented access to Mount Rainier National Park (“MRNP”) and Crystal Mountain Resort (Appendix A). Flood inundation extended north of MRNP into Mt. Baker Snoqualmie National Forest (“MBSNF”) to Silver Creek, crossing Crystal Mountain Boulevard near its junction with SR 410 immediately north of the MRNP gate and impacting cabins on either side of SR 410. Emergency actions in 2003 required to limit damage and re-open the highway included (Figure 1):

MP 58.05-58.09

Reconstruction and hardening (rock wall) of highway embankment undercut by erosion.

MP 58.30-58.40

Excavation of a small drainage channel and construction of a temporary containment levee along highway.

MP 58.40-57.00

Clearing of sediment and debris from about 1 mile of the road surface.

MP 58.62

Construction of a temporary engineered logjam (ELJ) using locally available wood on river bars to deflect river flow away from SR 410.

The temporary ELJ successfully diverted flow that was threatening SR 410 and allowed the highway to be re-opened early in November 2003. Due to limitations in the quantity of wood debris and construction time, the ELJ was constructed only as a temporary measure for the winter of 2003-2004. The ELJ has exceeded its design life by continuing to provide critical protection to SR 410 through December 2004. But repeated engagement with the river has resulted in scour has begun to compromise the structure's integrity and highlight the need for additional actions to protect SR 410. As of the recent flooding on January 18, 2005, the temporary ELJ remained intact but was not preventing high water from invading Highway 410 (Appendix A).

If no additional erosion protection measures are taken, SR 410 will remain at high risk of damage and closure that would limit access to Crystal Mountain Resort and have significant economic impacts to the region. Crystal Mountain Ski Resort submitted a letter to WSDOT (August 25, 2004; Appendix B) stating concern that flooding and erosion issues with Highway 410 in the vicinity of Crystal Mountain Boulevard pose a significant threat to public access to the resort. Flow into the side channel running along SR 410 is likely to recur at relatively low magnitude, high frequency flows (≤ 1 year recurrence peak flow). Flow along and over the highway also will continue to have negative environmental impacts. Flooding similar to October 2003 has occurred again on January 17-18, 2005 (Appendix A).

This memo outlines viable emergency measures that could be implemented during the winter 2004 and 2005 by WSDOT in conjunction with MRNP and MBSNF to protect SR 410 and limit potential road closures that could severely impact winter traffic to Crystal Mountain Resort. The memo also identifies long-term actions necessary to protect SR 410 between MP 57 and 59 that will be addressed in a forthcoming Reach Analysis that will be completed by Herrera in the summer of 2005.

Background

Much of SR 410 along the Upper White River within Mt. Baker Snoqualmie National Forest and MRNP is constructed on the alluvial sediments within the floodplain and channel migration zone (CMZ) of the upper White River. The upper White River originates at the Emmons Glacier on Mount Rainier approximately 14 miles southwest of the (northern) MRNP boundary. The river is characterized by a wide, shallow braided channel flanked by forested floodplains. Braided channels are typical of glacial rivers which have an extremely high supply of coarse sediment. Channel aggradation resulting from the high sediment supply raises the elevation of the river bed through time and creates a distinctive convex valley cross-section in which the active river channel is situated higher than its adjacent floodplains. This situation creates a high potential for channel avulsions into the lower lying floodplain areas. Heavily forested conditions on the floodplains of the upper White River prevent major changes in the river's course by providing frictional resistance that dissipate and disperse flood waters and facilitate floodplain sedimentation. Frequent over bank flows create and sustain a network of side channels within forested floodplains. While these channels only convey a fraction of the river's discharge during peak flows, they still pose a significant threat to SR 410 due to their high gradients, such as occurred in October 2003 near MP 58 (Figure 1). Energy dissipation and flow dispersion

provided by the large trees and woody debris located between the active river channel and SR 410 at MP 58.0-58.6 prevented much more catastrophic damage to the highway.

Erosion risk to SR 410 is greatest where SR 410 is situated adjacent to the active braided river channel and lacks a buffer of mature forest (MP 59). Where the highway is situated on floodplain lying below the river's grade it is subject to substantial flood and erosion risk, no matter how far from the active (unvegetated) river channel (MP 58). Erosion risk is primarily a function of the erodibility of the road embankment. Similarly, the flood risk is primarily a function of the relative elevation of the road embankment.

October 2003 Storm Event

A large rainfall event in October 2003 caused widespread flooding in western Washington that resulted in federal disaster assistance throughout the region. While flows in the Upper White River were not exceptionally high during this event, the combination of channel aggradation described above, led to over bank flooding and a small avulsion approximately 250 feet west of MP 58.6 (Figure 1). Flow from the avulsion traveled almost due north about 800 feet to where it intersected SR 410 at MP 58.4. Flooding resulted in deposition of sand, gravel, and cobble across much of the floodplain and incision of at least two side channels that flowed northeast from the river into SR 410 (Appendix A). The avulsion sent flow to the northeast toward SR 410 at a gradient of over 2 percent. When flow reached SR 410, it spread out onto the Highway and deposited a lot of sediment and debris (Appendix A). Local scour undermined the western embankment of the highway between MP 58.05-58.10 (Appendix A). SR 410 was closed to traffic while WSDOT maintenance crews contained flooding, repaired the highway, and constructed the emergency ELJ designed by Herrera. During this time there was limited access to Crystal Mountain Resort or MRNP.

In response to this flood event and road closure, the MRNP asked Herrera to access emergency hazards along the White River from the park boundary up to the White River Campground (Figure 1). Herrera also developed and implemented emergency measures to protect SR 410 between MP 58 and 59 from further flooding and erosion during the winter 2003-2004. Herrera recommended construction of an engineered logjam upstream from where the river avulsed into the floodplain where the most advantageous topographic conditions existed for deflecting the river channel to the west away from SR 410. Construction materials were limited to logs and snags found on gravel bars within approximately 0.1 km of the proposed 2003 ELJ location. No functional material forming pools was used, only loose material that had accumulated on bars. The ELJ was constructed directly adjacent to the right (east) bank of the river about 500 feet upstream of the avulsion. No cable or imported material was used in construction of the ELJ. The ELJ immediately deflected the river's flow and resulted in a dramatic decrease in flow running along SR 410 (right bank). When inspected on December 21, 2004, the ELJ was continuing to achieve the desired goals (deflecting flow away from the right bank), but has experienced scour at its upstream end and lost several of the racked logs facing the structure. However, this racked material should be replaced in the near future to ensure its structural integrity. During high water on January 18, 2005, flow was going over and around the ELJ but the structure remains intact.

December 2004 Field Reconnaissance

Herrera conducted a two-day field reconnaissance visit on December 20 and 21, 2004 of the potential emergency hazards to SR 410 that persist as a result of the October 2003 emergency. During this site visit, Herrera completed field topographic surveys with an optical autolevel to document the elevation of SR 410 relative to the river, floodplain and side channels (Figure 2). The topographic surveys included a valley cross-section perpendicular to SR 410 at MP 58.42 (Figure 3a); three short transects also perpendicular SR 410 at MP 58.31, 58.30, and 58.38 (Figures 3b, 3c, 3d); a profile of the river channel from MP 58.42 to 58.63 (Figure 4); and a profile of the highway grade from MP 58.63 to 57.8 (Figure 4). Herrera also documented observations of channel and floodplain conditions that posed significant risk to SR 410. A Trimble XTTM global positioning system (GPS) was used to record locations of observations and surveys.

The valley cross-section Herrera surveyed at MP 58.42 on December 20 clearly documents a convex cross-section across the Upper White River valley with the surface of SR 410 situated about 2 meters (6 feet) below the active river channel (Figure 3a). The floodplain in this locale has a lateral gradient from west to east of about 2 percent. Channel avulsions such as occurred upstream of this cross-section in October 2003 would have a gradient of over 2 percent and result in extremely high velocities without substantial flow resistance. The potential for erosion is clearly illustrated in the cross-section by the presence of a deeply incised side channel about halfway between SR 410 and the river (Figure 3a). Because the grade of SR 410 diverges from the general grade of the White River and its valley, sections of the highway in vicinity of MP 58 end up well below the grade of the river bed (Figure 4). Three short transects were measured perpendicular to the highway north (downstream) of the valley cross-section (Figure 2). These transects (Figures 3b-3d) illustrate that the elevation of the highway relative to the river grade diminishes north of cross-section no. 4 (Figure 3a). The energy of flow impinging on the highway at cross-sections 1-3 (Figures 3b-3d) is reflected in the deposition of large cobbles on the highway and adjacent floodplain surfaces at elevations equal or greater than the highway (Appendix A). Assuming the floodplain has a similar lateral gradient as found in the valley cross-section, the road lies as much as 3 meters (9 feet) below the river. The relatively low area along the eastern margin of the river's floodplain between MP 57.5 and MP 59 will continue to pose significant risk of flooding and erosion along SR 410. Inspections on December 20 and 21 indicate the temporary ELJ constructed in October 2003 is still effectively deflecting flow away from east floodplain. But the ELJ was constructed only as a temporary emergency measure. Failure of the ELJ or a change in channel conditions (location and bed elevation) could re-introduce a significant portion of the river's flow into the channel network that damaged SR 410 in October 2003.

Since the initial draft of this memorandum was submitted on December 24, 2004, SR 410 was again subjected to similar flooding as occurred in October of 2003 on January 17 and 18, 2005 (Appendix A). Based on the surveys conducted in December 2004 and evidence presented in this memorandum, SR 410 will continue to be at significant risk without immediate emergency response measures in 2005 and development of a long-term plan to raise and protect the highway.

Emergency Response Measures

Based on Herrera's previous emergency response work in October 2003 and a site reconnaissance conducted on December 20 and 21, 2004, the following emergency response measures are recommended for implementation to control flooding, prevent erosion and highway closures along SR 410 during the winter 2004-2005. These proposed response measures build upon the emergency action (logjam construction) that was built in October 2003 in response to a large rainfall event that flooded SR 410 and limited access to Crystal Mountain Boulevard.

The intent of these measures is to direct the river's flow away from the highway and the side channels that exist in the riparian area between the highway and the active river channel. Because the elevation of the river channel is higher than the road, it is important to help direct the rivers flow away from the right bank and the lower topography that exists between the river channel and the roadway.

Table 1 presents four categories of potential emergency response measures that could be employed during the winter 2004-2005. The recommended measures could be implemented as preventative actions to protect SR 410 or as part of an emergency reaction strategy should the road be threatened again in 2005, as has occurred with the January 17-18 flooding. These emergency response measures will not provide long-term protection, which will require raising a portion of the road grade.

Table 1. Recommended emergency response measures to protect SR 410.

No.	Action Measure	Physical Effect	Objective	Environmental Benefit
1	Road buffer hardening (either using wood debris or rock keyed into substrate)	Increased resistance of embankment to erosion and reduction in shear stresses along road	Prevent undermining and erosion of highway	Development of forest buffer between road and aquatic habitat
2	Add stable roughness elements to floodplain and side channels	Dissipate energy of flows impinging on highway, encourage sedimentation	Prevent undermining and erosion of highway	Increase terrestrial and aquatic habitat complexity
3	Flow deflection structures (engineered logjams)	Deflect river flow away from high risk areas, reducing flow impinging on highway	Diminish potential for flooding and erosion	Pool formation, complex cover and channel complexity
4	Reduce roughness along preferential flow paths in floodplain	Reduce flow resistance and encourage side channel development away from highway.	Reduce chances of channel development adjacent to highway	Development of side channels in floodplain away from road

Unlike traditional river protection measures such as blanket rock revetments, levees or flood walls which have adverse environmental impacts, each of the potential emergency response measures presented in Table 1 can be implemented in manner that provides net environmental benefits and thus be self-mitigating. All recommended actions should be coordinated with appropriate WSDOT and MRNP personnel and directed by a qualified professional civil engineer and hydrologist or hydrogeologist with expertise in fluvial geomorphology.

1. Erosion Protection: Road Buffer Hardening

Construction of hardened buffer of variable width along toe of highway grade using log cribbing or large rock overlain by topsoil and reforested.

Recommended Treatment Sites for Winter of 2004-2005 [Figure 5a]

1. MP 57.92-57.98: Directly adjacent to SR 410.
2. MP 58.65-58.66: Directly adjacent to SR 410.
3. MP 59.18-59.24: Foothills Creek Stockpile site, 130 feet west of SR 410.

2. Energy Dissipation: Stable Floodplain and Side Channel Roughness Elements

Construction of embedded logs and rootwads within low-lying areas and potential flow pathways that pose potential erosion risks to highway embankment.

Recommended Treatment Sites for Winter of 2004-2005 (Figure 5b)

1. MP 58.75: Approximately 100 feet in low lying swale impinging on road embankment.
2. MP 58.72-58.78: Approximately 300 feet on surface of old road grade through forest floodplain and adjacent to site above.
3. MP 58.40: Approximately 100 feet near where October 2003 avulsion channel impinges on SR 410.

3. Flow Deflection: Engineered Log Jams

Construction of ELJ structures along right (east) bank of White River to deflect river flow away from SR 410 without precluding non-threatening over-bank flows from depositing sediment to buildup floodplain surface.

Recommended Treatment Sites for Winter of 2004-2005 (Figure 5b)

1. MP 58.84-58.90: 1-2 ELJ structures along right bank of river near SR 410.
2. MP 58.77: Reinforce natural logjam along right bank.
3. MP 58.62: Repair and reinforce ELJ constructed in October 2003.
4. MP 58.53: Reinforce natural logjam at point of October 2003 avulsion along right bank of river.

5. MP 59.2: Two to three ELJ structures along eroding embankment adjacent to Foothills Creek Stockpile.

3. Preferential Flow Paths: Side Channel Encouragement Away from SR 410

This option would involve minor movement of existing wood debris on the floodplain to clear narrow pathways of reduced roughness that would encourage side channel development away from the road. This work could be done in combination with action no. 2 in some locations.

Recommended Treatment Sites for Winter of 2004-2005 (Figure 5b)

1. MP 57.75-58.50: Clear a 20 foot wide sinuous pathway through the forest in locations where there is high risk of flow capture by the highway. This action could possibly be done at other sites under supervision of qualified fluvial geomorphologist familiar with project site.

Conclusion

The above action items are emergency measures and are only intended for short-term interim action to maintain sections of SR 410 at immediate risk. Despite these interim actions, a two mile section of SR 410 closed in October 2003 due to flood and erosion damage remains at a high risk of additional damage. A set of four potential emergency response measures at specific sites have been recommended to be implemented either proactively or in response to additional flood impacts during the winter of 2004-2005. Surveys conducted on December 20-21, 2004 clearly demonstrate that SR 410 will require much more substantial improvements to provide long-term protection, particularly increasing the elevation of the road grade. Herrera will present long-term recommendations regarding long-term protection of SR 410 as part of a Reach Analysis currently underway for WSDOT.

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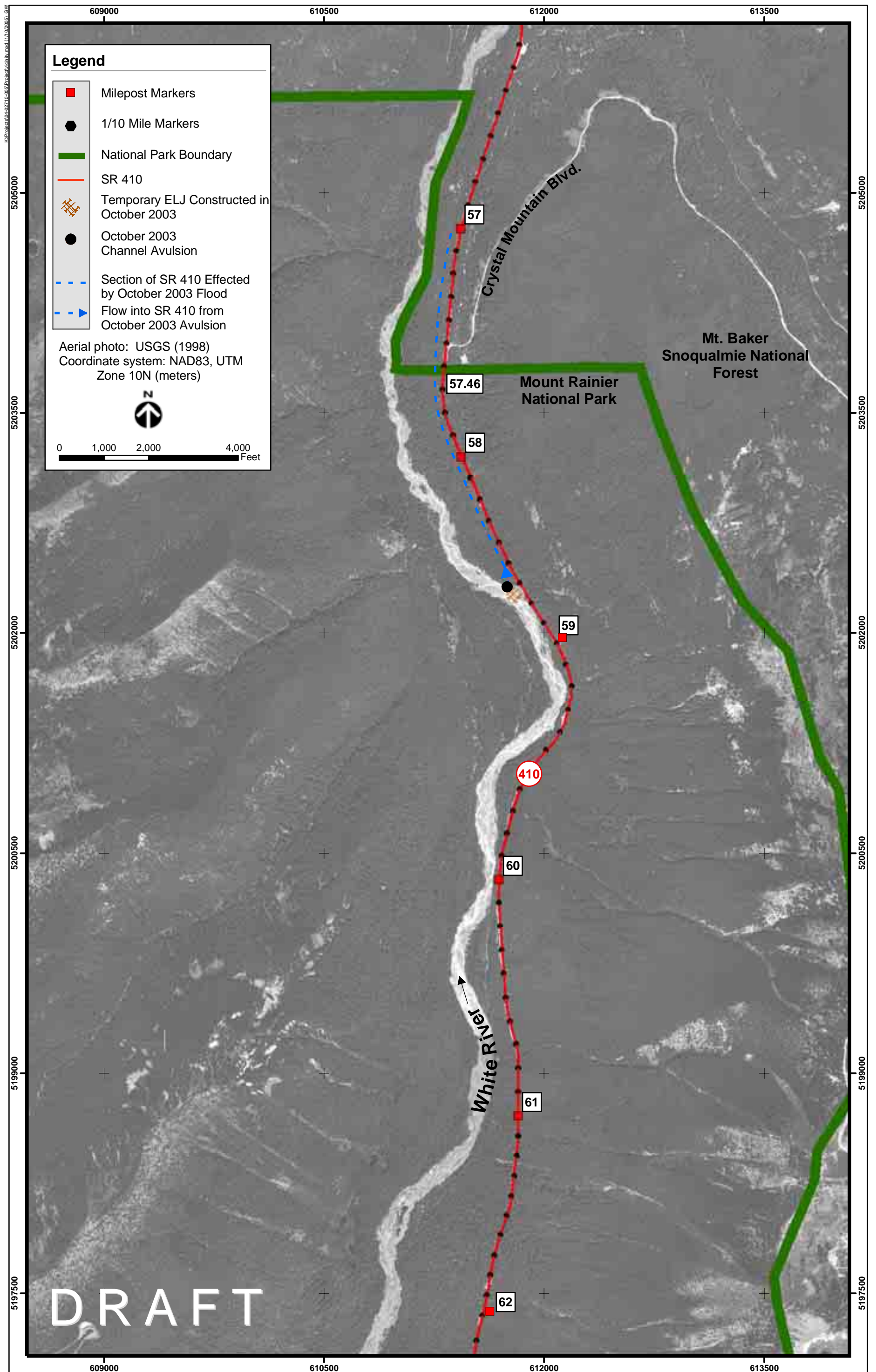


Figure 1. Upper White River and SR 410 vicinity map, Pierce County, Washington.

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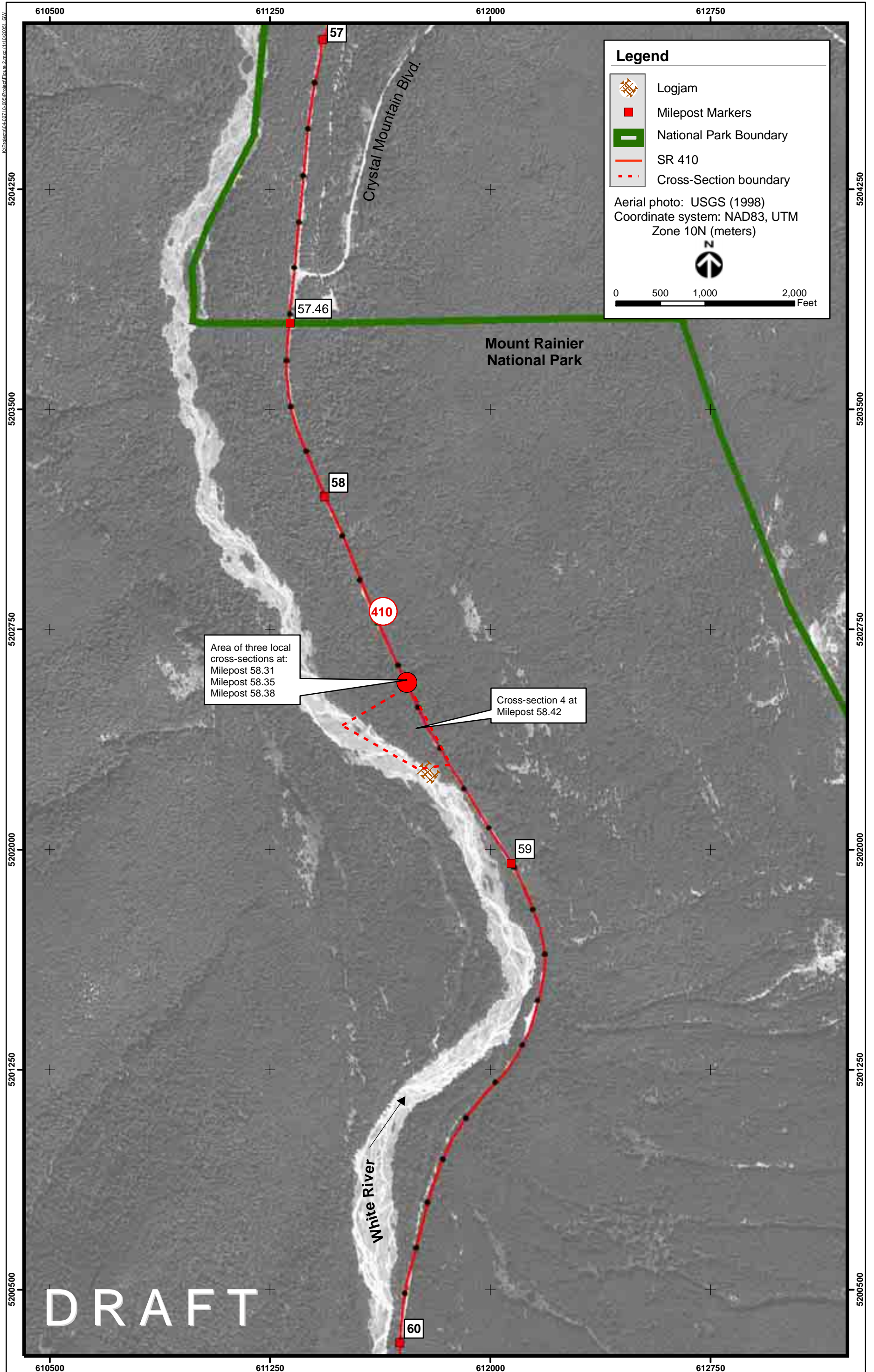


Figure 2. Upper White River December 20 and 21, 2004 site reconnaissance cross-section survey locations, Pierce County, Washington.

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Cross Section 4 (MP 58.42)

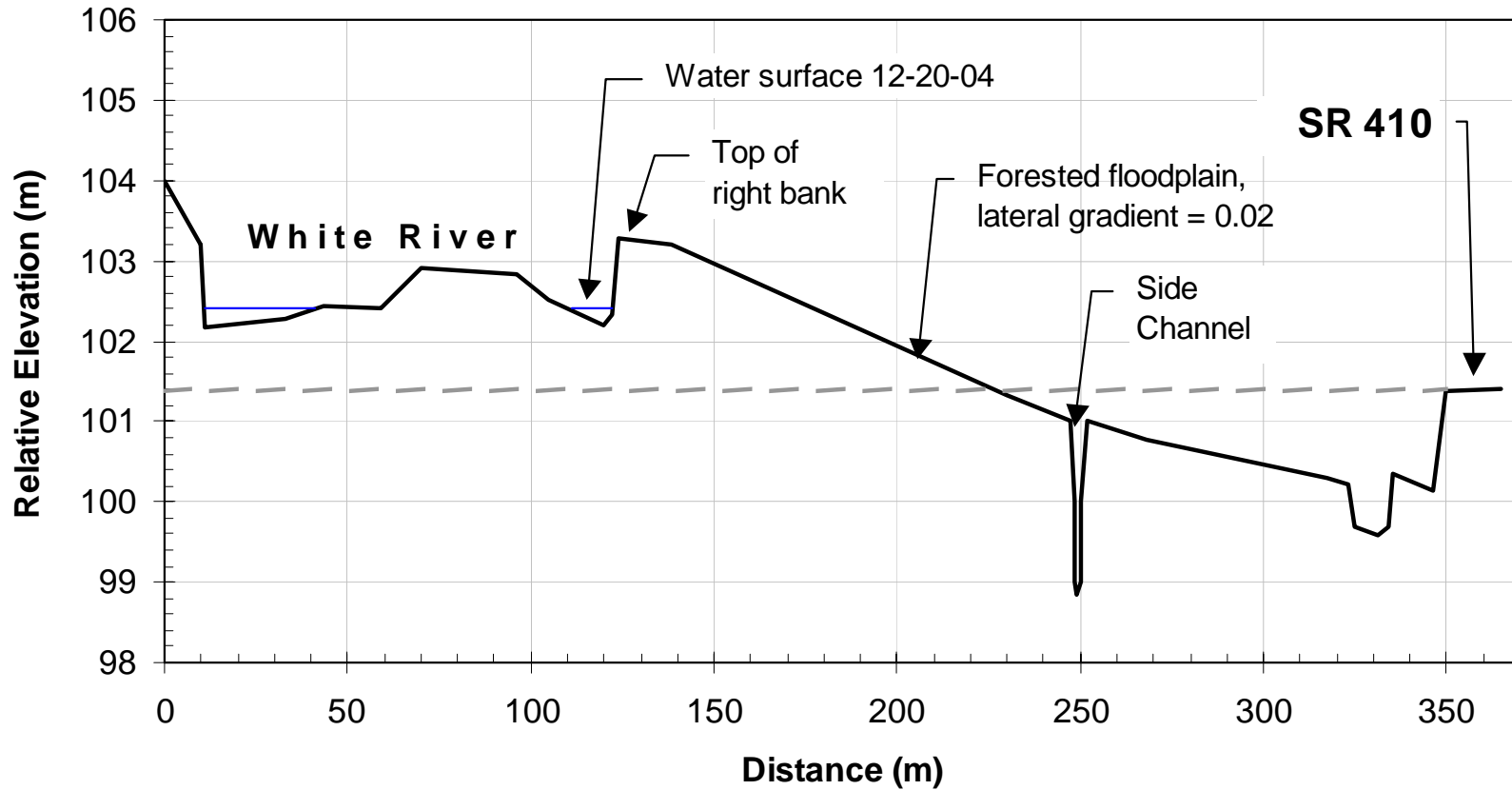


Figure 3a. Valley cross-section no. 4 surveyed on Monday December 20, 2004. River channel is situated 1 meter above surface of SR 410. Bankfull elevation in channel is 2 meters above highway surface.

Cross Section 3 (MP 58.38)

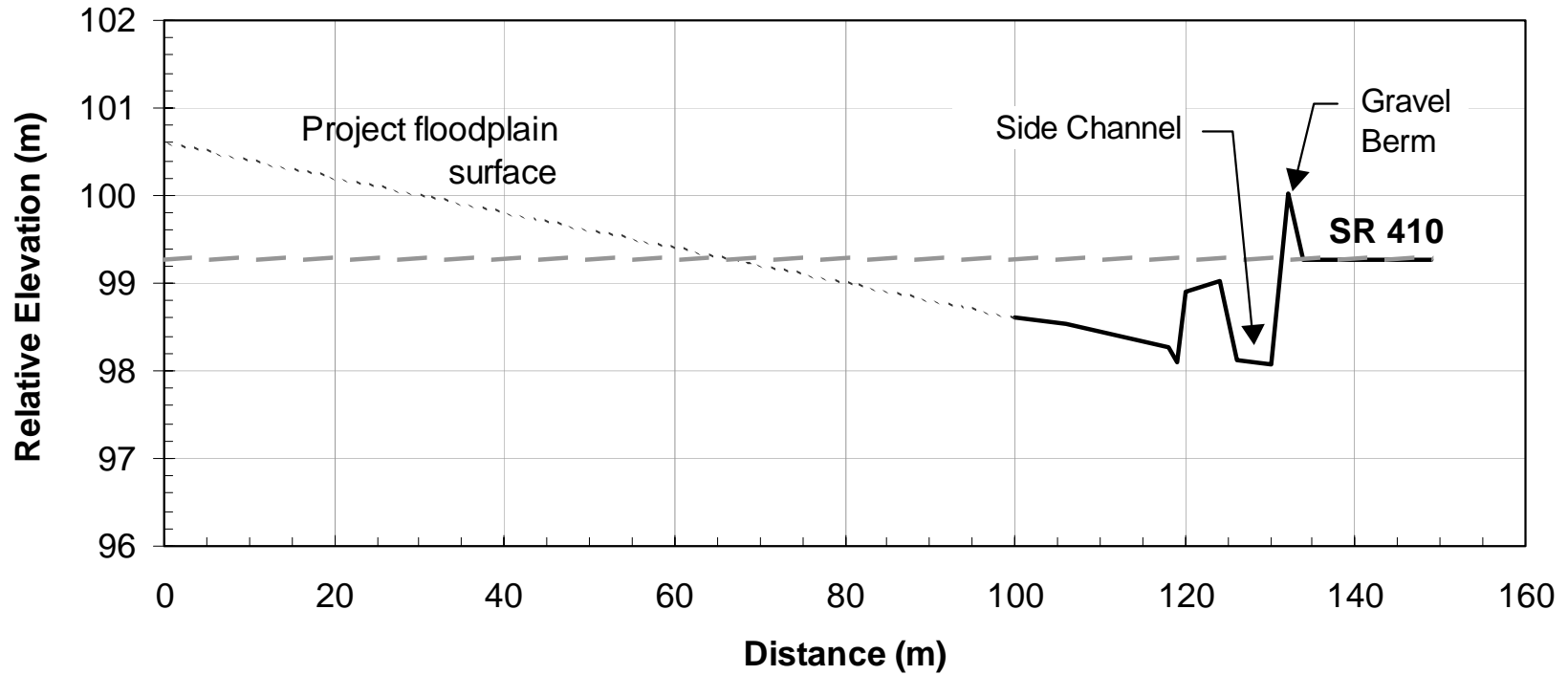


Figure 3b. Cross-section transect no. 3 surveyed Tuesday December 21, 2004. Projected floodplain surface (short dashed line) based on floodplain gradient in cross-section no. 4. Thick dashed line is projected elevation of SR 410 road surface.

Cross Section 2 (MP 58.35)

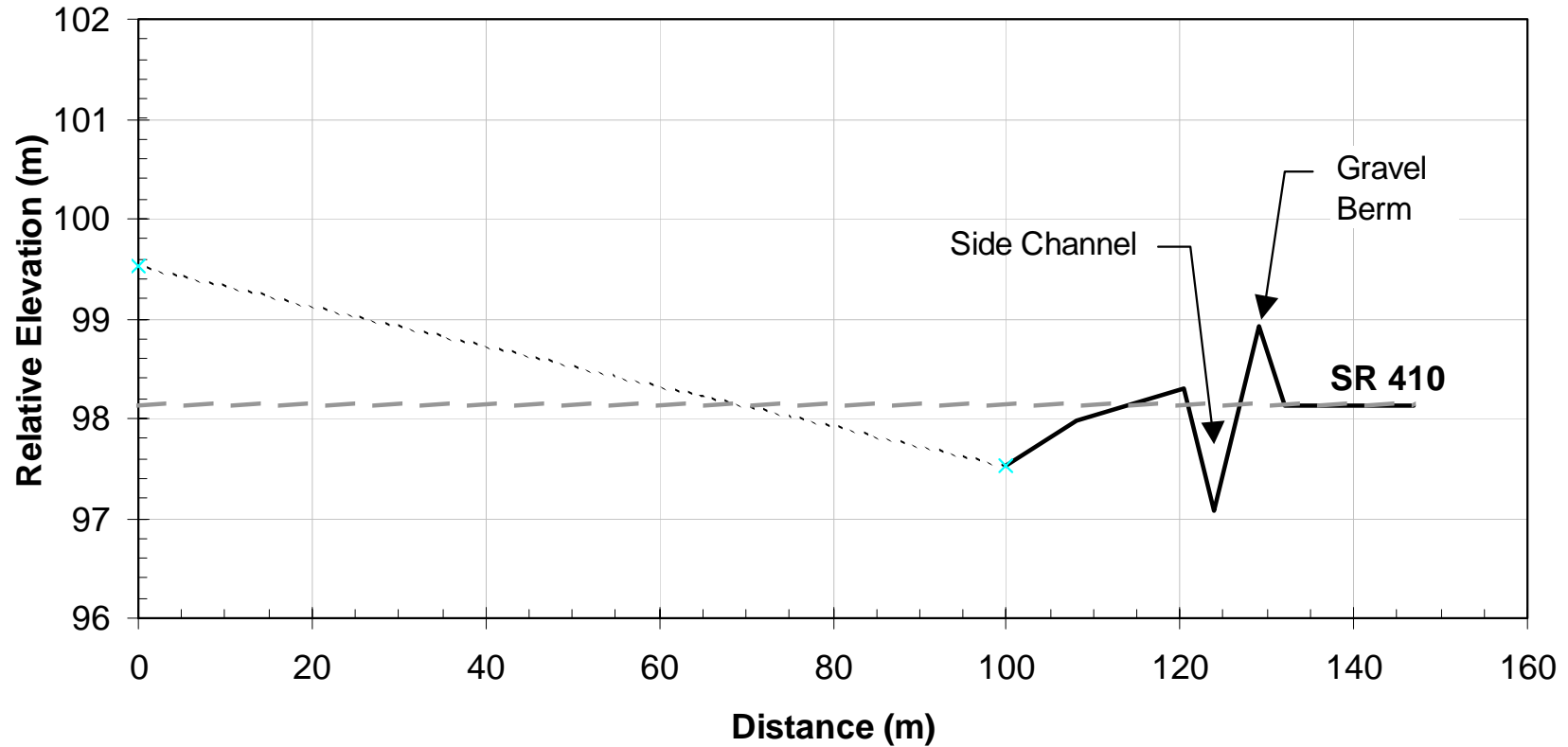


Figure 3c. Cross-section transect no. 2 surveyed Tuesday December 21, 2004. Projected floodplain surface (short dashed line) based on floodplain gradient in cross-section no. 4. Thick dashed line is projected elevation of SR 410 road surface.

Cross Section 1 (MP 58.31)

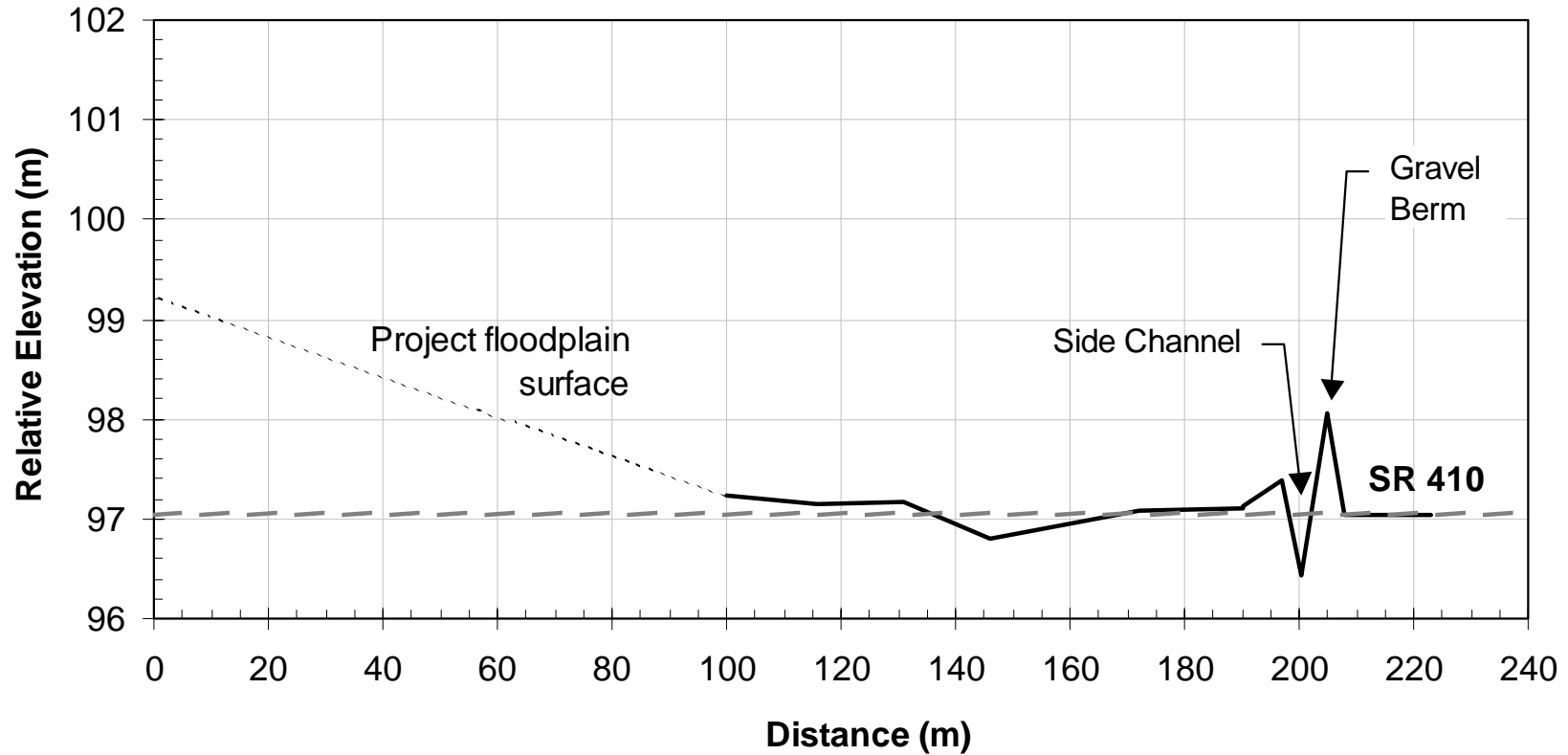


Figure 3d. Cross-section transect no. 1 surveyed Tuesday December 21, 2004. Projected floodplain surface (short dashed line) based on floodplain gradient in cross-section no. 4. Thick dashed line is projected elevation of SR 410 road surface.

Estimated Road and River Profile

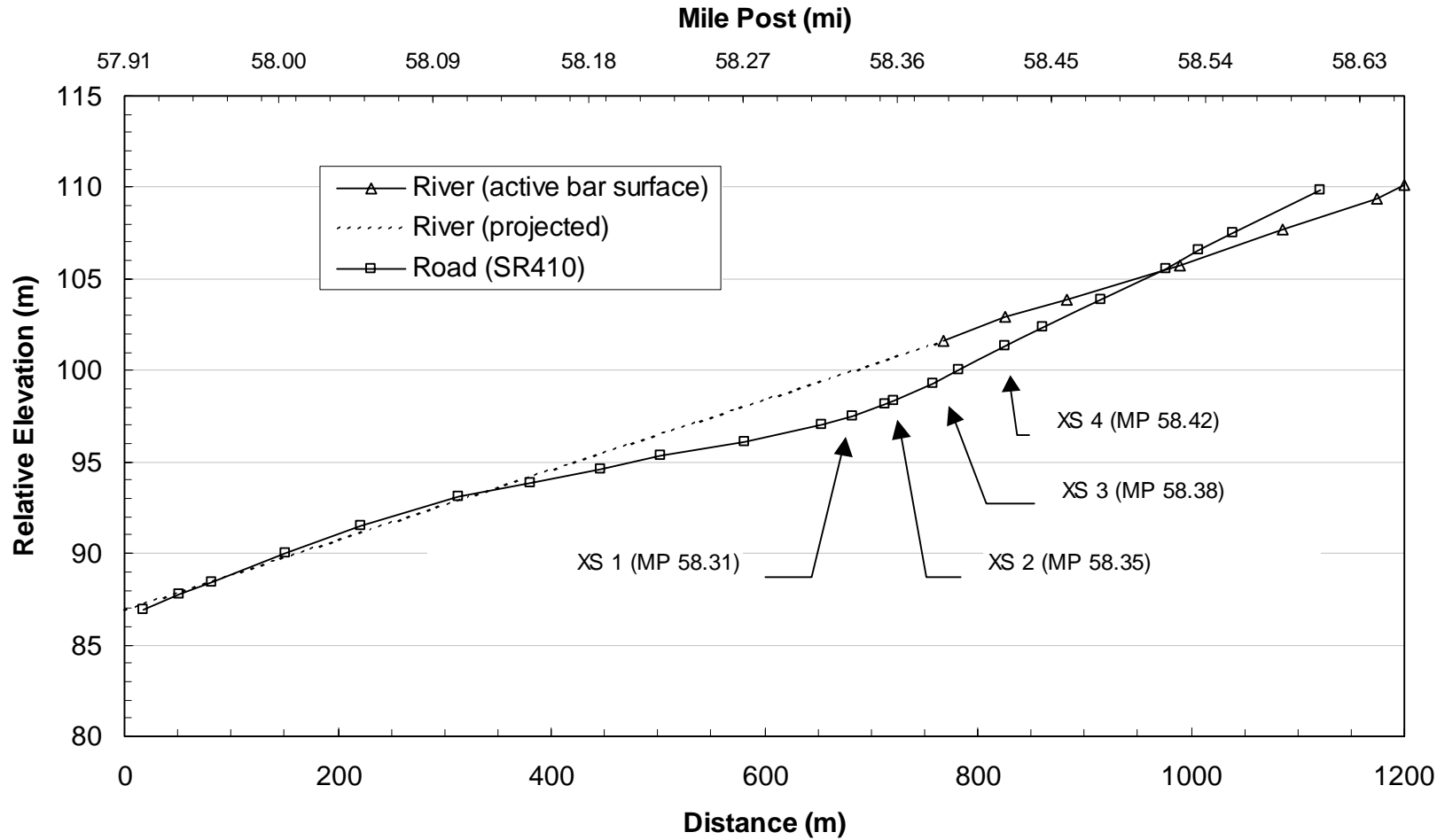


Figure 4. Profile of SR 410 road surface and bed surface of adjacent Upper White River, surveyed 12-20-04.

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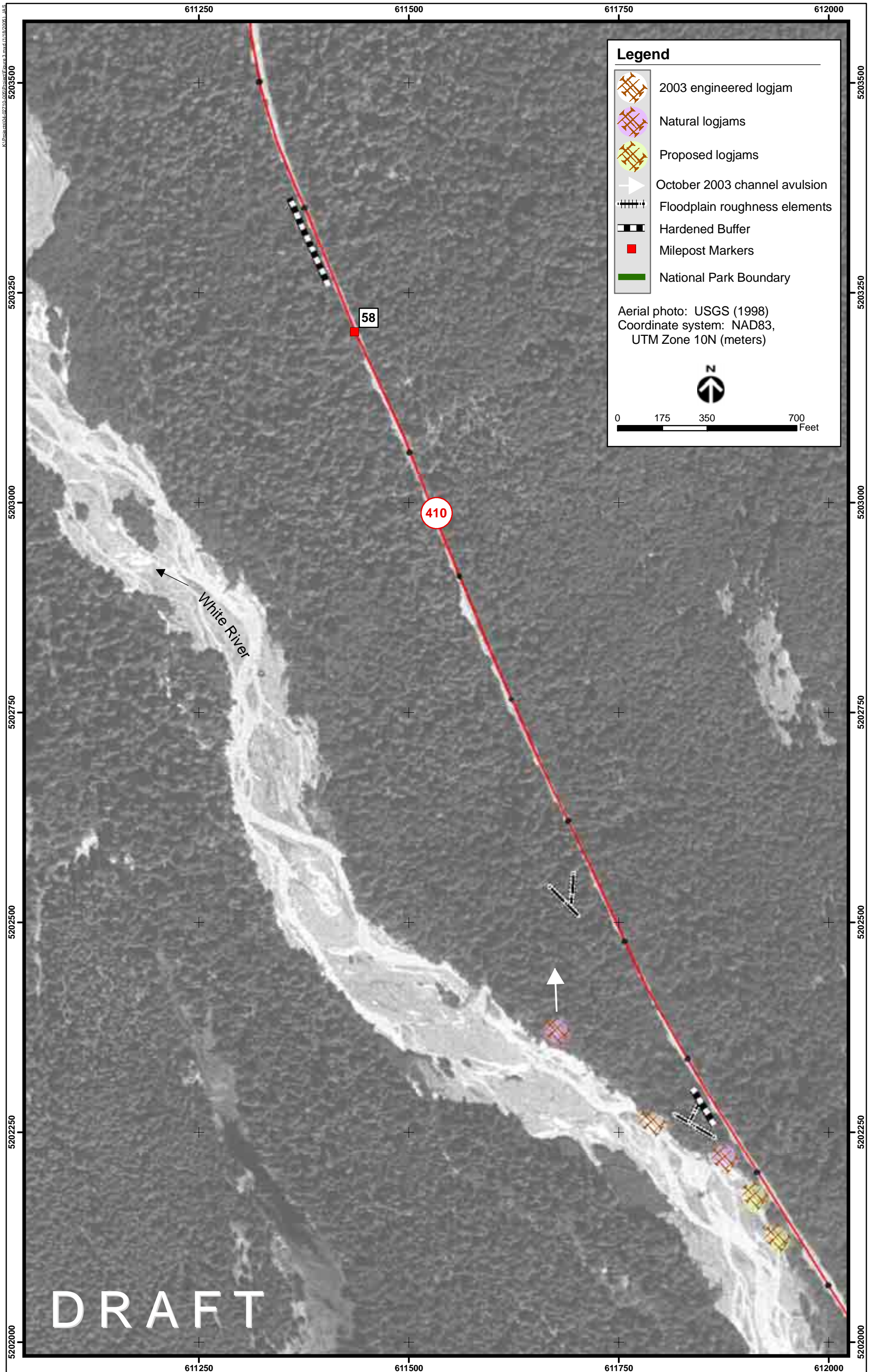


Figure 5a. White River 2004 - 2005 emergency response measures, Pierce County, Washington (1/2).

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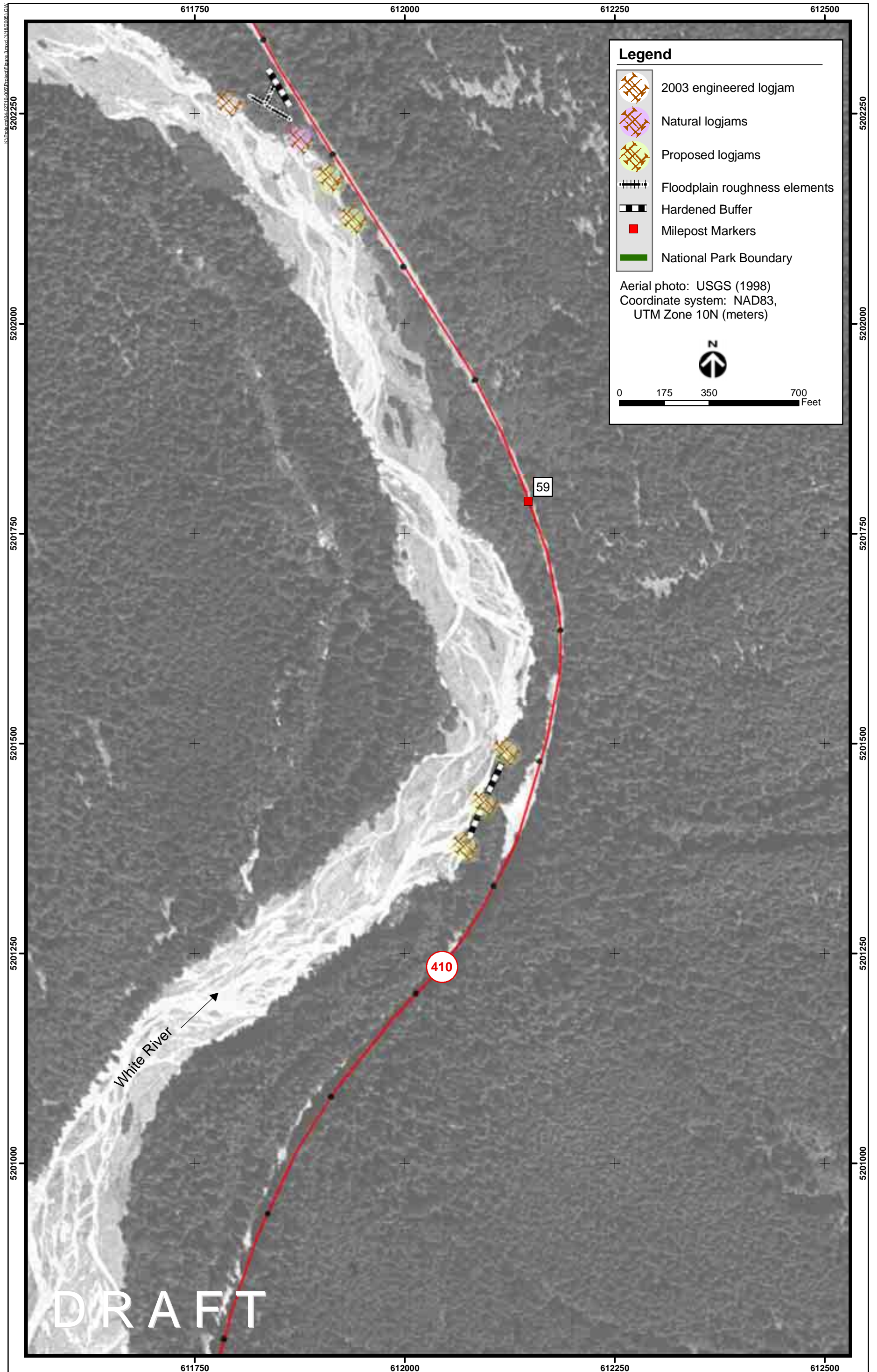


Figure 5b. White River 2004 - 2005 emergency response measures, Pierce County, Washington (2/2).

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APPENDIX A

SR 410 Emergency Memorandum Site Photographs

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MP 57.45

Photo taken standing in Mount Rainier National Park (MRNP) looking north (downstream) along SR 410 during October 2003 flood at boundary with Mt. Baker-Snoqualmie National Forest (MBSNF). Crystal Mountain Boulevard is just beyond park boundary on the right (east). Photo by Ed Burnside, WSDOT.

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~MP 58.05

Erosion undercutting highway embankment of SR 410, October 24, 2003. Photo looking south (upstream).

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~MP 58.30

WSDOT maintenance crews clearing sediment and debris from SR 410 during October 2003 flooding. Photo looking south (upstream). Photo by Ed Burnside, WSDOT.

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~MP 58.30

WSDOT maintenance crews clearing sediment and debris from SR 410 during October 2003 flooding. Photo looking south (upstream). Photo by Ed Burnside, WSDOT.

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~MP 58.30

WSDOT maintenance crews constructing temporary gravel berm to contain flow to west margin of SR 410 during October 2003 flooding. Photo looking south (upstream). Photo by Ed Burnside, WSDOT.



Similar view of site on January 18, 2005.

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MP 57.92

Eroding bank along SR 410 at culvert crossing, MP 57.92, 12-20-04. Lower section of concrete culvert pipe was transported about 50 feet downstream. Construction of an armored toe to embankment is recommended for this site.

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MP 57.42

Photograph taken 12-20-04 looking north-northeast (downstream) at SR 410 directly downstream of valley cross-section (no. 4) at MP 58.42. Floodplain forest is buried in cobble delivered in October 2003 flood. Construction of roughness elements (embedded logs and snags) to dissipate energy are recommended for this site.

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MP 58.62

Upstream margin of Emergency ELJ on 08-07-04 (a) and 12-20-04 (b), looking west toward left bank of river. River flow is from left to right. ELJ has experienced some erosion. Placement of additional wood debris at upstream end of structure is recommended.

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MP 58.75

Standing on old road grade and looking north-northeast toward SR 410 down side channel directed at highway embankment, 12-20-04. Construction of roughness elements (embedded logs and snags) within channel and at toe of road embankment to dissipate energy are recommended for this site.

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MP 58.76

Standing on old road grade and looking upstream (south-southeast) toward SR 410 and White River, 12-20-04. Construction of roughness elements (embedded logs and snags) along old road grade to dissipate energy are recommended. Reinforcement of natural logjam along right bank of river (upper right of photo) is also recommended.

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MP 58.82

Looking downstream along right bank, 12-21-04. Temporary ELJ constructed in October 2003 is at center left of photo (i) and SR 410 to far right. Natural logjam recommended for reinforcement is at right center of photo where old road grade emerges from floodplain forest (ii). Construction of one to two additional ELJ structures is recommended directly adjacent to right bank at far right.

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MP 59.20

High eroding bank at stockpile site, MP 59.2 looking upstream along old road grade, 10-31-03 (a) and 12-21-04 (b). Bank here has eroded approximately 3 feet between October 2003 and December 2004 (undercut stump in right center of photo). Based on planform of the river, erosion is likely to continue at this site and poses a significant threat to stockpile site. Construction of an armored toe to embankment and engineered logjams to deflect flow away from bank are recommended for this site.