Entiat River 3D Reach Assessment and

Conceptual Project Development

Provided for:

Confederated Tribes and Bands
of the Yakama Nation
P.O. Box 151, Fort Road
Toppenish, WA 98948

Submitted by: Inter-Fluve, Inc.
1020 Wasco St., Ste I, Hood River, OR 97031 541-386-9003

March 2, 2010

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INTRODUCTION

In 2009, the Yakama Nation Fisheries Program contracted Inter-Fluve Inc. to undertake field investigations and analyses required to provide fish habitat project alternatives for reach 3D of the Entiat River. Reach 3D starts at river mile (RM) 24 and ends at RM 25. An understanding of current habitat conditions, fluvial geomorphic history, hydrology and inundation hydraulics was used as a foundation to identify and support project opportunities.

Several studies have been completed on the Entiat River and, where applicable, we used and referenced this information in our analyses. This report presents our project alternatives, including summary of analysis techniques and results, discussion of potential ecological benefits, and planning estimates for design and construction.

SITE VISITS

In December 2009, Inter-Fluve Inc. staff Dan Miller PE and Mike Brunfelt LG visited the site and completed a topographic survey sufficient for hydraulic analysis. The goal of the hydraulic analysis was to determine relative inundation of adjacent topography. We used an understanding of relative inundation to identify or confirm field observations of potential stream enhancement or restoration opportunities and to help develop planning level construction costs.

EXISTING SITE CONDITIONS

The following is an assessment of existing site conditions using field observations, survey, hydraulic analysis and previous reports.

Maps and Historic Aerial Imagery

We used LIDAR maps, historical air photos, and mapped alluvial deposits to aid our existing conditions analysis. Particularly valuable was a comprehensive map atlas of the Entiat River produced by the U.S. Bureau of Reclamation (2009). This was used to support field observations of the geomorphology of the area.

Fluvial Geomorphology

Reach 3D is a relatively small, one mile sub-reach of the larger Stillwater reach. Reach 3D occurs between RM 24 and 25, while the Stillwater reach begins at RM 16 and extends to RM 25 and runs within a glacial U-shape valley. The glacier that eroded the valley extended down to RM 16 where it left a terminal moraine. The terminal moraine also signifies the transition between a relatively steep, more confined channel below and the relatively flat, unconfined channel above.

The Stillwater reach is influenced by several steep drainages and their associated alluvial fans that extend into the valley and impinge on the river in several locations. Alluvial fans in the Stillwater reach were created by both gradual stream channel deposition and rapid debris torrents.

Debris torrents occur under intense rainfall conditions in steep, confined drainages with unstable slopes. They can be characterized as high energy, fast moving mixtures of water, sediment, rock, wood and trees that rapidly move down valley until encountering lower gradient and/or less confined valley segments, where energy is dissipated and debris transport stops.

Where steep confined valley-wall drainages intersect the Entiat River valley floor, rapid gradient reduction occurs, resulting in debris torrent deposition and fan morphology. At these intersection points in the valley, the boulder and finer sediments essentially bury the valley and channel because the Entiat River is not large enough to transport these larger materials.

Following the last glacial advance, alluvial fans have grown and "dammed" the river in several locations, reducing channel slope upstream of the fan deposits. Generally, river gradients upstream of alluvial fans are flatter and river meander corridors are wide. But across the face of the fan, the river channel is steep as the river attempts to erode down through the relatively immobile debris torrent materials.

Reach 3D is bounded downstream by the Brennegan Creek alluvial fan near RM 24 and upstream by the Grandma and McCrea Creek alluvial fans near RM 25. Reach 3D is between alluvial fans and is vertically controlled at the downstream end by the Brennegan Creek alluvial fan. Reach 3D channel has a low-gradient valley-wide meander corridor with several old channel alignments running through it. A large beaver complex is located in the southeastern segment of the floodplain and extends from the confluence of Brennegan Creek and the Entiat River upstream to the Entiat Valley Road prism. Historical channels that feed into this segment of the valley extend further upstream to a high terrace near RM 25.

Historical Channel Changes

The Entiat River has been subjected to a range of direct river channel and watershed scale disturbances. Road building, grazing, timber harvest, riparian clearing, log drives, river channel large wood removal, catastrophic fire, bank revetment and development within the river meander corridor have cumulatively disrupted natural habitat processes and historical fish habitats.

Although habitat in reach 3D is better than that of the lower 16 miles of the Entiat River, it is still below its historical conditions and existing potential. Much of this is due to past in-channel wood removal and valley bottom clearing that removed existing and future sources of wood within the Entiat River meander corridor.

Although much of the channel riparian area is healthy, the large cottonwood trees and valley bottom forests essential to creating large complex log jams, slowing bank erosion rate, creating side channels and fish habitat are limited due to previous land clearing. The removal of in-channel wood and clearing of valley bottom trees has left a void of natural processes and fish habitat that cannot be quickly recovered. Godaire (2009) found many large Entiat River meanders cut off (avulsed) between 1962 and 1975 that decreased channel sinuosity and increased local channel slope. Large floods in 1948 (100-year) and 1972 (50-year) likely played a significant role in the channel changes (reduced sinuosity) that were observed between the 1948, 1962, 1975 aerial photographs. Between 1975 and 2009, changes in sinuosity have been relatively small and limited to gradual lateral bank erosion, which over time will increase sinuosity and reduce channel slope.

Erosion occurs faster on the Entiat River within the Stillwater reach than in similar streams running within relatively undisturbed valley bottoms. It is suggested by Woodsmith and Bookter that this could be due to low frequency of in-channel large wood jams and lack of adjacent mature riparian forests to provide materials for log jams. Standing mature trees as well as wood in the channel reduce bank erosion rates, and both are limited within the Entiat River (Woodsmith and Bookter, 2009).

<u>Field Observations and Processes</u>

Our field observations supported the historical record that reach 3D has limited in-channel large wood material. One bar jam exists in the lower third of the reach but it only influences the channel at greater than bankfull discharges and does not provide habitat during low flows. There are limited opportunities for natural large wood additions throughout the reach. Much of the adjacent riparian forest is composed of immature cottonwood and understory woody vegetation.

Our field observations of reach 3D agree with the results of Woodsmith and Bookter (2009) who completed baseline comparative analysis of large wood processes between the Stillwater reach and climatically similar reference reaches in other watersheds. They found that bank migration rates in the Stillwater reach were substantially greater than in intact reference reaches, suggesting the degree of previous disturbance in the Stillwater reach may have accelerated erosion potential.

Our field observations, analysis and conclusions are consistent with previous studies. We believe that large wood processes have been interrupted. To improve conditions, future large wood sources can be established throughout the valley. To improve immediate conditions, a strategy of imported large wood loading and log jam construction could be completed to bridge the gap between relatively poor existing conditions and natural wood loading in the future as riparian forests mature.

<u>Fish Habitat Limiting Factors</u>

The three primary anadromous fish species that use reach 3D are Steelhead, Spring Chinook and Summer Chinook. Archibald (2009) indicated that for all these species, improvements to large wood size and distribution, pool habitat complexity, and off-channel rearing habitats should be considered. This type of work would also improve bank resiliency and reduce erosion rates indicated in the Woodsmith and Bookter (2009) study.

Based on a review of previous studies, field observations and analysis, we have identified opportunities to increase large wood habitat, improve off-channel habitats and restore floodplain processes. To confirm and further identify projects, an understanding of inundation in segments of the reach was completed. Site survey, hydrologic estimates and hydraulic models were completed for inundation analysis.

HYDROLOGY

A substantial effort to estimate the Entiat River hydrology was undertaken in 2009 by the U.S. Bureau of Reclamation (BOR). Sutley (2009) used previous hydrologic studies, gage data and GIS integration to estimate flood frequency by river mile. Results of this study were used for our hydraulic analysis and are presented in the table below for the reach 3D.

Return Interval Flood Discharge	***2-Year***	***5-Year***	***10-Year***	***25-Year***	***50-Year***	***100-Year***
Entiat River Hydrology at RM 25	2560 cfs	3500 cfs	4120 cfs	4890 cfs	5460 cfs	6030 cfs

HYDRAULIC ANALYSIS

Inter-Fluve Inc. completed a hydraulic survey and analysis for two segments of reach 3D. Channel cross sections were surveyed in the field. These were extended to the edge of the valley by appending existing LIDAR data. The cross sections were used for hydraulic modeling. Hydraulic model data is in Appendix B.

Methods

The U.S. Army Corps of Engineer's 1-dimensional HEC-RAS (version 4.0) hydraulic modeling program was used to estimate hydraulic conditions in each modeled channel segment.

Methods described by Arcement and Schneider (1989) were used to estimate Manning's n roughness coefficients for the channel and floodplain. These methods provide a systematic approach to estimating Manning's n as a function of channel or floodplain geology, degree of irregularity, variation in channel cross section, effects of obstructions, amount of vegetation and degree of meandering. We estimated values for Manning's n at each cross section for the channel and floodplain using field observations and digital photos that were taken during the survey.

Hydraulic Analysis Findings

Hydraulic analysis results indicate that the Entiat River, within the areas modeled, shows a close correlation between the 2-year flood frequency volume and the stage associated with the top of banks on sharp meander bends and top of gravel bars in relatively straight channel segments.

The models show that adjacent valley bottom surfaces can be inundated frequently (between the 2 and 5-year flood frequency). As channel length and natural large wood roughness increases over time, one could expect the inundation frequency shown in the existing conditions model to occur at lower flood frequencies and discharge volumes.

Bank heights ranged between 6 and 10 feet. Variation in bank height can be caused by channel incision, local channel slope, meander bend amplitude, local roughness, older flood terraces and valley width. For example, the higher bank elevation surveyed in the upstream hydraulic model near RM 25 is the downstream terminus of the McCrea Creek alluvial fan. Hydraulic output data is in Appendix B.

HABITAT PROJECT RECOMMENDATIONS

Habitat Improvement Goals to Address Limiting Factors

Habitat improvement goals for reach 3D focus on the limiting factors, large wood log jam habitat and off-channel rearing, identified in previous studies, field observations, and hydraulic analysis. Our field observations/analysis and hydraulic findings are consistent with those reports and conclude that habitat could be enhanced through project work. The following sections explain opportunities to enhance habitat within reach 3D, including recommended project locations and planning level estimates for design and construction.

Log Jam Habitat

Reach 3D is well suited for large wood habitat enhancements. If log jams are constructed in areas that would naturally accumulate wood, migration rates can be slowed while improving fish habitat. Nine log jam sites were identified in the field. Large wood will be partially buried in adjacent banks and extend out into the active channel. Buried vertical snags will be associated with each log jam site to provide stability and increase wood recruitment. Dynamic adjustment to wood loading such as pool formation and bank scalloping around log jams is natural and should be expected at all sites. Conceptual designs, locations and planning level estimates were determined using survey data, existing LIDAR, and hydraulic analysis. Log jam locations can be viewed in Appendix A and planning estimates are in Appendix C.

Backwater and Off-Channel Rearing

There are five locations where backwater or off-channel rearing habitats for juvenile salmonids could be constructed. These types of habitats are located in existing natural backwater areas that can be enhanced by widening and lengthening to increase the total usable area during low flow stage and discharge. Imported large wood will be used at each site for cover habitat.

There are two types of off-channel design based on how they will function with the river. The first type does not have water running through it but behaves like a cutoff oxbow channel and fluctuates in wetland and habitat area based on the stage of the Entiat. In this type of channel, the excavated segments will be free draining to prevent fish stranding as water levels drop in the summer. The backwater channel would extend its length and area as river stage rises. Large wood will be imported and vertical snags buried for cover habitat within enhanced backwater areas. This type of habitat is possible at site locations labeled OC1, OC2, OC3 and OC4 in the drawing set.

A second type of off-channel habitat is proposed in areas that could be associated with surface water running through constructed off-channel habitats. In these locations, more complex pool forms could be created. The pools will be maintained by surface water, reducing the risk of stranding and mortality as Entiat River flows reduce in the summer. Locations suitable for this type of work are labeled as OC1 and OC5 within the site map. Based on slope and possible groundwater availability, site OC1 has the potential for a ground water gallery to provide running water. Further survey, test pits and pump tests will have to be conducted during the summer (low water) to evaluate this site and determine if a ground water gallery is feasible. The second site (OC5) takes advantage of Brennegan Creek. At OC5, an old Entiat River channel will be excavated to increase total habitat area, allowing Brennegan Creek to feed water through it to the mainstem.

Created off-channel habitats will fill in with sediment over time as the Entiat River migrates throughout the valley and floodplain sediments accumulate. This is a natural process exhibited in all rivers. As some side channel habitats decay, others come into existence. The intent/strategy of this work is to create habitat that fish can use now to help make up the habitat deficit that has occurred following human disturbance. As large wood habitats are constructed and existing floodplain riparian forests age, the physical mechanisms will be in place for natural processes to create backwater and side channel habitats naturally via large trees falling into the river, mature meander bend development, and channel avulsions into mature forested valley bottom segments.

Re-grade and Reclaim Floodplain Gravel Mine Site

A former gravel mining operation existed circa 1965 on the right side of the valley near RM 25. A large spoil pile and pit are remnant features of the mine, and they both prevent natural inundation across this segment of valley bottom. Eventually the river will erode into the spoil pile transporting the fine sediments downstream, risking impact to spawning areas.

A project at this site will bury the existing pit using the natural gravel/sand piles left behind in a manner consistent with natural fluvial deposition. The restored floodplain will then be replanted with cottonwood. Excess pit material will be graded out at the base of the adjacent valley bottom slope outside the active migration corridor. It is likely that since 1965 the existing pit has filled with upstream derived sediment and will have less volume than is needed to eliminate the existing piles of waste sand and gravel. Differences in cut and fill would be identified during survey and incorporated into the grading design.

Conclusions

Our review of recently completed studies on the Stillwater reach, field survey and hydraulic analysis has led us to conclude that substantial portions of the 3D (a sub-reach of the Stillwater Reach) reach can be enhanced to improve natural large wood processes, increase off-channel rearing, and restore floodplain function. A series of habitat enhancement and restoration projects, locations, and planning cost estimates have been provided.

Field observations and hydraulic analysis indicates existing bar surfaces and signatures of channel forming discharge are very close to the BOR estimate of the 2-year flood frequency. Hydraulic model inundation of adjacent flood surfaces shows that back water off-channel habitats could be constructed to increase inundation area and habitat at lower flows. Five sites to complete off channel habitat can be viewed in the drawing set.

Mainstem habitat can be enhanced by emulating large wood log jams. Log jam habitats that could be constructed were sited within zones that would tend to accumulate natural large wood. Wood volume estimates and construction costs were based on survey data collected at two sites where large wood could be established. Nine proposed log jam sites and typical treatments can be viewed in the drawing set.

A former gravel mine site can be reclaimed on the right side of the valley near RM 25. This project will restore natural floodplain function and reduce future fine sediment loads that could enter the channel if the river migrates up against a large pile (hillsides) of waste sand and gravel left behind by the gravel mine operation. Existing waste gravel and sand will be graded into an existing pit so that the area looks and behaves like a natural fluvial surface within the valley bottom.

All projects presented in this report could be constructed during one field season. The possibility of a ground water gallery to supply flow to side channel (OS1) needs further field investigation to determine viability. Test pits, pump testing and survey will determine whether a ground water gallery could be installed to produce a flowing side channel habitat during late summer low flow conditions. If a ground water gallery is not feasible, the site can be used as a backwater off-channel habitat similar in design to OS2, OS3 and OS4.

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Sutley, D. 2009. Appendix B – Hydrology Data and Geographic Information Systems. Entiat Tributary Assessment, Chelan County, Washington. U.S. Bureau of Reclamation. Technical Service Center, Denver, CO Flood Hydrology and Meteorology Group (86-68250).

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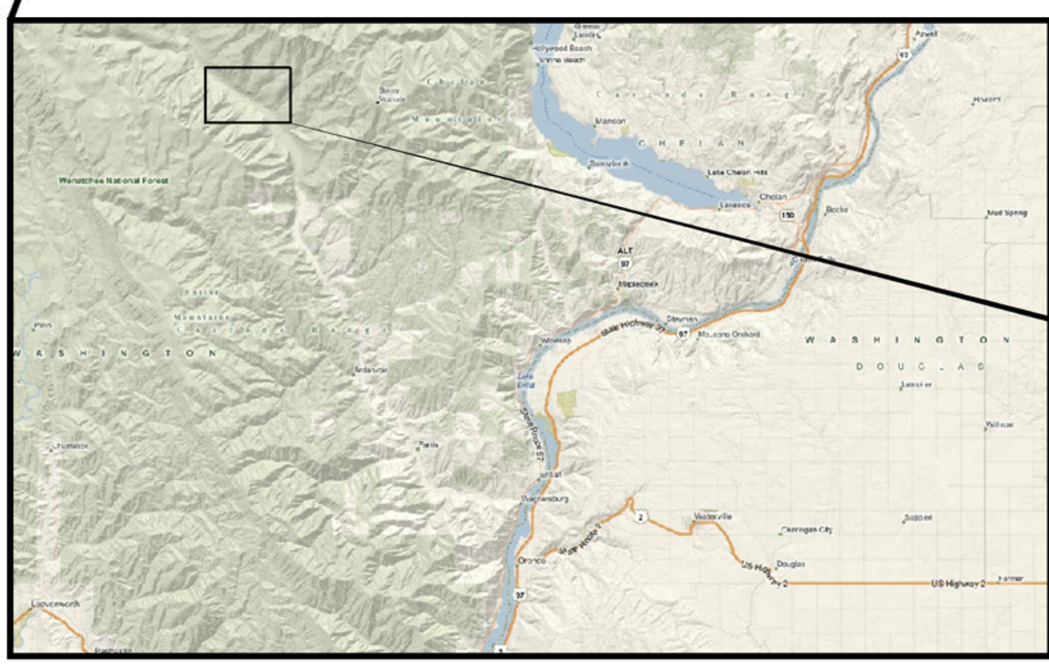
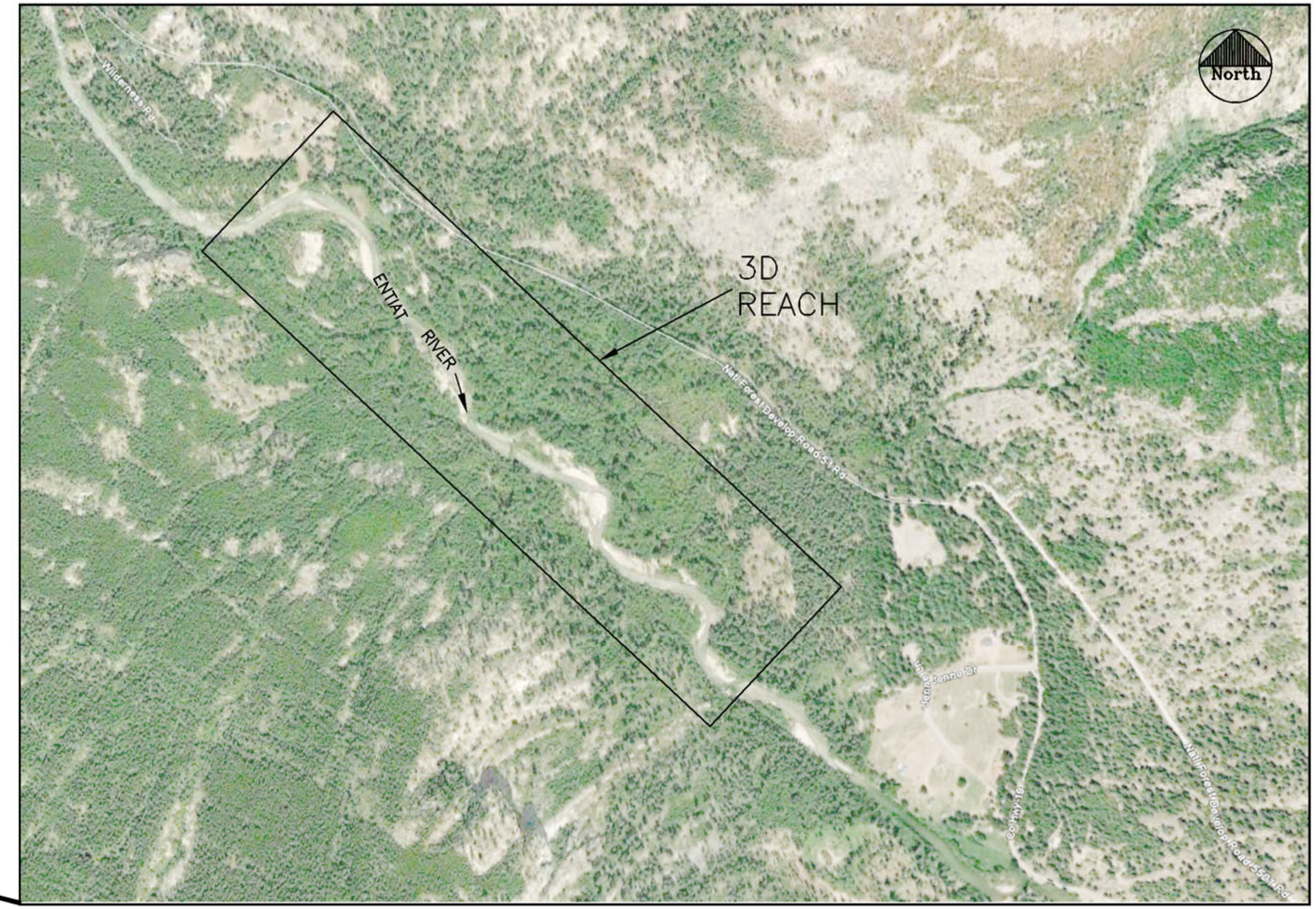
APPENDIX A: SITE MAPS AND TYPICAL DRAWINGS

LOCATION MAP
STATE OF WASHINGTON



VICINITY MAP



SITE MAP

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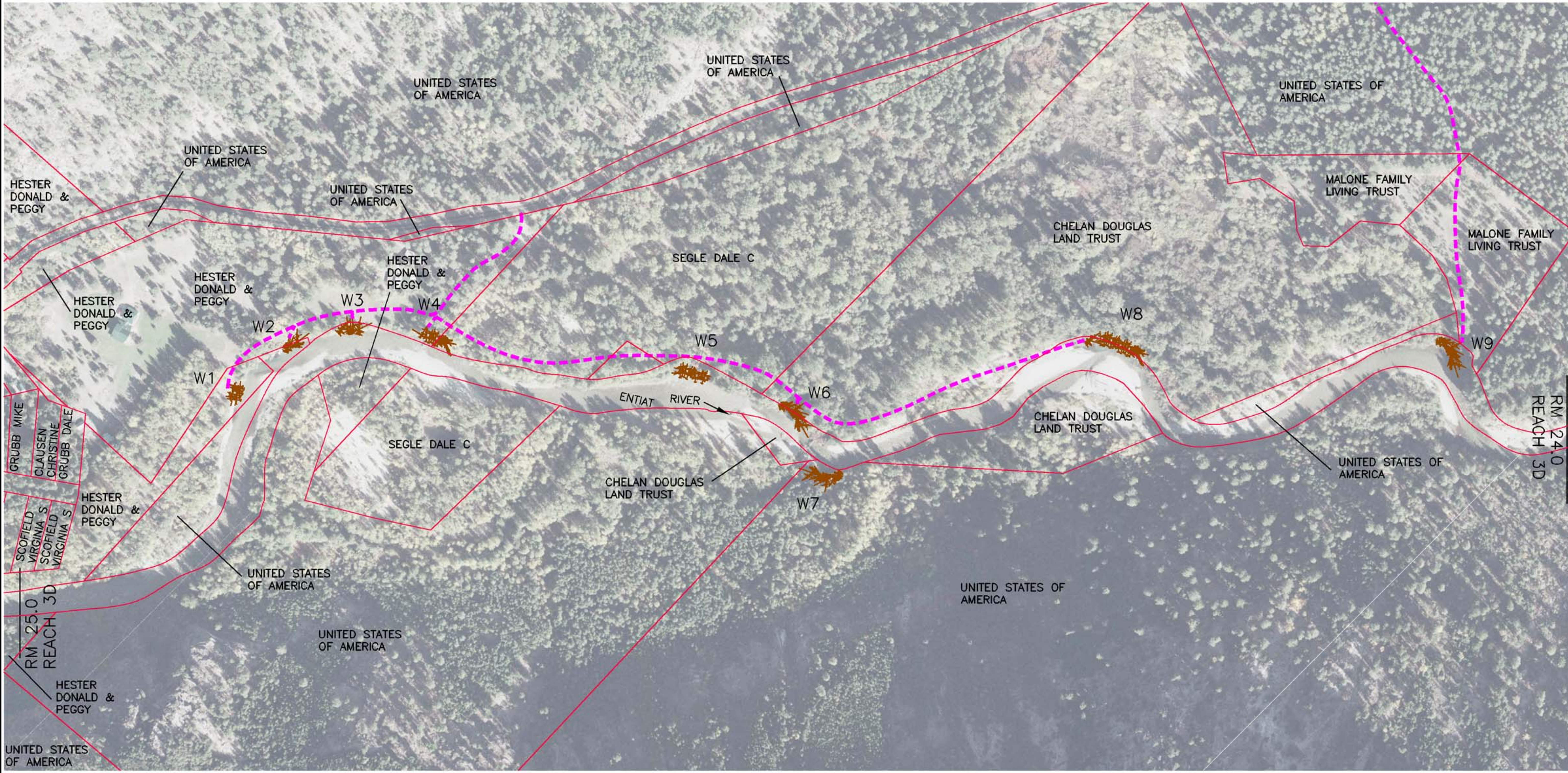
COVER, SHEET INDEX, AND VICINITY MAP



PLAN VIEW

LEGEND

LOG JAM LOCATIONS

ESTIMATED DOZER, EXCAVATOR, AND LOADER ACCESS

PROPERTY LINES

0 300 600
SCALE IN FEET

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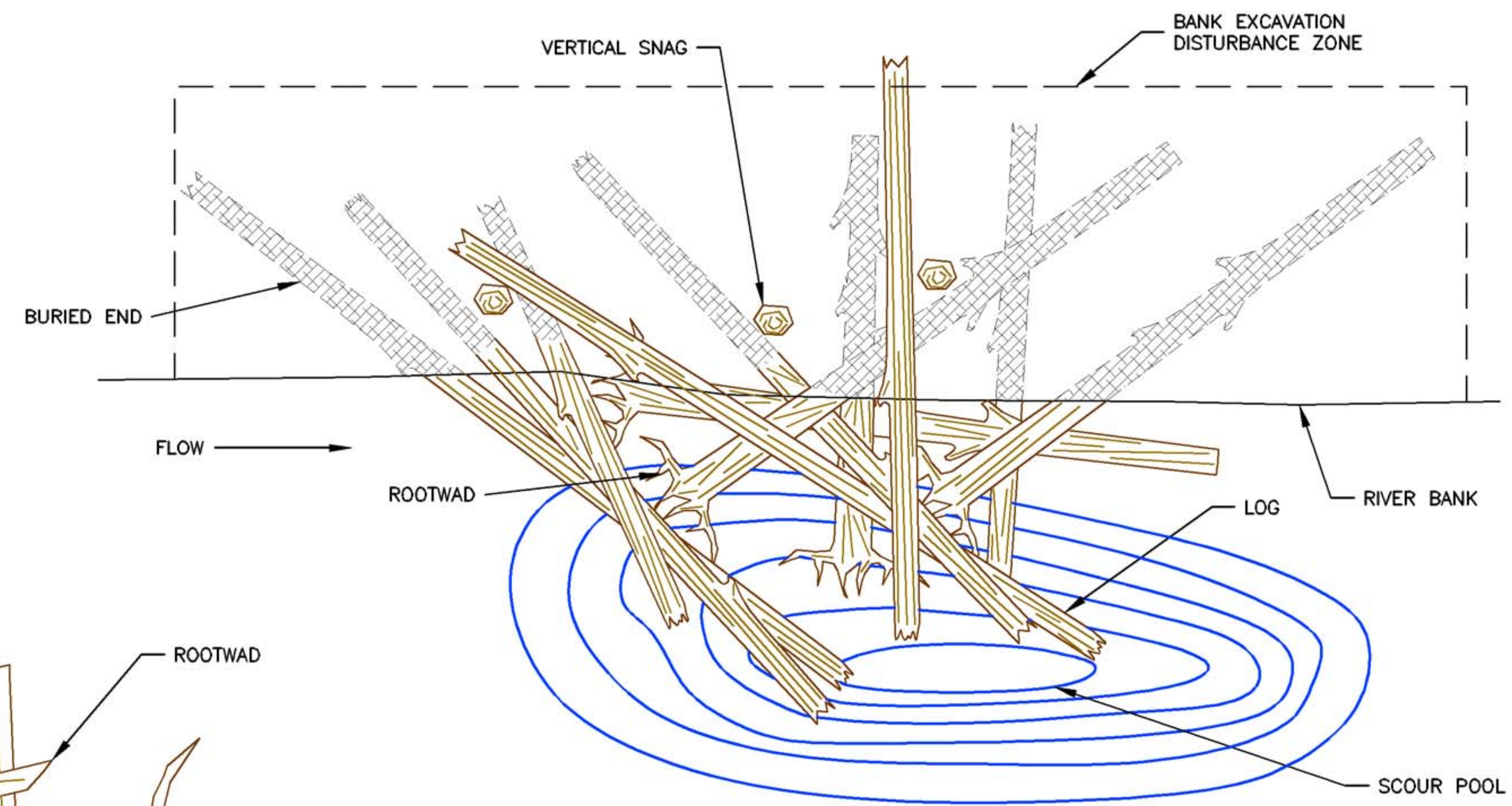
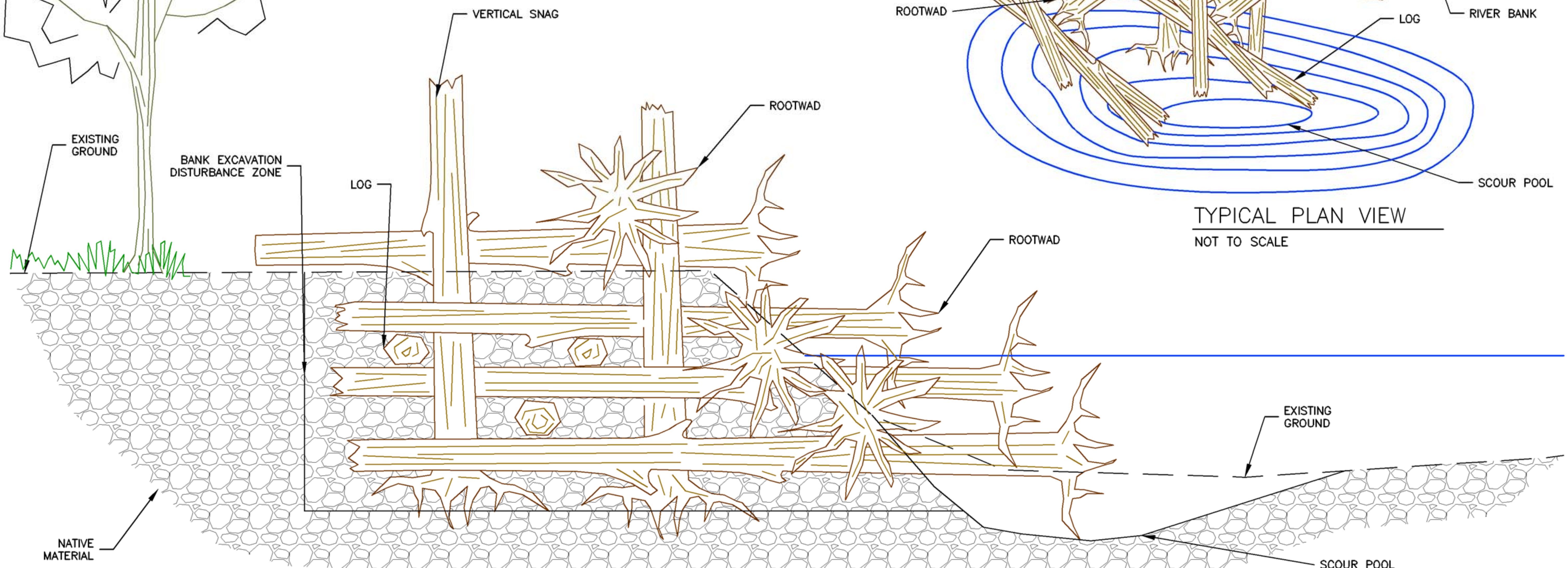
2 OF 5

LARGE WOOD LOG JAM LOCATIONS



TYPICAL PLAN VIEW

NOT TO SCALE



TYPICAL SECTION VIEW

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TYPICAL DETAILS LARGE WOOD JAMS

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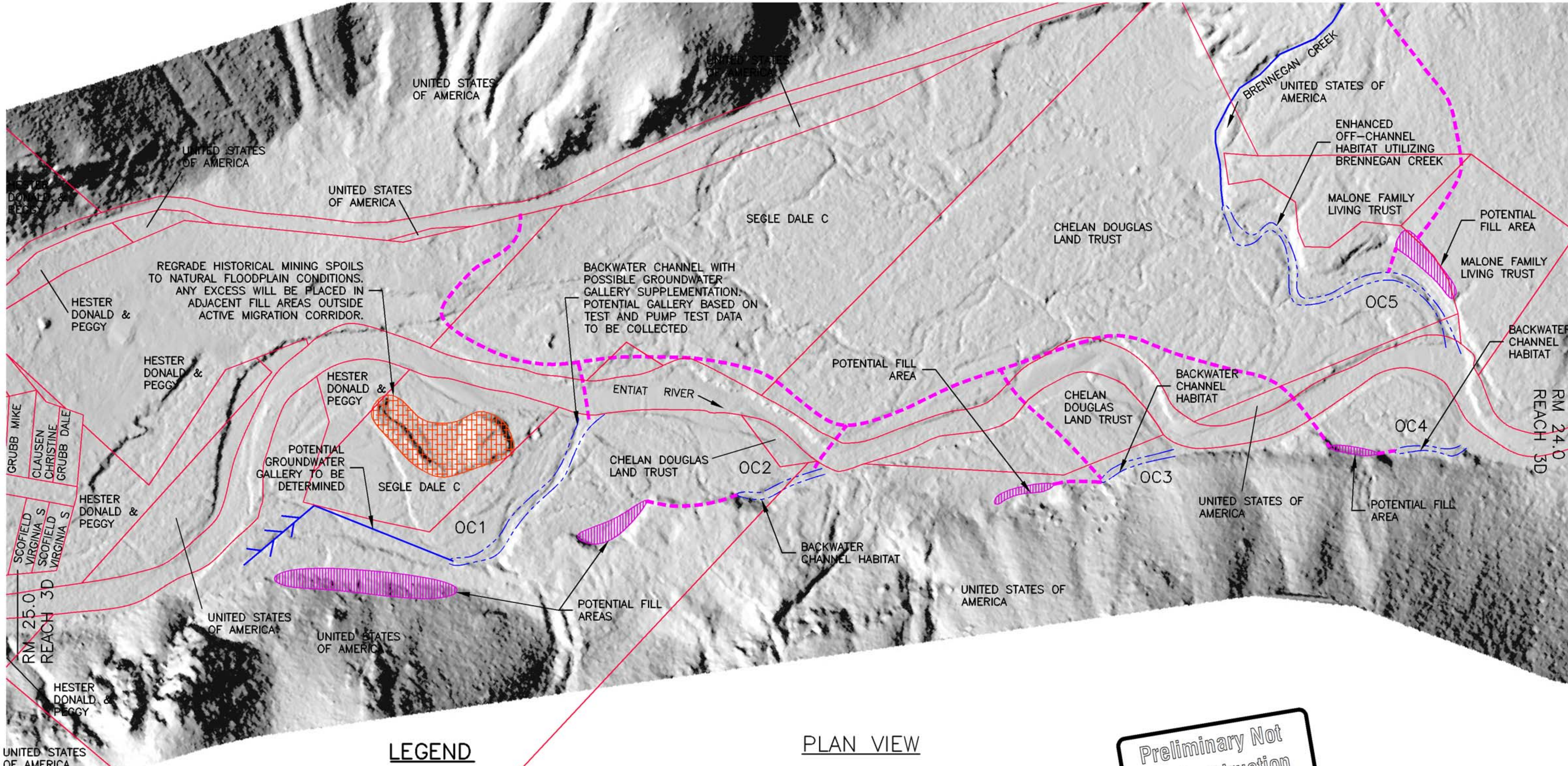

PLAN VIEW

LEGEND

- GROUNDWATER GALLERY
- REGRADE AREA
- POTENTIAL FILL AREAS
- BACKWATER OFF-CHANNEL HABITAT (OC2,OC3,OC4) AND FLOW THROUGH OFF-CHANNEL HABITAT USING GROUNDWATER GALLERY (OC1) OR BRENNEGAN CREEK (OC5)
- ESTIMATED DOZER, EXCAVATOR, AND LOADER ACCESS
- PROPERTY LINES

0 300 600
SCALE IN FEET

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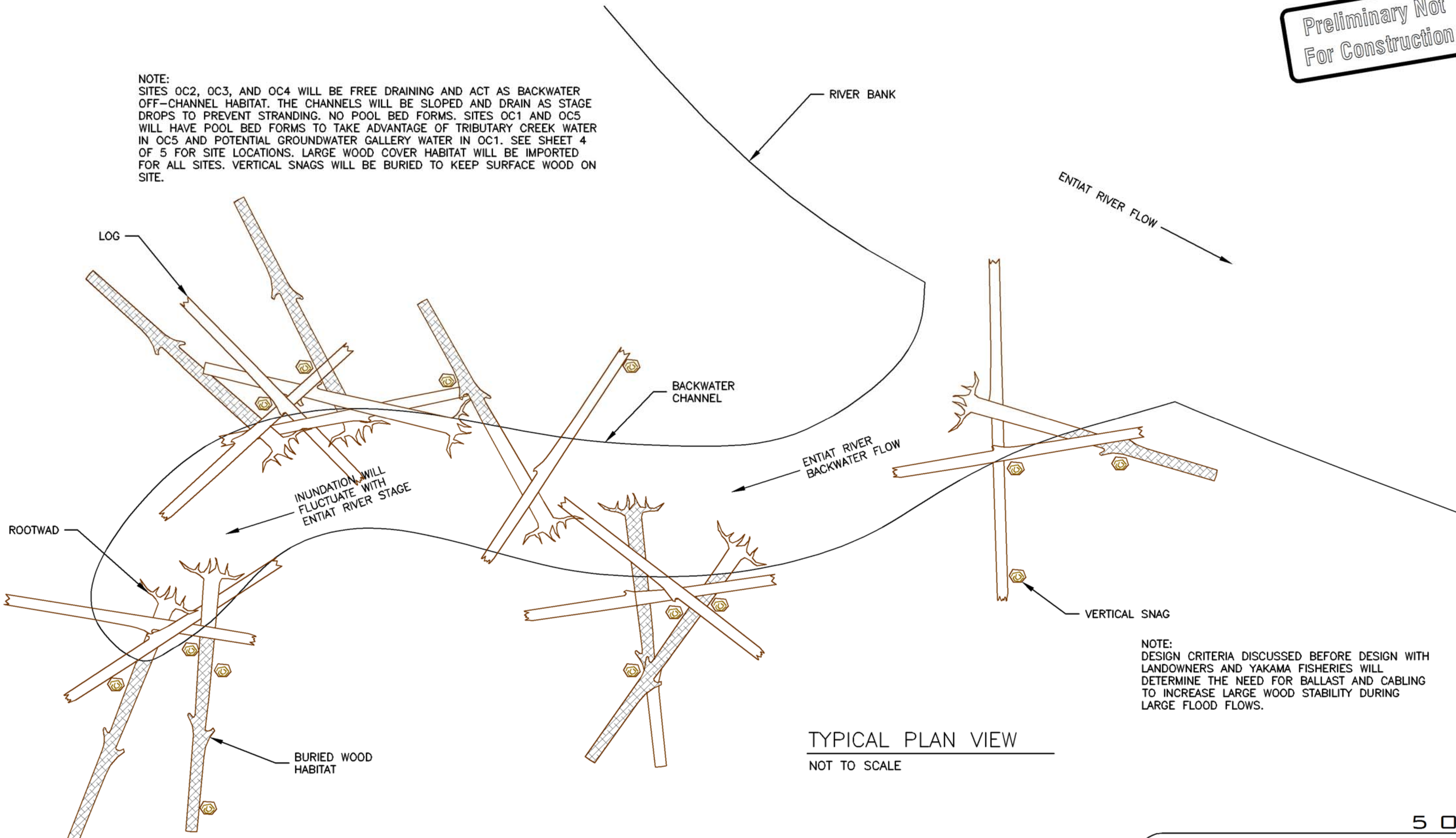
OFF-CHANNEL HABITAT LOCATIONS

NOTE:
SITES OC2, OC3, AND OC4 WILL BE FREE DRAINING AND ACT AS BACKWATER OFF-CHANNEL HABITAT. THE CHANNELS WILL BE SLOPED AND DRAIN AS STAGE DROPS TO PREVENT STRANDING. NO POOL BED FORMS. SITES OC1 AND OC5 WILL HAVE POOL BED FORMS TO TAKE ADVANTAGE OF TRIBUTARY CREEK WATER IN OC5 AND POTENTIAL GROUNDWATER GALLERY WATER IN OC1. SEE SHEET 4 OF 5 FOR SITE LOCATIONS. LARGE WOOD COVER HABITAT WILL BE IMPORTED FOR ALL SITES. VERTICAL SNAGS WILL BE BURIED TO KEEP SURFACE WOOD ON SITE.



NOTE:
DESIGN CRITERIA DISCUSSED BEFORE DESIGN WITH LANDOWNERS AND YAKAMA FISHERIES WILL DETERMINE THE NEED FOR BALLAST AND CABLING TO INCREASE LARGE WOOD STABILITY DURING LARGE FLOOD FLOWS.

TYPICAL PLAN VIEW

NOT TO SCALE

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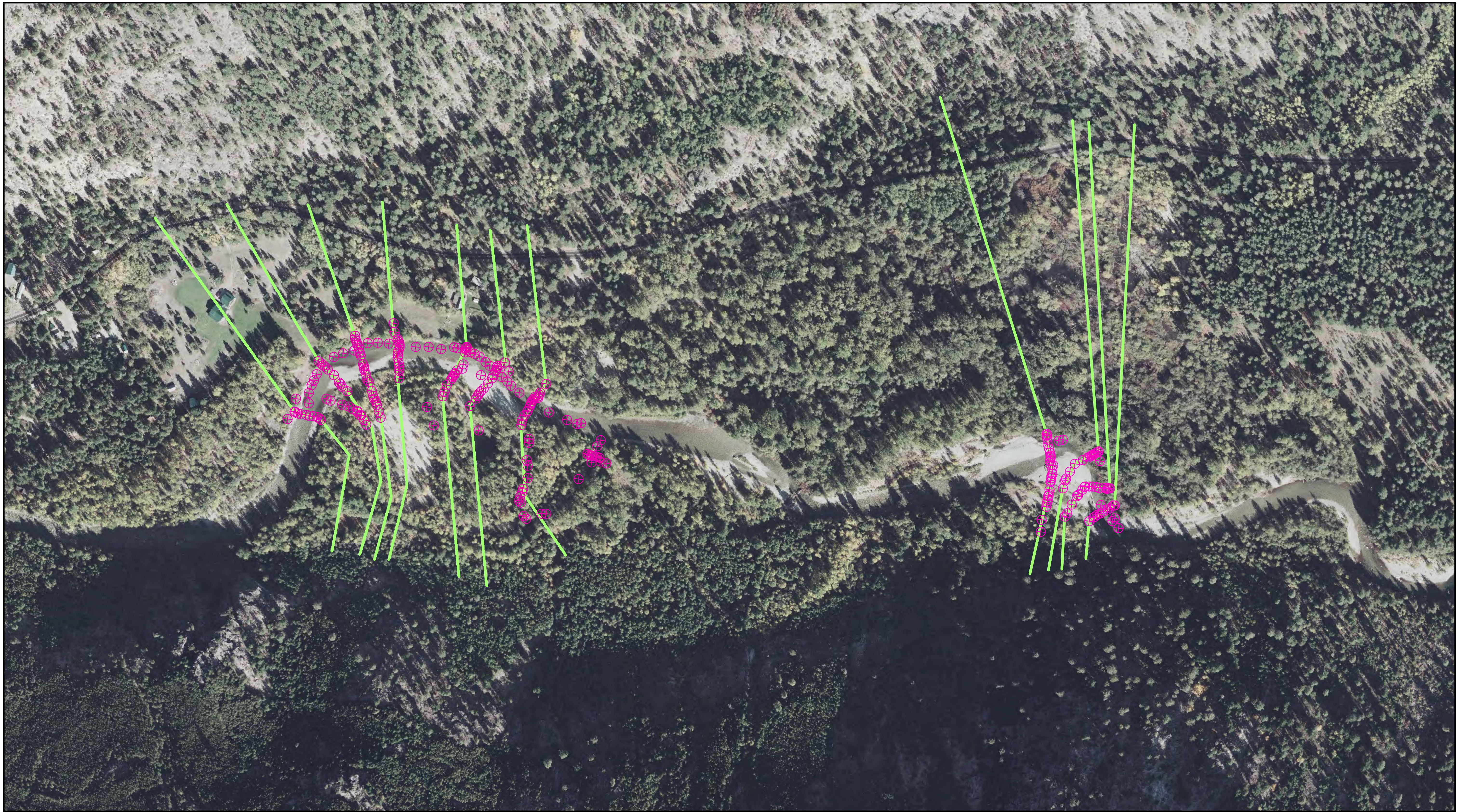
TYPICAL PLAN VIEW OFF-CHANNEL HABITATS

Appendix B: Hydraulic Model Output



0 125 250 500 750 1,000
Feet

Hydraulic Cross-Sections
December 2009 Survey Points

N E S W

Entiat River

3D Reach
Plan View
Hydraulic Cross-Sections

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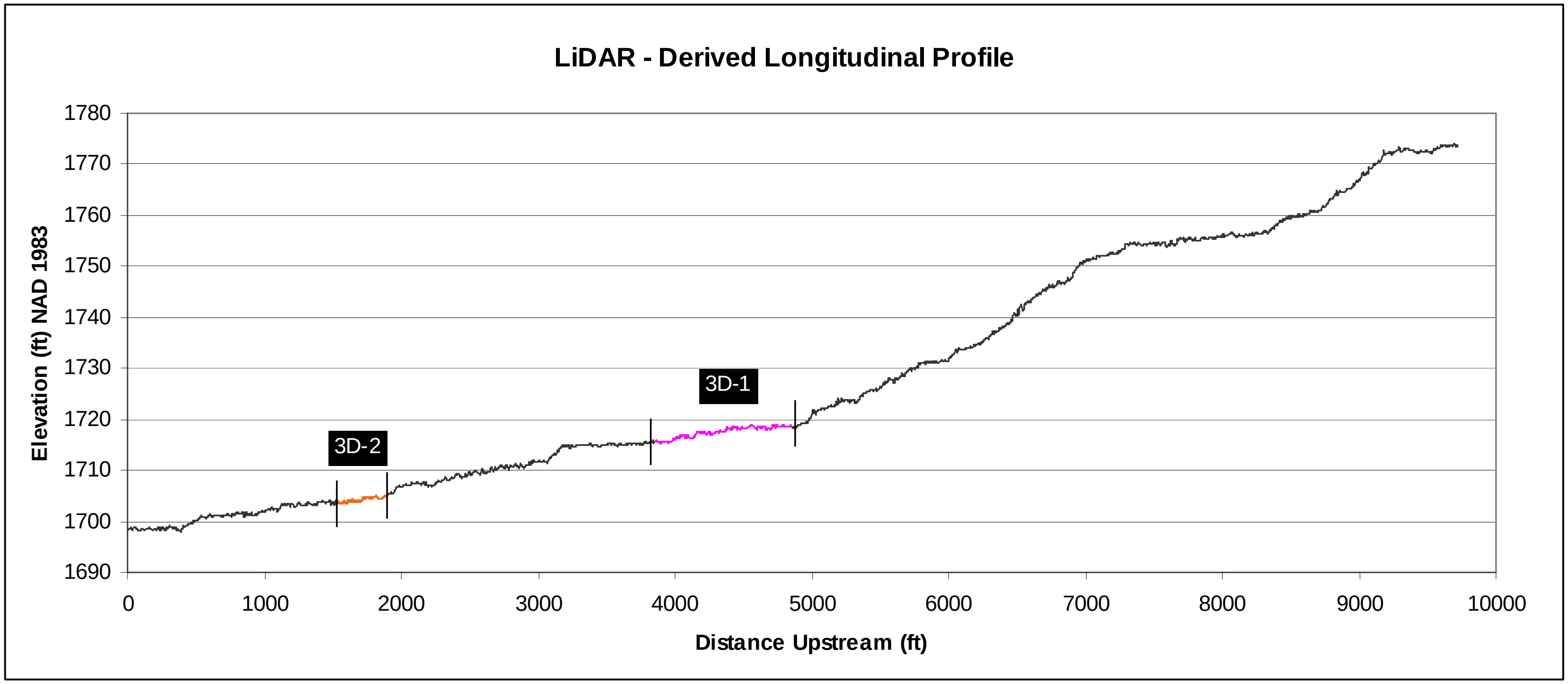
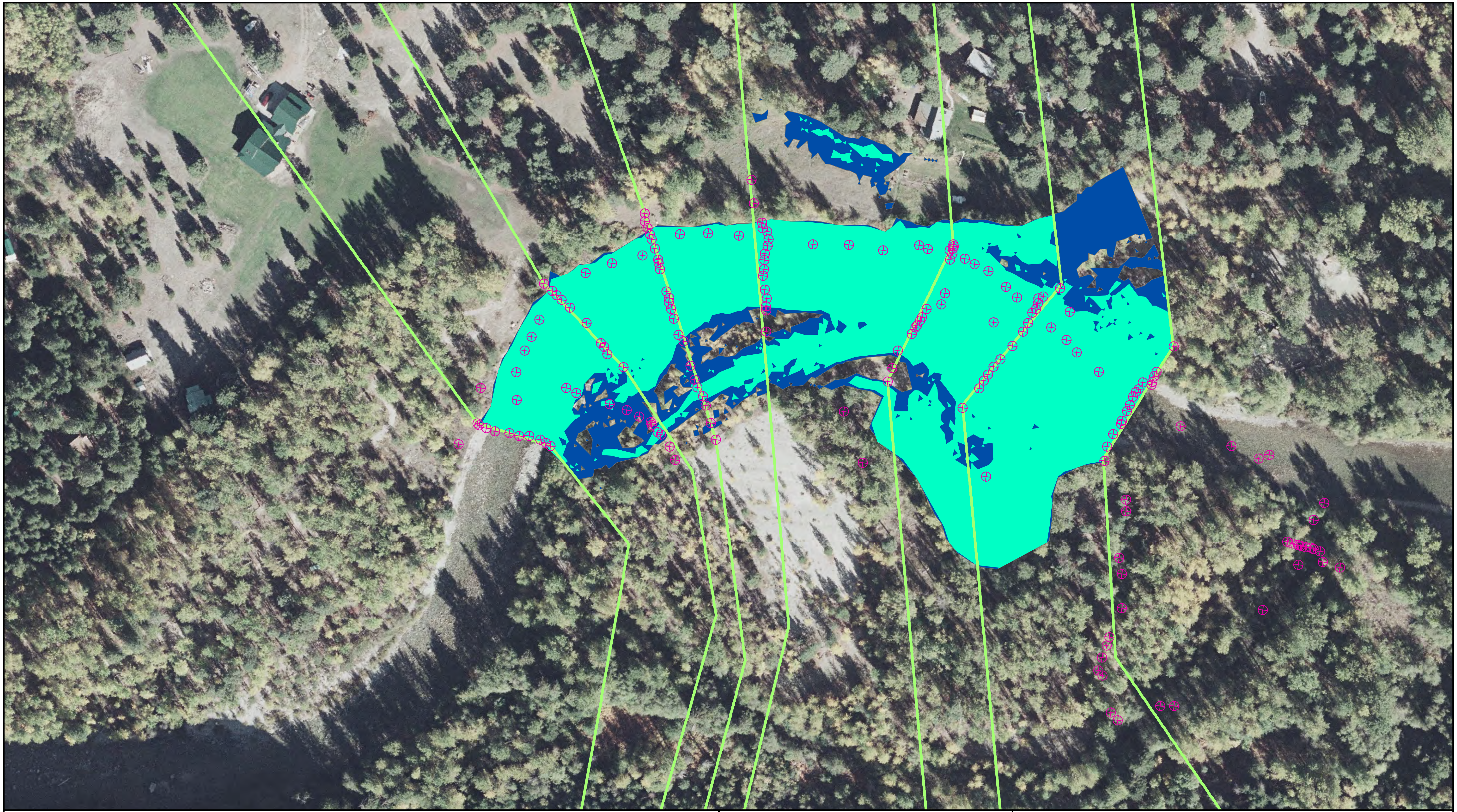

LiDAR - Derived Longitudinal Profile
Elevation (ft) NAD 1983
1780
1770
1760
1750
1740
1730
1720
1710
1700
1690
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance Upstream (ft)
3D-1
3D-2



Entiat River

3D - 1 Reach
Plan View
Floodplain Inundation

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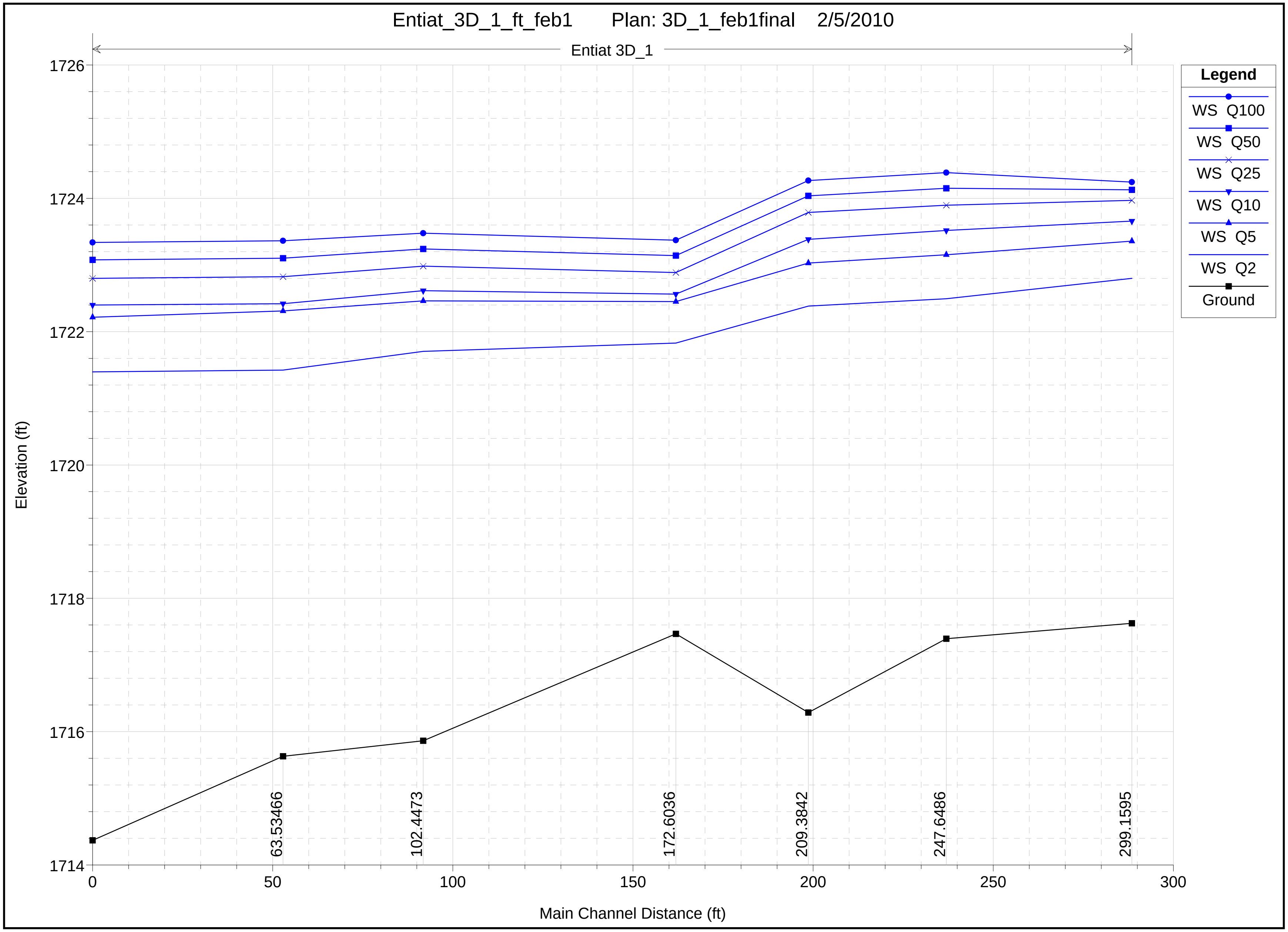
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Entiat 3D_1
Legend
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
Ground
Elevation (ft)
1726
1724
1722
1720
1718
1716
1714
63.53466
102.4473
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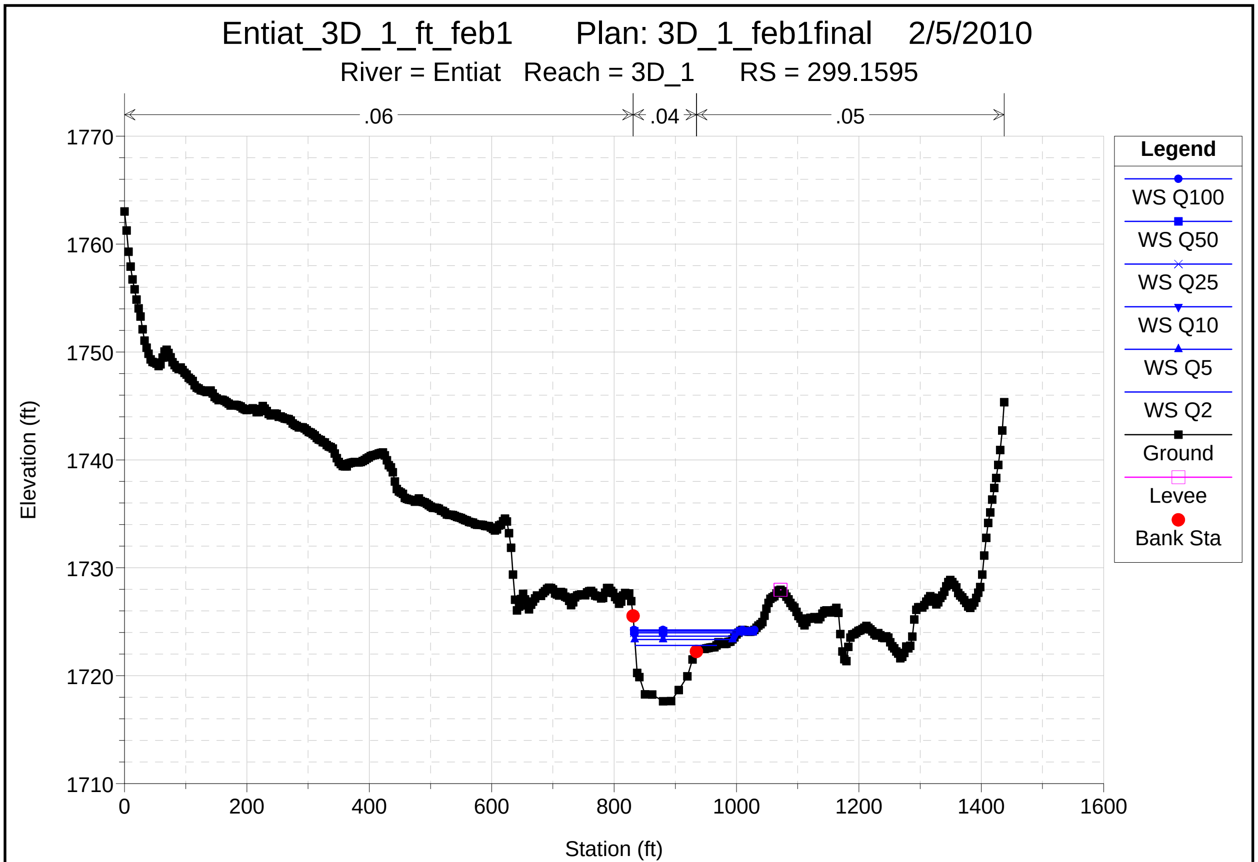
209.3842
247.6486
299.1595
0
50
100
150
200
250
300
Main Channel Distance (ft)



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.06
.04
.05
Elevation (ft)
Station (ft)
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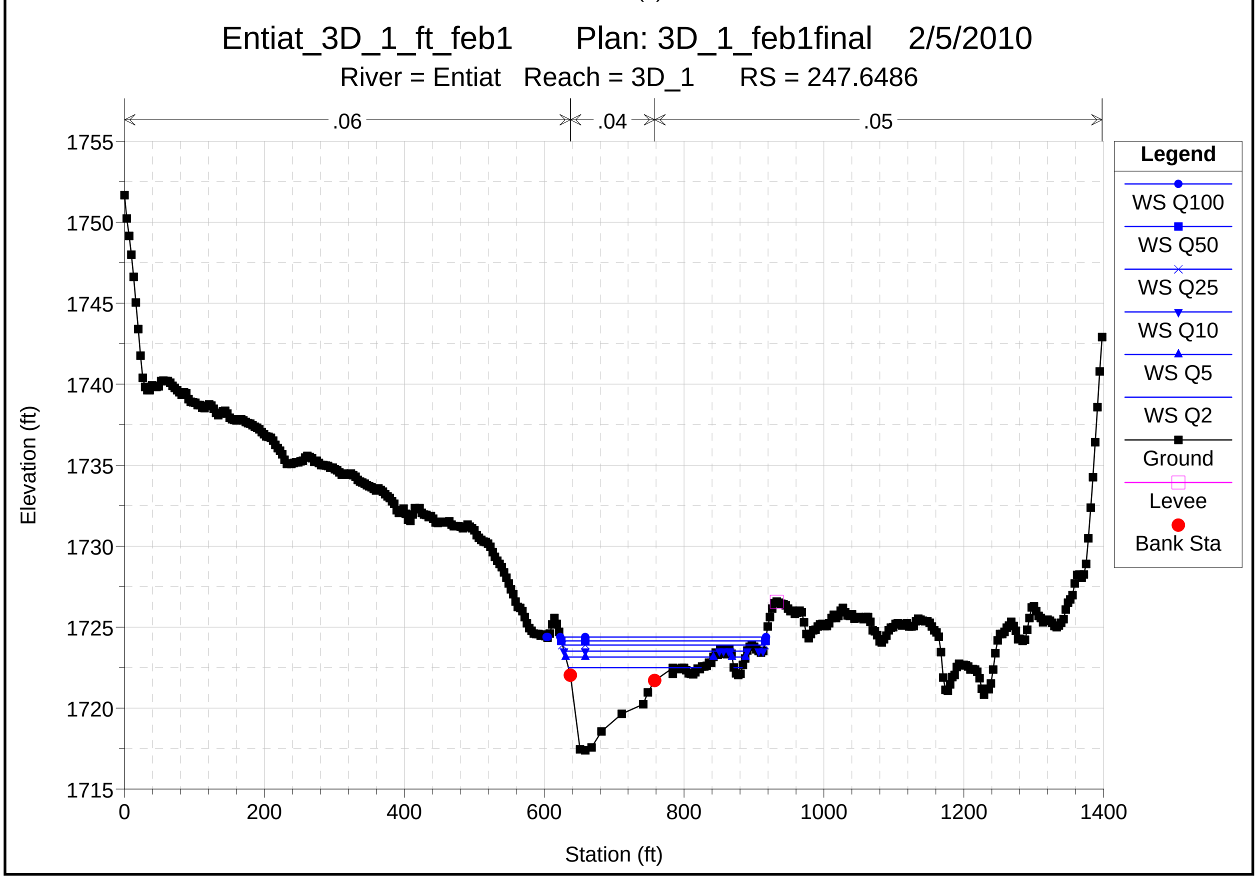
Ground
Levee
Bank Sta



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.06
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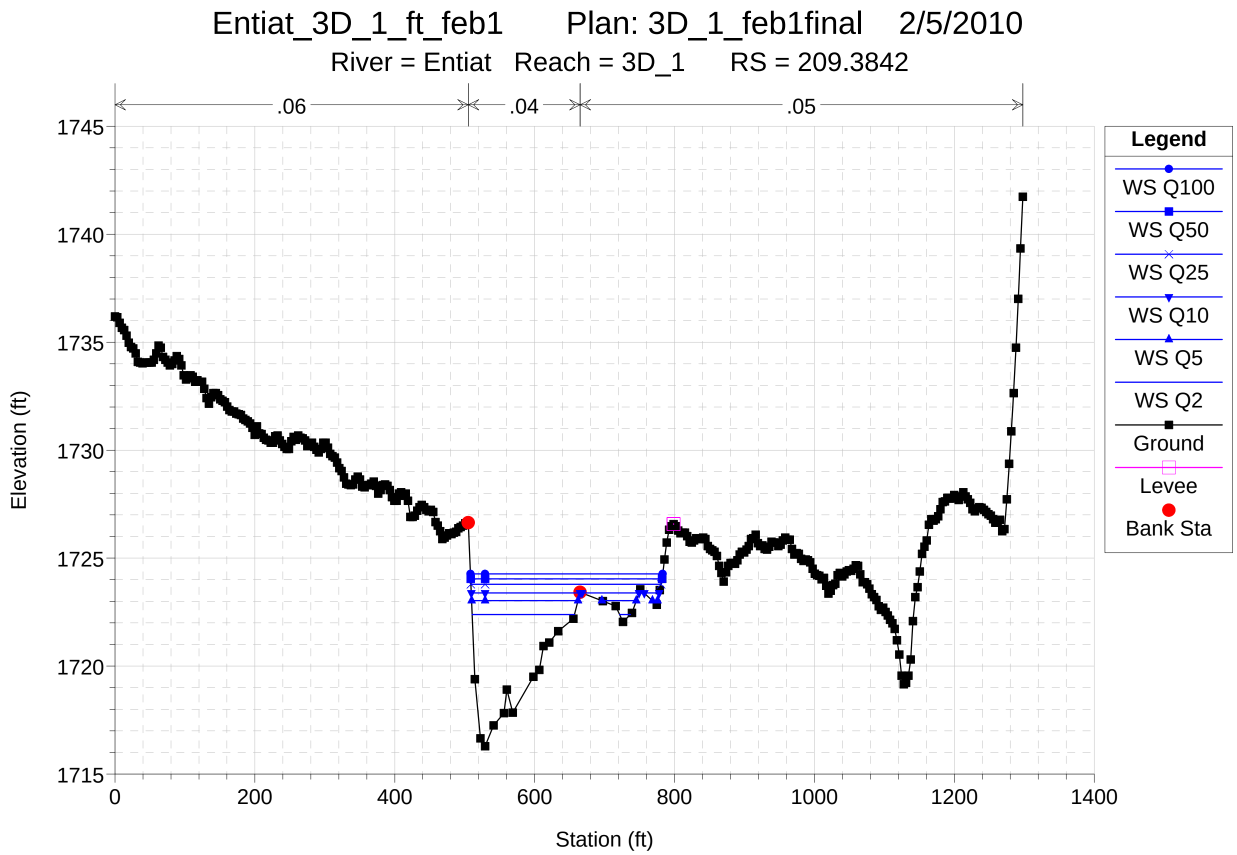
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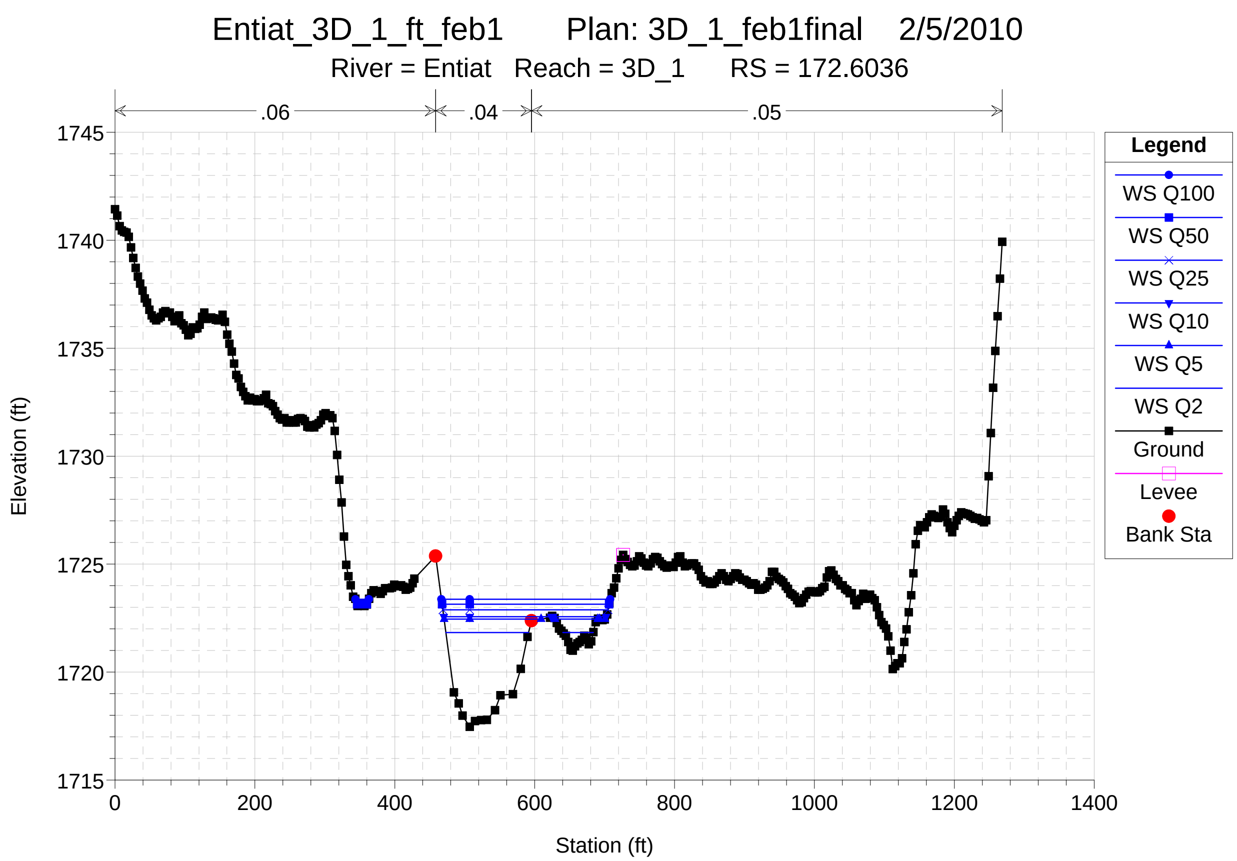
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Station (ft)
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Ground
Levee
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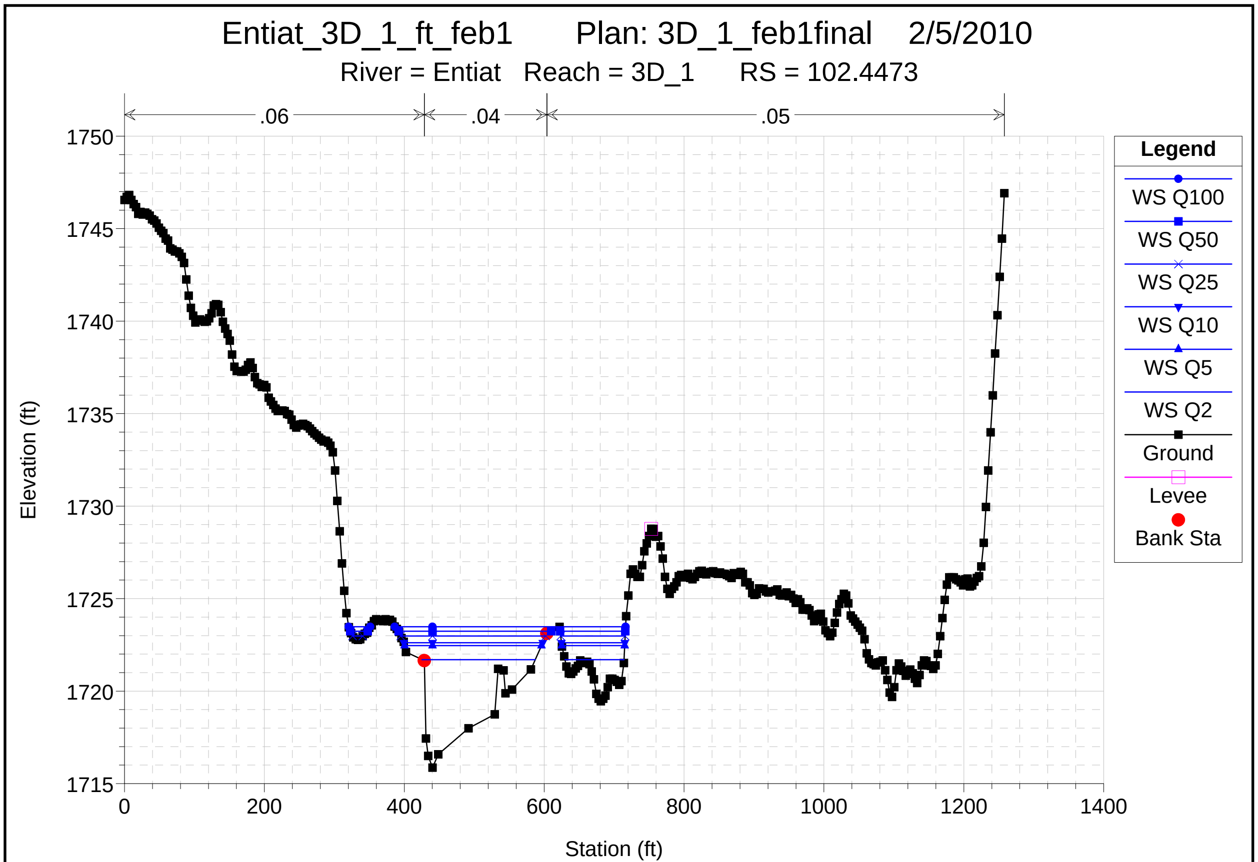
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.06
.04
.05
Elevation (ft)
1750
1745
1740
1735
1730
1725
1720
1715
0
200
400
600
800
1000
1200
1400
Station (ft)
Legend
WS Q100
WS Q50
WS Q25
WS Q10
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WS Q2
Ground
Levee
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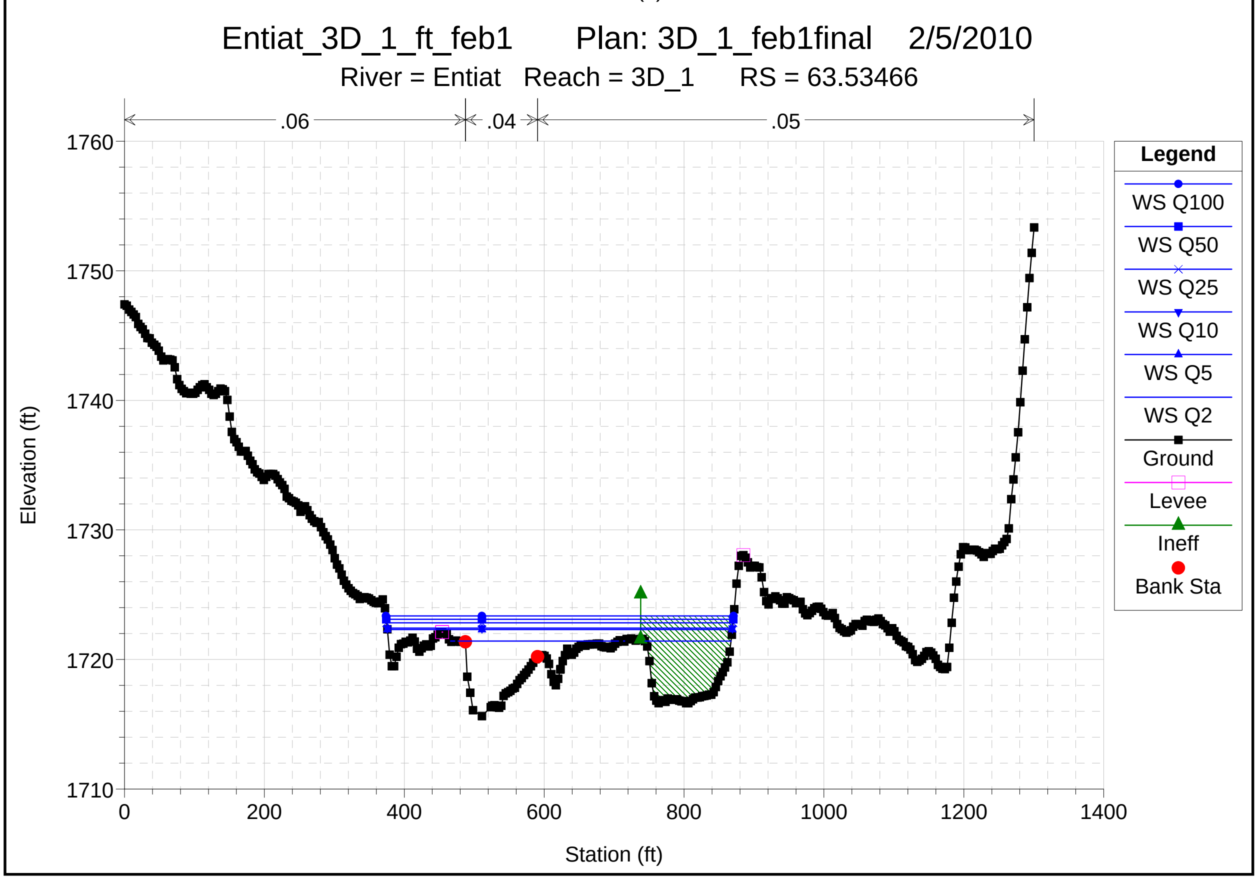
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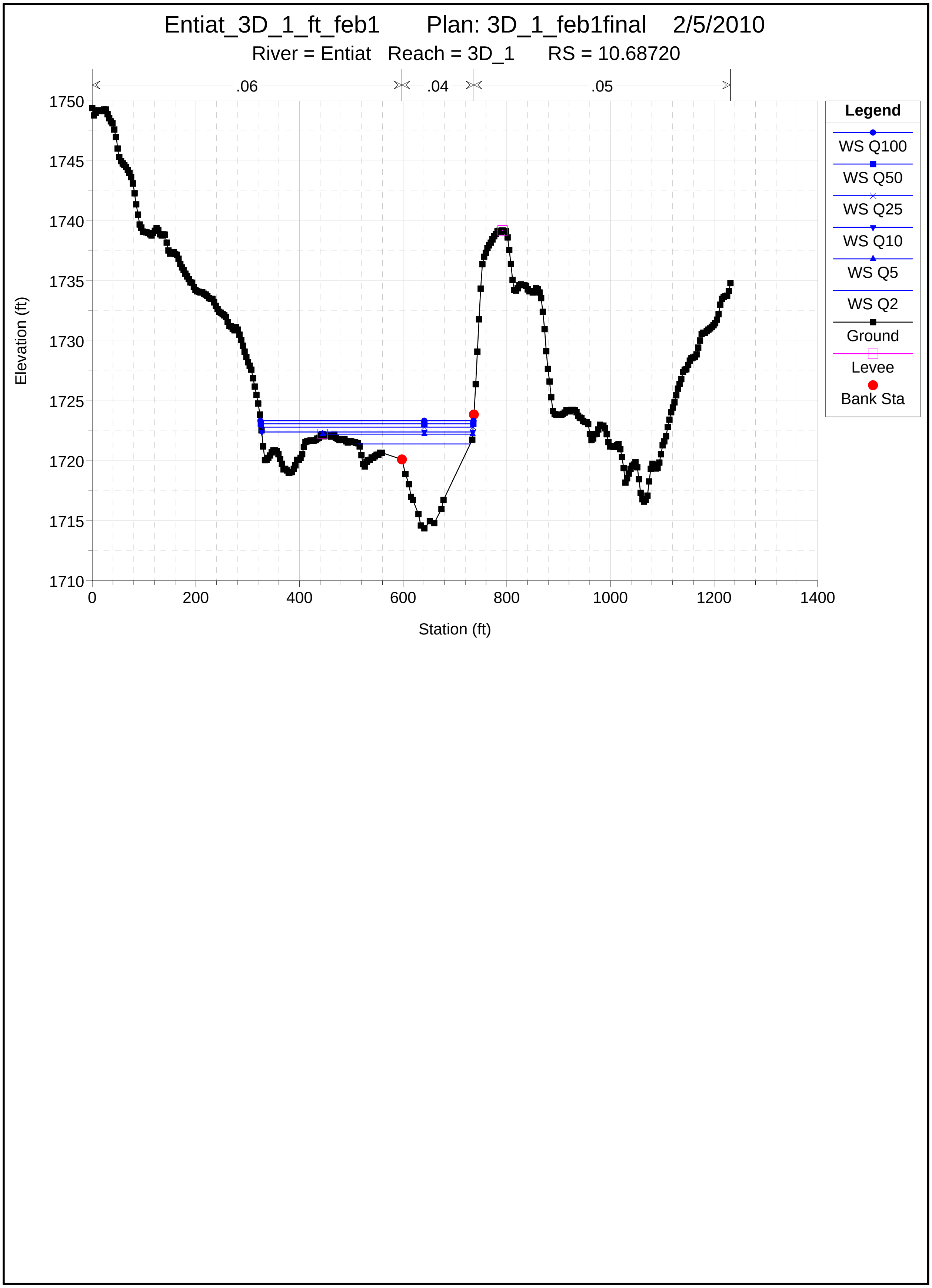
River = Entiat Reach = 3D_1 RS = 63.53466
.06
.04
.05
Elevation (ft)
1760
1750
1740
1730
1720
1710
0
200
400
600
800
1000
1200
1400
Station (ft)
Legend
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
Ground
Levee
Ineff
Bank Sta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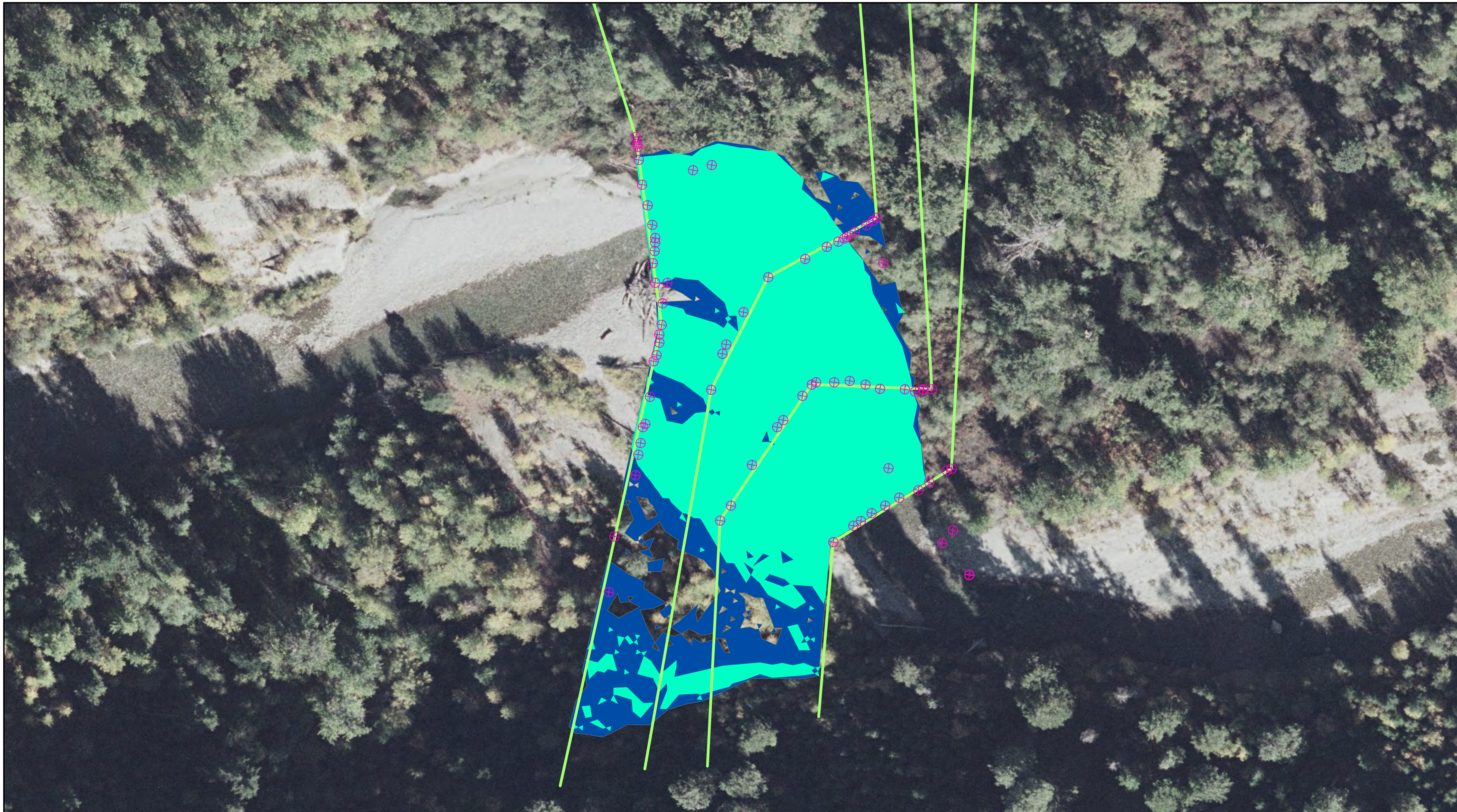
River = Entiat Reach = 3D_1 RS = 10.68720
.06
.04
.05
Legend
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)
1750
1745
1740
1735
1730
1725
1720
1715
1710
0
200
400
600
800
1000
1200
1400

HEC-RAS Plan: 1 River: Entiat Reach: 3D_1

Reach	River Sta	Profile	Cum Ch Len	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Depth C
			(ft)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)
D3_1	299.1595	Q2	288.47	2560.00	1717.63	1722.80	1721.58	1723.47	0.005311	6.60	396.01	132.74	0.59	1.26	3.86
D3_1	299.1595	Q5	288.47	3500.00	1717.63	1723.36	1722.31	1724.28	0.006219	7.77	478.21	159.60	0.65	1.68	4.39
D3_1	299.1595	Q10	288.47	4120.00	1717.63	1723.66	1722.81	1724.74	0.006783	8.46	527.02	164.54	0.69	1.95	4.67
D3_1	299.1595	Q25	288.47	4890.00	1717.63	1723.97	1723.40	1725.26	0.007557	9.29	578.84	169.91	0.73	2.30	4.97
D3_1	299.1595	Q50	288.47	5460.00	1717.63	1724.13	1723.73	1725.61	0.008397	9.99	606.34	182.48	0.78	2.63	5.11
D3_1	299.1595	Q100	288.47	6030.00	1717.63	1724.24	1724.02	1725.95	0.009447	10.74	627.99	196.26	0.83	3.02	5.22
D3_1	247.6486	Q2	236.96	2560.00	1717.40	1722.49	1721.72	1723.17	0.006795	6.60	406.88	201.43	0.65	1.34	3.19
D3_1	247.6486	Q5	236.96	3500.00	1717.40	1723.15	1722.37	1723.92	0.006241	7.17	551.13	230.47	0.64	1.49	3.85
D3_1	247.6486	Q10	236.96	4120.00	1717.40	1723.52	1722.87	1724.34	0.006062	7.51	639.28	259.56	0.64	1.58	4.21
D3_1	247.6486	Q25	236.96	4890.00	1717.40	1723.90	1723.26	1724.80	0.006112	7.98	743.41	288.92	0.66	1.74	4.59
D3_1	247.6486	Q50	236.96	5460.00	1717.40	1724.15	1723.53	1725.09	0.006039	8.23	817.45	291.80	0.66	1.81	4.85
D3_1	247.6486	Q100	236.96	6030.00	1717.40	1724.39	1723.80	1725.36	0.006008	8.47	886.04	295.96	0.66	1.89	5.08
D3_1	209.3842	Q2	198.70	2560.00	1716.29	1722.38	1721.04	1722.89	0.005337	5.69	452.25	161.43	0.57	1.01	3.08
D3_1	209.3842	Q5	198.70	3500.00	1716.29	1723.03	1721.78	1723.65	0.005446	6.36	567.26	208.93	0.59	1.20	3.59
D3_1	209.3842	Q10	198.70	4120.00	1716.29	1723.38	1722.23	1724.08	0.005549	6.75	650.10	258.30	0.60	1.32	3.86
D3_1	209.3842	Q25	198.70	4890.00	1716.29	1723.79	1722.64	1724.54	0.005416	7.09	758.64	271.84	0.61	1.41	4.25
D3_1	209.3842	Q50	198.70	5460.00	1716.29	1724.04	1722.90	1724.84	0.005435	7.37	826.64	273.70	0.61	1.50	4.49
D3_1	209.3842	Q100	198.70	6030.00	1716.29	1724.27	1723.27	1725.12	0.005481	7.64	889.22	274.87	0.62	1.58	4.71
D3_1	172.6036	Q2	161.92	2560.00	1717.47	1721.83	1721.20	1722.61	0.008598	7.14	372.57	161.68	0.73	1.60	3.00
D3_1	172.6036	Q5	161.92	3500.00	1717.47	1722.45	1721.96	1723.38	0.008638	7.84	481.74	207.37	0.74	1.85	3.44
D3_1	172.6036	Q10	161.92	4120.00	1717.47	1722.56	1722.35	1723.76	0.010755	8.92	506.46	229.17	0.83	2.37	3.54
D3_1	172.6036	Q25	161.92	4890.00	1717.47	1722.89	1722.89	1724.22	0.011017	9.50	582.27	236.26	0.86	2.62	3.83
D3_1	172.6036	Q50	161.92	5460.00	1717.47	1723.14	1723.14	1724.52	0.010760	9.75	642.89	250.97	0.85	2.70	4.05
D3_1	172.6036	Q100	161.92	6030.00	1717.47	1723.37	1723.37	1724.80	0.010600	9.99	702.29	260.63	0.85	2.79	4.25
D3_1	102.4473	Q2	91.76	2560.00	1715.86	1721.70	1720.43	1722.08	0.004341	5.03	559.05	246.37	0.51	0.80	3.02
D3_1	102.4473	Q5	91.76	3500.00	1715.86	1722.46	1721.17	1722.84	0.003643	5.18	764.42	285.69	0.48	0.80	3.59
D3_1	102.4473	Q10	91.76	4120.00	1715.86	1722.62	1721.45	1723.09	0.004357	5.79	808.55	289.09	0.53	0.99	3.71
D3_1	102.4473	Q25	91.76	4890.00	1715.86	1722.98	1721.85	1723.50	0.004403	6.10	918.61	314.43	0.54	1.07	3.98
D3_1	102.4473	Q50	91.76	5460.00	1715.86	1723.24	1722.06	1723.79	0.004367	6.30	1002.30	336.64	0.54	1.12	4.20
D3_1	102.4473	Q100	91.76	6030.00	1715.86	1723.48	1722.27	1724.07	0.004437	6.59	1085.07	360.75	0.55	1.20	4.44
D3_1	63.53466	Q2	52.85	2560.00	1715.63	1721.42	1720.07	1721.91	0.003974	5.79	518.81	359.91	0.51	0.96	3.95
D3_1	63.53466	Q5	52.85	3500.00	1715.63	1722.31	1720.78	1722.72	0.002870	5.63	858.00	493.23	0.45	0.85	4.84
D3_1	63.53466	Q10	52.85	4120.00	1715.63	1722.42	1721.12	1722.94	0.003570	6.37	897.23	493.62	0.50	1.08	4.95
D3_1	63.53466	Q25	52.85	4890.00	1715.63	1722.82	1721.90	1723.35	0.003435	6.59	1044.13	495.12	0.50	1.13	5.35
D3_1	63.53466	Q50	52.85	5460.00	1715.63	1723.10	1722.16	1723.64	0.003361	6.74	1144.99	496.14	0.50	1.16	5.63
D3_1	63.53466	Q100	52.85	6030.00	1715.63	1723.36	1722.33	1723.92	0.003305	6.89	1239.87	497.11	0.50	1.19	5.89
D3_1	10.68720	Q2		2560.00	1714.37	1721.40	1719.06	1721.70	0.002203	4.48	635.49	215.87	0.39	0.57	4.15
D3_1	10.68720	Q5		3500.00	1714.37	1722.22	1719.78	1722.57	0.002202	4.95	842.51	289.40	0.40	0.66	4.82
D3_1	10.68720	Q10		4120.00	1714.37	1722.40	1720.24	1722.74	0.002196	5.06	1107.69	407.42	0.40	0.68	4.99
D3_1	10.68720	Q25		4890.00	1714.37	1722.80	1720.90	1723.16	0.002201	5.31	1271.09	409.03	0.40	0.73	5.37
D3_1	10.68720	Q50		5460.00	1714.37	1723.08	1721.16	1723.45	0.002201	5.48	1384.64	410.15	0.41	0.77	5.63
D3_1	10.68720	Q100		6030.00	1714.37	1723.34	1721.43	1723.73	0.002204	5.64	1491.82	411.21	0.41	0.80	5.87



0 25 50 100 150 200
Feet

Hydraulic Cross-Sections
2-yr Flood
December 2009 Survey Points
5-yr Flood

N E S W

Entiat River

3D - 2 Reach
Plan View
Floodplain Inundation

1020 Wasco St.
Suite I
Hood River, OR 97031-1159
www.interfluve.com

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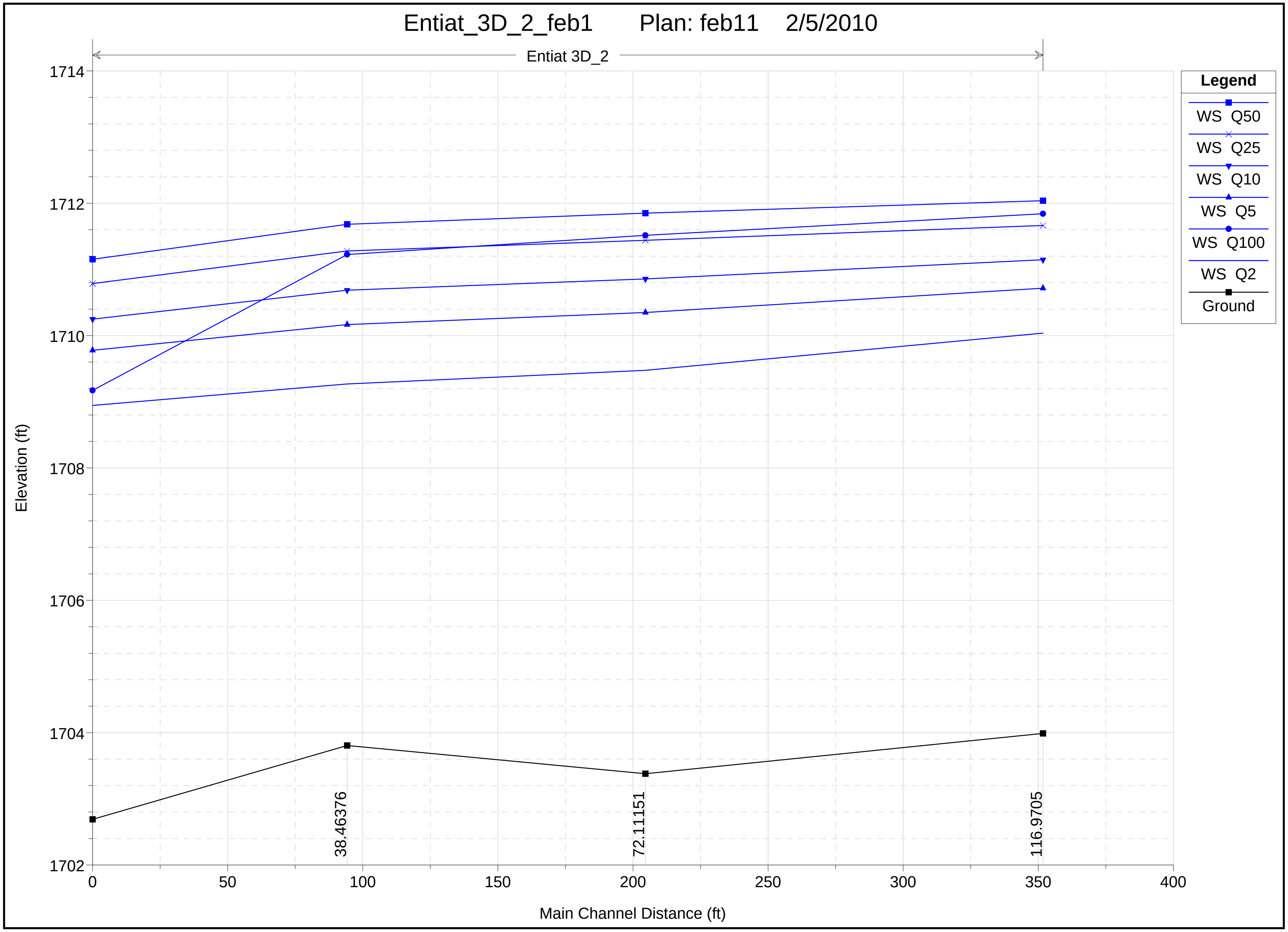
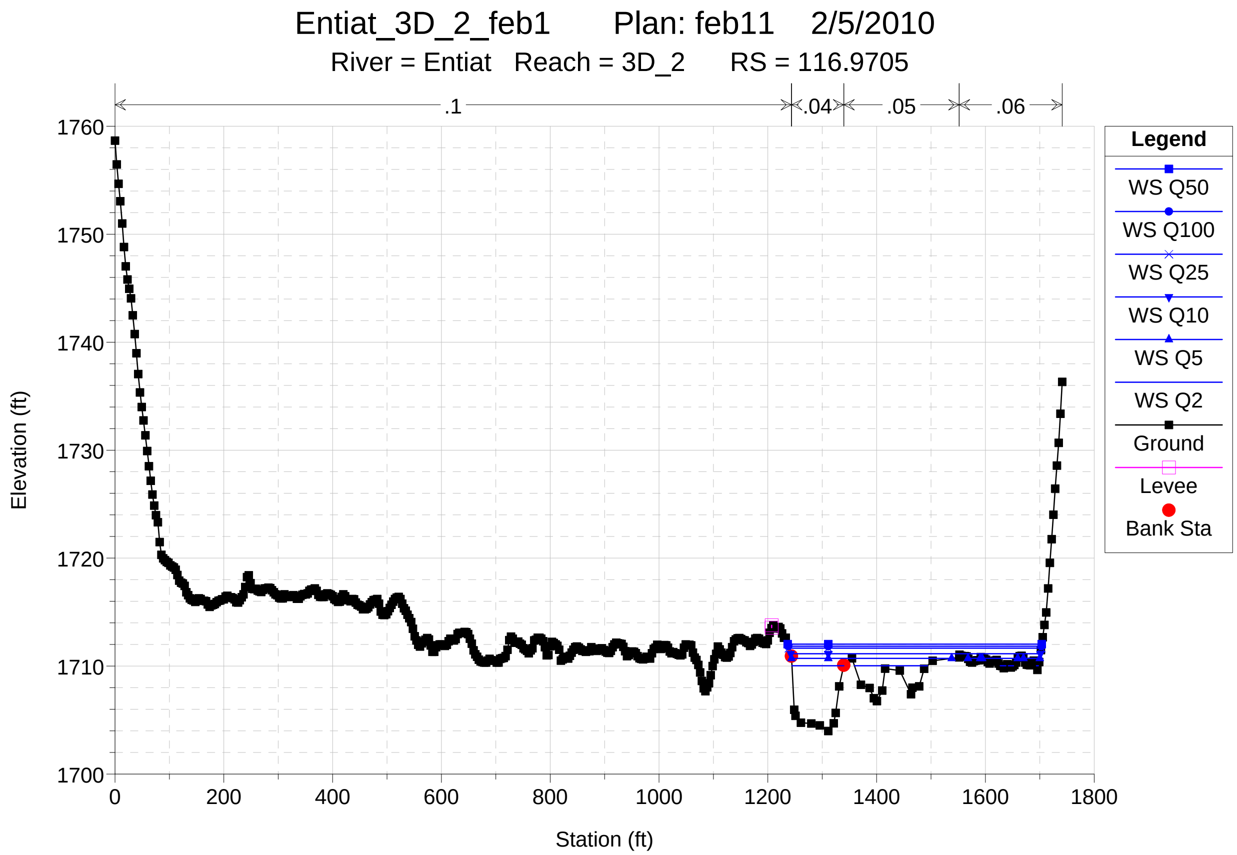

Entiat_3D_2_feb1 Plan: feb11 2/5/2010
Entiat 3D_2
Legend
WS Q50
WS Q25
WS Q10
WS Q5
WS Q100
WS Q2
Ground
Elevation (ft)
1714
1712
1710
1708
1706
1704
1702
0
50
100
150
200
250
300
350
400
Main Channel Distance (ft)
38.46376
72.11151
116.9705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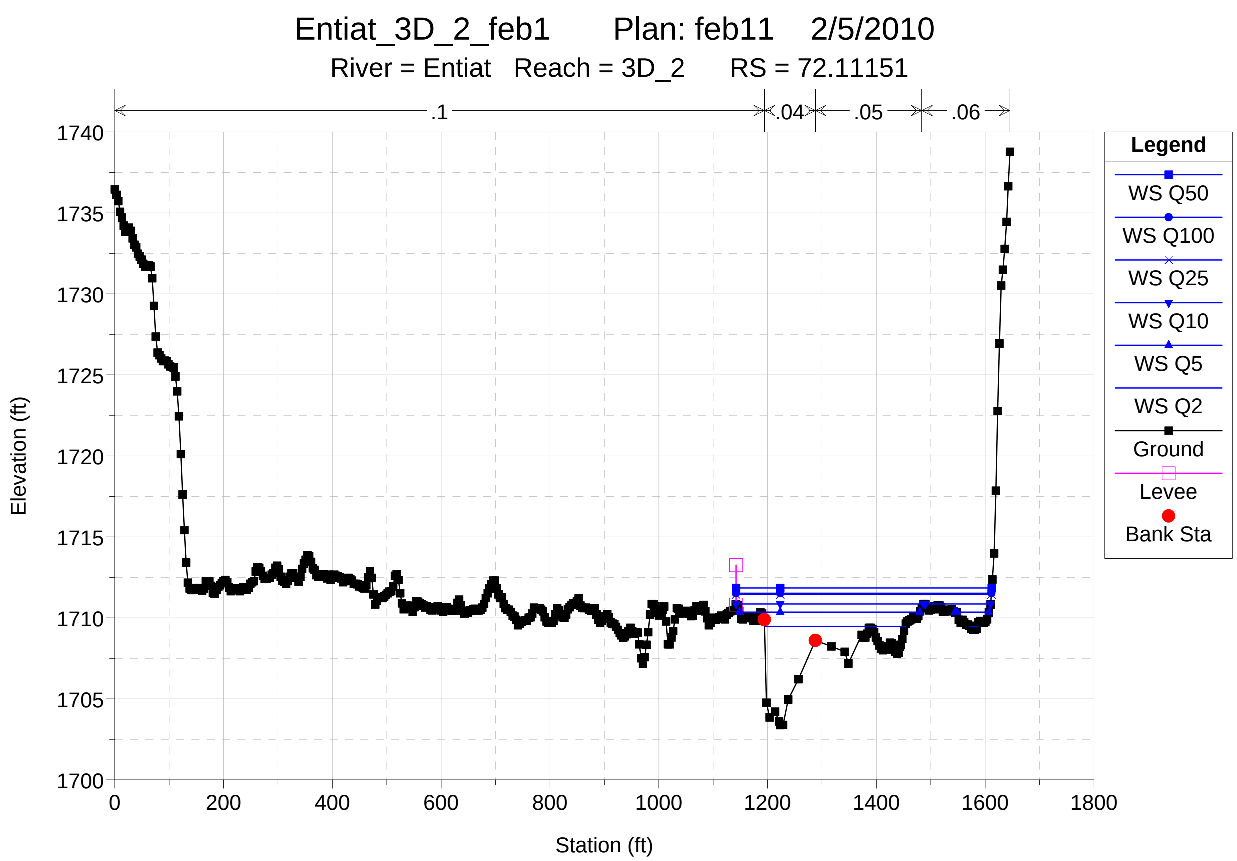
River = Entiat Reach = 3D_2 RS = 116.9705
.1
.04
.05
.06
Legend
WS Q50
WS Q100
WS Q25
WS Q10
WS Q5
WS Q2
Ground
Levee
Bank Sta
Elevation (ft)
1760
1750
1740
1730
1720
1710
1700
0
200
400
600
800
1000
1200
1400
1600
1800
Station (ft)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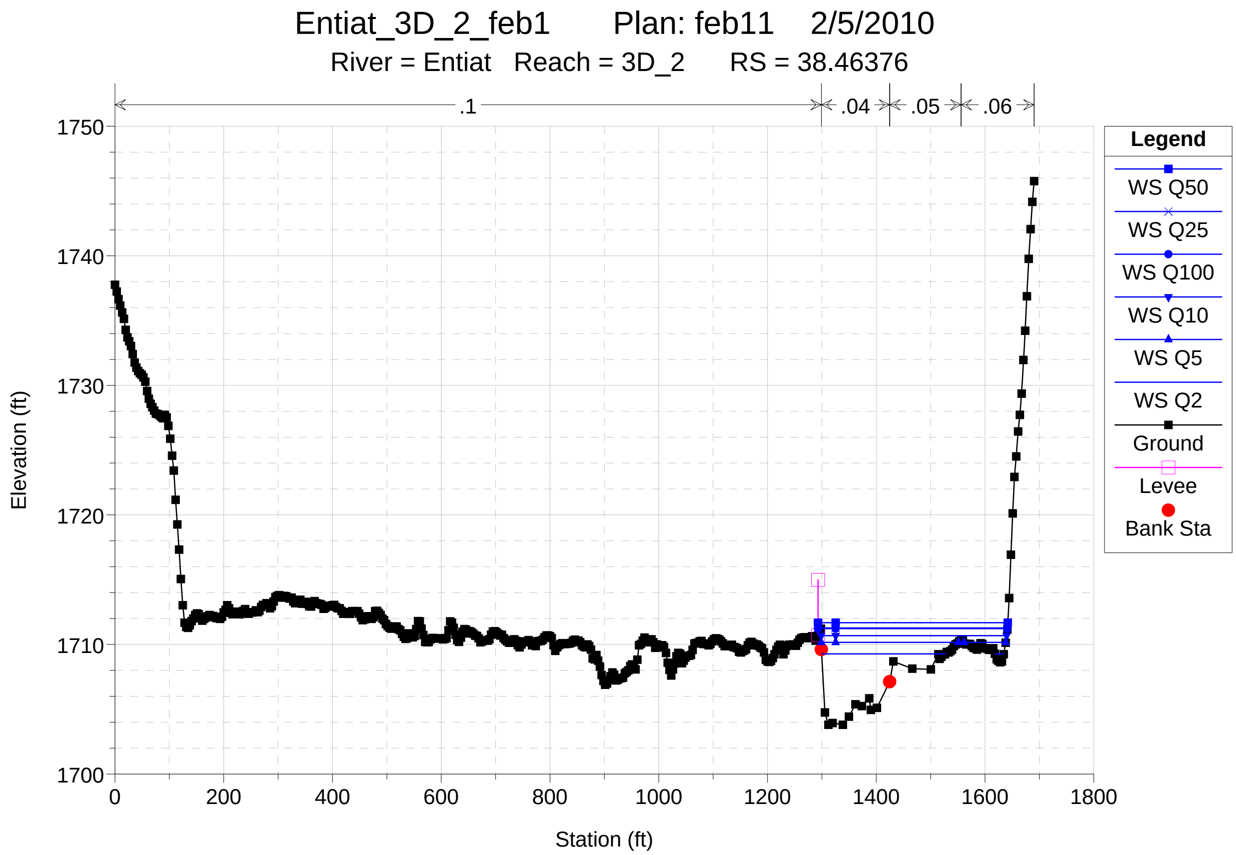
River = Entiat Reach = 3D_2 RS = 72.11151
.1
.04
.05
.06
Legend
WS Q50
WS Q100
WS Q25
WS Q10
WS Q5
WS Q2
Ground
Levee
Bank Sta
Elevation (ft)
1740
1735
1730
1725
1720
1715
1710
1705
1700
0
200
400
600
800
1000
1200
1400
1600
1800
Station (ft)



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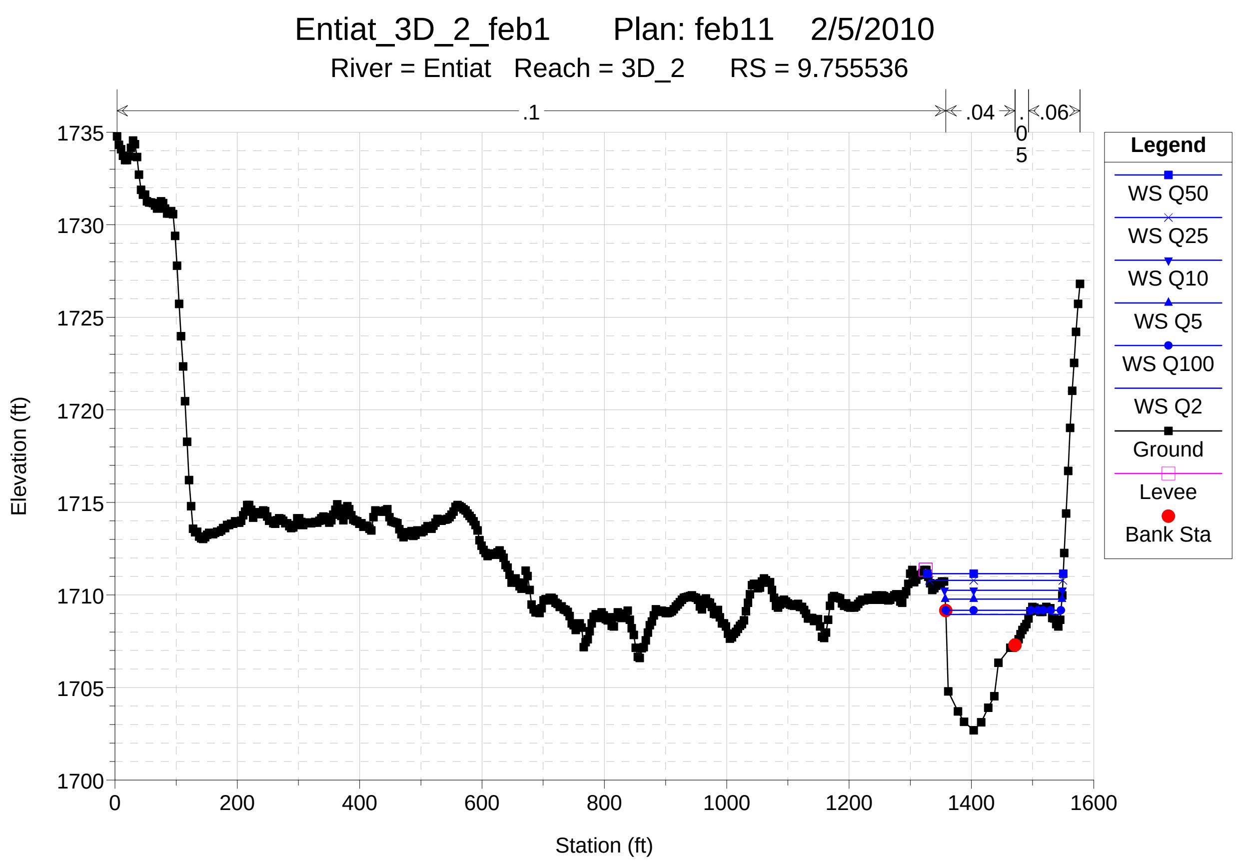
River = Entiat Reach = 3D_2 RS = 38.46376
.1
.04
.05
.06
Legend
WS Q50
WS Q25
WS Q100
WS Q10
WS Q5
WS Q2
Ground
Levee
Bank Sta
Elevation (ft)
1750
1740
1730
1720
1710
1700
0
200
400
600
800
1000
1200
1400
1600
1800
Station (ft)



Entiat_3D_2_feb1 Plan: feb11 2/5/2010
River = Entiat Reach = 3D_2 RS = 9.755536
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.04
.05
.06
Legend
WS Q50
WS Q25
WS Q10
WS Q5
WS Q100
WS Q2
Ground
Levee
Bank Sta
Elevation (ft)
1735
1730
1725
1720
1715
1710
1705
1700
0
200
400
600
800
1000
1200
1400
1600
Station (ft)

HEC-RAS Plan: feb1_1 River: Entiat Reach: 3D_2

Reach	River Sta	Profile	Cum Ch Len	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Depth C
			(ft)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)
D3_2	116.9705	Q2	351.77	2560.00	1703.99	1710.04	1707.98	1710.37	0.002306	4.91	646.64	252.80	0.40	0.66	4.70
D3_2	116.9705	Q5	351.77	3500.00	1703.99	1710.72	1708.87	1711.12	0.002531	5.59	864.69	411.70	0.43	0.82	5.33
D3_2	116.9705	Q10	351.77	4120.00	1703.99	1711.15	1709.24	1711.55	0.002381	5.70	1055.24	459.14	0.42	0.83	5.75
D3_2	116.9705	Q25	351.77	4890.00	1703.99	1711.66	1709.58	1712.04	0.002109	5.68	1294.04	463.81	0.40	0.80	6.27
D3_2	116.9705	Q50	351.77	5460.00	1703.99	1712.04	1710.08	1712.39	0.001928	5.65	1468.48	467.16	0.39	0.78	6.64
D3_2	116.9705	Q100	351.77	6030.00	1703.99	1711.84	1710.39	1712.34	0.002761	6.63	1376.61	465.40	0.46	1.08	6.44
D3_2	72.11151	Q2	204.59	2560.00	1703.38	1709.48	1708.72	1709.95	0.004273	5.92	555.17	271.99	0.53	1.01	3.92
D3_2	72.11151	Q5	204.59	3500.00	1703.38	1710.35	1709.27	1710.76	0.003180	5.82	846.13	391.83	0.47	0.92	4.78
D3_2	72.11151	Q10	204.59	4120.00	1703.38	1710.86	1709.62	1711.23	0.002688	5.72	1065.94	464.60	0.44	0.86	5.29
D3_2	72.11151	Q25	204.59	4890.00	1703.38	1711.44	1709.87	1711.77	0.002201	5.55	1340.25	469.17	0.40	0.78	5.87
D3_2	72.11151	Q50	204.59	5460.00	1703.38	1711.85	1710.22	1712.16	0.001947	5.46	1532.17	470.03	0.38	0.74	6.28
D3_2	72.11151	Q100	204.59	6030.00	1703.38	1711.52	1710.37	1712.00	0.003138	6.69	1375.02	469.33	0.48	1.13	5.95
D3_2	38.46376	Q2	94.19	2560.00	1703.81	1709.27	1707.38	1709.59	0.002311	4.62	624.15	243.35	0.40	0.60	4.22
D3_2	38.46376	Q5	94.19	3500.00	1703.81	1710.17	1707.93	1710.50	0.002007	4.88	876.99	328.74	0.38	0.63	5.11
D3_2	38.46376	Q10	94.19	4120.00	1703.81	1710.69	1708.38	1711.02	0.001827	4.97	1052.14	341.03	0.37	0.63	5.63
D3_2	38.46376	Q25	94.19	4890.00	1703.81	1711.28	1708.93	1711.61	0.001649	5.05	1257.04	348.30	0.36	0.63	6.22
D3_2	38.46376	Q50	94.19	5460.00	1703.81	1711.68	1709.19	1712.02	0.001556	5.11	1397.80	348.84	0.35	0.63	6.62
D3_2	38.46376	Q100	94.19	6030.00	1703.81	1711.23	1709.42	1711.74	0.002604	6.31	1238.64	348.23	0.45	0.99	6.17
D3_2	9.755536	Q2		2560.00	1702.69	1708.95	1706.92	1709.34	0.002683	5.09	522.50	151.41	0.43	0.72	4.39
D3_2	9.755536	Q5		3500.00	1702.69	1709.78	1707.66	1710.27	0.002681	5.71	670.39	190.85	0.44	0.86	5.22
D3_2	9.755536	Q10		4120.00	1702.69	1710.25	1708.04	1710.79	0.002684	6.05	760.72	192.64	0.45	0.93	5.69
D3_2	9.755536	Q25		4890.00	1702.69	1710.79	1708.50	1711.39	0.002684	6.43	870.45	218.28	0.45	1.02	6.23
D3_2	9.755536	Q50		5460.00	1702.69	1711.15	1708.83	1711.79	0.002685	6.68	951.22	222.11	0.46	1.08	6.60
D3_2	9.755536	Q100		6030.00	1702.69	1709.17	1709.17	1711.14	0.012482	11.34	557.97	164.54	0.93	3.52	4.61

APPENDIX C: PLANNING COST ESTIMATES

Entiat River 3D Planning Estimates For Mainstem Log Jams

Cut and fill quantities are estimates based cross section survey work for two local hydrualic models and exrtrapolated to all sites.
Does not include permitting.

Location	Activity	Unit of Measure	Unit	Cost	Total
W1 - Mainstem Log Jam (75')	Excavate and backfill for log jam	CY	562	$4	$2,248
Buried in Alluivum no boulder ballast.	Excavate, load, haul, & grade excess cut	CY	544	$8	$4,352
	Install logs	EA	72	$100	$7,200
	Large wood purchased and delivered to site	EA	72	$500	$36,000
	Dewatering sediment control	LS	1	$2,500	$2,500
	Revegetation	LS	1	$500	$500
	Construction oversight	HR	48	$121	$5,808
	Construction costs				$58,608
	Construction cost with 15% contingency				$67,399
	Design cost (20% construction estimate)				$13,480
	Total				$80,879
W2 - Mainstem Log Jam (60')	Excavate and backfill for log jam	CY	450	$4	$1,800
Buried in Alluivum no boulder ballast.	Excavate, load, haul, & grade excess cut	CY	435	$8	$3,480
	Install logs	EA	72	$100	$7,200
	Large wood purchased and delivered to site	EA	72	$500	$36,000
	Dewatering sediment control	LS	1	$2,500	$2,500
	Revegetation	LS	1	$500	$500
	Construction oversight	HR	48	$121	$5,808
	Construction costs				$57,288
	Construction cost with 15% contingency				$65,881
	Design cost (20% construction estimate)				$13,176
	Total				$79,057
W3 - Mainstem Log Jam (60')	Excavate and backfill for log jam	CY	450	$4	$1,800
Buried in Alluivum no boulder ballast.	Excavate, load, haul, & grade excess cut	CY	435	$8	$3,480
	Install logs	EA	72	$100	$7,200
	Large wood purchased and delivered to site	EA	72	$500	$36,000
	Dewatering sediment control	LS	1	$2,500	$2,500
	Revegetation	LS	1	$500	$500
	Construction oversight	HR	48	$121	$5,808
	Construction costs				$57,288
	Construction cost with 15% contingency				$65,881
	Design cost (20% construction estimate)				$13,176
	Total				$79,057
W4 - Mainstem Log Jam (80')	Excavate and backfill for log jam	CY	600	$4	$2,400
Buried in Alluivum no boulder ballast.	Excavate, load, haul, & grade excess cut	CY	580	$8	$4,640
	Install logs	EA	72	$100	$7,200
	Large wood purchased and delivered to site	EA	72	$500	$36,000
	Dewatering sediment control	LS	1	$2,500	$2,500
	Revegetation	LS	1	$500	$500
	Construction oversight	HR	48	$121	$5,808
	Construction costs				$59,048
	Construction cost with 15% contingency				$67,905
	Design cost (20% construction estimate)				$13,581
	Total				$81,486
W5 - Mainstem Log Jam (80')	Excavate and backfill for log jam	CY	600	$4	$2,400
Buried in Alluivum no boulder ballast.	Excavate, load, haul, & grade excess cut	CY	580	$8	$4,640
	Install logs	EA	72	$100	$7,200
	Large wood purchased and delivered to site	EA	72	$500	$36,000
	Dewatering sediment control	LS	1	$2,500	$2,500
	Revegetation	LS	1	$500	$500
	Construction oversight	HR	48	$121	$5,808
	Construction costs				$59,048
	Construction cost with 15% contingency				$67,905
	Design cost (20% construction estimate)				$13,581
	Total				$81,486
W6 - Mainstem Log Jam (80')	Excavate and backfill for log jam	CY	600	$4	$2,400
Buried in Alluivum no boulder ballast.	Excavate, load, haul, & grade excess cut	CY	580	$8	$4,640
	Install logs	EA	72	$100	$7,200
	Large wood purchased and delivered to site	EA	72	$500	$36,000
	Dewatering sediment control	LS	1	$2,500	$2,500
	Revegetation	LS	1	$500	$500
	Construction oversight	HR	48	$121	$5,808
	Construction costs				$59,048
	Construction cost with 15% contingency				$67,905
	Design cost (20% construction estimate)				$13,581
	Total				$81,486
W7 - Mainstem Log Jam (80')	Excavate and backfill for log jam	CY	600	$4	$2,400
Buried in Alluivum no boulder ballast.	Excavate, load, haul, & grade excess cut	CY	580	$8	$4,640
	Install logs	EA	72	$100	$7,200
	Large wood purchased and delivered to site	EA	72	$500	$36,000
	Dewatering sediment control	LS	1	$2,500	$2,500
	Revegetation	LS	1	$500	$500
	Construction oversight	HR	48	$121	$5,808
	Construction costs				$59,048
	Construction cost with 15% contingency				$67,905
	Design cost (20% construction estimate)				$13,581
	Total				$81,486
W8 - Mainstem Log Jam (200')	Excavate and backfill for log jam	CY	1,500	$4	$6,000
Buried in Alluivum no boulder ballast.	Excavate, load, haul, & grade excess cut	CY	1,450	$8	$11,600
	Install logs	EA	180	$100	$18,000
	Large wood purchased and delivered to site	EA	180	$500	$90,000
	Dewatering sediment control	LS	1	$5,000	$5,000
	Revegetation	LS	1	$1,500	$1,500
	Construction oversight	HR	120	$121	$14,520
	Construction costs				$146,620
	Construction cost with 15% contingency				$168,613
	Design cost (20% construction estimate)				$33,723
	Total				$202,336
W9 - Mainstem Log Jam (100')	Excavate and backfill for log jam	CY	750	$2	$1,500
Buried in Alluivum no boulder ballast.	Excavate, load, haul, & grade excess cut	CY	725	$6	$4,350
	Install logs	EA	108	$7	$756
	Large wood purchased and delivered to site	EA	108	$500	$54,000
	Dewatering sediment control	LS	1	$2,500	$2,500
	Revegetation	LS	1	$500	$500
	Construction oversight	HR	64	$121	$7,744
	Construction costs				$71,350
	Construction cost with 15% contingency				$82,053
	Design cost (20% construction estimate)				$16,411
	Total				$98,463

Entiat River 3D Planning Estimates For Off Channel Habitat and Gravel Pit Reclamation

Cut and fill quantities are estimates. Actual channel grading plans will be determined following survey and design.
Does not include permitting.

Location	Activity	Unit of Measure	Unit	Cost	Total
OC1 - Backwater Channel	Excavate to Grade Use Native Gravel and Haul within 1500 feet. Assumes 12 foot channel top width.	CY	1,000.0	$22	$22,000
	Large wood purchased and delivered to site	EA	90.0	$500	$45,000
	Dewatering Sediment Control	LS	1.0	$2,500	$2,500
	Wood habitat construction	EA	90.0	$100	$9,000
	Channel grading and habitat construction	LF	600.0	$20	$12,000
	Revegetate disturbed area.	LS	1.0	$5,000	$5,000
	Construction road access	LS	1.0	$2,000	$2,000
	Construction oversight	HR	40.0	$121	$4,840
	Construction costs				$102,340
	Construction cost with 15% contingency				$117,691
	Design cost (20% construction estimate)				$23,538
	Total				$141,229
OC1 - Ground Water Gallery	Excavate to Grade. Native Gravel and Haul within 1500 feet. Assumes 12 foot channel top width.	CY	1,000.0	$22	$22,000
	Ground Water Gallery Installed	EA	1.0	$120,000	$120,000
	Large wood purchased and delivered to site	EA	110.0	$500	$55,000
	Dewatering Sediment Control	LS	1.0	$5,000	$5,000
	Channel grading and Large Wood habitat construction	LF	600.0	$30	$18,000
	Revegetate disturbed area.	LS	1.0	$7,500	$7,500
	Construction road access	LS	1.0	$2,000	$2,000
	Construction oversight	HR	240.0	$121	$29,040
	Construction costs				$258,540
	Construction cost with 15% contingency				$297,321
	Design cost (20% construction estimate)				$59,464
	Total				$356,785
OC2 - Backwater Channel	Excavate to Grade. Native Gravel and Haul within 1500 feet. Assumes 12 foot channel top width.	CY	466.0	$22	$10,252
	Large wood purchased and delivered to site	EA	45.0	$500	$22,500
	Dewatering Sediment Control	LS	1.0	$2,500	$2,500
	Channel grading and Large Wood habitat construction	LF	280.0	$20	$5,600
	Revegetate disturbed area.	LS	1.0	$2,500	$2,500
	Construction road access	LS	1.0	$500	$500
	Construction oversight	HR	36.0	$121	$4,356
	Construction costs				$48,208
	Construction cost with 15% contingency				$55,439
	Design cost (20% construction estimate)				$11,088
	Total				$66,527
OC3 - Backwater Channel	Excavate to Grade. Native Gravel and Haul within 1500 feet. Assumes 12 foot channel top width.	CY	416.0	$22	$9,152
	Large wood purchased and delivered to site	EA	45.0	$500	$22,500
	Dewatering Sediment Control	LS	1.0	$2,500	$2,500
	Channel grading and Large Wood habitat construction	LF	250.0	$20	$5,000
	Revegetate disturbed area.	LS	1.0	$2,500	$2,500
	Construction road access	LS	1.0	$2,000	$2,000
	Construction oversight	HR	60.0	$121	$7,260
	Construction costs				$50,912
	Construction cost with 15% contingency				$58,549
	Design cost (20% construction estimate)				$11,710
	Total				$70,259
OC4 - Backwater Channel	Excavate to Grade. Native Gravel and Haul within 1500 feet. Assumes 12 foot channel top width.	CY	250.0	$22	$5,500
	Large wood purchased and delivered to site	EA	36.0	$500	$18,000
	Dewatering Sediment Control	LS	1.0	$2,500	$2,500
	Channel grading and Large Wood habitat construction	LF	150.0	$20	$3,000
	Revegetate disturbed area.	LS	1.0	$2,500	$2,500
	Construction road access	LS	1.0	$2,000	$2,000
	Construction oversight	HR	48.0	$121	$5,808
	Construction costs				$39,308
	Construction cost with 15% contingency				$45,204
	Design cost (20% construction estimate)				$9,041
	Total				$54,245
OC5 - Side Channel	Excavate to Grade. Native Gravel and Haul within 1500 feet. Assumes 12 foot channel top width.	CY	1,580.0	$22	$34,760
	Large wood purchased and delivered to site	EA	210.0	$500	$105,000
	Dewatering Sediment Control	LS	1.0	$5,000	$5,000
	Channel grading and Large Wood habitat construction	LF	950.0	$30	$28,500
	Revegetate disturbed area.	LS	1.0	$7,500	$7,500
	Construction road access	LS	1.0	$10,000	$10,000
	Construction oversight	HR	216.0	$121	$26,136
	Construction costs				$216,896
	Construction cost with 15% contingency				$249,430
	Design cost (20% construction estimate)				$49,886
	Total				$299,316
Gravel Mine Reclamation	Grade existing gravel pile to natural condition	CY	18,500.0	$3	$55,500
	Revegetate disturbed area.	LS	1.0	$5,000	$5,000
	Dewatering Sediment Control	LS	1.0	$2,500	$2,500
	Construction costs				$63,000
	Construction cost with 15% contingency				$72,450
	Design cost (20% construction estimate)				$14,490
	Total				$86,940