



East Fork Lewis River Ridgefield Pits Restoration

Basis of Design Report Preliminary Design

Lower Columbia Estuary Partnership & Inter-Fluve

October 26, 2021

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1 Introduction

1.1 OVERVIEW

This report summarizes preliminary designs for aquatic habitat restoration for the Ridgefield Pits reach and adjacent upstream areas on the lower East Fork Lewis River (EF Lewis River). The project aims to restore habitat conditions for ESA-listed salmonids, including winter and summer steelhead, fall Chinook salmon, coho salmon, and chum salmon. The project will restore instream habitat, riparian habitat, and floodplain processes in a section of river that has been heavily impacted by past floodplain gravel mining, gravel mining capture (avulsion into floodplain gravel pits), and a host of past and ongoing land uses that have filled and encroached on the historical floodplain and channel migration zone.

This report provides background information on the project and serves as a Basis of Design report for the Preliminary Designs. It will be updated as part of subsequent design phases.

1.2 BACKGROUND

This preliminary design effort was led by the Lower Columbia Estuary Partnership (LCEP) and is funded by the Washington State Salmon Recovery Funding Board as part of Recreation and Conservation Office (RCO) Project #17-1070. The project included planning, data collection, analysis and stakeholder involvement to support the preliminary designs, including:

- Topographic survey (Attachment A)
- Geomorphic analysis (Attachment B)
- Hydraulics analysis (Attachment C)
- Sediment survey and analysis (Attachment D)
- Water temperature analysis (Attachment E)
- Restoration alternatives development and selection of preferred alternative (Attachment F).

Technical support and guidance for the project has been provided by a Technical Oversight Group (TOG) comprised of technical representatives from interested and involved stakeholders and resource agencies. The TOG and stakeholder involvement is further discussed in Section 1.4 and Attachment G.

1.3 SUPPORTING STUDIES

There has been considerable past analysis of the lower EF Lewis River and preliminary restoration planning for the project area. The following previous studies have evaluated habitat, land use impacts, and/or restoration opportunities in the study area and have been reviewed as part of this effort.

- Daybreak Mine Expansion Habitat Conservation Plan (HCP) (Storedahl & Sons 2003). Includes the main HCP document as well as the following attachments or follow-up work that are relevant to this effort:
 - Conceptual Restoration Plan for Ridgefield Pits (R2 Resource Consultants 1999) –Appendix B of the HCP
 - Geomorphic Analysis of the East Fork Lewis River (WEST Consultants 2001)–Appendix C of HCP
 - Daybreak Ponds Avulsion Mitigation (WEST Consultants 2001 and Ecological Land Services) – Addendum 1 to Appendix C of HCP
 - CM-10 Monitoring Report–Ridgefield Pits Bathymetric Survey (Tech Memo by WEST Consultants 2013) – monitoring requirement of HCP
- Assessment and Strategic Plan for East Fork Lewis River (Dover Habitat Restoration for Friends of

the East Fork 2003)

- East Fork Lewis River (RM 13 to RM 6), Including West Daybreak Park Project Reach – Fluvial Geomorphology and Erosion and Sediment Evaluation (Frank Reckendorf 2010).
- The Lower East Fork Lewis River Subbasin: A Summary of Habitat Conditions, Salmonid Distribution, and Smolt Production (WDFW 2001)
- East Fork Lewis River Basin – Habitat Assessment (SP Cramer & Associates 2005)
- Lower East Fork Lewis River Habitat Restoration Plan (Inter-Fluve and Cramer Fish Sciences, for LCFRB 2009). This effort identified the need for restoration of the pits reach and provided a coarse-scale description of opportunities and potential costs.

1.4 PROJECT GOALS

Project goals were established through the workgroup (TOG) process described above and are listed below. The project objectives and design criteria that fit within these goals are included in Section 4.1.

- Goal 1. Restore native vegetation communities: Restore a patchwork mosaic of age classes and native species that dominate riparian and floodplain areas, with vegetation supported by channel migration processes and high seasonal water table.
- Goal 2. Enhance thermal refuge and incorporate cold water areas into restoration efforts: Protect and enhance existing cold water areas in order to decrease thermal loading to the mainstem and provide thermal refuge to benefit pre-spawn holding and spawning for coho, Chinook, steelhead and chum and summer juvenile rearing habitat for coho, Chinook and steelhead. Improve habitat quantity and quality in the existing thermal refuge areas. Assess potential to leave pits that contain cooler water as refuge areas during the design and construction phases of the project.
- Goal 3. Increase the quality and quantity of Chinook, chum, steelhead and coho spawning and rearing habitat: Create habitat conditions that are consistent with the geomorphic setting. Restore a complex, multi-thread channel network that includes greater channel planform complexity, pools with instream cover, riffles for macroinvertebrate production, and tail-outs with abundant spawning gravel. Increase floodplain habitat availability and complexity in the form of abandoned oxbows, floodplain wetlands, secondary and side- channel connectivity, and beaver dam complexes that are accessible to fish at a range of flows.
- Goal 4. Restore Channel Migration Zone and Floodplain Connectivity: Restore portions of the historical channel migration zone and restore natural rates of floodplain inundation, where possible, by 1) removing hydromodifications; and 2) achieving channel and floodplain geometry and elevation that encourage frequent overbank flows and natural rates of channel adjustment. Investigate the feasibility of expanding future restoration actions into the Daybreak Pits area.
- Goal 5. Create a dynamic channel that allows for natural rates of channel adjustment and sediment transport: Allow for natural rates of channel adjustment in concert with sediment supply and hydrology regime. Maintain depositional conditions, especially within the pits to promote sediment capture and to re-build the grade lost to avulsion, and to restore sediment transport processes into and through the area.
- Goal 6. Develop restoration approaches and actions that are consistent with existing land use: Avoid any increase of flood or erosion risk to public or private infrastructure. Take into consideration the potential for a future avulsion of the EFLR into the Daybreak Pits. Consider the implications of designs for recreation users along the river.

2 Site Conditions

2.1 SITE OVERVIEW

The study area extends from approximately river mile (RM) 7.3 (downstream of the Ridgefield Pits) to RM 10 (downstream of Daybreak Bridge). An overview map of the project area (Figure 1 and Sheet 5 in the Preliminary Design drawings- Attachment H) and photos of the individual site locations (Figure 2) are shown below. The project study area included four restoration sites, including: Ridgefield Pits (Figure 3); two side channels (referred to as Lower Side Channel and Upper Side Channel) located to the north of the main channel and upstream of the Ridgefield Pits, and the Mill/Manley Creek confluence with the EF Lewis River. The Ridgefield Pits and the Upper Side Channel project locations were identified as high priority sites in the Lower EF Lewis River Habitat Restoration Plan (2009).

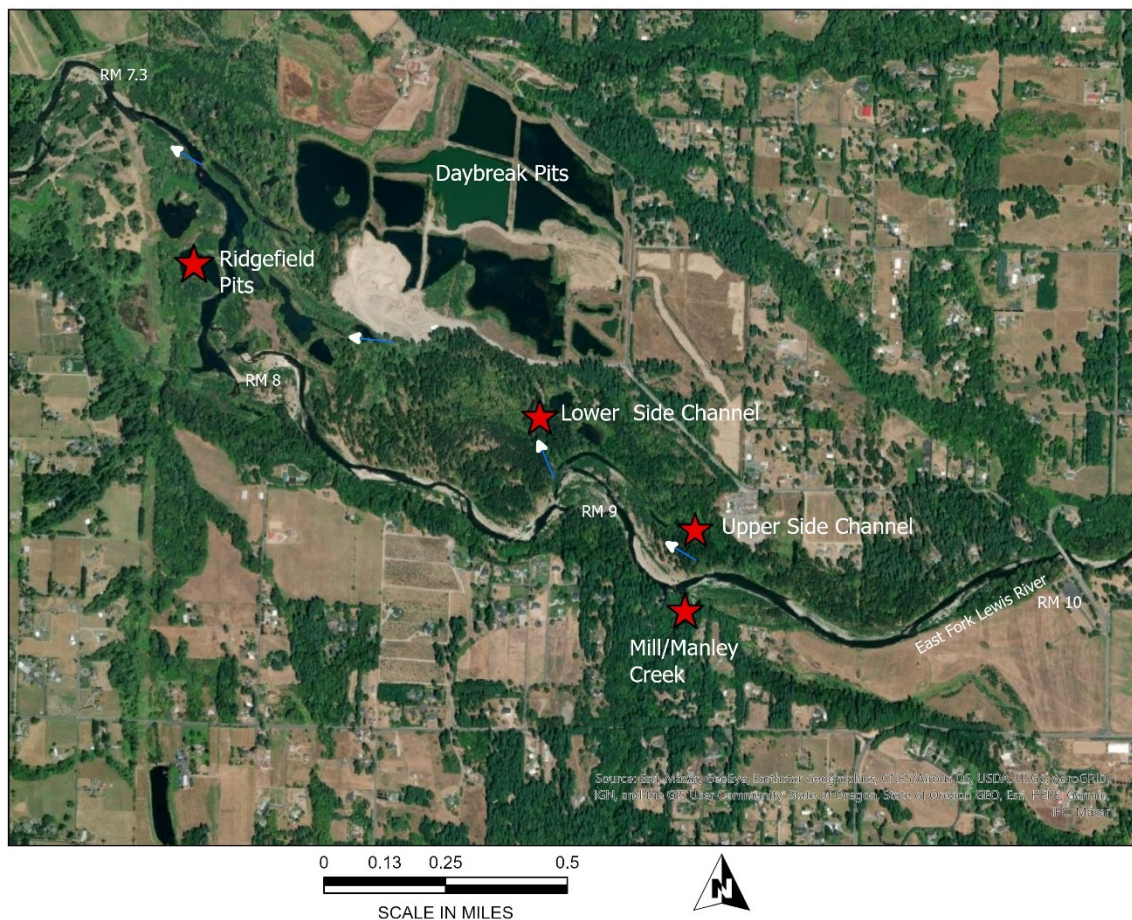




Figure 2. Project area photos including a) Upper Side Channel- confluence (star) with EF Lewis River (located to the right), looking upstream, spring flows; b) Lower Side Channel- confluence with EF Lewis River (background), looking upstream, early summer flows; c) Lower Side Channel- close to Ridgefield Pits, looking upstream, late summer conditions; 4) Mill/Manley Creek- confluence with the EF Lewis River (EF Lewis River in background), looking downstream, late summer flows.

A primary focus of the project is the Ridgefield Pits (RM 7.5-RM 8.0) which were mined for gravel starting in the 1950's (Figure 3). In 1996 the EF Lewis River avulsed into the Ridgefield Pits, which essentially captured the river routing all flow and sediment through the pits. The avulsion caused the abandonment of approximately 4,000 feet of former stream channel and the river still flows through the former gravel mining pits. In the area around Pits 1 and 2 a new delta formed of deposited riverbed material has developed since the avulsion.



Figure 3. Ridgefield Pits current conditions. There are nine pits total. Several of the pits have filled considerably with sediment while the majority have filled very little over the last 25 years. The delta forming at Pits 1 and 2 has led to increased habitat complexity. This location has shown some of the highest juvenile fish counts. Flow is towards the top of the image.

There is various infrastructure located adjacent to the project area. In the valley bottom and former floodplain to the north and east of the channel are the Daybreak Pits, some of which are still being actively mined. The processing area for the Daybreak Pits, and two older inactive gravel mine ponds, are located immediately adjacent to the Ridgefield Pits. The processing area is accessed via NE Storedahl Pit Road, which abuts the project area along the river-right side. Bank armoring separates the river and floodplain from the Daybreak Pits mining area and access road along most of project area. At the downstream end of the project area, Bonneville Power Administration (BPA) transmission lines cross the river and valley bottom, with 3 powerline towers located along the river-left (west) margin of the Ridgefield Pits. At the upstream end, on river-right, is a Clark County maintenance yard and an associated levee and armoring.

Landownership of the project area is a combination of private lands, County lands, conservation lands, and state lands (Figure 4). The Ridgefield Pits themselves are owned by CEMEX (formally Pacific Rock Products Environmental Enhancement Group). The majority of the adjoining floodplain lands upstream and

downstream are owned by Clark County, with some instances of private ownership. The river channel itself within the Ordinary High-Water line is State-Owned Aquatic Land, managed by the Washington Department of Natural Resources. The primary landowners within and adjacent to the project area are shown in the Preliminary Designs drawings.

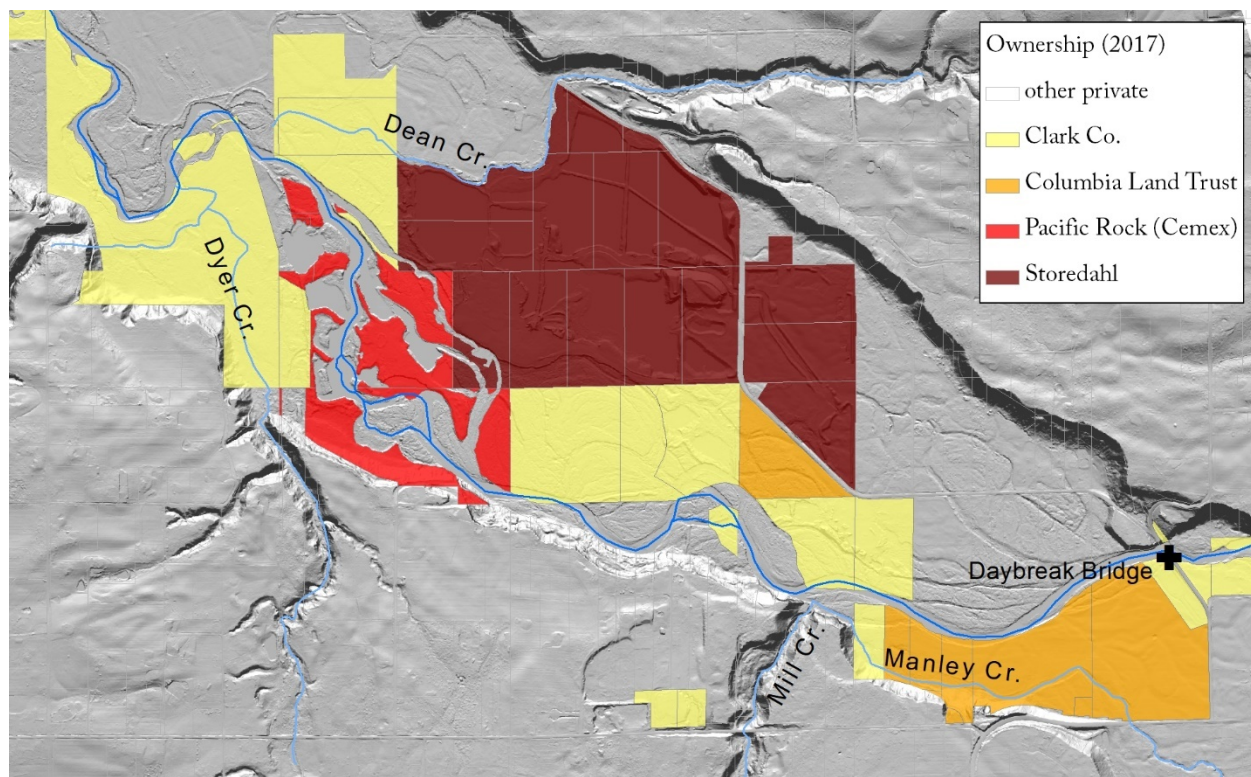


Figure 4. Land ownership (2017) in and adjacent to the East Fork Lewis River Ridgefield Pits restoration site.

2.2 STREAM SURVEYS

Inter-Fluve and LCEP staff collected bathymetric and topographic data in the spring of 2018. This work was performed using a combination of boat-based and ground-based survey techniques. Survey methods and results are described in the Survey Technical Memorandum, included as Attachment 1. The survey data was used in combination with available LiDAR data to support design, modeling, analysis and development of construction quantities.

An existing conditions digital terrain model (DTM), which represents the topographic and bathymetric surface of the project area, was created by LCEP using the field-collected data and LiDAR (Figure 5).

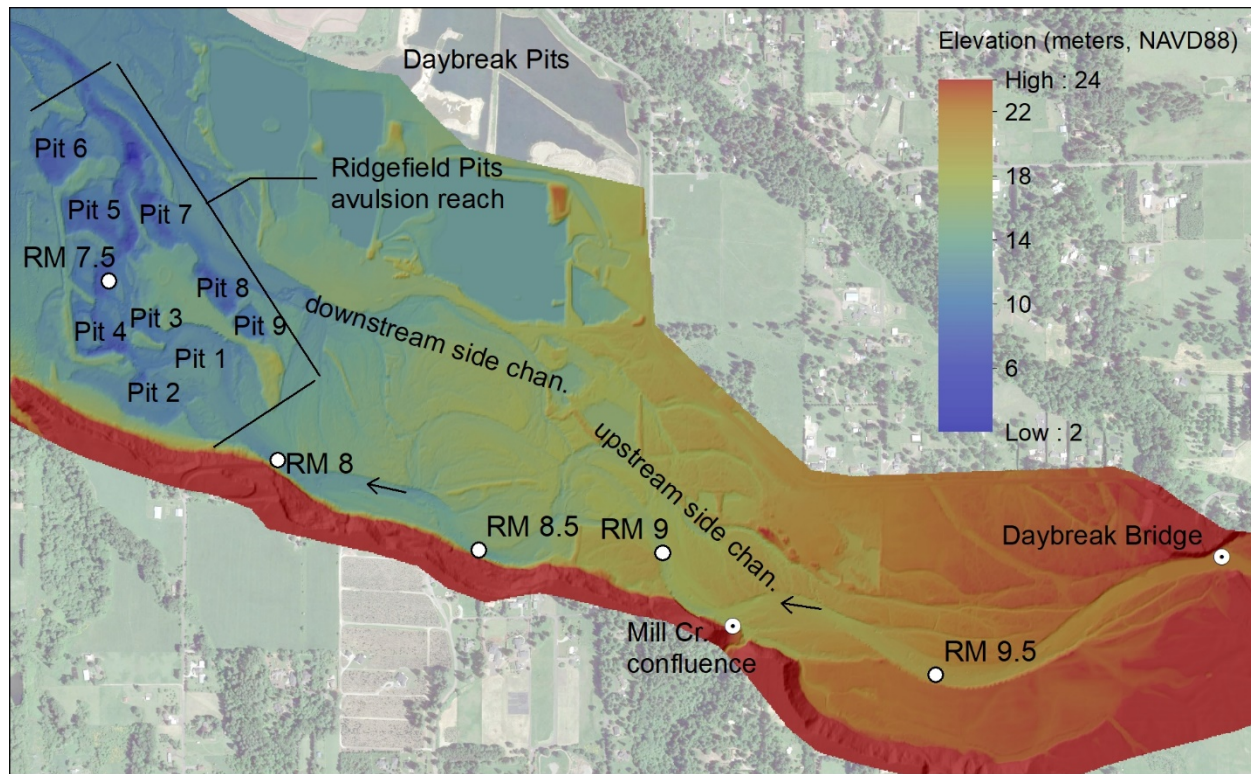


Figure 5. Digital terrain model created for the East Fork Lewis River Ridgefield Pits restoration site.

2.3 GEOMORPHOLOGY

A geomorphic investigation was performed and describes the geomorphic setting, the influence of human actions on geomorphic processes, and anticipated future trends. The geomorphic report is included in Attachment 2. A brief summary of the geomorphic setting is included here.

The headwaters of the EF Lewis River originate in the foothills of the Cascades at an elevation of approximately 4,100 ft. The river flows east to west, entering the lower North Fork Lewis River at sea level. The project site is located just above tidal influence, which extend up to approximately Mason Creek at RM 5.7, which is 1.5 miles downstream of the project area. Within the project area, the river flows through a wide (0.5 - 0.9 mile), unconfined valley with a very low gradient (<0.004 ft./ft). The entire river valley is composed of young (Holocene) alluvial sediments (fines to cobbles-see Attachment 4 for analysis of substrate). The modern river is confined to a narrower floodplain and channel migration corridor due to valley bottom development, fill, roadways, and mining. The river through the project area abuts the high valley wall on river-left in a few locations, causing erosion of the high walls, which are composed of various layers of highly erodible material including fines, gravels, and cobbles.

US Government land office maps from the 1850s indicate that the entire valley bottom was historically well-connected to the hydrology of the river. The valley bottom was labeled as a “low rich bottom subject to inundation” and was illustrated as an extensive wetland area. The river in the vicinity of the Ridgefield Pits was mapped as a multi-threaded channel, with as many as 6 or more interconnected channel threads. Upstream and downstream areas were drawn as highly sinuous with occasional secondary channels (Figure 6). This information suggests that the river through the Ridgefield Pits reach was historically anabranching, characterized by multiple channel threads separated by vegetated islands. Historical presence of this channel type is further supported by a regional (Columbia River Basin) channel typing analysis conducted by

Beechie and Imaki (2014), whose model predicts an anabranching channel type throughout the study area. Reckendorf (2010) also concluded that an anabranching channel type was the likely historical condition in the Ridgefield Pits area.

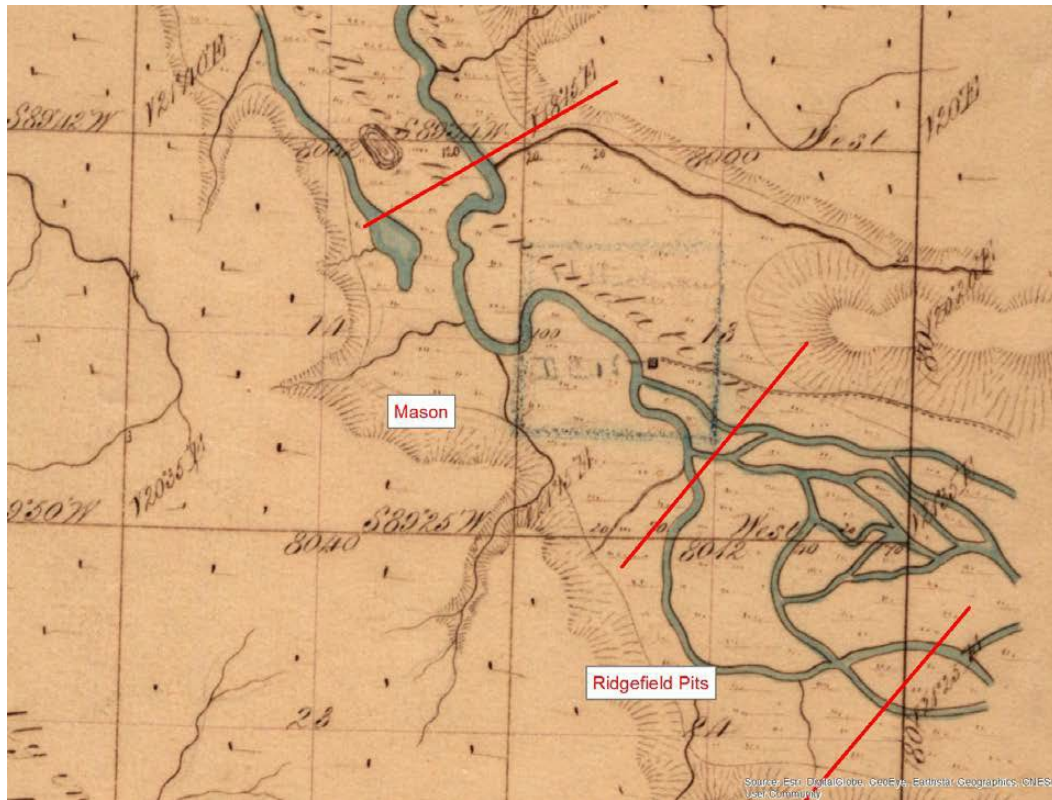


Figure 6. 1854 GLO Map- Ridgefield Pits area (between two red lines at bottom right). GLO map shows an anabranching channel planform in Ridgefield Pits area prior to human disturbances. The channel was highly connected to the adjacent floodplain. Flow is from bottom right to top left.

An aerial photo analysis was performed as part of the geomorphology report, and the imagery, along with a detailed chronology of changes, can be seen in the report (Attachment B). The analysis shows that impacts to the valley bottom were already well underway prior to the first aerial photos in 1939. The 1939 aerials show farms and residences throughout the valley bottom, although the valley bottom, including in the project area, was considerably more vegetated than today. Various episodes of instream and floodplain gravel mining can be seen throughout the lower river in the aerial photos, with mining occurring at least as early as the 1930s and continuing today. With the progression of time and increasing human impacts, the river gradually became more single-threaded, more incised, less complex, and less connected to its floodplain and channel migration zone. Aquatic habitat has suffered accordingly.

The geomorphology analysis also focused on the impact of the Ridgefield Pits avulsion (pit capture) in the mid-1990s and its potential implications to future channel processes and restoration (Figure 7). In summary, previous assessments (WEST Consultants 2001 & 2013) estimated that natural filling of the pits with river bedload and sediments would result in “recovery” (i.e. channel filling back up to a pre-1996 avulsion level) of the pits reach by 2026. Our analysis of pit filling rates, showed that full recovery based on natural filling is not likely to occur until at least the 2070s or later.



Figure 7. Ridgefield Pits avulsion, from Norman et al. (Washington DNR 1998). Flow is from right to left.

2.4 HYDROLOGY AND HYDRAULICS

2.4.1 Hydrologic Setting

The EF Lewis River has a rainfall-dominated hydrograph typical of western Cascades streams. Estimates of average monthly flows for the downstream end of the study area (RM 7.5) are included in Figure 8. An exceedance plot showing the estimated median and the 10 and 90 percent exceedance flows for RM 7.5 is included in Figure 9. These values were obtained by using a basin-area correction of data from the USGS gage at Heisson (RM 20), which is approximately 11 miles upstream of the study area. Note the relatively steady median winter flow of between 1,000 and 2,000 cfs but the wide daily range. This demonstrates the high variation in winter flows. In contrast, summer base flows are very consistent, with an average median daily flow of 89 cfs in August.

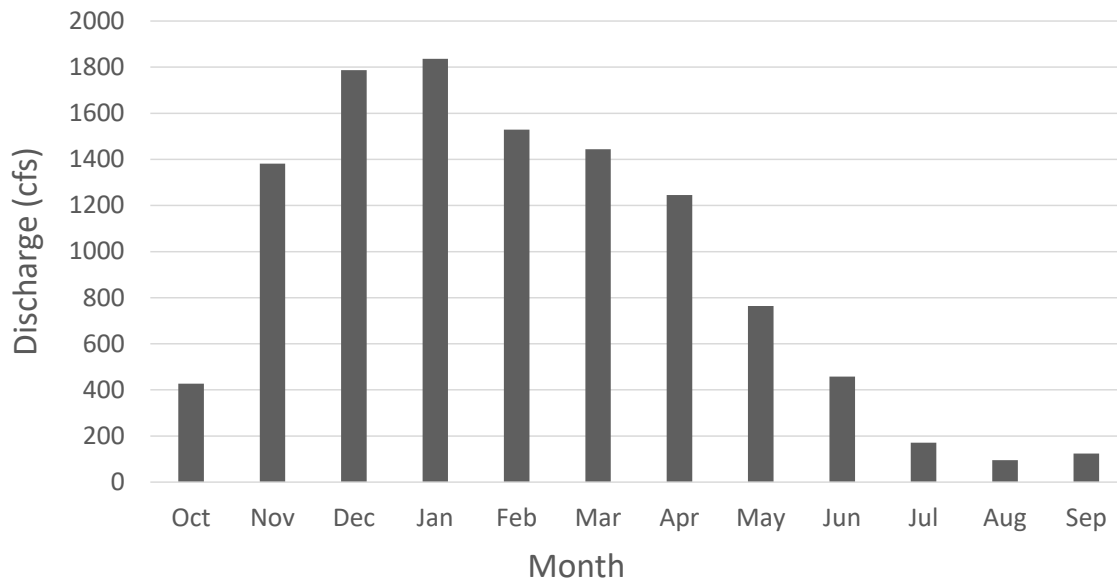


Figure 8. Estimate of monthly average flows for the project area, calculated using a basin-area correction on data from the Heisson Gage (USGS # 14222500) for the past 30 years.

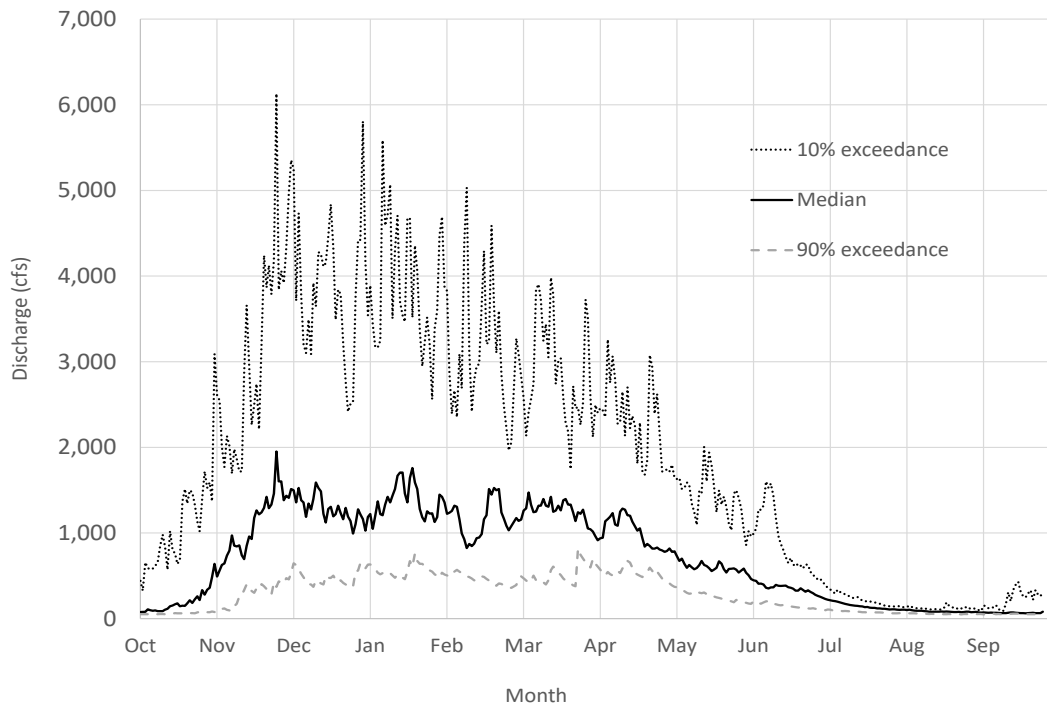


Figure 9. Daily flow exceedance estimated for River Mile 7.5. Based on a basin-area correction from the Heisson Gage (USGS # 14222500) for the past 30 years.

The flood recurrence intervals from the Heisson Gage are provided in Table 1, and a graphical display of annual peaks since the 1930s is provided in 10. As can be seen, three flood events in the past 25 years have met or exceeded the 50-year event; and the February 1996 event, which is the flood of record, is near the 500-year event. From Figure 10, it also appears that since the 1970s, there has been greater variation in the size of peak flows, which is possibly related to basin land use such as increases in the road drainage network, timber harvest, and conversion of forest to other uses.

Table 1. Flood recurrence intervals from Mastin et al. (2016) for the Heisson Gage (USGS #14222500), using 82 years of record.

Flood Recurrence Interval	Discharge (cfs)
2-Year	9,160
5-Year	12,900
10-Year	15,400
25-Year	18,500
50-Year	20,800
100-Year	23,100
200-Year	25,300
500-Year	28,300

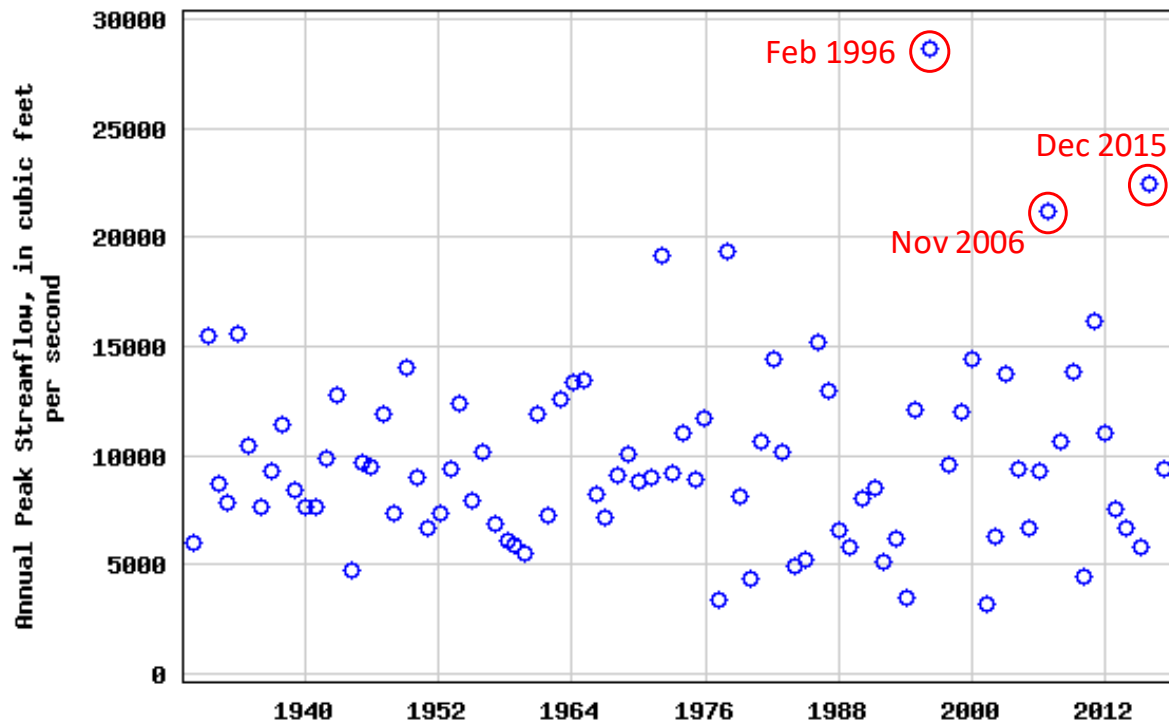


Figure 10 . Annual peak flows for the period of record from the Heisson Gage (USGS #14222500). Recent and prominent flood events over the past 25 years are highlighted.

2.4.2 Hydraulic Analysis

2.4.2.1 Overview

To evaluate surface hydraulics along the EF Lewis River and its floodplain throughout the project site, LCEP developed a 2D hydrodynamic model using the Tuflow FV modeling engine developed by the University of Queensland in Australia (and currently owned by British Maritime Technologies). The model is an upstream extension of an original model that was calibrated and applied as part of the completed EFLR La Center Wetlands project. The hydraulic model was used to evaluate existing hydraulic conditions and aid in the selection of preferred restoration design alternatives. Hydraulic model outputs also provide input to sediment and water quality modules used to evaluate geomorphic changes and water temperatures (see report sections 2.5 and 2.6, respectively). A summary of the hydraulic model analysis is presented below. Full details including model setup and results can be found in Attachment C to this report.

2.4.2.2 Results Summary

The Ridgefield Pits hydraulic model was used to help evaluate restoration Alternative 3 – within the Ridgefield Pits reach proper, and restoration Alternative 5 – the proposed overflow channel upstream of the Mill/Manley confluence with the EFLR. The model also serves as input for extended analyses of sediment transport and water temperature, using add-on modules within the Tuflow modeling package. These analyses are described in Sections 2.5 and 2.6 below, although sediment modeling has not been fully completed at this time. Inputs to the Ridgefield Pits model were derived from an initial model covering the entire EFLR downstream of the project reach, that was developed for the La Center Wetlands restoration project. That model was fully calibrated and validated, however this process has not yet been completed for the Ridgefield Pits model because required field observations are still being collected.

Model simulations of the preferred restoration Alternative 3 for the Ridgefield Pits reach generally show improved hydraulic conditions for the 3-channel hybrid network relative to the Existing Condition (EC). Bed shear and water surface profiles suggest improved sediment transport and channel stability through this reach for the 3-channel network. Currently, the reach shows significant channel instability, and a continued lack of sediment conveyance, as the reach continues to slowly adjust to the 1996 channel avulsion event. Bankfull flow occurrence as predicted by the model is somewhat less than what was predicted by channel calculations for the given channel design parameters. This is expected, as the model is not fully calibrated, and the model grid cell resolution is limited in the ability to fully resolve the relatively small channel widths incorporated in the design. Further grid refinements, and model calibration, will be incorporated into the next design phase to resolve these issues.

Model simulations of the overflow channel proposed in Alternative 5 at the Mill/Manley confluence did not show a significant improvement over the EC, relevant to the restoration objective of promoting scour at this confluence zone. A minor increase in bed shear was obtained after some refinement of the channel geometry, however increased bed shear upstream, as well as other potential concerns associated with this action that were expressed by the TOG, have generally deemed this restoration alternative unfavorable.

2.5 SEDIMENT TRANSPORT

A 2D morpho-dynamic sediment transport model with the capability to dynamically adjust bed elevations in response to hydraulically forced movement of bed and suspended load materials was developed to help characterize current transport conditions and inform the restoration alternatives that were assessed using the hydraulic model. The model used is included in the Tuflow FV modelling package, as an add-on module to the hydraulic modeling engine. LCEP and Inter-Fluve conducted surface and subsurface pebble count surveys at selected floodplain, and mainstem locations within the project reach, to characterization streambed information required by the model. The survey was completed in October 2018.

Preliminary simulations for the Project reach Existing Condition were run, however time did not allow for an analysis of the restoration alternatives that were considered for the Ridgefield Pits reach (preferred Alternative #3 three-channel network, and the Alternative #2 single channel network). Exact details of channel geometries have not yet been determined at the preliminary design stage, and because these will influence model simulation outcomes LCEP will complete the analysis once these have been defined. At that point, results will be analyzed to compare performance of the preferred multi-channel alternative (Alternative #3) to that of the Existing Condition and also to the single-thread channel concept (Alternative #2), which has been requested.

Details of the sediment sampling survey and grain size analysis, as well as model setup and results for the preliminary Existing Conditions simulations, are included in Attachment C.

2.6 WATER TEMPERATURE

2.6.1 Overview

LCEP completed a water temperature analysis for the Project Reach to analyze factors contributing to the existing summertime temperature profile and predict how water temperature may respond to various restoration alternatives. We relied on previous temperature studies as well as temperature surveys we completed in July of 2018 and August of 2020. These utilized continuous temperature loggers at several locations in the mainstem and floodplain, as well as a single thermal infrared survey completed for several mile of the East Fork Lewis River mainstem in 2020. We also developed a 2D water temperature model to compare temperature performance of restoration alternatives that were developed for the Ridgefield Pits reach, including the preferred Alternative #3 (three-channel network) and Alternative #2 (single-channel network). This model is an advective/dispersive heat transfer add-on module for the Tuflow FV hydraulic model engine, which includes atmospheric inputs for heat exchange at the air-water interface. The complete water temperature analysis is included as Attachment E to this report. A summary of the findings is presented below.

2.6.2 Results Summary

The following bullets summarize water temperature characteristics for the Project reach during low flow summer conditions when temperatures are of concern, as described in the preceding sections:

- EFLR mainstem temperatures already exceed most water quality standards at the upstream extent of the Project reach near RM 10 at Daybreak Park.
- Further degradation of EFLR temperature through the Project reach is minimal.
- EFLR mainstem temperature exhibits large diurnal variation in summer due to atmospheric heating and cooling. This variation is reduced through the Ridgefield Pits, where the high volume of slow-moving water attenuates heating and cooling effects, resulting in lower daily high and higher daily low temperatures relative to upstream and downstream reaches.
- Much of the spatial variation in temperature observed in the vicinity of the Pits can be attributed to the moderating effect of the Pits reach on atmospheric heating and cooling. Temperature modeling supports this conclusion.
- Some groundwater may currently influence water temperature through the Pits reach, but this appears to be a relatively small influence, at least during the period we monitored.
- Groundwater influence is tied to the water table, which fluctuates based on climate and weather patterns. Thus, influence of groundwater on the EFLR mainstem is likely to vary from year to year. This has been evidenced by LCEP's 2021 water temperature monitoring, which showed considerably less cold water in off-channel and side channel areas relative to 2018.

- Little evidence of mixing is observed between the larger Ridgefield Pits #5 and #7 and the EFLR mainstem despite being hydrologically connected throughout the summer. Model results support this conclusion.
- Several off-channel and side channel areas have been observed to hold cold surface water during the summer, presumably due to groundwater intrusion. Most of these however do not remain hydrologically connected to the EFLR mainstem during most summer flows, limiting their potential as thermal refuge for juvenile salmonids.
- The confluence of Mill and Manley creeks with the EFLR mainstem presents the largest area of current thermal refuge within the Project reach.
- Overall, the highly dynamic nature of the project reach results in a complex and dynamic water temperature profile. Restoration actions should retain and enhance positive aspects of this.

2.6.2.1 Implications for Restoration Alternatives

The following bullets summarize implications of the observed and simulated EFLR temperature performance for the restoration alternatives that have been considered for the Pits reach, relative to each other and the Existing Condition.

Existing Condition:

- Slow moving, large volume of water with reduced diurnal temperature variation relative to upstream and downstream. Lower daily maximum and higher daily minimum temperatures.
- No current riparian shading, and not likely to improve due to large channel widths.
- From a temperature standpoint, the larger pits (#5 and #7) which remain connected to the mainstem during summer do not appear to degrade its temperature. Other negative factors such as habitat for predators must also be considered.

Alternatives #2 and #3, relative to Existing:

- Based on modeling, water temperatures for both Alternatives will likely exhibit the larger diurnal temperature variations currently seen upstream and downstream of the Pits reach. Thus, daily peak temperatures will be higher, and daily minimum temperatures will be lower, relative to the Existing condition.
- Overall water temperature may be reduced relative to the Existing Condition due to an anticipated rise in the groundwater table from proposed grading.
- Extensive riparian planting along channels that are considerably narrower than the Existing Condition should provide extensive shading and reduce solar heating of the reach during the day, potentially reducing diurnal temperature variation.

Alternative #2 versus #3

- Model results indicate slight improvement in temperature performance for the hybrid three-channel network in Alternative 3 versus the single channel in Alternative 2. Despite the greater water depth and smaller width-to-depth ratio exhibited by Alternative 2, the corresponding reduction in heating is offset by a greater overnight cooling effect seen in the shallower, smaller Alternative 3 channels.
- Temperature performance in Alternative 3 was seen to be further enhanced by simulated groundwater inputs, which persist longer and have more influence in the shallower, lower volume multi-thread channels relative to the single channel.
- Due to time constraints, channels for the Alternative 3 design were not optimized for low flow. Further iterations of low-flow geometry may be possible to further enhance its temperature performance.

2.7 VEGETATION AND WETLAND RESOURCES

Valley bottom vegetation consists of a complex mosaic of aquatic, wetland, riparian, and upland species. Most of the valley bottom where active riverine processes (flood inundation, channel migration) are still intact contain native species communities; although non-native species are present throughout, especially in more disturbed areas. Some of the most common native plants are willow, cottonwood, alder, Oregonash, vine maple, Douglas spirea, red osier dogwood, salmonberry, sword fern, and bigleaf maple. Common non-natives are Himalayan blackberry, reed canary grass, and Japanese knotweed. Clark County continues to invest a lot of resources to combat non-native plants along the floodplain adjacent to the pits.

Most of the valley bottom is comprised of wetlands. The National Wetland inventory shows that nearly the entire project area can be characterized as wetlands, consisting of Freshwater Forested/Shrub Wetlands and Freshwater Emergent Wetlands. A wetlands assessment has not been completed for the project area. The approach to evaluating wetlands and project impacts to wetlands will be coordinated with permitting agencies in later design stages.

2.8 FISH USE- SALMONIDS

In 2001 WDFW produced a report (Project # 99- 1113P) that estimated coho and smolt production from the EF Lewis River above RM 6. Estimates of steelhead production in 2001 included hatchery production (prior to the EF Lewis River becoming a wild steelhead gene bank) included 12,481 wild smolts and 106,836 hatchery smolts. Smolt estimates for other species included: 5,716 coho, 2,060 chum and 1,068 sea-run cutthroat. Spawning data has not been collected by WDFW in the pits area (with the exception of the area above Pit 1) due to avulsion and lack of suitable habitat. Historical accounts of the area where the avulsion occurred suggest that it hosted valuable spawning and rearing habitat due to the availability of spawning gravels and suitable depths and velocities.

As part of the HCP (CM-10) R2 Consultants (2013) collected fish data in the Ridgefield Pits. There was no data collected within the EF Lewis River adjacent to the pits, upstream or downstream of the pits. The survey, which included 23 minnow traps and snorkeling, occurred from July 30-31. The results of the R2 survey showed 500 yearling coho around Pit 2 in an area fed by cooler groundwater. No other juvenile salmon or steelhead were observed.

The Estuary Partnership conducted presence/absence surveys for salmonids during the summers of 2018 and 2019. The data collection was accomplished using two teams and using a snorkel survey approach. Data collection occurred in June and August 2018 and again in August in 2019. The surveys began at Daybreak Park and terminated below the Ridgefield Pits. As part of the June 2018 survey we collected presence/absence data from each of the nine pits. Although the Estuary Partnership methodology was different from the R2 survey, the follow-up survey allowed us to validate R2's findings.

The results from our surveys show juvenile fish present in almost every section of the river throughout the project reach. Figure 11 shows results from the June 2018 survey, which includes salmon and steelhead observed within the project area from RM 7.5- 10. Locations of the juvenile fish shown in Figure 11 are approximate. Juveniles that were found included yearling and sub-yearling steelhead, coho and Chinook. Several adult steelhead were also observed (not shown). The juveniles were often found clustered (particularly coho and Chinook) in and around structure (wood), in areas that had cooler water and in tail-outs (primarily steelhead). In the June 2018 survey several of the pits (8 and 9) contained much cooler water and 360 juveniles were found in Pit 8. The 550 fish that were found around Pits 1 and 2 compare favorably to R2's findings and suggest that this is an important area for juveniles. Juvenile salmon and steelhead were also found in and around Pits 1, 2, 8 and 9. In the other pits, and in the river where depths

were greater than several feet, warm water species were frequently observed.

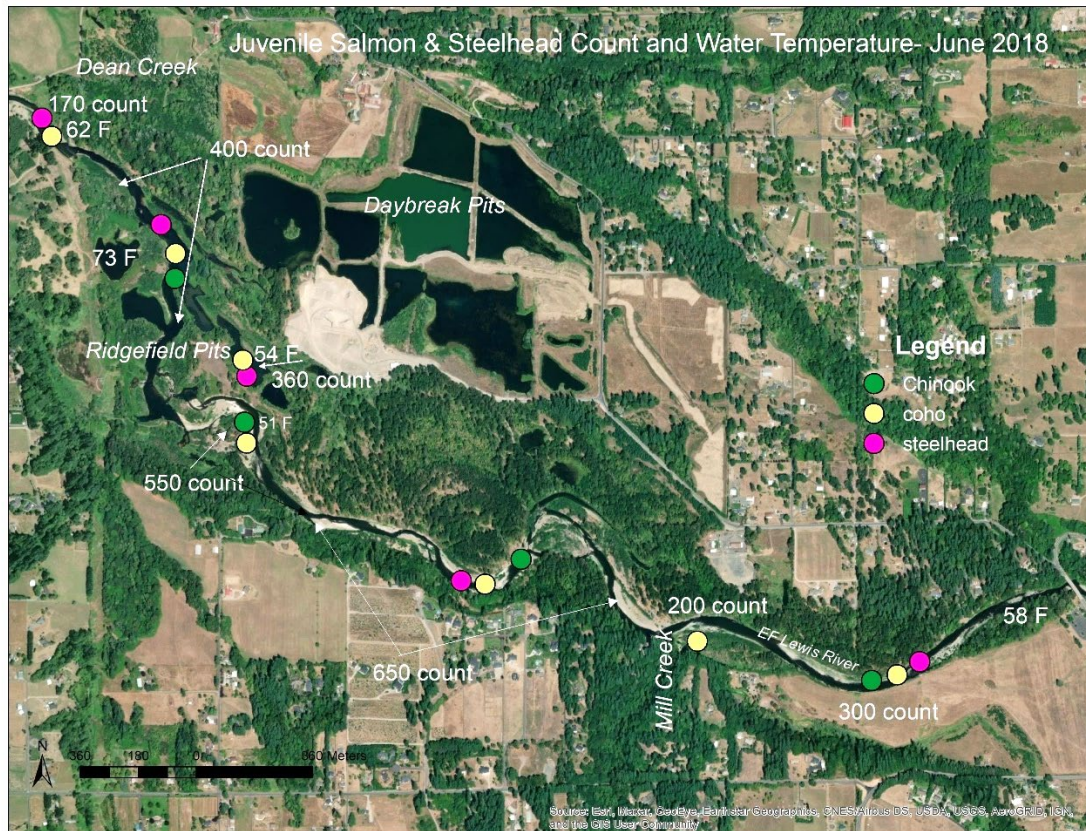


Figure 11. Count estimates for salmon and steelhead and temperature observations based on 2018 snorkel survey. Flow is from right to left.

3 Evaluation of Restoration Alternatives

3.1 SUMMARY OF RESTORATION ALTERNATIVES

The goals and objectives were presented to the TOG. The TOG reviewed and commented on the goals and objectives, which provided the foundation for the restoration alternatives. The restoration alternatives and the analysis is summarized in the Restoration Alternatives Analysis report (Attachment 6), which includes concept-level sketches of each alternative. The alternatives analysis involved the development and evaluation of 6 alternatives, including a No Action alternative. Not all of the alternatives were mutually exclusive, allowing for the selection of “a la carte” items that could be grouped together. The restoration alternatives evaluated are listed below:

- Alt. 1 – No action- passive recovery of Ridgefield Pits
- Alt. 2 – Relocate main channel EF Lewis River into pre-avulsion channel (single-thread)
- Alt. 3 – Full Ridgefield Pits re-grade and multi-thread channel network
- Alt. 4 – Side-channel enhancements at upper and lower sites
- Alt. 5 – Mill/Manley Cr. confluence improvements
- Alt. 6 – Mill/Manley Cr. channel migration expansion

Each alternative was evaluated with respect to how well it would be expected to achieve the project goals and objectives. This resulted in the following ordering (most to least) of how well each alternative achieved this: Alternative 3, Alternative 4, Alternative 6, Alternative 2, Alternative 5, Alternative 1.

3.2 SELECTION OF THE PREFERRED ALTERNATIVE

The Alternatives Analysis was completed in July 2020 and was distributed to the TOG members for their input. A follow-up meeting was held on November 4, 2020 to review and discuss the alternatives and to summarize and review the TOG input. Based on input on the report, discussions at the November 2020 meeting, and multiple follow-up discussions between LCEP and TOG members, further design refinement and analysis was performed. This work was primarily to address suggested edits to Alternative 3 and to further explore a single-thread alternative similar to Alternative 2. Based on this additional analysis, and in consideration of the TOG input and the best approach for accomplishing the project objectives, the following suite of actions were selected to move forward to Preliminary Design:

- Modified Alternative 3 – Full pits re-grade with modifications to reduce the number of channels, reduce grading at the upstream end of the reach where the delta has formed, and to better optimize grading to achieve an approximate cut-fill balance on the site.
- Modified Alternative 4/6 – This includes the side channel enhancements of Alternative 4 plus a partial removal of the levee identified in Alternative 6.

LCEP convened a meeting with the TOG in March 2021 to present the preferred Alternatives described above and the related analyses that were completed. During this time, it was requested that LCEP further explore the single-thread channel concept that was originally defined as Alternative 2. Because this alternative did not score well based on initial feedback from the TOG, LCEP did not do a comprehensive analysis of it prior to the March meeting. At that time some members expressed concern about Alternative 3, primarily related to the water temperature performance of its multi-thread network during low water conditions in the summer, and they suggested that the single channel would remain deeper, thereby

reducing potential heating impacts from solar exposure. LCEP agreed to run additional hydraulic, sediment and temperature analysis for Alternative 2. Due to budget and time considerations, LCEP was only able to complete the water temperature assessment in time for this report. Being the main concern, this was prioritized. The full hydraulic and sediment analysis will be completed before final design development commences in winter of 2022. If at that time the analysis suggests that Alternative 2 is a better approach, modifications will be made to the design accordingly.

Table 2 below provides a summary comparison of Alternatives 2, 3, and the Existing Condition, based on all analyses done to date. These include quantitative modeling results as well as qualitative knowledge gained through the Technical Oversight Group process and other data analysis. It should be noted that the Alternative 2 used for comparison assumes a specific set of parameters that were provided by the members who requested the additional analysis. Some of these may differ slightly from the original concept that was presented for consideration early on in the restoration alternatives process. The differences are outlined in Table 2.

Table 2. restoration alternatives comparison matrix for Alt. 1 (Existing Condition), Alt. 2 (single-thread channel), and Alt. 3 (multi-thread channel network).

Performance Factor	Comparison
<i>Channel Stability/Avulsion Risk</i>	The Existing Condition presents no avulsion risk as it has already occurred. Changes in planform are still occurring as the channel continues to adjust to the 1996 avulsion. Alt. 2 would provide channel stability through levees that would be required to fix the channel in place to prevent an avulsion risk into the existing Ridgefield Pits that would not be filled as part of this alternative. Risk of this avulsion occurring would not be eliminated however, as the levees are proposed to overtop flows that are just at or above the 1-year flood magnitude. Alt. 3 by design would have limited channel stability. No levees are included, which would allow channel migration through a reduced (relative to historical) floodplain extent, thereby restoring the dynamic channel network that was characteristic of this reach prior to anthropogenic influence, based on observations of early maps. This is a desired outcome based on feedback throughout the Technical Oversight Group process.
<i>Constructability</i>	Alt. 3 would require the most movement of material because it would fill the Ridgefield Pits. To minimize cost then, its grading plan must be carefully considered, and a significant level of effort went into this during preliminary design. Alt. 2 would be more straightforward since it would not fill the Pits.
<i>Hydraulics</i>	LCEP has not completed this analysis to date. A primary difference between Alts. 2 & 3 is that Alt. 2 is designed with a much lower bankfull elevation relative to Alt. 2 (~2,300 cfs versus ~5300 cfs). We believe that this would provide an overall habitat benefit by allowing greater magnitude and duration of floodplain inundation. Shear stresses would also be reduced at intermediate level flows however it remains to be seen as to whether or not this would have significant implications.
<i>Sediment Conveyance</i>	Channel width to depth ratios would be similar for Alts. 2 & 3, at bankfull conditions. Channel slope is uniform through the Reach for Alt 2, while slope is higher at the upstream end of the reach and lower downstream for the Alt. 3 channels. This is due to the grading required to optimize the cut-fill balance (thereby reducing cost and material requirements associated with filling the Pits) for Alt. 3. LCEP has not completed the analysis to date on what impact the differences in channel slope and geometries would potentially have on sediment conveyance through the reach.
<i>Water Temperature</i>	Complete analysis can be found in the Water Temperature attachment. In summary, both alternatives will likely result in a larger diurnal temperature variation (higher daily maximum temperatures and lower daily minimum temperatures) through the Ridgefield Pits reach than what is currently seen for the Existing Condition. This is because the current high volume and depth of water currently in this slow-moving reach acts to moderate atmospheric heating effects. However, overall mean temperatures may be reduced for the alternatives through groundwater interaction, which currently seems to exhibit minor impact on the large volume of water in this reach. The effects from groundwater would likely be more beneficial for Alt. 3 versus Alt. 2 for two reasons: 1) the multi-thread channel provides more spatial opportunity for interaction; and 2) lower channel volumes in Alt. 3 would result in less dilution. Model results indicate that Alt. 2 does not perform better than Alt 3. with respect to atmospheric heating. In fact, Alt. 3 temperature performance was observed to be better, because the nighttime cooling effect on its respective lower channel volumes exerted a greater effect than daytime heating, which occurs over shorter period. In short, Alt. 3 was shown to have better temperature performance than Alt. 2 from both a groundwater and atmospheric heating perspective, and this was true at the lowest flow modeled (35 cfs). Finally, from a riparian perspective the narrower channels of Alt. 3 may provide improved shade benefits relative to the wider Alt. 2 channel.

4 Description of Preliminary Design

4.1 DESIGN OBJECTIVES AND CONSTRAINTS

Design objectives are included below nested under the corresponding goals. These were developed as part of the alternatives analysis process. More information, and additional documentation, is provided in the Restoration Alternatives Analysis report. These design objectives have served as design criteria to guide the development of the Preliminary Designs.

Goal 1. Restore native vegetation communities.

Objectives

- 1a. Promote conditions where channels are well-connected to the floodplain and CMZ and are able to self-initiate and self-maintain riparian vegetation through channel scrolling processes and overbank deposition of fines. Decrease the depth to the alluvial aquifer.
- 1b. Promote a patchwork mosaic of native vegetation communities with a range of age classes consisting of older coniferous forests, cottonwood galleries, willow-dominated shrub communities, and sedges and rushes.
- 1c. Encourage vegetative growth along stream channels, with persistent vegetation abutting the primary channel and side channels that provides hydraulic roughness, natural stability, shade, and habitat complexity.

Goal 2. Enhance thermal refuge and incorporate cold water areas into restoration efforts.

Objectives

- 2a. Protect, enhance, and expand access to existing known cold-water refugia including at tributary confluences (e.g. Mill and Manley), in north-side side-channels, and in Pits 8 and 9 of the Ridgefield Pits.
- 2b. Achieve a low flow channel width-to-depth ratio that is below 15 and ideally below 12.2c. Increase canopy closure from vegetation to greater than 50%.
- 2d. Increase juvenile salmonid over-summer thermal refugia by creating head gradients that result in strong hyporheic exchange flows – i.e. highly sinuous meanders that create strong gradients across gravel bars where hyporheic flow contributes to backbar alcoves; occasional valley wall contacts with alcoves fed by wall-based channels; and offset riffles around islands.

Goal 3. Increase the quality and quantity of Chinook, chum, steelhead and coho spawning and rearing habitat.

Objectives

- 3a. Achieve a moderate-to-high channel sinuosity (>1.3) to increase planform complexity.
- 3b. Achieve a pool (and riffle) frequency greater than 10 pools per mile in the main channel, co-dominant channels, and active side-channels.
- 3c. Increase large wood quantities to exceed the Fox and Bolton (2007) 75th percentile quantities of wood and key pieces that would be expected under undisturbed conditions. A range of wood size classes should be present, with abundant large pieces exceeding the NOAA 'properly functioning condition' threshold of 80 pieces/mi for wood over 24 inches diameter and 50 feet in length. Wood placements to include individual pieces and jams to provide habitat complexity and to encourage structural formation of bars, pools, and other geomorphic features. Where suitable, jams should recruit mobile wood over time. Wood placements should also occur on floodplains, especially where vegetation is sparse or young, to emulate hydraulic roughness found in natural vegetated floodplains.

- 3d. Increase occurrence of co-dominant and secondary channels (i.e. side-channels) so that 2 to 5 perennial channels (including main channel) occur at any given valley-bottom cross-section.
- 3e. Achieve a low-flow channel margin length that is at least five times the corresponding valley-bottom length.
- 3f. Achieve the presence of zero velocity areas during seasonal high flows in order to provide for flood refuge by juvenile salmonids.
- 3g. Create abundant (>8 acres/mile of stream) connected off-channel wetlands and beaver dam complexes that are accessible to fish throughout the year.

Goal 4. Restore Channel Migration Zone and Floodplain Connectivity.

Objectives

- 4a. Expand Channel Migration Zone and floodplain inundation extent by removing (or setting back) levees, riprap, fill, and other hydromodifications impeding channel adjustment or flood inundation to the extent possible given private property and infrastructure constraints.
- 4b. Achieve an active valley width (i.e. extent of intact CMZ and floodplain) that is at least 6 times the active channel width.
- 4c. Achieve overbank flows and significant floodplain inundation that occurs annually for at least 1 month of the year, on average. Five-year flood should create very large inundation.

Goal 5. Create a dynamic channel that allows for natural rates of channel adjustment and sediment transport.

Objectives

- 5a. Achieve slope and channel geometry conditions that are depositional, especially in the Ridgefield Pits segment where net deposition is needed to help build grade lost to gravel mining, but also in other segments that exhibit incision.
- 5b. Achieve bank erosion at meander bends that occurs at a natural rate. Minor erosion may occur every year (<5 feet), with larger adjustments at the 2- to 5-year event (e.g. scrolling) and more dramatic changes (e.g. chute and neck cut-off avulsions) occurring during large floods (>10-year event).
- 5c. Achieve a streambed that is composed of a mix of sediment sizes, with channel bed dominated (>70%) by coarse gravel and cobble and floodplains eventually topped with fine sand and silt. Increase substrate patchiness. Decrease fines to less than 15% in potential spawning areas.

Goal 6. Develop restoration approaches and actions that are consistent with existing land use.

Objectives

- 6a. Do not increase flood damage risk to public or private property or infrastructure unless landowner agreement is obtained.
- 6b. Decrease, or at minimum avoid increase of, potential avulsion of the EFLR into the Daybreak Pits.
- 6c. Design actions that adequately address potential risks to river recreational users.

There are several potential constraints in the project area. These include limitations to the extent of potential channel, floodplain and channel migration zone restoration that can occur at the site. The project area is assumed to be limited by a hard boundary on the river-right side due to the floodplain encroachment starting with the County maintenance yard, then along NE Storedahl Pit Road, the Daybreak Pits processing area, and the downstream-most Daybreak Pit. These constraints limit the ability to restore full channel migration and floodplain inundation to these areas and are not being considered as part of the project area at this time. Another likely constraint to full restoration is the BPA transmission lines and towers at the downstream end of the site and in the river-left floodplain. At the upstream end of the

project site, there is bluff erosion on river-left downstream of the Mill Creek confluence. This high bluff erosion is currently threatening a residence, which has already been affected by the erosion. This risk limits the ability to significantly affect channel dynamics in this area. River recreational use is another potential constraint, which could affect the size, location, and configuration of instream log structures. And lastly, the large deficit of coarse riverbed and floodplain material created by the mining of the Ridgefield Pits limits the ability to recover this area to full floodplain connectivity.

4.2 DESIGN COMPONENTS

The Preliminary Design includes three main components: 1) the Ridgefield Pits, 2) the downstream side-channel, which is located just upstream of the Pits, and 3) the upstream side-channel, which is located just upstream of the downstream side-channel and across the river from the Mill-Manley confluence area.

4.2.1 Ridgefield Pits

At the Ridgefield Pits, the design includes re-grading most of the former gravel mining ponds to create a multi-threaded channel network that is well-connected to an extensive floodplain wetland complex. The objectives/design criteria (Section 4.1) provided the guidelines from which design iterations and decisions were made. In order to accomplish objectives 3d, 3e, and 3f, a 3-channel network was developed with connected alcoves strategically located in existing pond areas. The river-right alcove is located within Pond 9, a known cold-water source from temperature monitoring. In order to accomplish the floodplain connectivity objective (4c), channels were designed to overtop at approximately 2,600 cfs, which is the 10% exceedance flow (flow that is exceeded approximately 10% of the time on average; this equates to channel bank overtopping for a little over one month per year, on average. This resulted in the 3 channels each having a top width of from 60-75 feet and total depths of approximately 6 feet.

A primary feasibility consideration is to achieve an approximate cut-fill balance on the site, in order to avoid the potentially very high cost of importing streambed and floodplain material. Because of the past mining activity that removed over 1 million cubic yards of alluvial material, this will result in a designed floodplain surface that is lower in elevation than the historical floodplain surface, and lower than the floodplain surfaces upstream and downstream of the site. In addition to achieving an on-site cut-fill balance, this configuration also helps to achieve other objectives and constraints, including well-connected floodplains to support native vegetation (1a), small channel width-to-depth ratios to benefit temperature and shading (2b, 2c), presence of off-channel habitat (3f, 3g), greater channel migration zone and floodplain connectivity (4b, 4c), and maintaining depositional conditions (5a). The lower floodplain surface also allows for creating frequent floodplain inundation within the project area while avoiding an increase in flooding to adjacent areas outside the project area that could present a risk to infrastructure or habitat (6a, 6b).

In order to develop the channel and floodplain grading plan, the existing conditions DTM was modified to create a proposed conditions DTM. The proposed conditions DTM was then used in the hydraulic model to evaluate the effects on inundation extents and hydraulic conditions. This was done via an iterative process of repeat DTM refinement and modeling to optimize proposed conditions. For this Preliminary Design stage, the grading plan was developed to a level of detail that confirmed that achieving the objectives and satisfying constraints is possible. It is anticipated that the channel and floodplain geometry will continue to be refined in subsequent design stages. Channel details including pools, riffles, asymmetrical cross-section geometry, and profile complexity have also not been incorporated at this stage, nor has microtopography throughout the floodplain wetland complex to support a range of wetland types and vegetation communities. These details will be added in subsequent design stages.

In addition to the channel and floodplain re-grading, a variety of large wood additions are planned for the channels, alcoves, and floodplain areas. The large wood habitat is designed to primarily accomplish the large wood objective (3c), but will also help support other objectives including pool frequency (3b), high flow refuge (3f), and substrate deposition (5a) and patchiness (5c). Instream wood placements include a variety of wood structure types. These include 1) bar apex log jams at flow splits to support split flow and maintain island vegetation, 2) jams in pools to support pool scour and provide cover, 3) channel-spanning jams in smaller channels or off-channel areas to support sediment deposition and initiate planform changes, 4) general complexity jams to provide juvenile hiding cover and complexity throughout, and 4) floodplain roughness structures that provide hydraulic roughness and high flow refuge habitat throughout the floodplain. Overall, a very high density of in-channel and floodplain wood placements will be necessary to provide hydraulic roughness that will be necessary to support depositional processes, erosion control, and vegetation growth, especially in the first few years immediately following construction due to exposed soils and young vegetation.

Planting of native wetland, riparian, and floodplain vegetation will occur throughout the project site following construction. This will include a patchwork mosaic of species assemblages selected based on the range of elevations, soil conditions, and inundation frequencies. Two primary planting zones have been identified for the preliminary design. These include: 1) a riparian buffer zone, which extends approximately 25 feet from either side of the channels and will primarily include planting of willow and cottonwood live stakes, and 2) a floodplain wetlands zone that includes the remainder of the site and will consist of a wide range of native species found throughout undisturbed portions of the site and listed in the design plans. These will likely be bare root seedlings. Planting plan details including proportions of each species, type of planting stock, browse control, and any irrigation or maintenance needs will be determined in later design stages.

4.2.2 Lower Side-Channel

Enhancements at the lower side-channel include large wood habitat additions and beaver dam analogs. At the upstream end of the side-channel there are multiple entry points. Apex log jams will be placed at these entrances in order to encourage scour and split flow conditions into the side channel. Various log jam types will be placed throughout the side channel. These are the same as the log jam types described above for the Ridgefield Pits site, with the exception of floodplain roughness, which is not necessary due to the already heavily vegetated floodplain. In addition, we anticipate that some riparian trees will be felled into the side-channels, mostly pushed over by machinery to retain the rootwad. This action provides high complexity habitat of whole trees and can also be used to help facilitate access routes.

At the lower end of the side-channel, beaver dam analogs will be installed. These will be post-supported structures racked with small wood and slash. These will be designed to provide immediate functions of off-channel habitat, sediment deposition, vegetation growth, and increasing groundwater tables, but are also anticipated to support additional beaver activity.

At this preliminary design stage, no excavation work is planned in the side-channels to increase hydrologic connectivity. However, this will be re-visited in later design stages and will also partly depend on the eventual channel configuration and degree of connectivity as the main channel connections and the side-channels continue to naturally adjust.

4.2.3 Upstream Side-Channel (Mill-Manley Confluence Area)

Enhancement work in the upstream side-channel will include the same work as described above for the lower side-channel, including habitat wood placements and beaver dam analogs. In addition, the push up levee adjacent to the County maintenance yard will be modified. This levee currently abuts the maintenance yard on its south side and extends westward into the floodplain. Two older, partially in-filled former gravel pits are located to the north of the western half of the levee. This western half of the levee will be removed to increase floodplain connectivity through this area. The eastern portion of the levee (and armoring) will remain where it may be serving to provide some protection to the maintenance yard. The material from the removed portion of the levee could potentially be used to further fill the two former gravel ponds to the north, configured in a way to increase the function of these wetland areas. The material could also be hauled downstream to provide coarse material to the Ridgefield Pits site. The plan for the material will be further refined and developed as part of later design stages.

4.3 SUMMARY OF ECOLOGICAL BENEFITS

This project will provide a range of aquatic habitat and river process benefits. The primary benefit will be addressing the currently severely degraded conditions in the Ridgefield Pits reach. This work will immediately improve aquatic habitat and floodplain connectivity at the site and will re-set the geomorphic trajectory to support future channel dynamics, stream temperature improvements, establishment of native vegetation, and continued deposition of streambed material to re-build the channel and floodplain elevations lost due to gravel mining. The Alternatives Analysis (Attachment F) identified the degree to which alternatives help to achieve the project goals and objectives. Although somewhat modified since the Alternatives Analysis, the Preliminary Design for the Ridgefield Pits will have essentially the same ecological benefits as Alternative 3. Of the 23 objectives identified, Alternative 3 is expected to “very much” accomplish 19 of them, “very much” to “somewhat” accomplish 3 of them, and “somewhat” accomplish one of them. The one that it only “somewhat” accomplishes is not an ecological objective but a social one – the consideration of river recreational users. This is because the multi-thread channel and high large wood loading may provide challenges for recreational boaters at some flows, a consideration that will need to be factored into the design.

The ecological benefits of the side-channel work include increased habitat complexity and floodplain connectivity. In the Alternatives Analysis, of the 23 objectives, the side-channel alternative “very much” accomplishes 10 of them, “very much” to “somewhat” accomplishes 7 of them, “somewhat” accomplishes 4 of them, and “somewhat” to “does not” accomplish 2 of them. The objectives it only somewhat accomplishes are ones that the side-channel work simply would not have a significant impact on, including sinuosity, sediment deposition, substrate type, and confinement. One of the two lower ranked objectives relates to the removal of hydromodifications; however, the levee removal work was added to this alternative after the alternatives analysis, so it does provide some benefits there. The other lower ranked objective relates to avoiding an avulsion into the Daybreak Pits, which this alternative doesn’t affect one way or the other.

4.4 CONSTRUCTION CONSIDERATIONS

Preliminary considerations have been developed for project construction methods, sequencing, and phasing. Construction methods will be further analyzed as part of later design stages, and will also be affected by the approach taken by the construction contractor. River channel conditions at the time of construction, which are likely to change between now and then, will also affect construction methods. Preliminary access and staging areas have been indicated on the design drawings; however, discussions with landowners and additional site investigation and planning will be necessary to refine those areas.

The greatest construction challenge will be the re-grading of the Ridgefield Pits reach and the construction of the multi-thread channel system, especially with respect to management of water. Management of water will be necessary to facilitate construction and to limit impacts to meet environmental permit requirements. We anticipate that the re-grading of the site will occur using a multi-part work isolation strategy, where river flow is routed to one side of the site to facilitate construction of the other side. Based on the current location of the main channel through the pits, the sequence would likely entail using cofferdams and pumping to isolate and facilitate the construction of the river-right portion of the site first, then re-routing the main channel flow into the newly constructed portion, and again using cofferdams and pumping to facilitate completion of the river-left portion. However, multiple shifting of the main channel flow may be required. We also anticipate that full dewatering will not be possible due to subsurface seepage but that pumping will nevertheless be needed to reduce water levels in active construction areas and to manage turbidity. The use of sheet pile, turbidity curtains, and long pumping distances to land-apply construction water may be necessary.

Construction of the side-channel enhancements is straightforward. Wood additions and construction of BDAs in these areas will be conducted at low flow periods when the side channels are either dry or have very little flow that can easily be managed to facilitate construction and limit environmental impacts. Management of water for the side-channel work will occur via localized cofferdams and pumping, if necessary. In order to limit impacts to the existing riparian and floodplain vegetation along the side-channels, we anticipate using “inside-out” construction where possible, which includes using the channel itself to access the areas for large wood additions. This will only occur in side-channel areas that are dry during construction and will be limited to areas where existing large wood or other habitat conditions in the side-channels would not be significantly impacted by machinery.

In-water work will need to occur during the permitted in-water construction window. This is listed as August 1 – 15 by WDFW. Because this effort will take considerably longer than 2 weeks, it will be necessary to work closely with WDFW and project designers to develop a sequencing plan that works for the permitting agencies and the project. This will likely entail a worksite isolation strategy that allows for significant portions of the project re-grading to occur in isolation from the main channel flow outside of the work window period. It is also possible that all of the work for the project will not be able to occur in one construction season, and that the project will need to be phased over multiple years.

4.5 OPINION OF PROBABLE CONSTRUCTION COST

Opinion of Probable Construction Costs - Preliminary Design				
Lower East Fork Lewis River - Ridgefield Pits Restoration Project				
28-Jun-21				
<i>Note: Costs do not include permitting, final design, fish management/rescue during construction, construction staking, or construction oversight</i>				
ITEM	UNIT	UNIT PRICE	QUANTITY	SUBTOTAL
Primary Construction Elements				
Channel and floodplain grading (includes cut and fill)	CY	\$ 6	450,000	\$2,700,000
Channel shaping and detail work	LF	\$ 15	12000	\$180,000
Remove/push in levee near County maintenance yard	CY	\$ 10	3000	\$30,000
Furnish and install logs with rootwads	EA	\$ 1,500	526	\$789,000
Furnish and install logs without rootwads	EA	\$ 1,000	479	\$479,000
Furnish and install vertical snags/pilings	EA	\$ 800	581	\$464,800
Whole trees from on-site	EA	\$ 300	85	\$25,500
Slash incorporated into jams (haul from off-site)	CY	\$ 40	1490	\$59,600
Fell riparian trees	EA	\$ 500	45	\$22,500
Furnish materials and install beaver dam analogs	EA	\$ 4,000	9	\$36,000
Subtotal				\$4,786,400
Site Prep, Access, and Environmental Controls				
Environmental controls (SWPPP, hydraulic fluids, erosion control measures, etc.)	LS (2.5%)	\$ 119,660	1	\$119,660
Temporary access and haul roads (includes temporary culvert and/or bridge crossings)	LS (3%)	\$ 143,592	1	\$143,592
Cofferdams, diversions, dewatering and water management	LS (6%)	\$ 287,184	1	\$287,184
Subtotal				\$550,436
Revegetation				
Seeding and planting - channel banks	AC	\$ 5,000	19	\$95,000
Seeding and planting - floodplain	AC	\$ 3,000	83	\$249,000
Subtotal				\$344,000
Mobilization and demobilization	LS (7%)	\$ 397,659	1	\$397,659
Construction Subtotal				\$6,078,495
Construction Subtotal with 25% Contingency				\$7,598,118

Abbreviations: CY = Cubic yard LF = Lineal foot AC = Acre EA= Each

5 Attachments

A. Topographic Survey- Technical Memorandum

continues on next page

TECHNICAL MEMORANDUM



To: Lower Columbia Estuary Partnership
From: Inter-Fluve
Date: September 25, 2018
Subject: East Fork Lewis River, Ridgefield Pits – Survey Methods and Results

Introduction

The Ridgefield Pits project area is located between River Mile 7.2 & 9.5 on the East Fork Lewis River near La Center, WA. The Lower Columbia Estuary Partnership (LCEP) is developing designs for habitat restoration along the mainstem East Fork Lewis River, including an area of former gravel ponds captured by the river during the 1996 flood and two adjoining side channels. The project will seek to improve salmonid habitat throughout the project site. Habitat quality was adversely impacted during the 1996 flood event resulting in channel erosion and instability, habitat simplification, impaired floodplain function, increased water temperatures, impaired flow, and an increase of habitat types that favor invasive predatory fish.

Inter-Fluve and LCEP staff collected bathymetric and topographic data in the spring of 2018 to be used by LCEP, and in combination with LiDAR data, to develop a topographic surface representing existing conditions throughout the project site. This surface will be used to perform hydraulic modeling and to support designs for habitat restoration actions. This technical memo summarizes the field survey data collection and data processing effort.



Figure 1. Boat-based survey data collection in the mainstem East Fork Lewis River.

Survey Methods

Topographic and bathymetric data were collected throughout the project site using boat-based and land-based data collection methods. Boat-based survey was utilized along the mainstem of the East Fork Lewis River from river mile 10.0 (Daybreak Bridge) to river mile 6.3. Land-based survey was used to capture data in areas of the channel which were inaccessible by boat; channel tops and toes, gravel bars, select floodplain areas, and select side channels where restoration treatments are likely to be located. A map of topographic and bathymetric survey points is depicted in Figure 2.

BOAT-BASED DATA COLLECTION

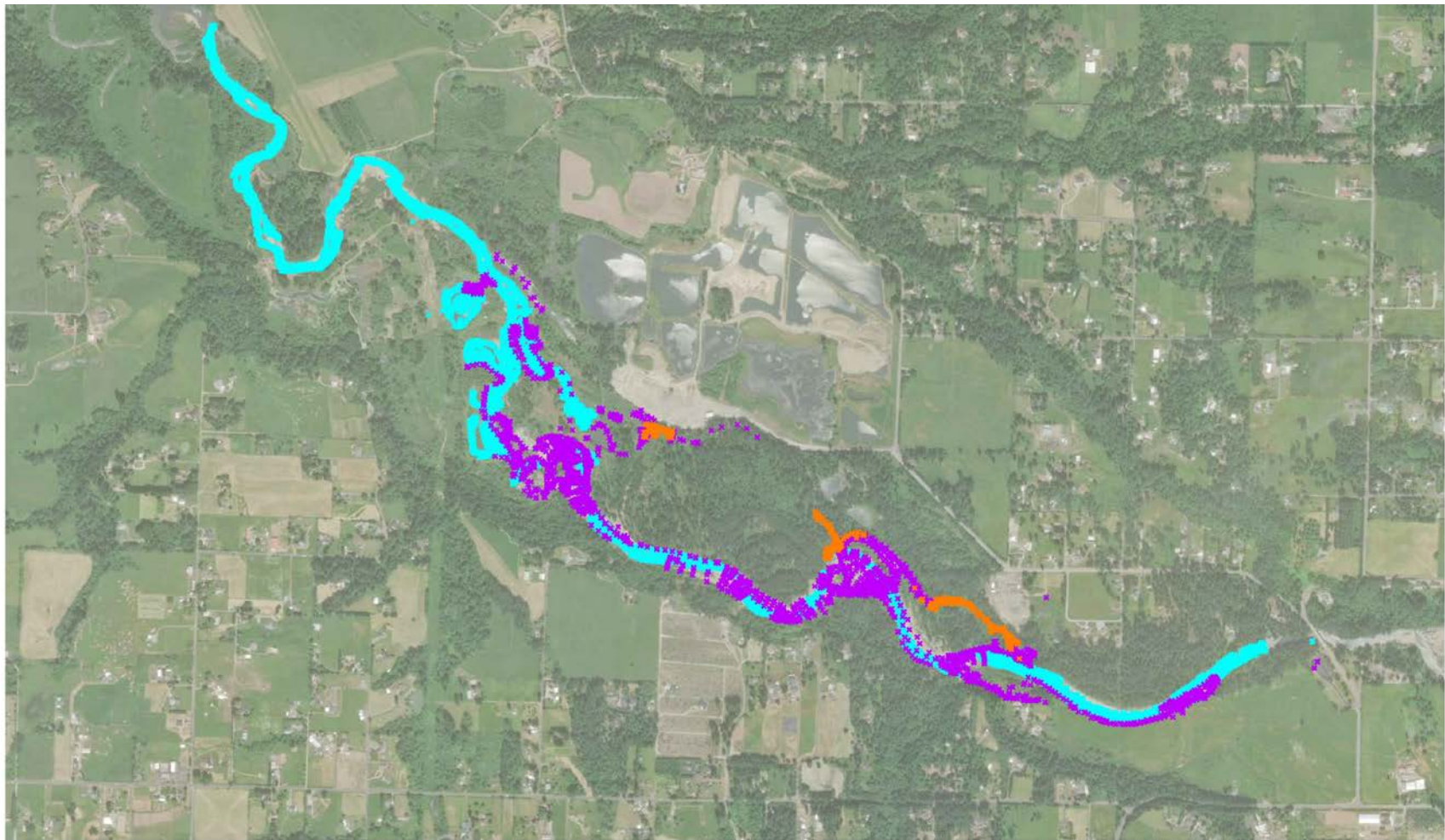
Bathymetric survey was performed by Inter-Fluve staff on April 12 & 13, 2018. Bathymetric data were collected using a single-beam echosounder (Seafloor SonarMite MILSpec) mounted on a boat with an outboard jet drive engine. The echosounder was coupled with an RTK GPS rover. An RTK GPS base station was established within the project site and static GPS data were collected throughout the day. Radio signal between the base station and GPS rover was maintained throughout the survey. Using this system, horizontal and vertical position are collected by the RTK GPS rover and paired with water depth measurements collected by the echosounder. The resulting data forms a point cloud representing the bathymetric surface of the waterbody surveyed. Water depth measurements were filtered using sonar quality information and points were only stored when established data quality targets were met for both the GPS rover and the echosounder. Surveyed depths were assumed to be collected in a direct vertical orientation and no correction was made for vessel movement (i.e. pitch and roll), which was assumed to be minor and to have a negligible effect on the data.

In addition to the bathymetric survey, a minimum of three ground control points were occupied by the RTK rover during each day of the boat-based survey.

LAND-BASED DATA COLLECTION

Topographic and bathymetric data were collected on May 21 & 22, 2018 by Inter-Fluve and LCEP staff. Data were collected using RTK GPS and total station. RTK GPS was used to define the tops and toes of the existing mainstem channel and ponds, to collect additional topographic and bathymetric data in shallow areas of the main channel where boat-based survey was impractical, and to define existing bar features. A total station was used to collect topographic data of wetted side channels on river-right (north side) where tree canopy cover precluded the use of RTK GPS, where canopy cover likely limits the accuracy of LiDAR, and where habitat enhancement is likely to occur.

An RTK GPS base station was established within the project site each day and static GPS data were collected. A minimum of two previously established control points were occupied by each surveyor, each day.



LEGEND

-  RTK GPS SURVEY POINTS
-  BATHYMETRIC SURVEY POINTS
-  TOTAL STATION SURVEY POINTS

EAST FORK LEWIS RIVER RIDGEFIELD PITS

TOPOGRAPHIC AND BATHYMETRIC SURVEY
APRIL 12&13, MAY 21 & 22, 2018

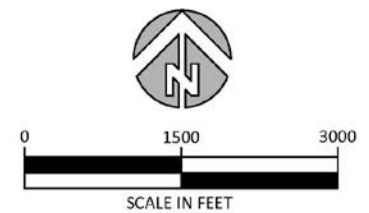


Figure 2. Map of survey data collected at the site.

SURVEY CONTROL

Control points were established during the survey (Table 1). Permanent control, including rebar with plastic caps and PK nails imbedded in paved areas, were established throughout the project site and marked with flagging. Additional temporary control points (wooden stakes) were set to aid in completion of the survey but are not expected to be recoverable in the future. The locations of survey control points are depicted in Figure 3. Photos of selected points are included in Table 2

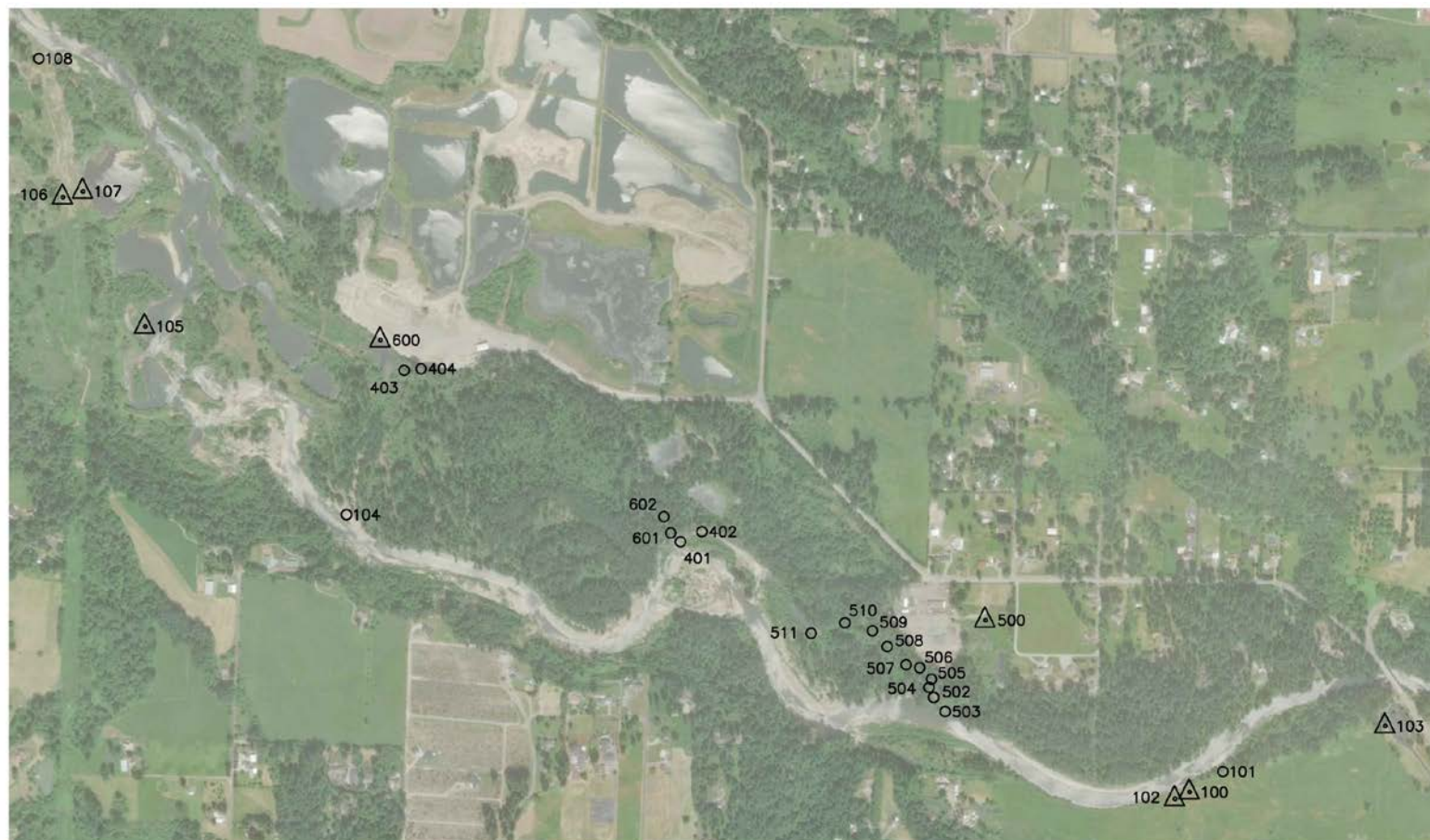
Multiple control points were occupied each day by each surveyor. GPS static data were collected each day and processed using the National Geodetic Survey Online Positioning User Service (OPUS). Ground-based survey data were corrected to the OPUS solutions for control points 500 & 600. Boat-based survey data were corrected to the OPUS solutions for control points 100 and 105. Repeat occupations of control points which were corrected to different OPUS solutions were compared and found to match closely. Coordinates of control points with multiple occupations were averaged to establish the final northing, easting and elevation values. These coordinates are provided in Table 1.

A Washington State Department of Transportation benchmark (monument ID: 4880) was surveyed on September 13, 2018 to compare to the site survey data. The elevation difference was within 0.06 ft. and the horizontal difference was within 0.01 ft.

Table 1. Survey control established by Inter-Fluve, Inc. Coordinate system is NAD83 WA State Plane South zone, US Feet, NAVD88.

Point #	Northing (ft)	Easting (ft)	Elevation (ft)	Description	Notes
100	181622.13	1105673.59	76.50	CP	Permanent – Rebar (OPUS solution)
101	181776.01	1105925.50	76.16	TBM	Temporary – Wooden stake
102	181570.38	1105564.03	77.04	Rebar	Permanent – Rebar
103	182120.67	1107148.41	77.26	Nail	Permanent – PK nail
104	183711.27	1099320.03	41.38	TBM	Temporary – Wooden stake
105	185130.21	1097802.86	31.97	Rebar	Permanent – Rebar (OPUS solution)
106	186104.11	1097183.41	36.27	Rebar	Permanent – Rebar
107	186148.61	1097335.74	33.11	Nail	Temporary – PK nail
108	187149.97	1097001.57	33.85	TBM	Temporary – Wooden stake
401	183506.32	1101837.42	50.07	CP	Temporary – Wooden stake
402	183582.88	1101998.23	50.01	CP	Temporary – Wooden stake
403	184800.12	1099755.42	35.56	CP	Temporary – Wooden stake
404	184811.48	1099881.42	36.55	CP	Temporary – Wooden stake
500	182917.67	1104135.92	63.84	Rebar	Permanent – Rebar (OPUS solution)
502	182336.38	1103744.82	58.95	CP	Temporary – Wooden stake
503	182228.90	1103832.33	60.20	CP	Temporary – Wooden stake
504	182411.10	1103710.65	58.76	CP	Temporary – Wooden stake

Point #	Northing (ft)	Easting (ft)	Elevation (ft)	Description	Notes
505	182473.26	1103727.51	56.21	CP	Temporary – Wooden stake
506	182559.34	1103640.55	56.17	CP	Temporary – Wooden stake
507	182583.00	1103536.49	55.22	CP	Temporary – Wooden stake
508	182719.70	1103394.25	52.59	CP	Temporary – Wooden stake
509	182837.66	1103283.41	54.45	CP	Temporary – Wooden stake
510	182897.62	1103076.87	54.31	CP	Temporary – Wooden stake
511	182819.47	1102822.32	52.59	CP	Temporary – Wooden stake
600	185026.98	1099576.57	43.30	Rebar	Permanent – Rebar (OPUS solution)
601	183573.11	1101763.93	48.24	CP	Temporary – Wooden stake
602	183696.45	1101712.06	48.63	CP	Temporary – Wooden stake



LEGEND

- △ PERMANENT CONTROL POINT
- TEMPORARY CONTROL POINT

EAST FORK LEWIS RIVER RIDGEFIELD PITS SURVEY CONTROL

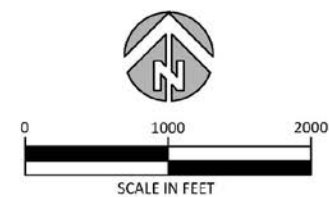


Figure 3. Survey control locations.

Table 2. Photos of selected control points.

CP 100 – Rebar with orange plastic cap



CP 101 – Wooden stake



CP 103 - PK nail in pavement



CP 106 - Rebar with orange plastic cap



CP 107 – PK nail in log



CP 500 – Rebar with orange plastic cap



Data Processing

BOAT-BASED SURVEY DATA PROCESSING

Boat-based survey data were corrected using the OPUS solution obtained for the RTK GPS base station used that day. A triangular irregular network (TIN) was created using the boat-based survey data. Contours were generated from the TIN and were used to identify survey points containing elevational outliers. These points were excluded from the dataset.

LAND-BASED SURVEY DATA PROCESSING

Survey control was established and corrected using the OPUS solution obtained for the RTK GPS base station used that day. Land-based RTK and total station data were corrected to the established control points, and the solution was verified by comparing the coordinates for multiple control points occupied during the survey.

Survey Quality Evaluations

REPEAT SURVEYS OF CONTROL POINTS

Many control points were occupied multiple times throughout the survey. Coordinates from repeat occupations were compared against established criteria for maximum vertical variability of less than 0.1 meter (0.33 ft). The elevations surveyed during repeat occupations for the majority of control points matched within 0.05 ft. Elevations for all repeat control occupations matched within the established criteria of 0.1 m (0.33 ft). These data are summarized in Figure 4.

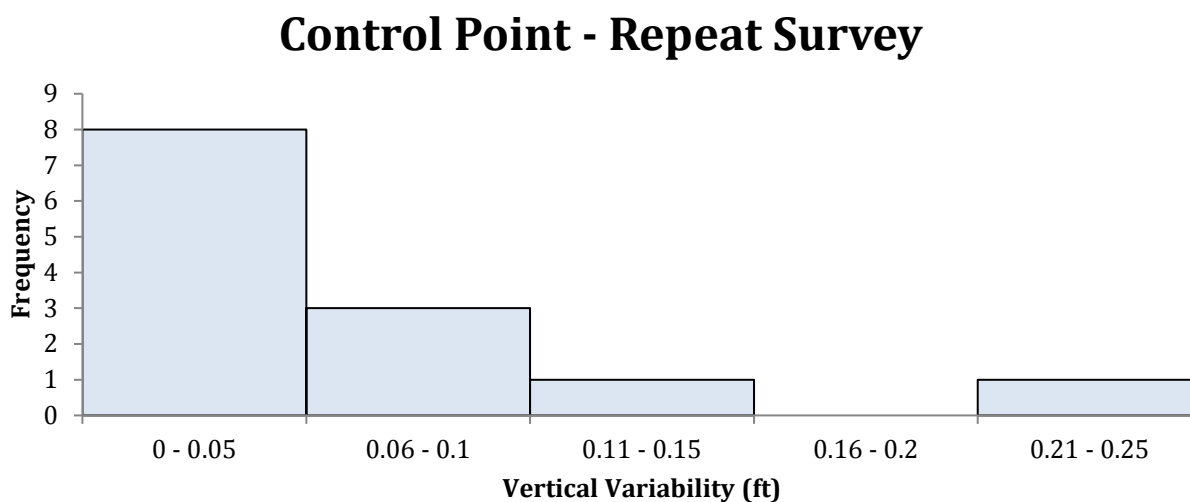


Figure 4. Vertical variability in repeat control point occupations.

ACCURACY OF SONAR READINGS

Sonar depth readings were compared to measurements of water depth by stadia rod in two locations. The locations selected exhibited little variation in bed surface and included the concrete boat ramp at Daybreak Park and a section of cobble-bedded river near river mile 8.8. These comparisons were used to verify that the accuracy of the sonar readings met the established tolerance for maximum vertical variability of less than 0.1 meter (0.33 ft). At the boat ramp, the measured depth was 0.02 ft deeper than the sonar reading. In the cobble-bottom location the measured depth was 0.05 ft deeper than the sonar reading.

Accuracy of the boat-based survey methods were also compared to the ground-based RTK survey by selecting nearby point pairs where points had been collected via each method. This occurred at several locations throughout the project area. These points were not collected with the original intent of comparison, and are located on a variety of bed surfaces including gravel and cobble – so some variation is to be expected. The elevations of the majority of the survey points compared matched within 0.2 ft. These data are summarized in Figure 5.

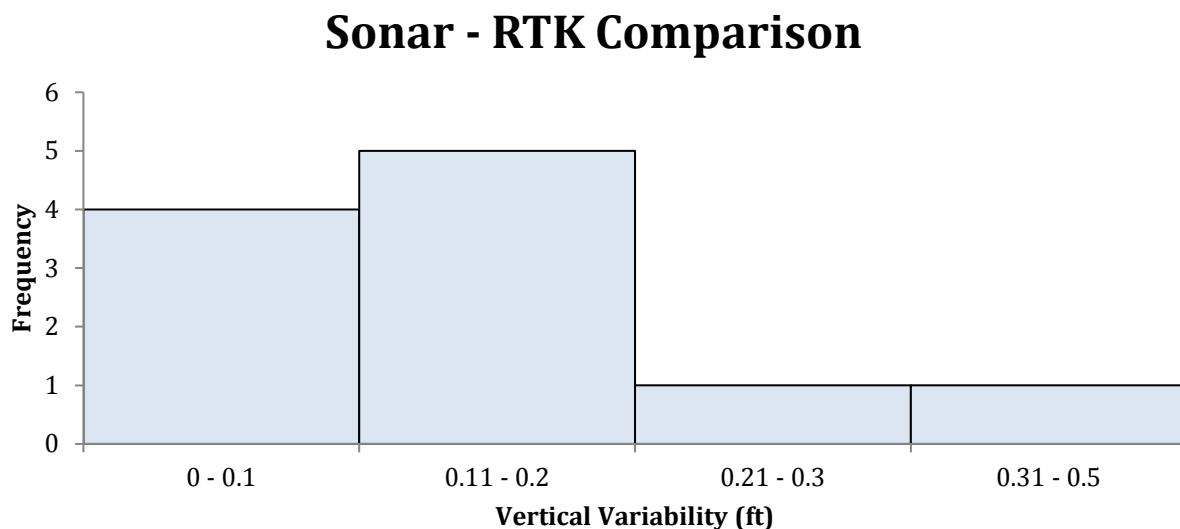


Figure 5. Vertical variability in land-based RTK survey data and boat-based sonar survey data.

COMPARISON WITH LIDAR

Light detection and ranging (LiDAR) data flown in 2010 by the US Army Corps of Engineers (USACE) was obtained for the project area. These data were compared to land-based survey data collected on site. Comparison points were chosen in areas where the LiDAR was expected to correspond closely with the survey data. These points included areas which were not inundated during the LiDAR flight and which were unlikely to have experienced erosion and/or deposition since the LiDAR flight. A total of 30 survey points were compared to the LiDAR surface. Elevations for all of the comparison points were within 1.0 ft of LiDAR surface and the majority of the points matched the elevation of the LiDAR surface within 0.4 ft. Results are summarized in Figure 6.

LiDAR - Survey Comparison

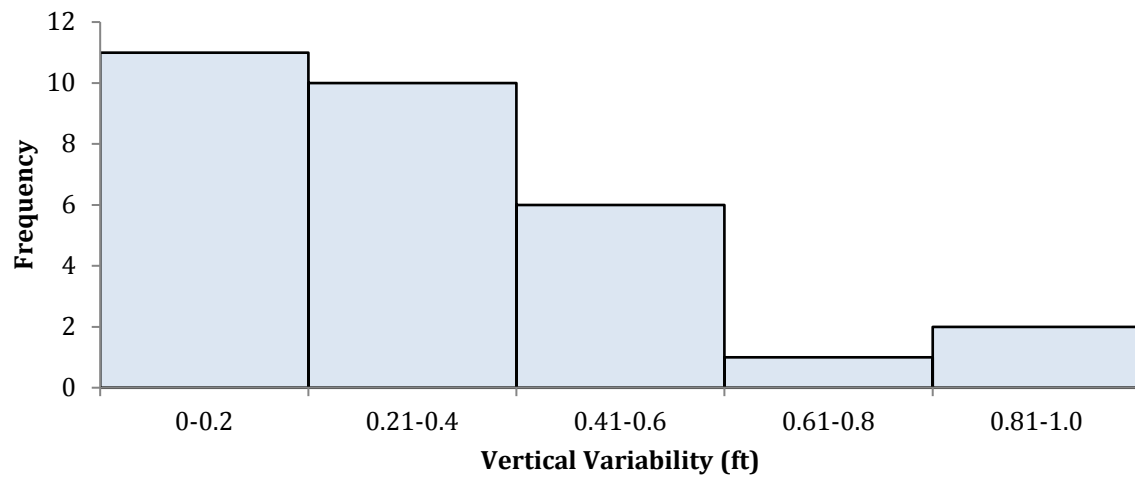


Figure 6. Vertical variability in land-based survey data and 2010 USACE LiDAR.

B. Geomorphic Conditions- Technical Memorandum

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East Fork Lewis River Ridgefield Pits Restoration

Geomorphology Report

SUBMITTED TO

Lower Columbia Estuary Partnership

January 2020

East Fork Lewis River Ridgefield Pits Restoration

Geomorphology Report



SUBMITTED TO

Lower Columbia Estuary Partnership
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January 2020

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1. Introduction

1.1 BACKGROUND AND OBJECTIVES

Inter-Fluve is assisting the Lower Columbia Estuary Partnership (EP) in assessing restoration feasibility of approximately two miles of the lower East Fork Lewis River near La Center, WA. The study area extends from approximately river mile (RM) 7.0 (just downstream of the Ridgefield Pits) to RM 10 (near Daybreak Bridge). The project, in part, seeks to address impacts associated with the avulsion of the river into the Ridgefield Pits gravel mining area in the mid-1990s and the associated impacts to habitat at the avulsion site and in the upstream channel and floodplain. It also seeks to identify and evaluate other potential aquatic habitat enhancement opportunities in the study area.

This report supports the restoration planning effort by characterizing the fluvial geomorphologic processes operating in the project area. It is based partly on previous studies and partly on new work performed as part of this effort. The primary objectives of this study can be summarized by the following:

1. Characterize fluvial geomorphologic processes and trends in the study area – this evaluation supports the identification of habitat restoration actions that are set within the appropriate geomorphic context of the study area. It also helps to understand how future river dynamics may affect or interact with restoration actions.
2. Update estimates of system recovery from the 1995-1996 Ridgefield Pits avulsion – recovery of the avulsion area is assumed to occur once the avulsed pit area fills with sediment over time, as it has been doing since the initial avulsion. Previous estimates for recovery time have been made. This effort evaluates the current status of the natural recovery process and provides an updated estimate of pit recovery time. This information is helpful for determining if restoration of the avulsed reach is warranted, and how it might be performed.
3. Provide recommendations for modeling analysis scenarios – the EP is performing the hydraulic and sediment modeling for potential restoration scenarios. Based on the findings of this geomorphology study, recommendations for modeling scenarios are provided.

1.2 PRIOR STUDIES

The following previous studies have evaluated habitat, land use impacts, and/or restoration opportunities in the study area and have been reviewed as part of this effort.

- Daybreak Mine Expansion Habitat Conservation Plan (HCP) (Storedahl & Sons 2003). Includes the main HCP document as well as the following attachments or follow-up work that are relevant to this effort:
 - Conceptual Restoration Plan for Ridgefield Pits (R2 Resource Consultants 1999) – Appendix B of HCP
 - Geomorphic Analysis of the East Fork Lewis River (WEST Consultants 2001) – Appendix C of HCP

- Daybreak Ponds Avulsion Mitigation (WEST Consultants 2001 and Ecological Land Services) – Addendum 1 to Appendix C of HCP
- CM-10 Monitoring Report-Ridgefield Pits Bathymetric Survey (Tech Memo by WEST Consultants 2013) – monitoring requirement of HCP
- Assessment and Strategic Plan for East Fork Lewis River (Dover Habitat Restoration for Friends of the East Fork 2003)
- East Fork Lewis River (RM 13 to RM 6), Including West Daybreak Park Project Reach – Fluvial Geomorphology and Erosion and Sediment Evaluation (Frank Reckendorf 2010).
- The Lower East Fork Lewis River Subbasin: A Summary of Habitat Conditions, Salmonid Distribution, and Smolt Production (WDFW 2001)
- East Fork Lewis River Basin – Habitat Assessment (SP Cramer & Associates 2005)
- Lower East Fork Lewis River Habitat Restoration Plan (Inter-Fluve and Cramer Fish Sciences, for LCFRB 2009)

2. River Segment Delineations

The study area, and adjacent upstream and downstream areas, have been split out into 5 segments for the purposes of this evaluation. The locations of the segments are displayed in the map in Figure 1.

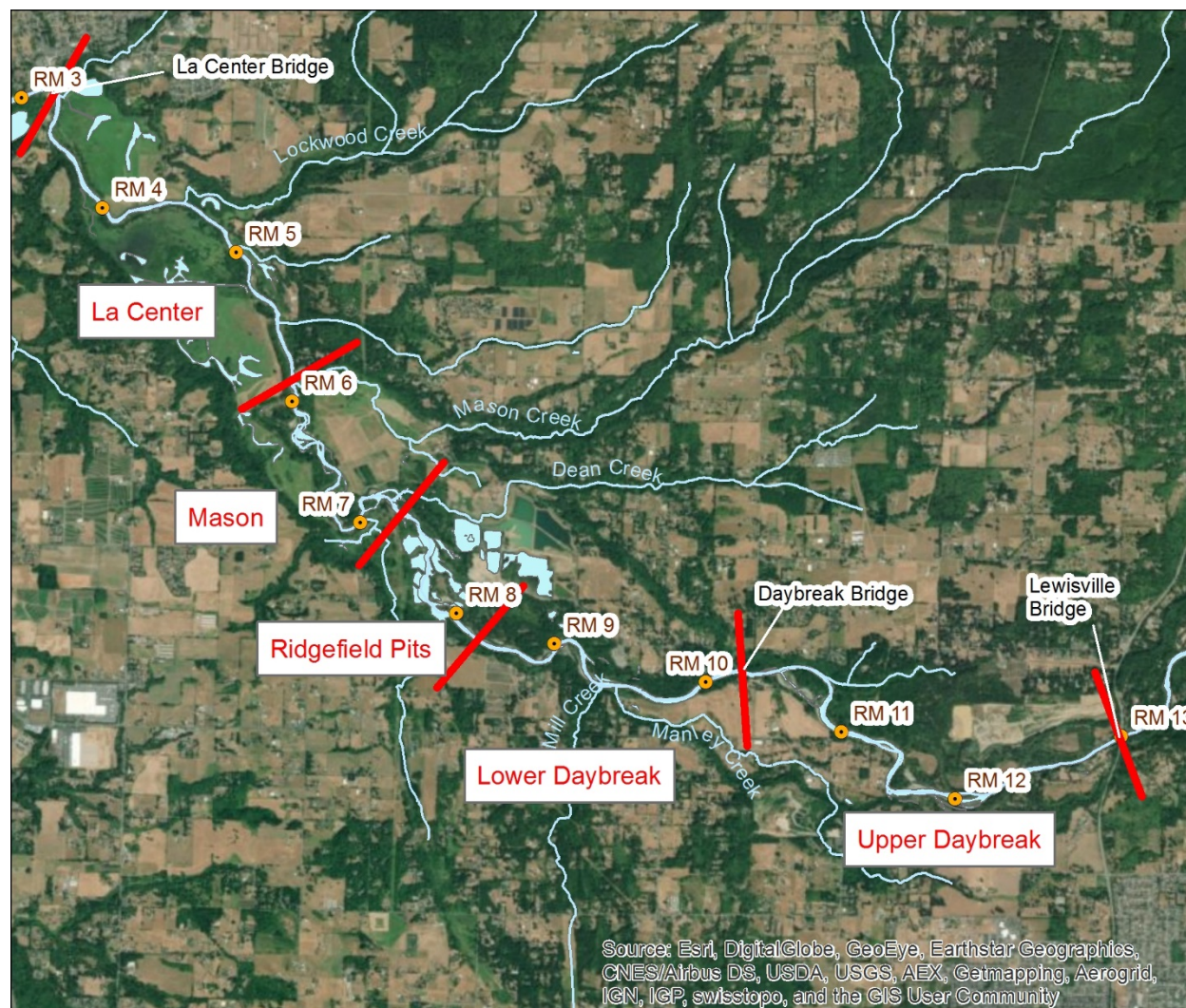


Figure 1. Location of segments used in the geomorphology assessment.

3. River Hydrology and Flood History

A brief description of basin hydrology and flood history is included here as it provides important context for understanding geomorphic changes in the system and can inform stream restoration planning. The EF Lewis has a rainfall-dominated hydrograph typical of western Cascades streams. An exceedance plot showing the median and the 10 and 90 percent exceedance flows from the past 30 years for the USGS gage at Heisson (RM 20) are included in Figure 2. The Heisson Gage is approximately 10 miles upstream of the study area, with Lower Rock Creek (RM 16.2) being the primary tributary that enters between the site and the gage, so flows at the study area would be

slightly greater, but seasonal patterns would be generally the same. Note the relatively steady median winter flow of around 1,000 cfs but the wide daily range. This demonstrates the high variation in winter flows, and therefore the unpredictability of occurrence of channel forming flows. Some years may have multiple high flows that can mobilize sediment and cause adjustments in channel form, whereas other years may see no bed mobilizing events. In contrast, summer base flows are very consistent, with an average median daily flow of 69 cfs in August.

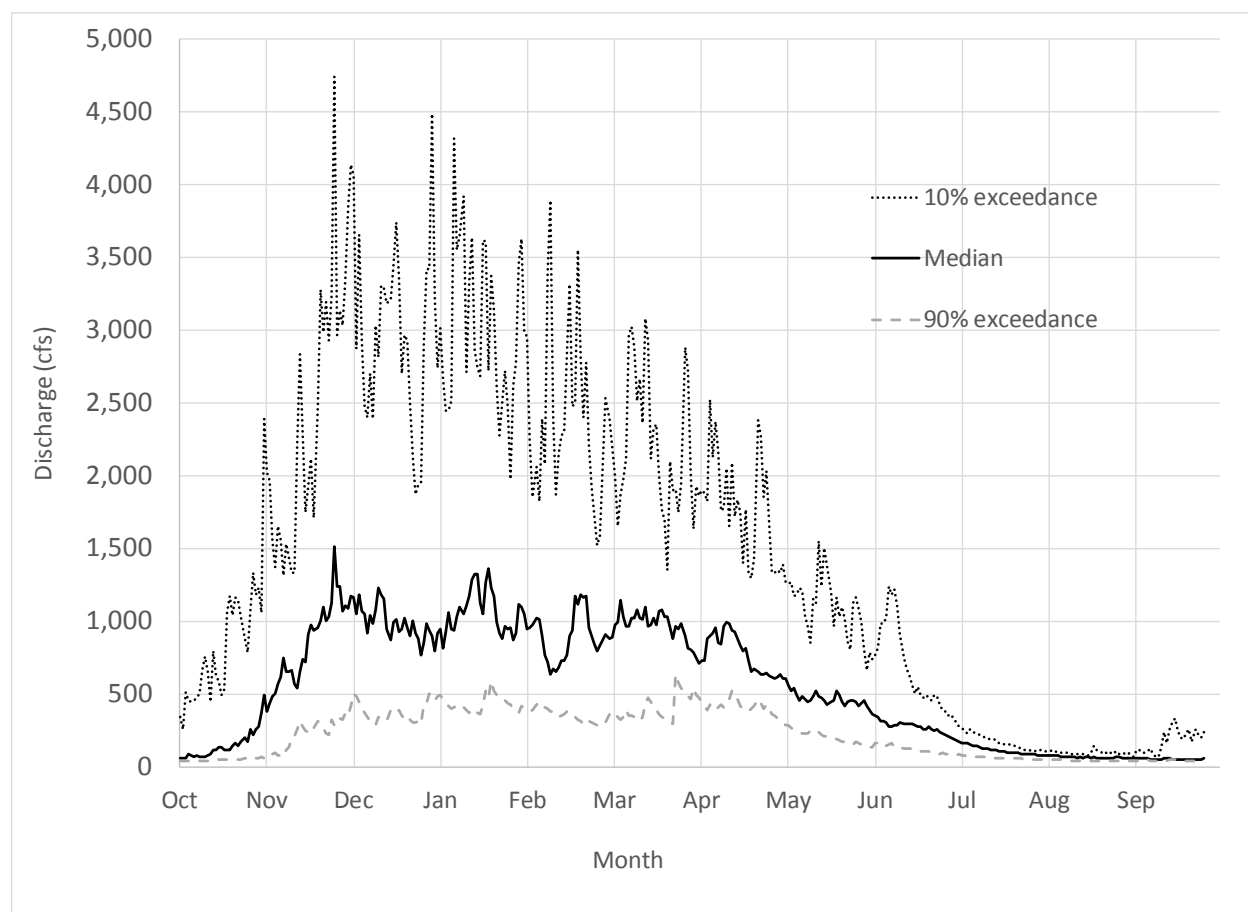


Figure 2. Daily flow exceedance chart from the Heisson Gage (USGS # 14222500) for the past 30 years (normals) – water years 1989-2018.

The flood recurrence intervals from the Heisson Gage are provided in Table 1, and a graphical display of annual peaks since the 1930s is provided in Figure 3. As can be seen, three flood events in the past 25 years have met or exceeded the 50-year event; and the February 1996 event, which is the flood of record, is near the 500-year event. From Figure 3, it also appears that since the 1970s, there has been greater variation in the size of peak flows, which is possibly related to basin land use such as increases in the road drainage network, timber harvest, and conversion of forest to other uses.

Table 1. Flood recurrence intervals from Mastin et al. (2016) for the Heisson Gage (USGS #14222500), using 82 years of record.

Flood Recurrence Interval	Discharge (cfs)
2-Year	9,160
5-Year	12,900
10-Year	15,400
25-Year	18,500
50-Year	20,800
100-Year	23,100
200-Year	25,300
500-Year	28,300

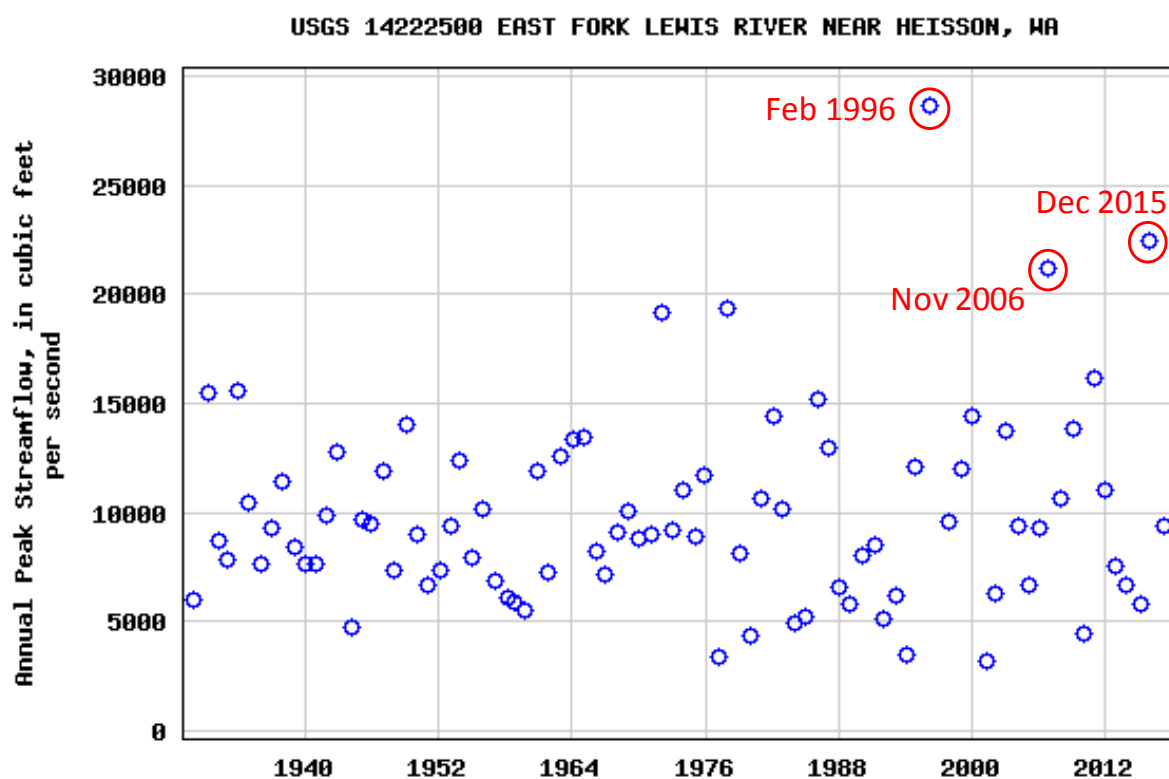


Figure 3. Annual peak flows for the period of record from the Heisson Gage (USGS #14222500). Recent and prominent flood events over the past 25 years are highlighted.

4. Analysis of Geomorphic Changes in the Study Area

4.1 TIMELINE OF LAND USE AND CHANNEL CHANGES

A chronology of land use and river changes in the study area was put together using available aerial photos and maps. The oldest maps are the Government Land Office (GLO) survey maps, obtained on-line from the US BLM general land office on-line maps database (US BLM 2019, www.glorerecords.blm.gov). These are the oldest known maps of the study area and date back to 1854. A US Army Corps of Engineers map based on surveys from 1910 was also obtained, as well as a topographic map from 1935 presumably created as part of the evaluation of the once-proposed Eddy Rock Dam site on the EF Lewis near Paradise Point. Beginning in 1939 there are regular, at least decadal, aerial photos that were obtained for the study area. Sources include Earth Explorer (<https://earthexplorer.usgs.gov>), Clark County maps online (<https://gis.clark.wa.gov/mapsonline/index.cfm>), and Google Earth. These maps and photos were georeferenced in a GIS and used to understand the land use history of the study area and to take measurements of channel form and position to assess geomorphic trends. Since the late 1990s, aerial photos are available for almost every year, providing a relatively thorough chronology of river planform changes since the 1996 Ridgefield Pit avulsion.

A timeline of land uses and channel conditions within the river corridor is provided in Table 2. A brief summary of the geomorphic history of each segment is included below:

Upper Daybreak. There were split flow conditions with large forested islands until the 1970s, then a single thread channel the last 5 years. It has recently returned to two primary split flow segments. Early instream mining (1930s) has had a large impact on channel dynamics. Artificial confinement at Daybreak Bridge has likely affected sediment transport processes. Channel migration has been halted at the Daybreak Bridge crossing, which has been in place since at least the 1930s; the bridge also constrains flood flows, contributes to channel incision, and affects floodplain inundation patterns. The river segment between Manley Creek and Lewisville Bridge has lost approximately 50% of its historical channel migration zone (CMZ, SP Cramer & Associates 2005). Very little wood was visible in old photos, and it is assumed that wood has been regularly removed from the channel in the past. New wood accumulations are present, particularly at the downstream end where the channel has newly avulsed upstream of the park; but few large key pieces exist and jams are transient. There has been some restoration work including large wood placements in off-channel areas.

Lower Daybreak. The downstream portion changed from complex multi-thread to single-thread from 1910-1940. The channel has shifted and avulsed regularly throughout the photo record, including rapid southward scrolling at Lower Daybreak bank due at least in part to vegetation removal, avulsion into the RM 9 pit, and impacts of extensive instream gravel mining in the 1950s. The CMZ has been constrained by at least 50% compared to historical conditions (SP Cramer & Associates 2005). Very little wood was visible in old photos except for at the downstream end in 1939. It is assumed that wood was regularly removed from the channel in subsequent years. New wood accumulations are present, particularly at the deposition zone near RM 9.1; but few large key

pieces exist and jams are transient. Some restoration work has been conducted, including bank work that was altered by flows river-left RM 8.8 and removal of a spur dike river-right near RM 9.5.

Ridgefield Pits. There was gradual conversion from multi-thread to single thread in the Pits reach and just upstream and downstream from 1910 to 1950. The 1939 photos show flood overflow channels leaving the channel and entering the floodplain, with some appearing to not return at all, or appearing to flow into Dean or Mason Creeks. Throughout the photo record, there can be seen a gradual increase in clearing for agriculture and mining. Since the 1950s, there has been extensive instream and floodplain gravel mining with large impacts to channel and habitat complexity. The 1996 gravel pit avulsion severely impacted the reach, abandoning 4,300 feet of former pool-riffle channel in exchange for slow deep pools through the pits. For the foreseeable future, the channel is likely to be contained within the pits, significantly constraining the CMZ. The 1939 photos show relatively abundant large wood jams on bars, in side-channels, and in the floodplain. It is assumed that wood was regularly removed from the channel in subsequent years. New wood accumulations are present on the delta forming in the pits; but few large key pieces exist and jams are transient. There has been some restoration work, including large wood jams at the downstream end of the pits and invasive species control.

Mason. There was early (1930-1950) simplification and reduction in channel sinuosity, possibly related to mining and downstream channel dredging for steamship traffic (discussed in SP Cramer 2005), then increased scrolling and sinuosity from the 1950s to 1980s, and then armoring to stop scrolling in multiple locations. Approximately 64% of the historical CMZ has been lost (SP Cramer & Associates 2005). Only a few jams were visible in the 1939 photos, and it is assumed that wood has been regularly removed from the channel in the past. New wood accumulations are present, particularly at the upstream end along the bank near RM 7-7.1; but few large key pieces exist and jams are transient. There has been some recent restoration work including backwater channels, chum spawning channels, and instream large wood placements.

La Center. Floodplain clearing, levee construction, and armoring have been the primary impacts. Channel planform has remained relatively unchanged but channel incision and floodplain disconnection has occurred, which is likely related to early dredging and stream cleanouts to facilitate steamship traffic (late 1800s/early 1900s; SP Cramer & Associates 2005). Floodplain and off-channel connections have been improved with restoration projects over the last 10 years. Very little wood is visible in the photo record, although sunken wood is known to be present in small quantities throughout the reach currently. Recent restoration work includes levee removal, levee breaching, and enhancement of off-channel and lower tributary habitats.

Table 2. Timeline of land use and channel changes.

Source	Year	Description of key conditions by Segment				
		La Center	Mason	Ridgefield Pits	Lower Daybreak	Upper Daybreak
GLO Maps	1854-1858	Single-thread channel with floodplain wetlands. For the valley bottom, map notes “Low rich bottom subject to inundation”	Upstream portion shows a complex multi-thread channel network. For the valley bottom, map notes “Low rich bottom subject to inundation”	Complex multi-thread channel network. For the valley bottom, map notes “Low rich bottom subject to inundation”	Downstream portion shows a complex multi-thread channel network. For the valley bottom, map notes “Low rich bottom subject to inundation”	Mostly single thread with one long side channel.
USACE topo Map	1910	Mostly single-thread. Appears to be a bridge at La Center	For Ridgefield Pits segment and a portion of Mason and Lower Daybreak, shows a complex multi-thread channel network. No bridge at Daybreak.			Shows a crossing (not necessarily a bridge) at Lewisville
USACE topo Map	1935	Single thread with extensive floodplain wetlands	Extensive floodplain wetlands near mouth of Mason Creek	Mostly single-thread with some small side channels and backwater areas	Mostly single-thread, with some backwaters. A bridge crossing shown at Daybreak.	Multiple split flow sections and one long smaller side channel. A bridge crossing shown at Lewisville
Air photo	1939	Single thread with extensive scrub-shrub wetlands and abandoned oxbows throughout the floodplain. Instream gravel bars visible. Very little wood visible.	Mostly single thread channel with some remaining split flow at upstream end. Beginning of extensive agricultural development in floodplains. Floodplain overflow channel network in far river-right floodplain. Only small gravel bars. A few large wood jams visible.	Two or three prominent side channels and evidence of old channel scars. Significant agricultural production and possible grading activity in former channel locations. Extensive gravel bars and scour features. Abundant large wood jams as margin jams, apex jams, and rafted jams on floodplain surfaces.	Mostly single thread with evidence of side channels and abandoned oxbows in downstream portion. Downstream portion mostly still forested. Lower Daybreak site is cleared of floodplain and riparian vegetation. Original Daybreak Bridge is in place. Extensive gravel bars and scour features. Several large wood jams visible.	Two major split flow areas around forested islands (RM 10.5-12). Extensive instream gravel mining (gravel bar scalping) in lower portion near current Daybreak Park and just upstream. River-left floodplain at downstream end in agricultural fields. Beginning agricultural development upstream river-right. Extensive gravel bars and scour features, especially at downstream end. Bridge crossing at Lewisville. Only a few large wood jams visible.
Air photo	1951	Single thread. Clearing of floodplain vegetation both sides. Perpendicular levee in river-left floodplain at RM 5.1 is in place. There is a narrow bridge crossing at RM 5.1. La Center Levee is in place. Very little wood visible.	Multiple avulsions have reduced sinuosity. Mostly single thread, except for some split flow at upstream end. Extensive gravel bars. Near total clearing of floodplain on river-left and additional clearing on river-right. Very little wood visible.	Only one remaining split flow area, from RM 7.5-7.2. Some re-growth of previously cleared riparian/floodplain forests. Extensive scoured bars. A couple of large wood jams visible. Old channel scars continue to disappear. Very little wood visible.	Mostly single-thread with short split flow segments. Instream gravel mining near RM 9.4 from north side. Upstream left-bank (Lower Daybreak area) cleared. Very little wood visible.	Extensive instream gravel mining with many mining scars around RM 11. Previous flow splits still present RM 10.5-12. Less extensive gravel bars compared to 1939. Very little wood visible.
Air photo	1955	La Center Wetlands outlet channel has been ditched. Ford crossing river-left floodplain outlet channel near RM 4. No other significant changes since 1951. Very little wood visible.	Mostly single thread, except for some split flow at upstream end. Continued disconnection of former channel scars. Meander scrolling into cleared riparian/floodplain both sides RM 6.6-6.8. Extensive gravel bars. Very little wood visible.	Large open-water area RM 7.6-8, assumed to be from instream gravel mining. Split flow downstream. Appears heavily manipulated (grading). Very little wood visible.	Recent channel changes initiating split flow conditions. Intensive gravel mining river-right RM 9.4. Very little wood visible.	Mining activity may have ceased, vegetation is colonizing previous mining scars. Secondary channels beginning to cut off. Expansion of agricultural clearing. Very little wood visible.
Air photo	1960	Bridge gone at RM 5.1. No other significant changes since 1955. Very little wood visible.	Single thread except for upstream end. Continued meander scrolling into cleared riparian/floodplain both	Open-water area still present. Split flow upstream, single-thread downstream (old split flow cut off). Additional floodplain clearing river-	RM 9.4 mining scars still visible but might have ceased instream mining. Mostly single-thread. Long small	No evidence of mining. Gravel mining area near RM 11 becoming more single thread and vegetated.

Source	Year	Description of key conditions by Segment				
		La Center	Mason	Ridgefield Pits	Lower Daybreak	Upper Daybreak
			sides RM 6.6-6.8. Extensive gravel bars. Very little wood visible.	left has occurred. Very little wood visible.	side-channel RM 8.7-8.2. Very little wood visible.	Secondary channels continuing to cut off. Very little wood visible.
Air photo	1970	No significant changes since 1960.	Continued meander scrolling into cleared riparian/floodplain both sides RM 6.6-6.8, as well as at other bends. Increased overall sinuosity. Small split flow RM 6.8. Extensive gravel bars. Some re-growth of floodplain forest river-left but more clearing in river-right floodplain. Very little wood visible.	Mostly single-thread except for split flow within active channel at upstream end near RM 8.1. Signs of active floodplain gravel mining river-left at upstream end. Open-water area from previous photos is gone. Former downstream side-channel is fully cut off. Very little wood visible.	Channel avulsed into RM 8.7 side-channel. Floodplain gravel pits at RM 9 and near County yard river-right near RM 9.3. Beginning erosion of Lower Daybreak bank. New bridge at Daybreak. Very little wood visible.	Continued cut off of side-channels. No mining. Beginning of Daybreak Park. New bridge at Lewisville. Very little wood visible.
Air photo	1975	No significant changes since 1970.	Continued meander scrolling, some development of short split flow sections, increasing sinuosity. Very little wood visible.	Beginning of more mining activities river-left. Possibly some new instream mining near RM 7.7. Establishment of new roads along in floodplain. Very little wood visible.	Single-thread, except for significant scaring (from instream gravel mining?) near RM 9.4. More erosion at Lower Daybreak bank. Very little wood visible.	Continued cut off of side-channels. Mostly single-thread. No mining. Very little wood visible.
Air photo	1990	Culvert crossing in place on river-left floodplain outlet channel near RM 4. No other significant changes since 1975. Very little wood visible.	Some short sections of split flow remaining. Airstrip in place river-right floodplain. More clearing downstream end of river-right floodplain towards Mason Cr. Meander scrolling has been halted at multiple locations via riprap, including river-left RM 6.9 & 6.7 and river-right along the airstrip. Very little wood visible.	Ridgefield Pits fully present and maybe still actively being mined. River entering upstream end of Pit 7 (at least at high flows). Mainstem is fully single-thread. Very little wood visible.	Single-thread. Erosion and meander development at Lower Daybreak. No active mining at floodplain pits, which are isolated from river. Recovered river channel near RM 9.4. Significant rural residential development in riparian and floodplain areas. Very little wood visible.	Single-thread except for small split flow near RM 12. New rural residential development in riparian areas and throughout floodplain. New bank armoring work river-left RM 11.6. Very little wood visible.
Air photo	2005	Fish ladder in place at La Center Wetlands outlet channel. No other significant changes since 1990. Very little wood visible.	Some channel changes at up- and downstream ends but a general reduction in sinuosity and simplification. Less extensive gravel bars. Very little wood visible.	Mainstem avulsed through Ridgefield Pits. Delta growth at head of pits. Former channel becoming revegetated. Some pits remain isolated from mainstem. Very little wood visible.	Single-thread. Avulsion has occurred through RM 9 pit (1995). Significant meander scrolling to north at RM 9.1. Continued erosion and scrolling south at Lower Daybreak. Very little wood visible.	Mostly single-thread with new side channel forming at RM 10.5 in former main channel alignment. Additional clearing for residential development. Further bank armoring work river-left RM 11.6. Very little wood visible.
Air photo	2018	Restoration work in place including re-meandering of La Center Wetlands outlet ditch, removal of fish ladder at outlet, breaching La Center Levee, new bridge at culvert crossing of outlet channel near RM 4, and removing cross-levee at RM 5.1.	Greatest change is scrolling to the north at RM 7.2. Otherwise minor changes. Less extensive gravel bars. A few large wood jams visible.	Continued delta growth and channel changes at upstream end of pits. Filling and vegetation re-growth in other areas of pit margins. Abundant large wood jams and pieces deposited on new delta.	Mostly single-thread except for new split flow near RM 9.1 due to partial avulsion (chute cut-off) across bar in 2009. Continued erosion and scrolling south at Lower Daybreak. Several wood and jams, particularly abundant wood at RM 9.1 avulsion area.	Re-development of split flow conditions RM 10.5-12. Extensive gravel bar scour. Several large wood jams, especially at newly avulsed channel just upstream of Daybreak Park.

4.2 GRAVEL PIT AVULSIONS

Gravel pit avulsions can have a strong influence on river processes and habitat. In the case of the EF Lewis River avulsions, the past pit captures, particularly the Ridgefield Pit avulsion, have major implications to floodplain connectivity, degree of side-channel activation, sediment transport, and sediment storage. These changes, and the past and potential future trends in profile adjustment, can have an important influence on restoration planning, particularly when restoration objectives include side-channel activation, floodplain reconnection, and construction of features that may be affected by changes to the sediment transport regime. For these reasons, the pit captures on the lower river are described here and are further evaluated as an integral part of the geomorphology analysis.

4.2.1 Overview of Effects of Gravel Pit Captures

Gravel pit captures have occurred throughout modern history and their effects to river functions and aquatic habitat have been well-documented in the literature (e.g. Kondolf et al. 2002, Norman et al. 1998, Reclamation 2005). A gravel pit capture is when a river's path enters a floodplain gravel pit or series of pits. Pit captures occur either through lateral migration of the river into the pits or from overflowing floodwaters that results in a shift of the river into the pits. This later mechanism is frequently termed a gravel pit avulsion and is what occurred at the Ridgefield Pits in the fall of 1996, transforming the former floodplain pits into instream pits.

Pit captures also initiate upstream and downstream channel incision (lowering) (Kondolf et al. 2002). Upstream incision is caused by the upstream propagation of a knickpoint, sometimes referred to as headcutting. A knickpoint is a point along the longitudinal profile of the stream where the slope increases abruptly (Brush and Wolman 1960). Where the river enters the deep pits, a knickpoint is created. The knickpoint then propagates upstream over time, lowering the elevation of the bed as it goes. This process, and its occurrence in the EF Lewis, is described further in Section 4.3.2. Downstream incision is caused by a disruption in the bedload transport regime of the river. The slow deep pools become a sink for coarse bedload because they no longer have the available energy to transport the material. The downstream reach then becomes starved of bedload, resulting in "hungry water" downstream that results in erosion of the channel bed and banks (Kondolf 1997) (see diagram in Figure 4).

Figure reproduced from Norman et al. 1998

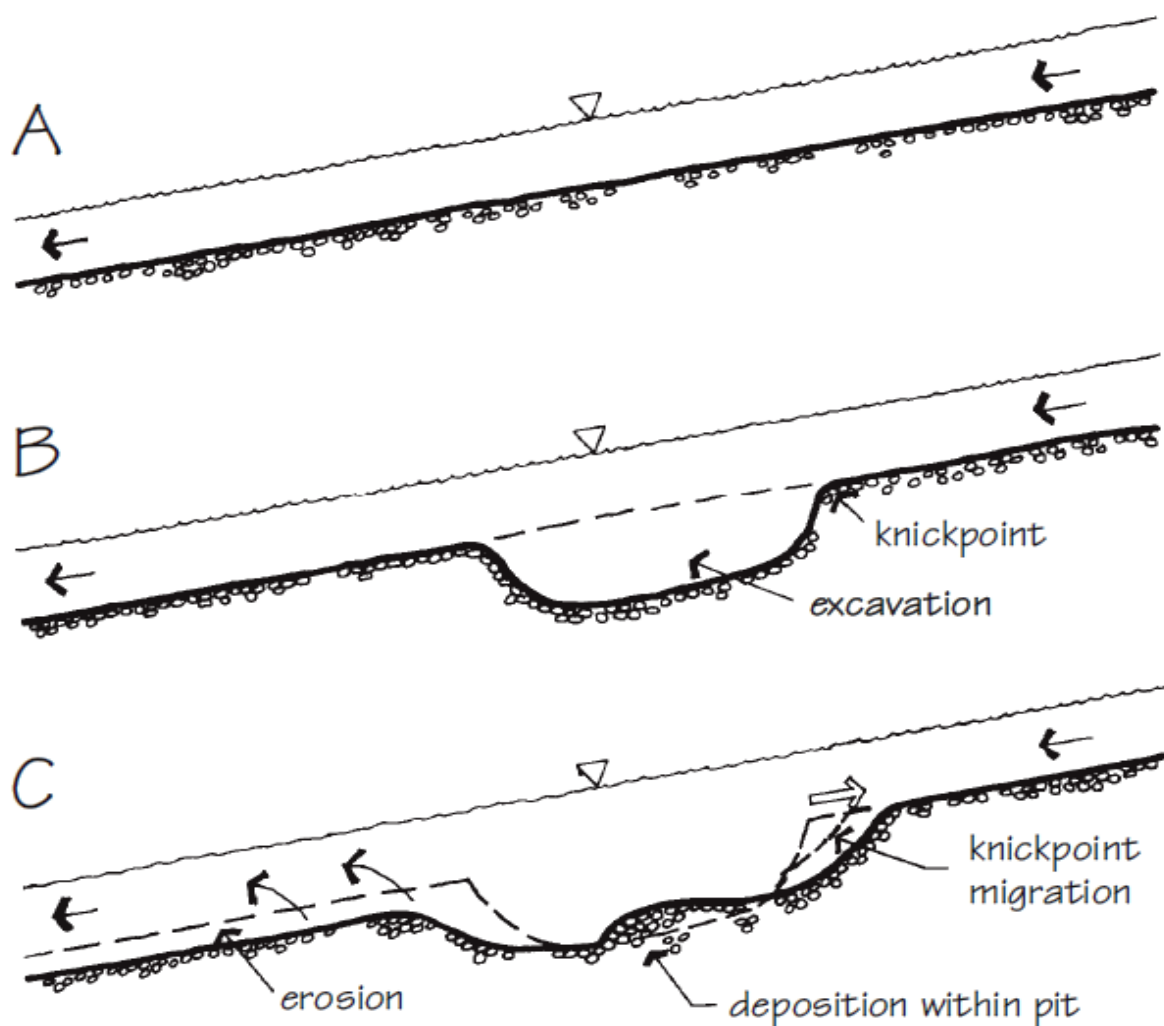


Figure 4. A. Hypothetical pre-pit capture longitudinal profile. B. Longitudinal profile showing the river flowing through a gravel pit (noted "excavation"). The location of the knickpoint is identified. C. Following avulsion, the knickpoint moves upstream and the eroded material deposits in the pit. The lack of bedload transport to the downstream reach causes erosion of the channel downstream due to the disruption in the sediment balance (Figure reproduced from Norman et al. 1998, which had been modified from Kondolf, 1993.)

Pit captures affect river processes and habitat. The transformation of the river from a formerly lotic (flowing) environment into a lentic (pond-like) environment can have negative impacts to channel migration, substrate/spawning conditions, vegetation, water quality, aquatic habitat complexity, and presence of invasive species (Kondolf et al. 1997, Kondolf et al. 2002, Norman et al. 1998, Clark 2003). The upstream and downstream incision can also cause channel instability, which can affect habitat and put infrastructure at risk (Kondolf et al. 1997).

4.2.2 Description of 1990s Pit Avulsions

During flooding in the 1990s, the EF Lewis avulsed into two separate floodplain gravel pits, the Mile 9 Pit and the Ridgefield Pits. These events had a strong effect on channel and floodplain processes

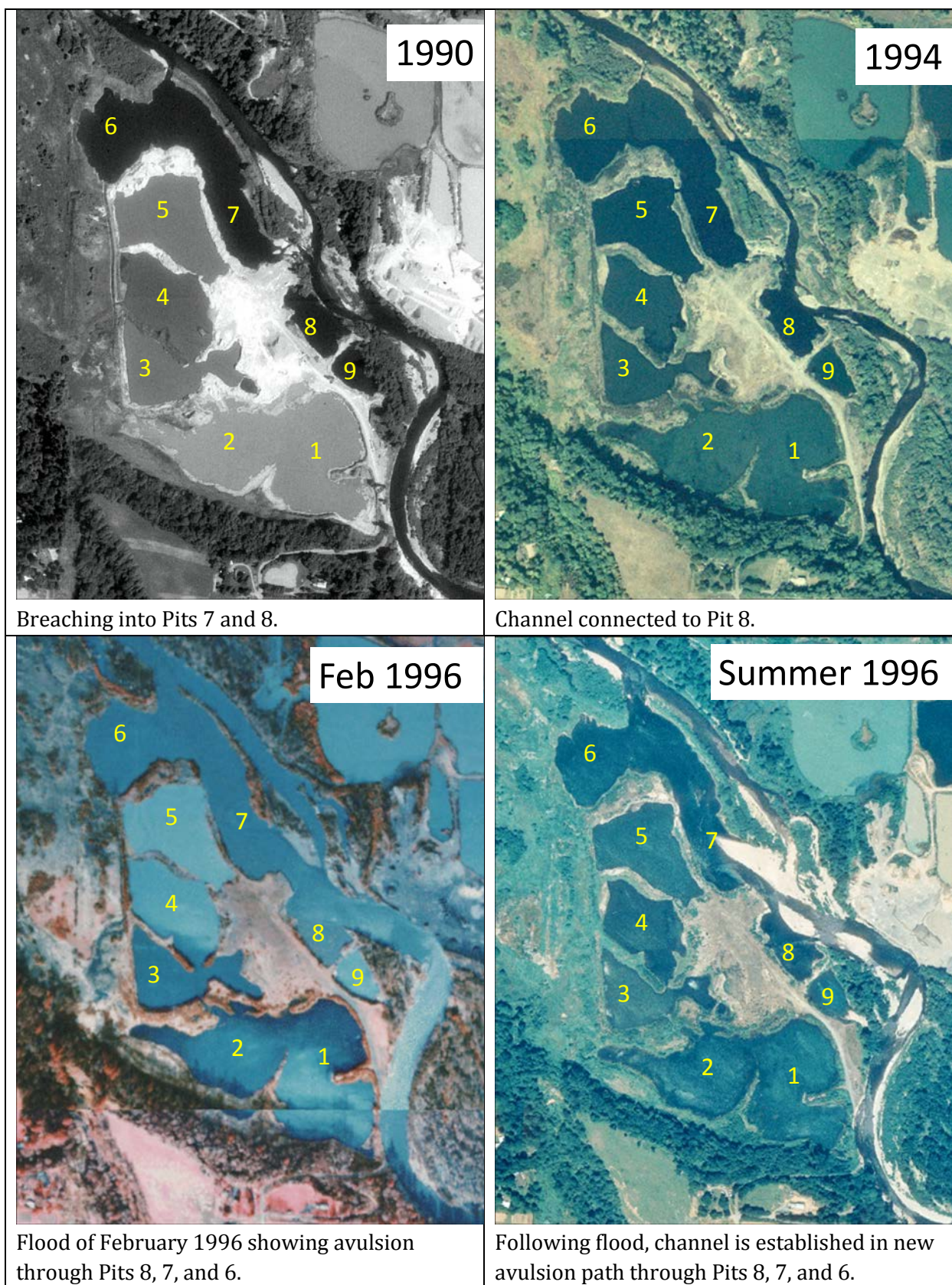
and are important context for restoration planning. The following discussion describes these avulsion events.

In November of 1995, the river avulsed through a floodplain gravel pit near RM 9. This is just upstream of the Ridgefield Pits. The location of the former pit is shown in the aerial photos in Figure 5.



Figure 5. Location of the Mile 9 Pit avulsion, which occurred in November 1995.

The Ridgefield Pits avulsion occurred over a longer period of time, with initial pit breaching occurring at least by 1990 and full avulsion through multiple pits in 1996. A sequence of the Ridgefield Pits breaching and avulsion is shown in Figure 6. Following full avulsion of the pits, 4,300 feet of former channel, which once contained high quality salmonid spawning and rearing habitat, was abandoned, and the channel then flowed through a series of slow-moving pools up to 30 feet deep.



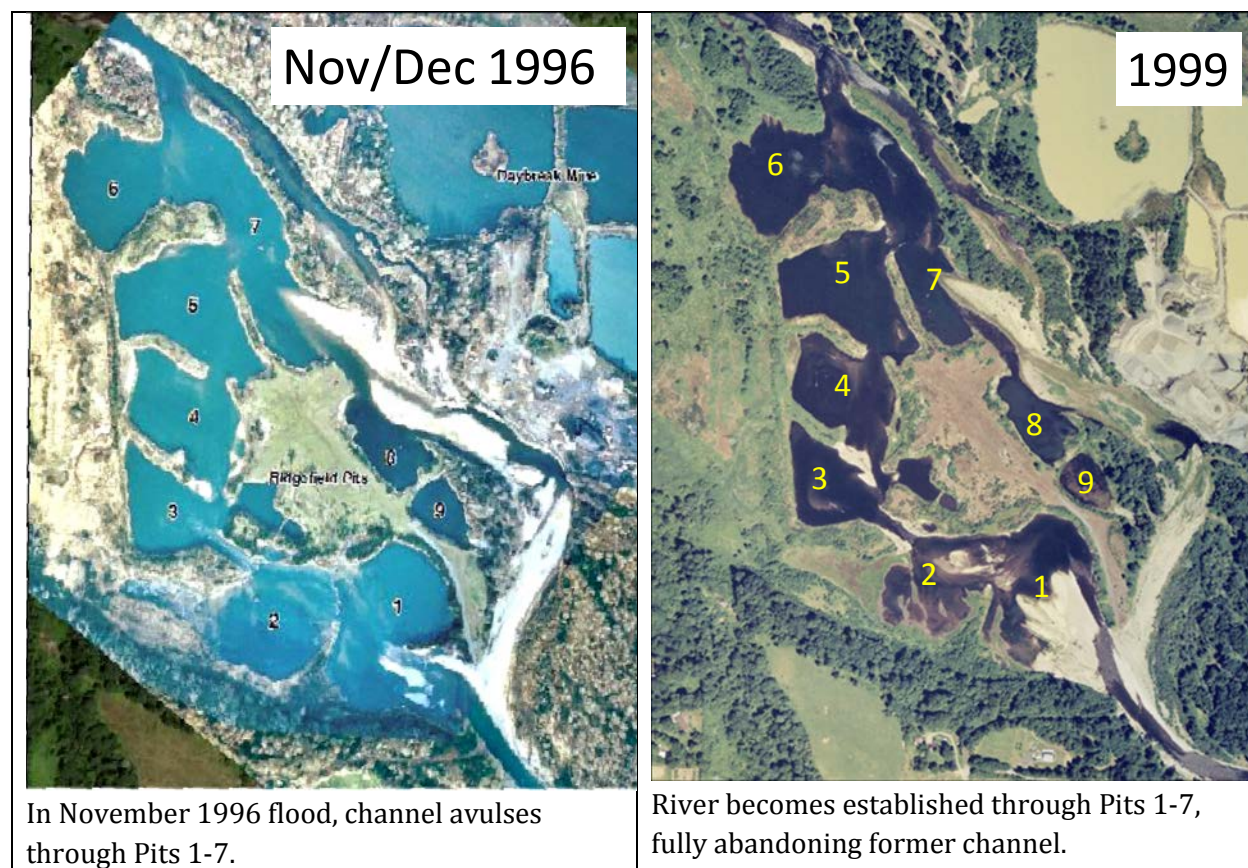


Figure 6. Breaching and avulsion sequence at the Ridgefield Pits.

4.2.3 Initial Observed Channel Response to Ridgefield Pit Avulsion

Aside from the abandonment of the former channel and conversion of the reach to a series of deep-water pits, there is little information from prior studies on the initial response of the upstream or downstream channel as a result of the pit avulsions. To our knowledge, there are only two measurements that were taken following the Ridgefield Pits avulsion that attempted to quantify the amount of change in channel elevation caused by the avulsion. One of these was 5 ft of channel bed degradation (i.e. lowering) that was measured immediately upstream of the pit entrance one month following the full Ridgefield Pit avulsion (WEST 1996 as cited in WEST 2001). It was also observed at this time that there was a slight increase in slope upstream of the pits (WEST 2001). This may have been the knickpoint moving upstream. The other measurement was 10 ft of channel bed lowering that was observed in approximately the same location (at upstream end of the abandoned channel) in 1998, approximately two years following the avulsion (Norman et al. 1998. See Figure 7). These are expected responses of the channel profile following gravel pit capture that have been noted in numerous other circumstances (Norman et al. 1998, Kondolf et al. 2002), and suggest that there were significant changes to the channel profile in response to the avulsion. Given the low overall slope of the channel (<0.3%), it would be expected that those changes likely propagated a considerable distance upstream. The following sections describe evaluations that were conducted in order to better understand changes to the channel profile and to understand current trends.

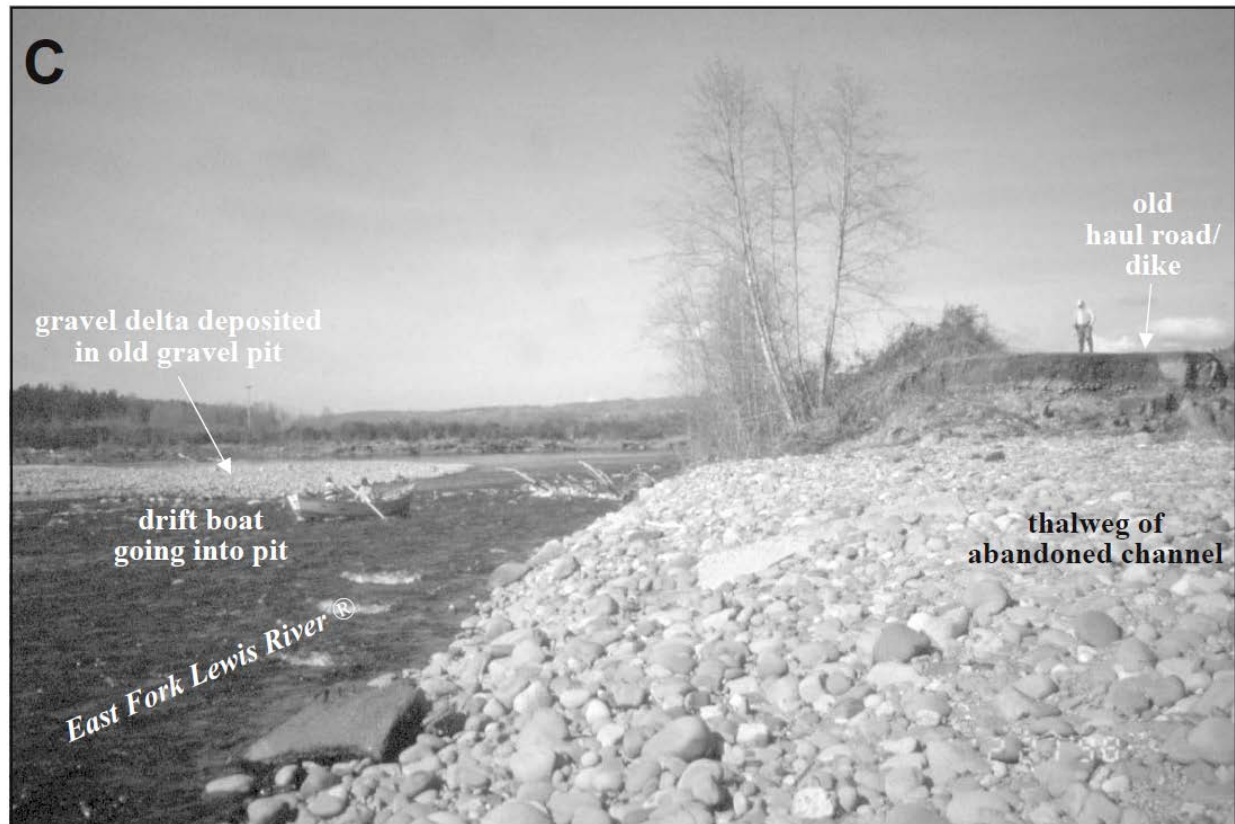


Figure 7. Re-print of Figure 20-C from Norman et al. 1998. This 1998 photo shows the elevation difference between the abandoned channel and the new avulsion channel just upstream of the entrance to Pit 1. This distance was estimated by the authors (Norman et al. 1998) as approximately 10 vertical feet.

4.3 LONGITUDINAL PROFILE ANALYSIS

4.3.1 Available Profile Data

In order to document changes in channel profile in the study area, we compared past and current (2018) channel profile surveys. There was relatively little historical profile information available for this analysis, particularly data that spanned a sufficient length of channel to make adequate comparisons. We ended up relying mainly on the two datasets presented in WEST (2001), which included data from a 1977 FEMA study (FEMA 1991 as cited in WEST 2001) and a survey performed in December 1996 shortly after the full Ridgefield Pits avulsion (WEST 2001). These historical data were compared with the 2018 topographic and bathymetry survey performed by Inter-Fluve as part of the current effort. This comparison allows for an evaluation of how conditions have evolved in the years following the avulsion.

The original survey data from the two older surveys were not available for analysis. Station and elevation data were therefore taken from Figure 6-5 in West (2001) using AutoCAD to scale the axes. West (2001) had normalized profile length in their comparison, adjusting 1977 data to the 1996 profile. These data were then matched to the 2018 profile data using common points such as the pit entrance and Daybreak Bridge. All elevation data were adjusted to the NAVD88 vertical datum. The 1977, 1996, and 2018 channel paths were very different. These changes in channel

length and thalweg location between survey periods poses practical challenges in matching the profiles from different time periods. For this reason, specific changes at any given point may not be accurate, and so we rely primarily on broader interpretations of the profile data.

4.3.2 Evaluation of Profile Changes

The profiles are depicted in Figure 8. Daybreak Bridge is just upstream of RM 10. There is a large wood accumulation zone at RM 9 (discussed later in Section 4.6), which may be causing a rise in the profile upstream to closer match the 1977 and 1996 profiles. The location of the Ridgefield Pits is identified for reference. The lower bed elevation in the pits is evident in the post-avulsion profiles, with the new delta forming in the pits evident in the 2018 profile between RMs 7.8 and 8.1. Additional accumulated sediments (fines) are evident in the more downstream portion of the pits. The 1977 profile, which represents the pre-avulsion condition, has an average overall slope of approximately 0.28%, which matches the slope upstream of the pits in 1996 (0.30%) and 2018 (0.27%), even though there is smaller-scale variation in these profiles. The slope within the pits is essentially flat for 1996, and also for 2018 (0.05%) for the portion downstream of the new delta. The slope downstream of the pits in 2018 is slightly flatter than the upstream segment, at 0.17%.

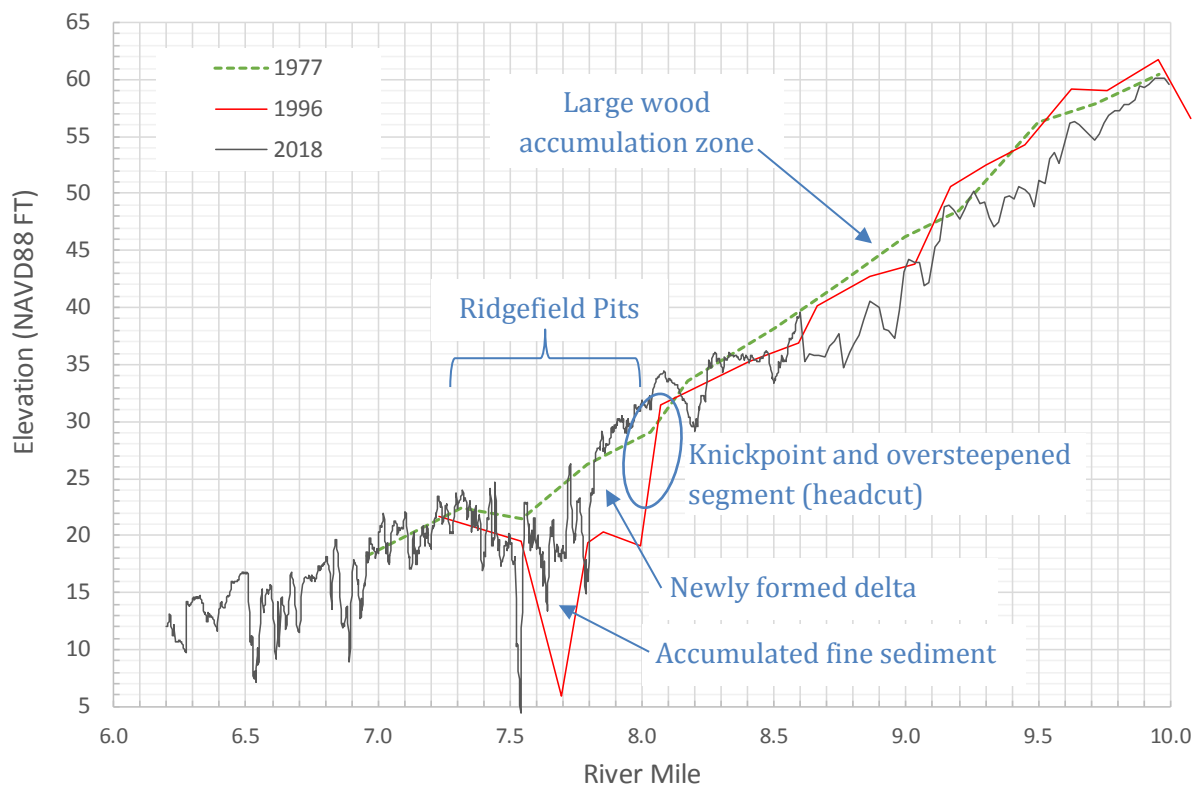


Figure 8. Longitudinal profiles from 1977, 1996 and 2018, with relevant features noted.

A longitudinal profile comparison was also made between the abandoned channel and the newly formed channel through the upper end of the pits. This comparison allows for another way to look at changes in the bed profile from the pre-avulsion condition and provides some insight into future trends. The locations of the profiles are shown in Figure 9 and the profiles themselves are shown in

Figure 10. This simple analysis shows that the new channel bed that has formed through the upstream end of the pits is 3-4 feet lower on average than the pre-avulsion channel. The newly formed section of channel has a slope of 0.26%, which matches the reach-average slope upstream and the slope of the pre-avulsion channel from 1977.



Figure 9. Location of profiles through upstream end of pits.

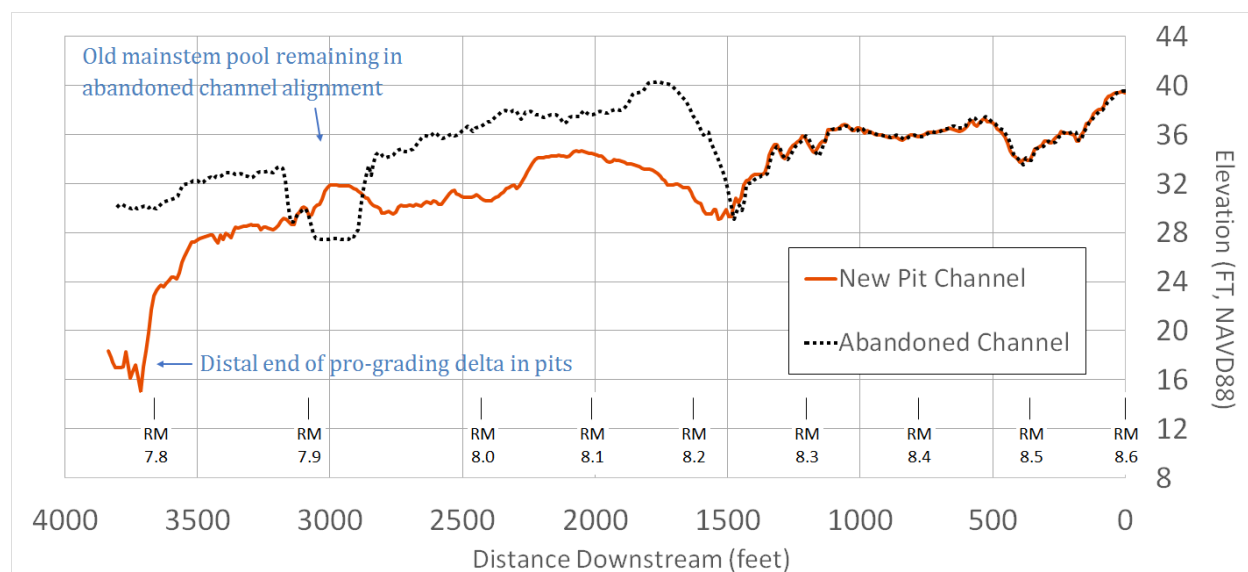


Figure 10. Profiles through upstream end of pits. Based on 2018 topographic/bathymetric data.

The immediate post-avulsion knickpoint and corresponding oversteepened segment can be clearly seen at the upstream end of the pits (RM 8.0-8.1) in the 1996 profile (Figure 8). This segment had a local slope of approximately 2.63% (over nearly 400 ft of channel); this is over 8 times that of the former reach-average slope. Observations described in Norman et al. (1998) indicated that this knickpoint moved upstream in the years following the avulsion.

In a flume study of knickpoint migration, Brush and Wolman (1960) investigated the rates and means by which knickpoints migrated upstream in non-cohesive bed materials, and the corresponding effects to the upstream and downstream reaches. They explain that the greatest amount of channel bed erosion occurs at the knickpoint location itself, where the slope steepens but depth remains high. This can be explained by the bed shear stress equation:

$$\tau = \gamma RS$$

Where τ is bed shear stress (the stress applied to the bed and banks and available to transport sediment), γ is the specific weight of water, R is hydraulic radius (approximates depth in large shallow channels), and S is channel slope. Therefore, all other things being equal, an increase in slope results in an increase in shear stress.

Reaches both downstream and upstream of the knickpoint have less erosive energy due to lesser depths (downstream reach) and lesser slopes (upstream reach) than the knickpoint location itself. Continued erosion at the knickpoint, and deposition downstream, causes the knickpoint to move upstream. As it moves, the knickpoint migration causes the longitudinal growth of the downstream oversteepened reach. This is due not only to the upstream movement of the knickpoint but also the downstream movement of the toe (downstream end of the oversteepened reach) as the newly eroded material is deposited downstream. In the case of the EF Lewis, the new toe is the distal end of the pro-grading delta of deposited material in the pits. As the length of the oversteepened reach increases, the slope decreases and slowly begins to rebound towards the reach average slope.

Although the specific upstream extent of knickpoint migration is unknown, evaluations of gravel pit captures and instream mining on other rivers have shown that channel incision can propagate considerable distances upstream, even on the order of miles, and can cause significant erosion and instability that can put habitat and infrastructure at risk (Kondolf et al. 2002). The upstream extent of knickpoint migration can be challenging to identify for low gradient channels with high natural profile complexity such as the lower EF Lewis. Brush and Wolman (1960) reasoned that once the profile has regained a slope to within 20% of the average slope of the channel, then the knickpoint can no longer be identified. If we were to apply this reasoning to the EF Lewis, we can then make estimates as to the upstream extent of knickpoint migration as a result of the Ridgefield Pit avulsion. Using the original reach average slope of 0.0027, once the oversteepened reach flattens to 0.0032 (within 20% of the average), we can assume the knickpoint has essentially disappeared. Assuming the avulsion lowered the base level of the channel at the pit entrance on the order of 5 to 10 feet (see Section 4.2.3), this equates to an upstream travel distance of 1.75 to 3.5 miles, or up to somewhere between RM 10 (near Daybreak Bridge) and RM 11.75. The travel distance may be somewhat less given the downstream movement and raising of the toe elevation of the oversteepened reach as the delta has grown within the pits.

During the period of knickpoint migration, bed material is eroded and then re-deposited downstream. Brush and Wolman's (1960) experiments showed that the re-deposition of material can also induce channel widening, which generates an additional source of material. This can lead to a complex erosion and depositional process, particularly in natural channels. The current profile and planform complexity of the Lower Daybreak Reach (and possibly the downstream portion of the Upper Daybreak Reach), as well as observations of significant channel adjustments in the reach in recent history, may be related to the instability caused by the knickpoint migration and channel steepening. The overall increase in channel slope increases the energy available to do work on (i.e. erode) the channel bed and banks. This can be explained by the Stream Power relationship:

$$\Omega = QS$$

Where Ω is Stream Power (the energy of the flowing water, which can be used as an indicator of the available stream energy to transport sediment), Q is the river discharge, and S is channel slope. Therefore, assuming no change in discharge, an increase in slope results in an increase in stream power.

This increase in stream energy would be expected to cause chaotic and dynamic patterns of erosion, deposition, and river planform changes as the river profile adjusts to its new equilibrium. It is therefore assumed that for a period of years following the avulsion, the upstream contributing reach was more efficient at eroding local bed and bank material and transporting that material (and any material entering the reach from upstream) down into the pits. The rapid extension of the delta in the pits observed in the years following the avulsion (and described further in Section 5.4) is the result of the erosion, transport, and deposition of this material. The chute cut-off at RM 9 in 2009, avulsions and channel changes upstream of Daybreak Bridge, and on-going bank erosion in numerous areas including lower Daybreak, are also possible sources of this material.

Although the original, pre-avulsion profile elevation will not fully recover unless and until the pits fully fill with sediment, the filling that has occurred to date has raised the toe of the upstream oversteepened reach and has moved it downstream, therefore reducing the overall slope of the oversteepened reach. This is evidenced by only a 3- to 4-foot difference in bed elevation seen now between the newly formed channel through the pits and the head of the abandoned channel (Figure 10). This is compared to a 5-10 ft difference shortly after the avulsion (Section 4.2.3). This has reduced the energy that was responsible for delivering abundant material to the pits in the early years following the 1996 avulsion. This early delivery of sediment following initial knickpoint migration was also observed by Brush and Wolman (1960) in their flume studies. This may explain the lower rates of delta growth and pit filling in recent years that is described later in Section 5.4.

However, without more profile data, it is difficult to determine the rates and the specific degree of profile adjustment that has occurred. There may be additional channel elevation data available from 1999 and 2013 that could further help fill in the intervening years between December 1996 and 2018 to better understand these dynamics – efforts are currently being made to obtain these datasets.

For the reach downstream of the pits, there is even less available data to evaluate profile adjustment. However, based on other studies of gravel pit captures, and sediment transport processes (see review in Kondolf 2002), one would expect an increase in channel size downstream given that the pits capture much of the coarse bedload. Channel expansion is the result of continued erosion of bed and bank material but without the replenishment of material from upstream. This expansion can result in widening and/or vertical incision and can lead to channel instability with effects on habitat and infrastructure. The specific effects on the downstream reach of the EF Lewis due to the avulsion is unknown as there is a lack of sufficient before and after data to evaluate it, but based on other studies of similar events, one would expect that channel expansion and an increase in bed instability has occurred in the downstream reach.

Although the above discussions focus almost solely on the effects of the pit avulsion, it is difficult to distinguish the observed channel dynamics in the reach from those caused by the various other human pressures acting within the system or from natural riverine processes. Other driving factors for channel change within the study area include the scour caused by the constriction at Daybreak Bridge (near RM 10), rapid erosion of the unvegetated Lower Daybreak cut-bank (RM 9.8), erosion of the large bluffs on the south bank, the chute cut-off near RM 9 in 2009, rapid erosion of the unvegetated river-right bank near RM 7.2, and riprap banks on both sides of the channel from RM 6.6 to 7.0. These factors and others have combined with the effects of the pit avulsion to result in the complex channel patterns and processes we have observed over the past two plus decades.

4.4 PLANFORM CHANGE ANALYSIS

A planform change analysis was performed to help understand past channel changes and potential future trends. The aerial photo and map analysis provided previously in Section 4.1 qualitatively described past planform changes in the study area. One of the most notable changes observed in the photo/map record was a change from a complex multi-thread channel system (anabranching) to primarily a single-thread system prior to the 1930s. Changes since then have been more subtle and less obvious, except for what appears to be a recent transition to more multi-thread conditions in the Upper Daybreak segment. The 2005 habitat assessment (SP Cramer & Associates)

In order to better understand planform changes, we used the aerial photo and map records to quantify planform changes using two simple metrics: 1) sinuosity, and 2) proportion of multi-thread channel segments. Sinuosity was calculated as the channel length measured from the maps or air photos divided by the down-valley length of the segment. The proportion of multi-thread channel was calculated by measuring the portion of the segment length that was comprised of more than one active channel. Due to poor photo quality of the older photos and unknown accuracy of the historical maps, this analysis required some judgment calls with respect to what constituted an active channel. Scour features (e.g. gravel bars, opening in vegetation) were used as the primary indicators of active channels where surface water could not be seen directly.

The sinuosity results are included in Table 3. The La Center segment was not included in this analysis because of the lack of channel changes in the historical record. The Mason segment has the greatest overall sinuosity compared to the other segments, with an average of 1.6 compared to an average of 1.2 for the others. The Mason segment also exhibits the greatest fluctuation in sinuosity

over the years. The segment with the second greatest fluctuation is the Ridgefield segment. Upper Daybreak has the least fluctuation. Currently (2018), Mason and Lower Daybreak have sinuosity's that are intermediate within their past ranges; whereas Ridgefield is on the high end of its historical range (same as 1854) and Upper Daybreak is on the low end of its range (also same as 1854). In general, there are not obvious trends in the sinuosity data, at least at the time steps analyzed. We can assume that various human perturbations, such as gravel pit captures and bank armoring, have affected localized sinuosity, but these may be off-set by upstream and downstream channel responses, which would tend to dilute the signal at the reach scale.

Table 3. Sinuosity results.

Year	Mason	Ridgefield	Lower Daybreak	Upper Daybreak	Total
1854	1.5	1.4	1.1	1.1	1.2
1910	1.4	1.3	1.0	1.3	1.2
1939	1.8	1.2	1.2	1.2	1.3
1951	1.4	1.1	1.4	1.2	1.3
1960	1.6	1.1	1.2	1.2	1.2
1975	1.8	1.1	1.2	1.2	1.3
1990	1.7	1.2	1.2	1.2	1.3
2005	1.6	1.3	1.2	1.2	1.3
2018	1.6	1.4	1.2	1.1	1.2
Averages	1.6	1.2	1.2	1.2	1.3

The results of the split flow analysis are shown by segment in Figure 11. Except for the La Center segment, which has remained single-thread throughout the historical record, all of the segments have shown a decrease in the amount of multi-thread channel segments. This decrease is most pronounced in the Ridgefield Pits segment, which is to be expected given the historical multi-thread pattern observed in the historical maps. Most of the segments show a decrease in multi-thread in the early years, variability from the 1930s until about 1980, and then a modest increase in the last 10-20 years. As expected, the greatest increase is in Upper Daybreak, where two prominent recent avulsions have created split flow conditions.

There is good evidence that the Ridgefield Pits segment, and possibly much of the lower river, had an anabranching channel pattern historically, consisting of a multi-thread channel network, abundant vegetation with a range of species and age-classes, and a well-connected valley bottom floodplain that is inundated frequently. This was believed to be a common channel type for many rivers in the region prior to river manipulations by Euro-American settlers (Cluer and Thorne 2013). An historically anabranching channel pattern is supported by the 1854-6 and 1910 maps for the Ridgefield Pits segments and just upstream and downstream. The historical presence of this channel type is further supported for much of the lower river by a regional (Columbia River Basin) channel typing analysis conducted by Beechie and Imaki (2014), whose model predicts an anabranching channel type throughout the study area, except for a significant portion of the La Center segment, which they classify as meandering.

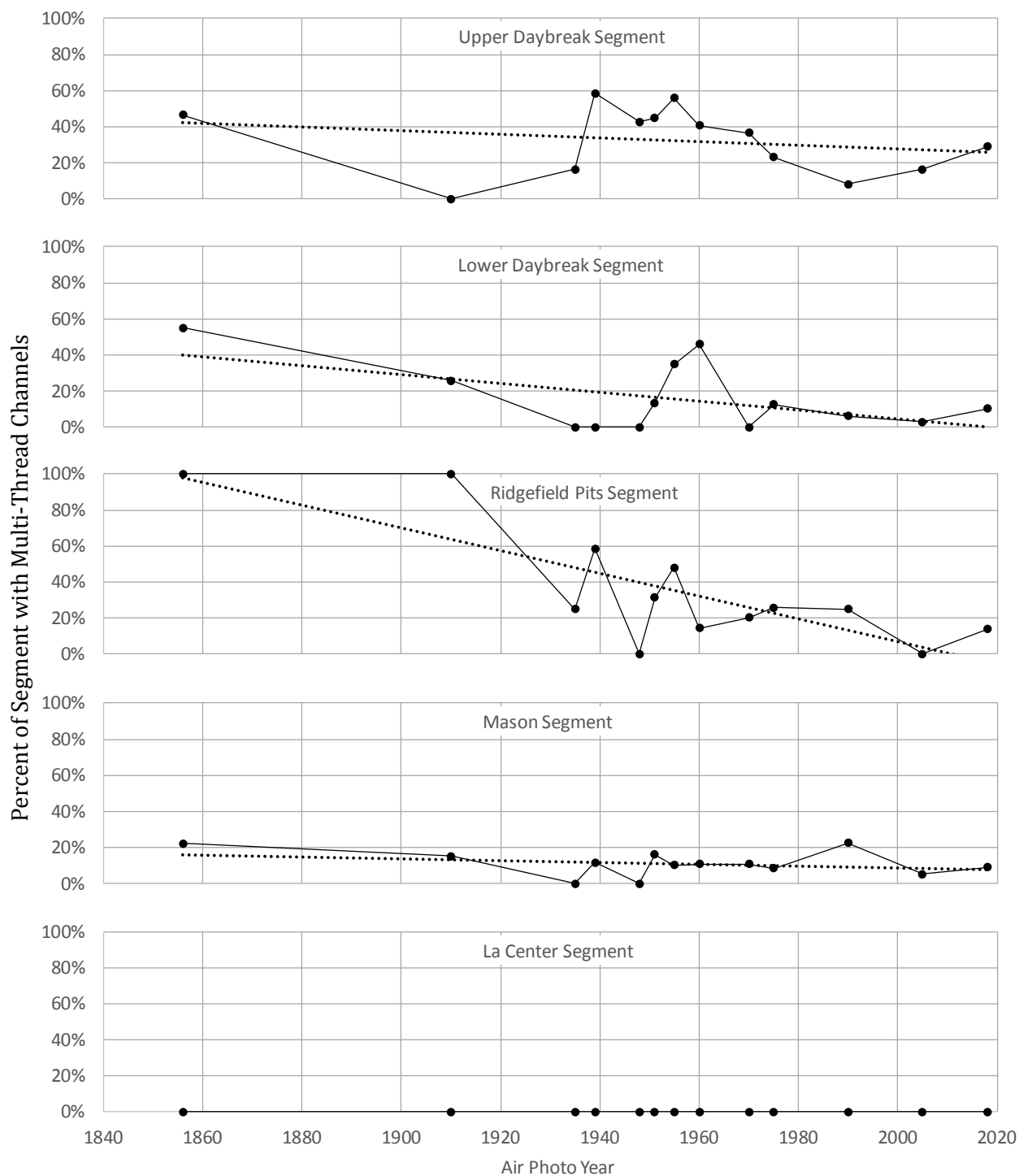


Figure 11. Time series of percentage of river segment with multi-thread channels or prominent flow-through side-channels. Dotted line is a linear trendline fit to the data.

4.5 SIDE CHANNEL CONNECTIVITY

Side-channel connectivity will be evaluated in further detail using the hydraulic modeling results, but some observations are made here based on the field surveys and geomorphic evaluations.

There are two prominent side-channel alignments that are being considered for enhancement. These are located in the Lower Daybreak reach and include the right bank side-channel from RM 9.45 to 9.1 and the right bank side channel from RM 9.0 to the pits (see Figure 12). Both of these side-channels have existing surface flow during high flows, with the upstream side-channel having greater surface water connectivity to the mainstem; however, both side-channels disconnect from surface flow during base flows in the summer.

The upstream side-channel was flowing with surface flows from the mainstem during surveys on April 26, 2018 (see Figure 13) and was still barely connected during surveys on May 22, 2018. The downstream side-channel was dry on May 22 (see Figure 14). Based on vegetation and scour features, it is assumed that the downstream side-channel flows during annual high flows and the upstream side-channel flows for much of the year but becomes disconnected from surface flows typically in late spring.



Figure 12. Location of side-channels being evaluated for enhancement.



Figure 13. View from top end of upstream side-channel, looking upstream towards inlet. Near RM 9.45. April 26, 2018.



Figure 14. *View of downstream side-channel near its upstream end, May 22, 2018.*

Site observations (Estuary Partnership and Inter-Fluve 2018/19) revealed that the connectivity of the upstream side-channel may have increased in recent years. The enhanced connectivity could be due to a number of factors: 1) aggradation of the riffle immediately downstream of the side-channel inlet, which is assumed to be the re-deposited material that has eroded from the Lower Daybreak bank just upstream. Erosion rates of up to 7-8 ft/year (since 1990) at the long lower Daybreak cut-bank and associated growth of the river-left point bar (15 ft/yr since 1990) at RM 9.4-9.5 supports this interpretation; 2) the northward migration of the meander bend at RM 9.4-9.5 towards and into the lower floodplain where the side-channel is located. Gravel mining from the 1950s to early 1970s in this floodplain area (see photos in Appendix A) would have lowered the floodplain elevation; and 3) A cross levee and rock barb on river-right at RM 9.5 were removed circa 2006, which has helped allow this meander migration to occur.

The downstream side-channel is located in a former main channel alignment from the 1960s, prior to a major avulsion to the south, possibly during the 1964 flood. The side-channel alignment is visible in the aerial photo series since then. The 1996 Ridgefield Pits avulsion and related profile adjustment (lowering) likely reduced the connectivity of this side-channel to the mainstem. Since the avulsion, connectivity has likely gradually increased as the longitudinal profile has recovered (Section 4.3.2) and as the deposition zone near RM 9.0 has grown.

4.6 LARGE WOOD PROCESSES

Instream large wood is an important part of channel and habitat form and function in the lower EF Lewis. In this section, we first discuss large wood numbers and describe how wood is distributed in the study area. We then discuss large wood conditions according to the three primary large wood processes; sources, recruitment, and retention. ‘Sources’ describes the wood that is available to the system. ‘Recruitment’ describes the processes required for the river to recruit wood into the channel. And ‘retention’ describes the ability of the channel to retain the wood.

4.6.1 Large wood counts and accumulation patterns

For the western Cascades, for target instream large wood numbers, the National Marine Fisheries Service (NMFS) defines “properly functioning” as wood counts (at least 50-ft long and 2-ft diameter) exceeding 80 pieces/mi. Although wood was not measured and counted in the field as part of this effort, observations during field surveys and coarse-scale counts from air photos show that this threshold is not met in any of the segments in the study area. However, Upper Daybreak, Lower Daybreak, and the Ridgefield Pits segments have in the range of 30-50 qualifying pieces per mile. Many more pieces of wood exist in these segments, but the vast majority of the wood does not meet the NMFS length or diameter criteria. In general, compared to historical conditions where much older forests would have been present in the valley bottom, the instream wood is smaller and more transient now.

Although wood quantities and sizes are low compared to index conditions, the air photo analysis suggests that there is likely more wood now than there was for much of the past several decades. The 1939 photos show some large jams, particularly in the highly depositional Pits Reach (Figure 15), but the photos since then show very little wood in the channel. This is assumed to be the result of wood removal activities, which were common throughout the region only until the last couple of decades.



Figure 15. Large wood accumulations in the Pits segment (near RM 7.4) in 1939.

We are now seeing some of the large wood numbers return, and along with it, some of the natural dynamic channel adjustments associated with wood. The current wood numbers are considerably greater than what was measured in the 2004 (SP Cramer & Associates 2005) and 2010 (R2 Resource Consultants 2011) habitat surveys (Table 4), indicating that wood numbers have risen in recent years. This is due to some of the recent (last 8 years) channel changes in the lower river where channel migration and avulsions have recruited large wood from riparian zones.

Table 4. Large wood counts from the 2004 SP Cramer & Associates (2005) and 2010 R2 Resource Consultants (2011) habitat surveys.

Segment	2004 total large ¹ pieces (Cramer survey)	2004 large ¹ pieces/mi (Cramer survey)	2010 total large ¹ pieces (R2 survey)	2010 large ¹ pieces/mi (R2 survey)
La Center	50	19	NA	NA
Mason	10	6	3	2
Ridgefield	7	8	4	5
Lower Daybreak ²	19	10	24	5
Upper Daybreak ²	9	3		

¹ Large pieces in the Cramer and R2 surveys used the WA TFW criteria, which is 50 cm (1.64 ft) diameter and 2 meters (6.56 ft) length.

² The reach break between Lower and Upper Daybreak in the Cramer study is Manley Creek, which is approximately a half-mile downstream of the segment break we use for this report (Daybreak Bridge). Lower and Upper Daybreak were considered as one reach in the R2 study.

The wood that is present today is primarily concentrated in a few prominent deposition zones that contain high densities of wood. These include above Daybreak Bridge where the channel has recently avulsed near RM 10.5, at the deposition zone near the 2007-8 avulsion near RM 9.1, and at the delta forming in the pits near RM 8.0. These are shown in the map in Figure 16 and in the images in Figure 17 – Figure 19. These are all areas of instability, in various measures affected by human stressors, yet they also exhibit some of the greatest habitat complexity in the lower river.

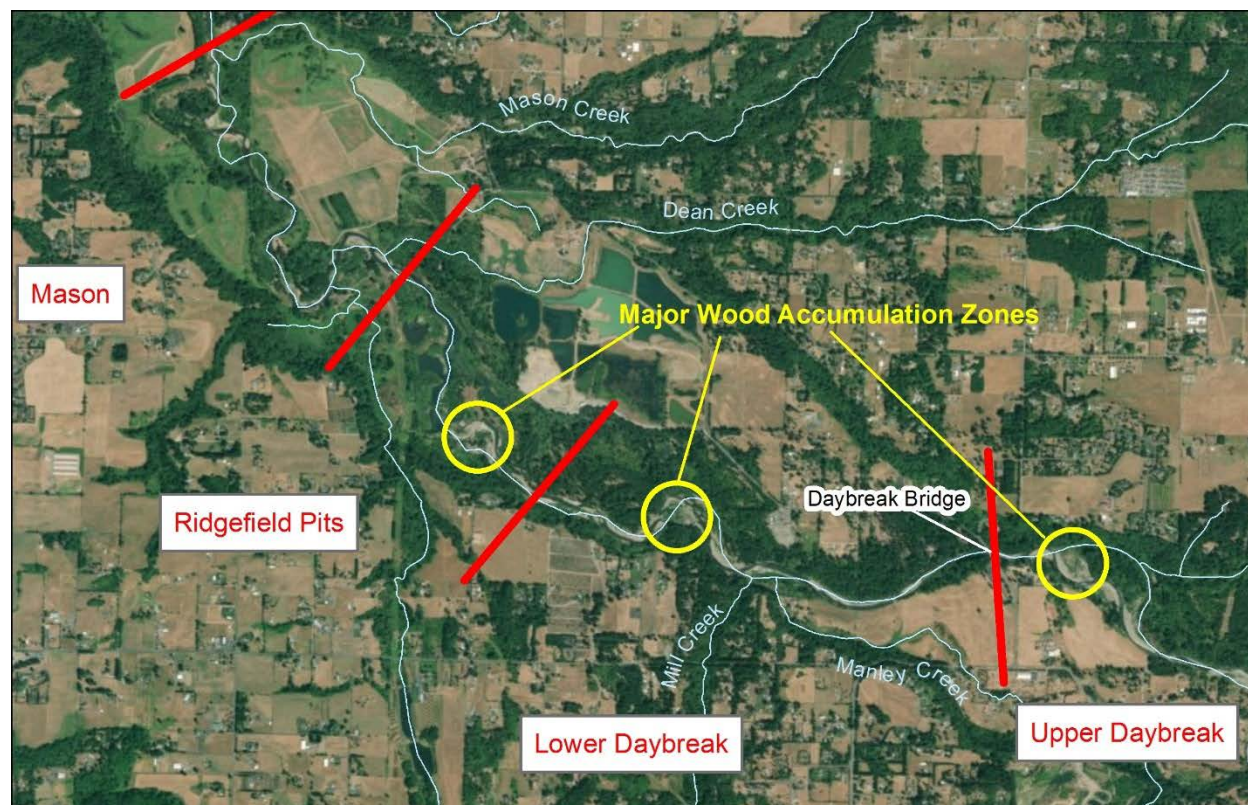
**Figure 16. Map showing the three prominent wood accumulation zones.**



Figure 17. Wood accumulation zone near RM 10.5 upstream of Daybreak Bridge. Gardner Johnston photo June 2019.



Figure 18. Wood accumulation zone near RM 9.1. Gardner Johnston photo June 2019.



Figure 19. Wood accumulation in the upstream end of the Ridgefield Pits. Gardner Johnston photo June 2019.

4.6.2 Sources

There are two primary sources of wood to the lower river. These include upstream fluvially-derived wood and local riparian/floodplain sources. Although the specific relative contributions of these sources to instream wood in the study area is unknown, it is clear that most of the current wood, particularly the larger pieces, has come from local sources and is related to relatively recent channel avulsions and bank erosion. The lack of wood upstream of the upstream avulsion in the Upper Daybreak segment, located near RM 11.5, suggests there may not be a significant contribution of wood from upstream in recent years. Upstream of Lewisville Park (RM 13 to 14.3), natural channel confinement increases and extends for many miles upstream, limiting the recruitment potential for wood. There is likely wood contributed from the upper watershed and tributaries; however, the wood that does make it to the lower river may be small and deteriorated due to the long travel distance.

Local riparian and floodplain sources have been heavily impacted by clearing of valley-bottom forests that began prior to 1900 and have continued to today. There are several areas where cleared riparian and floodplain conditions have been maintained. The most notable areas are the left bank near RM 10.9 in Upper Daybreak, the lower Daybreak cut-bank field (~RM 9.7) (Figure 20), throughout the Pits segment, and at the BPA transmission line crossing and along the airstrip on river right in the Mason segment. The La Center segment also has considerable past floodplain clearing that has been mitigated by the creation of new forested riparian buffers by the County and Clark Public Utilities. Even where there are forested riparian and floodplain areas, the timber is second growth and not as large as what would have been present historically.



Figure 20. Cleared riparian zone and floodplain at the Lower Daybreak cut-bank near RM 9.7. View looking downstream. Gardner Johnston photo June 2019.

4.6.3 Recruitment

The processes of wood recruitment have been altered in the study area. As described previously, most of the wood in the lower river is recruited from local riparian or floodplain sources. This occurs either through lateral bank erosion or from abrupt changes in the course of the channel (channel avulsions). Although recruitment processes are occurring in several areas as already mentioned, there are several areas where recruitment processes have essentially been stopped for the foreseeable future. These are areas where channel migration has been halted and include the Daybreak Bridge crossing, the portion of the channel flowing through the deep Ridgefield Pits, bank armoring river-right near the powerline crossing at RM 7.2, the riprap banks on river-left from RM 6.6 – 6.9, and the riprap banks on river-right along the airstrip (RM 6.5).

4.6.4 Retention

Although wood numbers have increased in recent years, the ability of wood to remain stable within the active channel has been reduced compared to historical conditions. The current wood is transient and highly mobile and shifts frequently with high flows. There are also few pieces of wood or jams that span the channel or even interact with the low-flow channel since much of the wood is located atop gravel bars. This reduction in the ability for the channel to retain wood is due to a couple of primary factors. For one, the size of wood available to the system is smaller than what would have been expected historically where very large trees, cottonwoods and conifers, would

have been available. Clearing of valley bottom forests since Euro-American settlement is the primary cause for the reduction in tree sizes. There is now a lack of functional “key pieces” of a size large enough to remain self-stabilized in the active channel. For low gradient alluvial systems like the lower EF Lewis, the availability of key pieces is necessary to initiate log jam formation.

The second factor affecting retention are the numerous modifications to the channel that have reduced complexity or affected natural river dynamics. These include artificial confinement such as that caused by the Daybreak Bridge crossing. Confinement increases stream energy and scour, and reduces channel complexity, thus reducing the ability of wood to remain in the channel.

4.7 SUMMARY OF GEOMORPHIC CHANGES AND TRENDS

Key pieces from the information in the sections above are summarized below.

4.7.1 Historical Conditions

- Portions of the lower river, particularly the area now occupied by the Ridgefield Pits avulsion, historically exhibited a complex, anabranching channel pattern. The Mason segment and Daybreak segments were highly sinuous meandering reaches with occasional side channels. The La Center segment was single-thread but with abundant abandoned oxbows. All of the lower valley bottom was a well-connected floodplain wetland system with large extents of annual inundation by high flows.
- There was historically abundant side-channel habitat, especially in the naturally laterally active segments including Mason, Ridgefield, and Lower and Upper Daybreak.
- There was likely abundant instream large wood creating stable jams and forested island features. Abundant large wood was present in the Ridgefield Pits segment, with lesser amounts in Mason and Lower Daybreak in the 1939 photos.
- The large wood in the channel, and large and robust riparian and floodplain vegetation, likely resulted in relative stability of the channel during regularly recurring floods (i.e. annual to 5-year event); with channel adjustments via scrolling and avulsions occurring during the larger, less common events (> ~5-year event). These disturbance events would create a complex patchwork mosaic of instream and floodplain aquatic habitats, with high productivity of fish and other aquatic species in the intervening years.

4.7.2 Land Use Impacts

- Conversion of valley bottom forests to agriculture and rural residential development began prior to 1900 and has continued to today. Recent trends show agricultural land being converted to residential uses.
- Instream mining occurred in the study area from the 1930s to at least 1975.
- Floodplain gravel mining has occurred throughout the photo record (since 1939) and continues today.
- Mainstem channel avulsions into gravel pits has occurred on multiple occasions.
- There was dredging in the lower reaches (mainly downstream of La Center but also up to Mason Creek) from the late 1800s to the 1920s.

- Roads and bridges, including the Lewisville Bridge, Daybreak Bridge, and La Center Bridge all constrict the channel and floodplain.
- There are multiple locations where bank armoring, primarily riprap, halts channel migration processes.
- There are levees in several areas, most notably in the La Center segment. These levees affect channel migration and floodplain inundation rates and patterns.
- There has been floodplain fill associated with roads and development. This has affected floodplain connectivity in some areas.
- Wood was assumed to have been regularly cleared from the channel in the mid-1900s.

4.7.3 Current Conditions

- Previous complex anabranching channel types have been replaced with meandering or confined reaches with none or only occasional side-channels.
- The once highly connected floodplain is now partially-to-fully disconnected, with less frequent inundation and less floodplain wetlands.
- There is a narrower channel migration zone compared to historical conditions, with much of the wide, formerly available CMZ now eliminated or significantly constrained.
- There is less large forest structure and less instream large wood and log jams compared to historical conditions.
- The reduction in structure and hydraulic roughness results in channel changes in some areas that occurs very frequently (~annually). These areas have relatively high habitat complexity but are also possibly more at risk of redd scour and burial issues.
- In other areas, artificial confinement or flow through former gravel pits results in channel changes that occur seldomly or not at all. These areas lack habitat complexity and have poor water quality. In areas with bridges or armoring, the confinement leads to high stream energy and a more erosive environment. Sediment is readily scoured and transported through these segments, depositing downstream in lower energy areas where it causes channel instability.
- There has been a moderate increase in channel dynamics and associated split flows and large wood recruitment over the last 5-8 years, particularly in the Upper Daybreak segment.
- There is currently a moderate amount of large wood in certain active deposition zones including the delta forming in the pits, at the bend at RM 9.1, and at the newly formed avulsion channel upstream of Daybreak Park (RM 10.5). But there are very few large enough pieces to serve as key pieces in the mainstem and jams are therefore transient.
- There is the potential for continued recruitment of wood from riparian zones within the study area as the channel continues to laterally migrate; however, the size of the available riparian trees are typically not big enough to serve as key pieces that would self-stabilize in the main channel and be able to rack additional wood and form large jams.
- The knickpoint from the 1996 Ridgefield Pits avulsion has traveled far enough and flattened out enough to have blended into the average channel slope, and can no longer be reasonably identified. There is, however, a slightly steeper slope in the Lower Daybreak Reach that may be causing greater instability in the reach. This slope will continue to flatten as the delta

continues to pro-grade into the pits, but it may take a very long time, if ever, for the slope to fully return to the pre-avulsion slope.

- The instability in the Lower Daybreak segment created by the pit avulsion has not been all negative with respect to habitat conditions. Although there have been dramatic channel changes as a result, and likely redds scour and burial that have impacted fish, there is also recruitment of riparian trees and new accumulations of large wood. The wood is providing habitat that did not exist previously, and it has increased dynamic channel processes in some areas, such as creating split flow conditions, which has further increased habitat quantity and quality.

5. Pit Filling Trends & Estimates of Recovery Time

5.1 BACKGROUND

Understanding the timeline for geomorphic recovery of this reach is important for determining how long and to what degree the reach will recover on its own without intervention. This information can form the basis of decisions for restoration planning, including whether or not active restoration is warranted and the types of approaches that would be appropriate. To that end, this section describes prior estimates of pit filling rates and then provides new and updated evaluations of pit filling rates, including new predictions for the timeline for the passive recovery of the reach. A multiple lines of evidence approach was used to evaluate pit filling rates. This includes three methods: 1) update to the volumetric filling analysis performed by WEST (2001 & 2013) (Section 5.3), 2) planview analysis of pit filling using the air photo record (Section 5.4), and 3) depth of refusal measurements of fine sediment accumulation (Section 5.5).

For the Ridgefield Pits reach to be considered geomorphically recovered from the impacts of the 1995-1996 avulsions, it is assumed that all the pits would need to fill with bedload/sediment and that the river channel and active floodplain longitudinal profile would need to return to a similar slope and elevation as the pre-avulsion profile. Previous estimates of recovery time defined geomorphic recovery as “when the channel has returned to an elevation similar to the pre-1996 avulsion channel” (West 2001). However, past estimates did not include the filling of all the pits in this definition; Pits 8 and 9 were excluded, even though current channel dynamics suggest that erosion of the main channel into these pits at some point in the future is likely. For the purposes of this assessment, we consider the filling of all the pits critical to full geomorphic recovery since future channel migration into non-filled pits would result in similar (albeit smaller) pit captures that would have detrimental impacts to river geomorphic function and would result in impaired habitat conditions similar to what is found in the existing pit reach.



Figure 21. Aerial oblique view looking downstream from near the upstream end of the Ridgefield Pits reach.

5.2 PRIOR STUDIES

Original estimates of pit filling rates were provided by WEST (2001) as part of the Daybreak Mine Expansion HCP studies. These estimates were then updated by WEST in 2013 (WEST 2013). The primary reasons for estimating pit filling rates were twofold: 1) to understand recovery times as an example of what might be expected if the river were to avulse into the Daybreak Pits, and 2) to understand recovery time with respect to risk to the Daybreak Pits, with the assumption that once the Ridgefield Pit reach recovers, lateral channel migration into the Daybreak Pits would be more likely to occur.

WEST (2001) originally estimated the timeline for recovery via 2 primary methods. The first involved calculating the volume of sediment that had filled the pits since the 1996 avulsion and then using that data, along with some assumptions of watershed sediment supply, coarse bedload supply, sediment transport capacity, sediment trapping efficiency, and volume of pits remaining to be filled, to make a filling rate prediction. This resulted in an estimate of 25 years (since the 1996 avulsion), or recovery by Year 2021, for the pit reach to recover. This analysis had inherent uncertainty for a number of reasons, including the need to rely on recollections of pit depths from workers at the mine to estimate the pre-avulsion pit volumes. This analysis also disregarded Pits 8 and 9, assuming that because they were not connected to the mainstem, they were not necessary for reach recovery.

The second method described in the WEST (2001) report for estimating recovery time involved calculating the growth rate of the gravel/cobble delta forming at the upstream end of the pits. Based on a delta growth rate of approximately 100 ft/year, they estimated it would take 30 years (by Year 2026) for the delta to reach the downstream end of the pits.

As part of their requirements under the HCP, Storedahl commissioned an analysis in 2013 to evaluate the status of pit filling and to update the recovery rate estimate. This analysis was described in a tech memo from WEST to Storedahl (WEST 2013). The method relied on a volumetric analysis of pit filling and built off of the previous pit volume calculations used for the pit filling predictions in the HCP described previously (WEST 2001). The results of this evaluation resulted in a geomorphic recovery prediction of 30 years, which was said to match the 25-30 year prediction from the HCP (WEST 2001), and meaning the reach was still on track to be recovered by 2026.

5.3 UPDATED PIT FILLING ESTIMATE BASED ON PIT VOLUME MEASUREMENTS

As part of this study, we compare 2018 pit volumes to past volume data in order to check the status of pit filling and to update the predictions for timeline to recovery. The pit volumes from prior studies and from this current study are presented in Table 5. The pre-avulsion data and 1999 data were presented in Appendix C of the HCP (WEST 2001). Note that Pits 8 and 9 were not included in this study, as mentioned previously. The pre-avulsion volumes are based on estimates of pit depths from a worker at the mine. The 1999 and 2013 data are based on surveys by WEST consultants. This study adds 2018 pit volume estimates to the time series based on 2018 bathymetric and ground survey data by Inter-Fluve and the Estuary Partnership (Inter-Fluve 2018) combined with the 2010 LiDAR (USACE 2010) to make a composite digital elevation model.

The pit volumes are in reference to an “average water surface elevation”, which WEST (2001) defined based on a groundwater contour map; those elevations are listed as the ‘Pit Top Elevation’ in Table 5. Although one would expect a reduction in the volume of the pits as they fill with sediment, this is not always the case, especially when considering changes in individual pits. For the pre-1996 to 1999 data, WEST (2013) attributes this to several factors, including lateral channel migration moving material out of the pits, using pit boundaries that may have been different from the original study, and potential under-estimation of the original pre-1996 volumes. When looking at the total volume changes with all pits combined, there is a 12% reduction in volume from pre-1996 to 1999 and a 57% reduction from pre-1996 to 2013. These data were used in 2013 to develop the 30-year estimate for pit filling (i.e. pit filling by 2026, WEST 2013). The 2018 data, however, show a reversal in trends in pit volumes for the pits, with an overall increase in total volume from 2013 to 2018. The reason for the increase in volume is unknown. The 1999 and 2013 topographic data were not available for this analysis, although efforts are being made to obtain it, which may help clarify the reason behind the differences. Some of the increase in volume in some pits could be due to lateral channel migration moving material out of the pit area; however, this would not apply to most of the pits and would not account for the increase in pit volume for the reach as a whole. In total, the 2018 data suggest a total decrease in pit volumes of 36% from pre-1996 to 2018, which is substantially less change in volume suggested by the 2013 data (57% decrease) and has different implications for timeline for reach recovery. The total changes in pit

volumes from these various time periods/studies are plotted in Figure 22. Linear trendlines show that without the 2018 data, the pits could be on a trajectory to fill by 2026, which was the conclusion from the WEST (2013) study. However, without the 2013 data, the trend suggests the pits may be on a longer trajectory to fill, by 2068. Both of these trendlines assume linear relationships using the 1999 data, when in reality, the rate of pit filling may not be linear, which is discussed further in Section 5.4.

Table 5. Pit volume estimates.

Pit	Values previously reported in Storedahl HCP Appendix C (WEST 2001) and 2013 Tech Memo (WEST 2013)							Values based on 2018 survey	
	Pre-1996 Pit Volume (2001 study)	Pre-1996 Pit Depth (2001 study)	Pit Top Elevation (2001 study)	1999		2013		2018	
				Volume	Volume Change	Volume	Volume Change	Volume	Volume Change
	(cy)	(ft)	(ft)	(cy)	(%)	(cy)	(%)	(cy)	(%)
1	157,700	12	35	118,583	-25%	21,958	-86%	69,777	-56%
2	102,900	12	34	130,131	26%	54,185	-47%	103,409	0%
3	108,500	20	33	124,203	14%	76,290	-30%	92,798	-14%
4	143,500	20	32	105,176	-27%	51,000	-64%	81,192	-43%
5	164,800	20	31	160,661	-3%	88,955	-46%	116,640	-29%
6	204,900	30	31	128,119	-37%	66,211	-68%	87,233	-57%
7	186,900	20	30	178,981	-4%	96,299	-48%	135,951	-27%
TOTAL	1,069,200			945,854	-12%	454,897	-57%	687,000	-36%

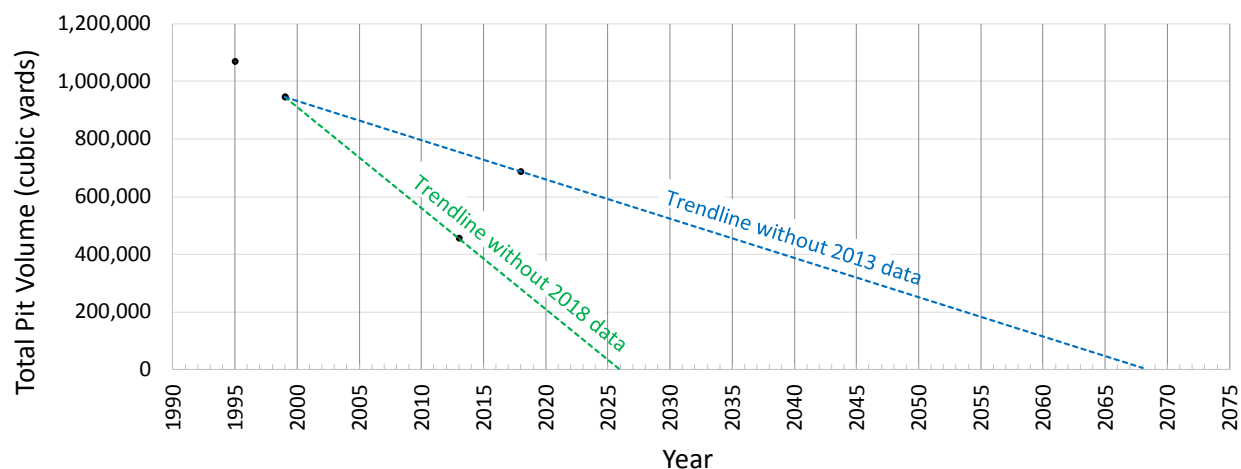


Figure 22. Pit volume estimates.

It should also be noted that this analysis does not include pits 8 and 9. If pits 8 and 9 were included, the total pit volume would be greater and the timeline to recovery would be even longer. Considering that lateral migration is likely to occur into these pits at some point in the future, it would seem reasonable to include these when making predictions for reach recovery.

5.4 PLANVIEW AREA ANALYSIS OF PIT FILLING

Due to uncertainties associated with the three-dimensional data required to compare changes in pit volumes over time, we also performed a two-dimensional “planview” analysis of pit filling using the historical photo record since just prior to the 1996 avulsion. For this 23-year period, we were able to obtain aerial photographs for 18 years, a nearly annual record. These photos were obtained from Clark County, Google Earth, and past reports. Although this analysis provides less detail than a 3D volumetric analysis, it avoids the uncertainty associated with the 3D survey data and also provides a nearly complete annual record to evaluate trends in pit filling rates since the avulsion.

A 1994 (pre-avulsion) air photo was used to draw initial pit boundaries for this analysis in a GIS, based on extent of open-water within the pits. For each photo set/year following the avulsion, polygons were then drawn around areas within the initial pit polygons that appeared to be above water. These represented areas considered “filled” with sediment within the pits. Although nearly all of the photos were taken during low water periods in the summer, the timing varies and so does river discharge, which affects the apparent amount of pit filling year-to-year. For this reason, there are some years where filling appears to decrease from a previous year or years, which would not be expected; but this is assumed to be related simply to higher water in the photo compared to previous years.

For each photo set/year, the area of pit filling was calculated and was compared to the initial pre-avulsion pit boundaries. These data are presented in Table 6. The chart in Figure 23 displays the annual trend in the data. The trendline that is fit to the data is a 4th order polynomial trendline, and does not include data from the 6 years where pit filling appears to decrease from a prior year. The table and chart also include the annual peak flow events during this period, from the USGS Heisson Gage (#14222500). These are included to evaluate whether or not pit filling rates appear to be

correlated with flood events. Appendix B shows all of the photo years and delineated fill polygons generated for this analysis.

Table 6. Pit filling calculations by photo year with peak flow information.

Air Photo Year	Pit Fill Area (acres)	Percent Fill (of pre-avulsion pit acreage)	Intervening annual peak flow events	
			Flow (cfs)	Date
<i>*pre-avulsion total pit acreage = 49.1</i>				
Summer 1996	0.3	1%	28,600	8-Feb-96
Late Fall 1996	3.1	6%	6,000	19-Nov-96
1998	9.3	19%	9,580	30-Oct-97
2000	17.6	36%	12,000 14,400	27-Dec-98 25-Nov-99
2002	19.0	39%	3,170 6,330	30-Apr-01 25-Jan-02
2003	22.2	45%	13,700	31-Jan-03
2005	21.1	43%	9,420 6,690	29-Jan-04 18-Jan-05
2006	22.1	45%	9,270	10-Jan-06
2007	21.1	43%	21,200	7-Nov-06
2009	26.8	55%	10,700 13,800	3-Dec-07 8-Jan-09
2010	26.4	54%	4,470	1-Jan-10
2011	27.2	56%	16,200	16-Jan-11
2012	27.7	56%	11,000	22-Nov-11
2013	28.0	57%	7,570	19-Nov-12
2014	27.7	57%	6,660	2-Dec-13
2015	26.0	53%	5,850	10-Feb-15
2016	28.3	58%	22,400	9-Dec-15
2017	27.2	55%	9,360	15-Mar-17
2018	29.8	61%	6,540	29-Dec-17

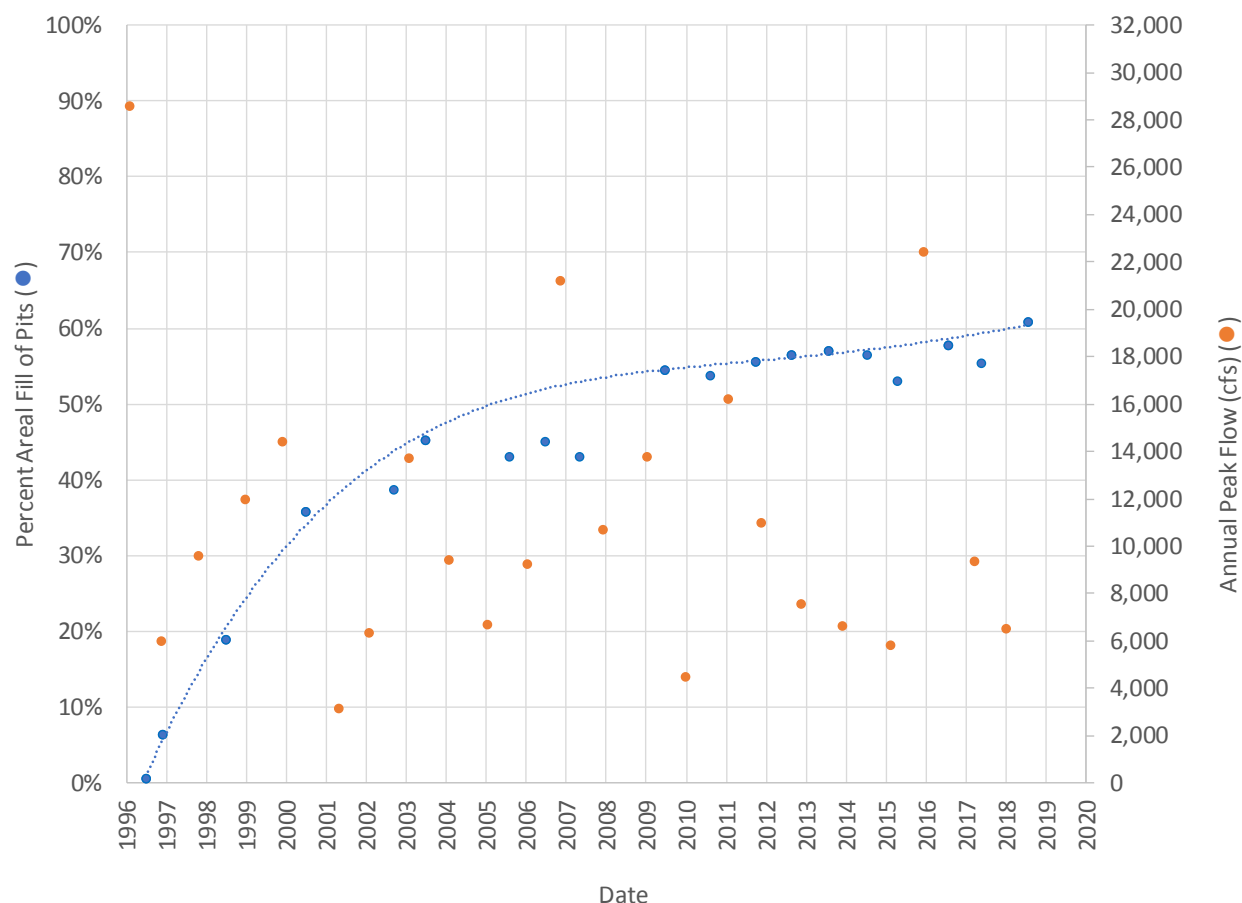


Figure 23. Trend in pit filling rates compared to peak flow data from the USGS Heisson Gage (#14222500).

This pit filling analysis indicates that the rate of pit filling has slowed and has become more consistent over the past 10 years. Whereas the average pit filling rate for the first 11 years post-avulsion was 1.9 acres/year, the average rate for the past 9 years has been 0.34 acres/year. One might expect that the reduction in pit filling rates could be a result of smaller floods in recent years; however, the peak flow data actually show that the largest post-avulsion peaks occurred after the pit filling rates slowed. It is assumed that the reduction in pit filling rates is instead due to cessation of the initial knickpoint migration following the 1996 avulsion and the subsequent recovery (rebound) of the longitudinal profile and thus a reduction in the contribution of bedload from upstream, as described previously in Section 4.3.2.

In Figure 24, the trend in pit filling rates is expressed as the amount of pits remaining ‘unfilled’ over time. If we assume that the recent (i.e. past 10 years) trend in filling rates continues (0.34 acres per year), then according to this analysis, the pits will fill by the year 2075. This is based on 19.3 acres remaining to be filled, at a rate of 0.34 acres/year, resulting in approximately 57 years. This “filling”, however, only constitutes sediment that is above water during the low water period, and may be a lower threshold than the filling that was described as necessary to achieve pit “recovery” by WEST (2001), specifically: “when the channel has returned to an elevation similar to the pre-1996 avulsion channel”. If this criterion were used, the timeline for recovery may be longer.

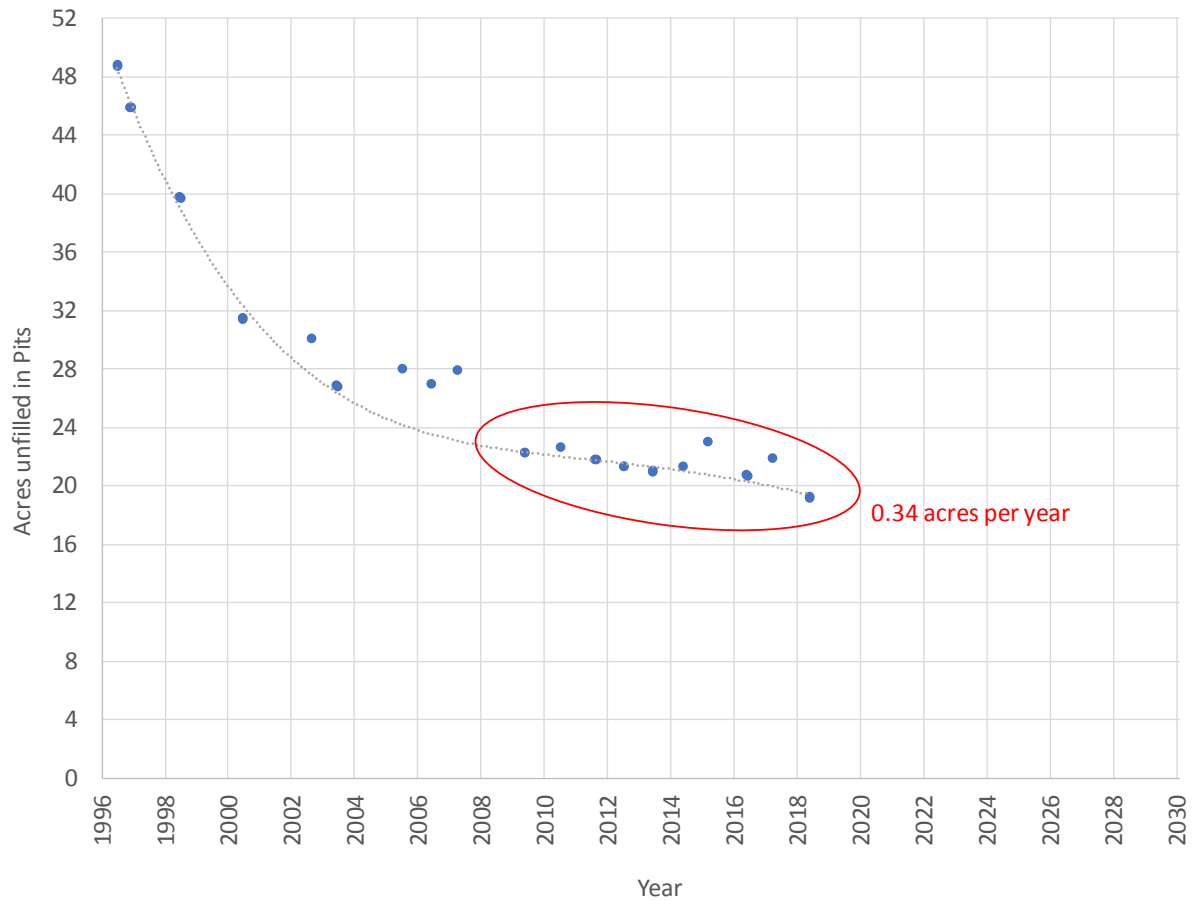


Figure 24. Area (acres) unfilled in pits by year since the avulsion. For the past 10 years, the pits have filled at an average rate of 0.34 acres per year, based on the two-dimensional “planview” analysis of filling.

This analysis revealed two primary modes of pit filling: 1) gravel-dominated bedload forming the delta at the upstream end of the pits, and 2) fine silts and sands filling the remainder of the pits. The delta has formed via bedload transport from upstream that is pro-grading into the pits. As the new channel aggrades, it has initiated meander migration that has eroded the former pit walls. The new material generated from this erosion has further contributed to pit filling. The areas downstream of the coarse delta, and the pits that are not directly in-line with the main channel, are comprised of fines (sands and silts). Similar to West (2001), we assume that this material is primarily contributed from upstream watershed areas. However, it is possible that this fine material could be re-suspended as the newly-forming main channel continues to pro-grade into the pits and shifts laterally into off-line pond areas. These dynamics could extend the timeline for reach recovery.

The growth of the delta is fairly easy to measure from the air photo series; however, the amount of accumulation of fines in the pits, and how long that would take to fully fill the pits, is more uncertain. This is further evaluated in Section 5.5.

5.5 DEPTH OF REFUSAL MEASUREMENTS OF ACCUMULATED SEDIMENTS

In order to better understand the rate of pit filling downstream of the coarse gravel delta, we performed a series of depth-of-refusal (DOR) measurements. We selected a sample area for these measurements in Pit #7, which was believed to be sufficiently downstream of the delta to avoid coarse sediment and to have a range of channel conditions and depths. A total of 17 samples were taken, including areas within the main channel through the pits, channel margins, and off-line pit areas (Figure 25). The DOR measurements were performed using a smooth metal rod pushed through the fine sediments until refusal depth was reached. This refusal depth is assumed to be the original bed of the pits prior to accumulation of fines following the avulsion. The refusal depth and the depth to the top of the sediment deposit were recorded in order to calculate the sediment thickness at each sample point. These data are presented in Table 7.

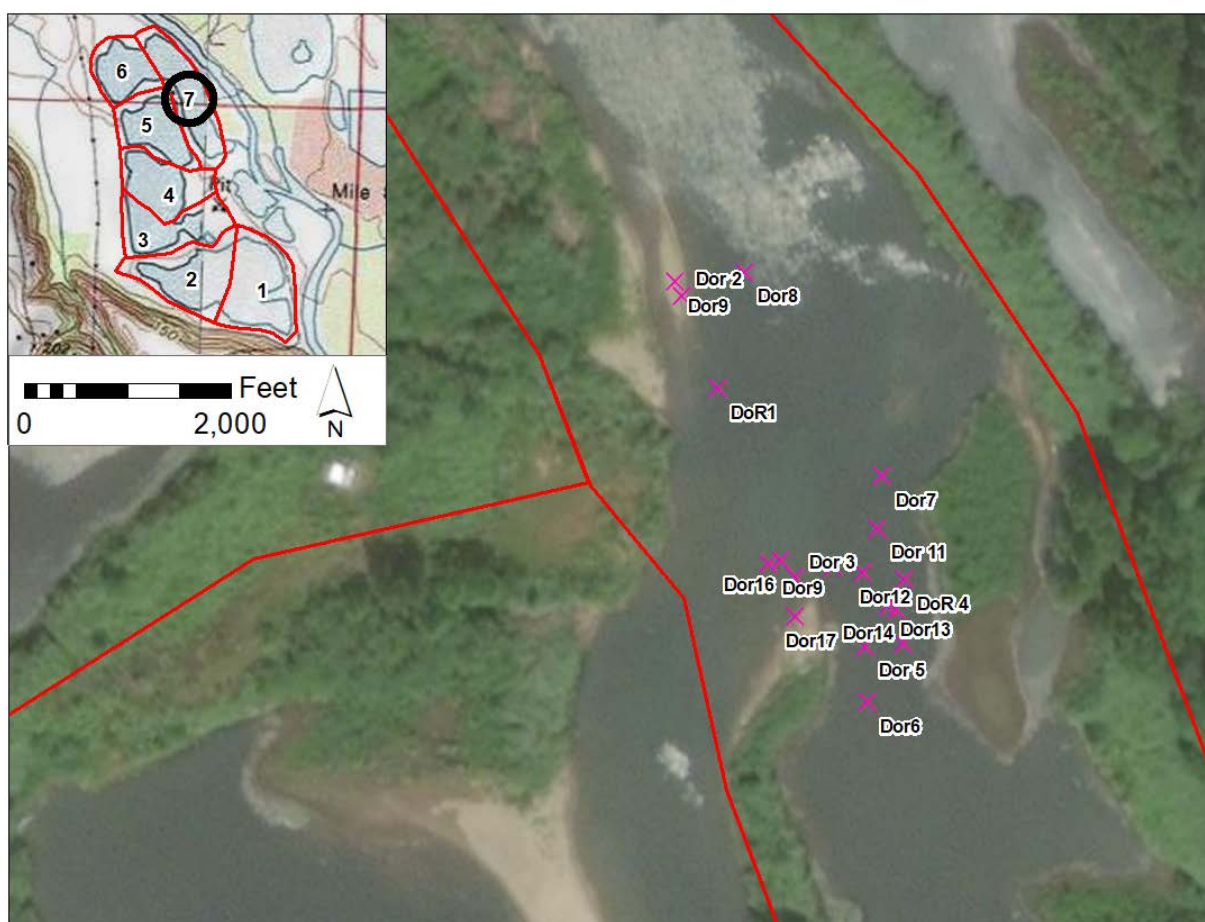


Figure 25. Location of depth-of-refusal measurements.

Table 7. Depth-of-refusal data.

Sample Location	Depth to top of sediment (ft)	Depth to Refusal (ft)	Sediment thickness (ft)
1	2.3	4.8	2.5
2	3.5	9.5	6.0
3	4.6	8.0	3.4
4	8.5	10.0	1.5
5	6.5	8.6	2.1
6	6.4	11.3	4.9
7	3.5	10.2	6.7
8	9.5	14.0	4.5
9	3.5	5.5	2.0
10	6.3	10.0	3.8
11	11.6	13.0	1.4
12	9.0	12.2	3.2
13	7.9	9.3	1.4
14	7.8	12.5	4.7
15	7.8	11.7	3.9
16	5.0	7.0	2.0
17	1.7	4.2	2.5
Averages	6.2	9.5	3.3

Sediment thickness ranged from 1.4 to 6.7 feet with an average of 3.3 feet. This equates to an average of 0.14 feet (1.7 inches) of sediment deposition per year for the 23 years since the 1996 avulsion. For each sample location, the estimated time for the site to fill was calculated by dividing the depth to the top of the sediment layer by the average feet/year of sediment accumulation for the sample location. The average of all of these estimates was approximately 58 years, or filling by 2076. This can be considered a low estimate since it assumes that filling is achieved when the sediment layer reaches the water level at the time of the survey, which was during a very low water period (Oct 18, 2018). It also only looks at filling via fine sediment deposition, and disregards the growth of the coarse gravel delta. However, it is reasonable to assume that in the downstream portion of the pits and in some of the off-line pits (or off-line areas of connected pits), filling is likely to occur via fine sediment accumulation only, since the delta may never reach these areas. It is also reasonable to assume that the fully disconnected Pit 9 and the mostly disconnected Pit 8 would have far less sediment deposition than the sample sites would suggest; and if these remain disconnected, they may take a much longer time to fill passively since they would not receive the same amount of fine sediment as those connected to the main channel.

5.6 SUMMARY

A multiple lines of evidence approach was taken to evaluate pit filling rates and to estimate the timeline to pit filling and reach recovery. Three methods were used, including evaluating trends in pit volumes, trends in the spatial area of pit filling, and DOR measurements of fine sediment accumulations. The results of these methods are included in Table 8.

These results indicate that the timeline for the recovery of the pit reach may be considerably longer than the previous estimate of recovery by Year 2026 (WEST 2001 and 2013). Based on the analyses presented in this report, and in consideration of the notes in Table 8, pit recovery is likely to take until at least Year 2075, and possibly considerably longer.

Table 8. Estimates of the timeline to pit recovery from the methods presented in this report.

Method	Estimate of years to recovery (from 2018)	Notes
Pit volume changes based on topo-bathy surveys	50 (filled by 2068)	• Disregards 2013 data from WEST (2013) for the reasons described in Section 5.3. • Doesn't include Pits 8 and 9, so estimate is likely low.
Planview area analysis of pit filling	57 (by 2075)	• Estimate may be low because measures are based on visible land at low flow, which would be less deposition than recovery of elevations that match the pre-avulsion channel.
DOR measurements of accumulated sediments	58 (by 2076)	• Estimate may be low because measures are based on recovery to a low water level during the survey, which would be less deposition than recovery of elevations that match the pre-avulsion channel.

6. Implications for Restoration

The geomorphology and pit filling evaluations have several implications for habitat restoration planning in the study area. These are listed below.

- Dynamic channel changes have always occurred throughout the study area and should be expected to continue. However, the rates of change and potential future changes have been affected by human actions, which has resulted in some areas with more frequent channel changes and other areas with less frequent channel changes.
- Restoration actions should assume that dynamic changes, especially planform (lateral) dynamics, will continue and that these dynamics are important for the recovery of habitat complexity and native vegetation.
- A sinuous and complex planform with occasional meander cut-offs and abundant former channel scars will increase aquatic habitat complexity. These conditions will also support temperature refugia by creating hyporheic flow paths with strong head gradients, such as subsurface flow across point bars that contribute cool water to back-bar channels.
- In some areas, restoration actions may be beneficial that add structure to mimic the historical structure of large standing trees and large instream log jams – elements that would have resisted annual adjustment but would have been deformable at 5-10 year flood recurrence events. Other areas may benefit from removing structures, such as artificial bank armoring, fill, or levees that limit the degree of dynamic change and adjustment.
- Projects should be designed for resiliency and deformation, with channel alterations that retain quality habitat with fluctuating sediment supplies. Adding new permanent structures that constrain floodplain or channel migration zone processes should be avoided unless they are part of a plan to improve overall river corridor function (e.g. set-back levees around critical infrastructure).
- The Ridgefield Pits are unlikely to fill for at least another 50-60 years, and it could possibly take considerably longer. Habitat conditions in the pits reach will slowly improve over time but the reach will remain significantly impaired until the pits fill. Continued impairment of pits over several more decades may bolster the need for active, as opposed to passive, restoration at the site. Alternatives should be considered for speeding the recovery process in the pits reach.
- Pit avulsion into the Daybreak Pits would cause significant impairment and it is paramount to prevent this in the future or to restore and reconnect a portion of those pits in a deliberate fashion.

- There will be continued, albeit subtle, longitudinal profile ‘rebound’ in the Lower Daybreak segment. This should work in concert with any side-channel reconnections that are considered.
- Relatively rapid erosion of the Lower Daybreak cut-bank is expected to continue. This has pros and cons with respect to restoration. Cons include the potential for redd scour and burial on an on-going basis, delivery of fines to the channel, and lack of large wood recruitment due to the cleared field. There is also very poor channel margin and riparian function in this area. Pros include the colonization of the opposite point bar with native vegetation and creation of more highly connected floodplain in this area. The rapid erosion of bedload also helps speed the longitudinal profile rebound and provides material to help fill the Ridgefield Pits. The re-deposition of this material just downstream also helps to keep the right-bank side-channel active. At the least, this site would benefit from revegetation throughout the floodplain. Of greater benefit would be a more targeted effort to slow (but not permanently stop) erosion, giving planted vegetation a chance to mature, and also increasing instream and channel margin habitat complexity.
- Restoration actions that work to further increase connectivity of the river-right side-channel across and downstream from the Lower Daybreak cut-bank, and work near the Manley/Mill confluence area, will need to take into account what future projects (if any) are likely to occur at the lower Daybreak cut-bank, since actions or the lack of actions at the cut-bank could affect channel dynamics and sediment/bedload sources that might impact those efforts. Ideally these various efforts would be considered as one cohesive group of actions.
- Although there is a lack of data to fully assess it, there has likely been incision in the Mason segment due to the bedload trapping of the pits. This will continue until the pits fill. This could affect projects including side-channel reconnections and large wood placements. Actions that help contribute or recruit bedload to the Mason segment would help to mitigate the effects of the pit capture. This could include removing any bank armoring in this segment.
- Wood delivery to the channel will continue. Wood numbers may continue to be high in localized depositional areas, but there is an overall lack of large key pieces that can remain stable in the main channel, so wood is expected to continue to be transient. Projects that create conditions for more stable wood structures and the ability to trap and retain mobile wood will create conditions that are more in line with historical wood jams that had greater retention time in the system.
- Areas of high channel complexity have less invasive plant species. Restoring complexity to some areas may be the best way to address invasive vegetation.
- The existing degree of connectivity of the upstream right bank side-channel is likely related to erosion at the Lower Daybreak cut-bank and subsequent re-deposition of this material at the riffle downstream. This process will likely continue if conditions remain the same at the cut-bank, at least until continued meander scrolling results in an avulsion.

7. Recommended Modeling Scenarios

Based on the site investigations and project objectives, recommendations for initial modeling scenarios are provided. This includes hydraulic and sediment transport modeling. The results of these model runs can be used to evaluate preliminary potential benefits, risks, costs, and constraints of key restoration alternatives.

No action/passive recovery of pits – This would include modeling existing hydraulic and sediment transport conditions. Sediment modeling could be used as another line of evidence to help understand potential rates and means of pit filling over time.

Relocate main channel back into pre-1996 avulsion channel – This scenario would use select grading and log jams to relocate the main channel into the former, abandoned channel alignment. Iterative modeling of proposed grading scenarios would help to understand the level of grading that would be necessary and the feasibility of this approach given the current elevation difference between the main channel and abandoned channel. If initial analysis shows this is likely to be infeasible without new levees and armoring, then full hydraulic modeling of this scenario may not be necessary.

Full pits reach re-grade – This scenario would include grading and filling to re-contour the pits reach into a multi-thread connected channel and floodplain wetland system. The elevation of the new channel/floodplain system would be lower than the pre-avulsion elevation given the amount of material removed by past mining. The objective would be to determine the amount of fill and grading necessary to achieve meaningful habitat improvement, and to determine whether there is enough material available on or near the site. The lateral extents of grading will also need to be determined, including interface with the BPA powerline towers. Sediment transport modeling could be used to help understand the effects of this alternative on sediment transport and aggradation within the pits reach compared to the No Action (existing conditions) alternative.

Side-channel re-connections – This scenario would include increasing flows in the two prominent right bank side-channel alignments in the Lower Daybreak reach. This would be accomplished using select excavation in the side-channel alignments as well as mainstem log jams to raise/divert water into the side-channels. The objective would be to understand the amount of grading and log jam work that would be necessary to achieve perennial connectivity.

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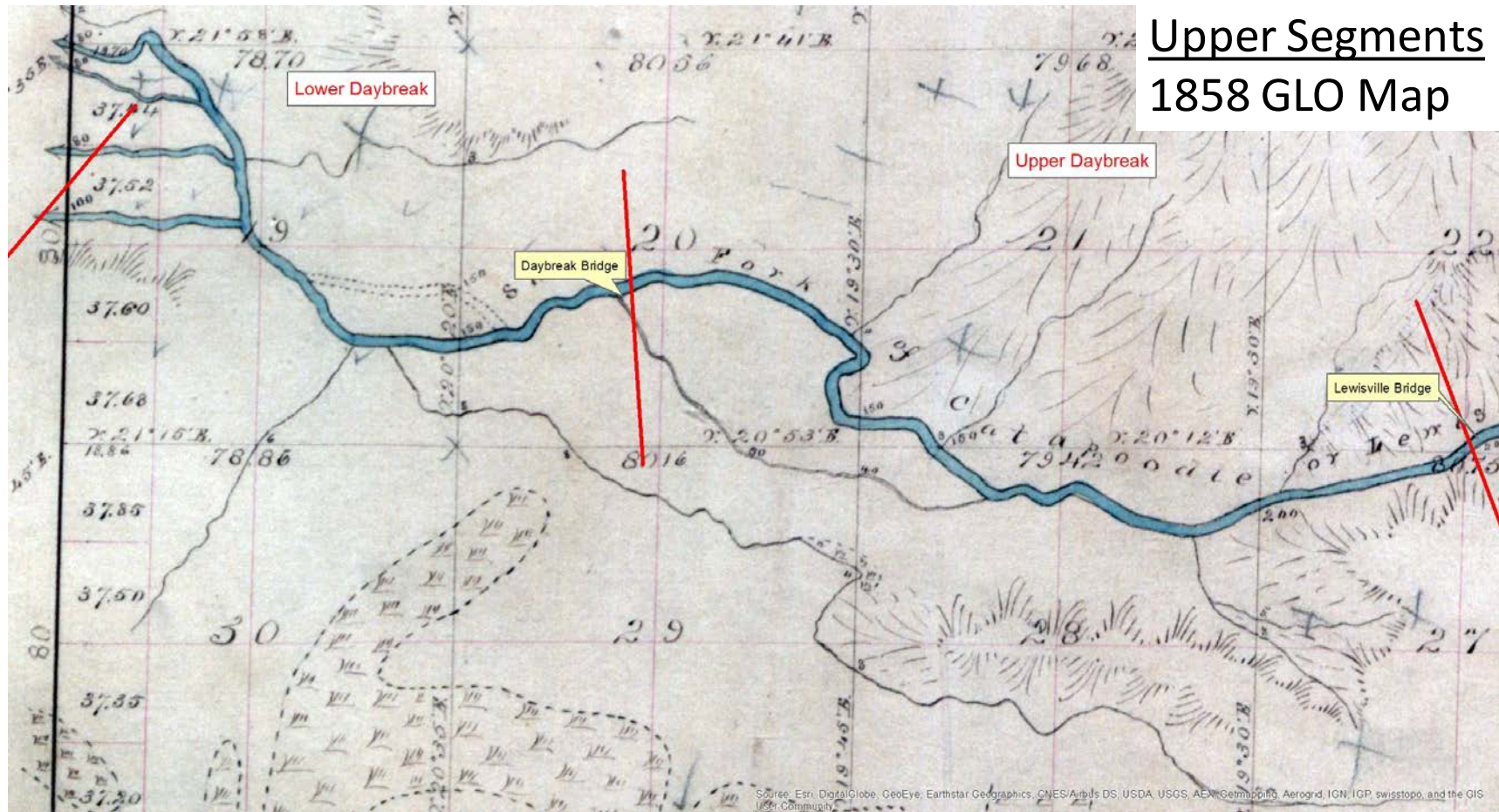
9. Appendices

APPENDIX A – HISTORICAL MAPS AND PHOTOS

APPENDIX B – PIT FILLING PHOTO ANALYSIS

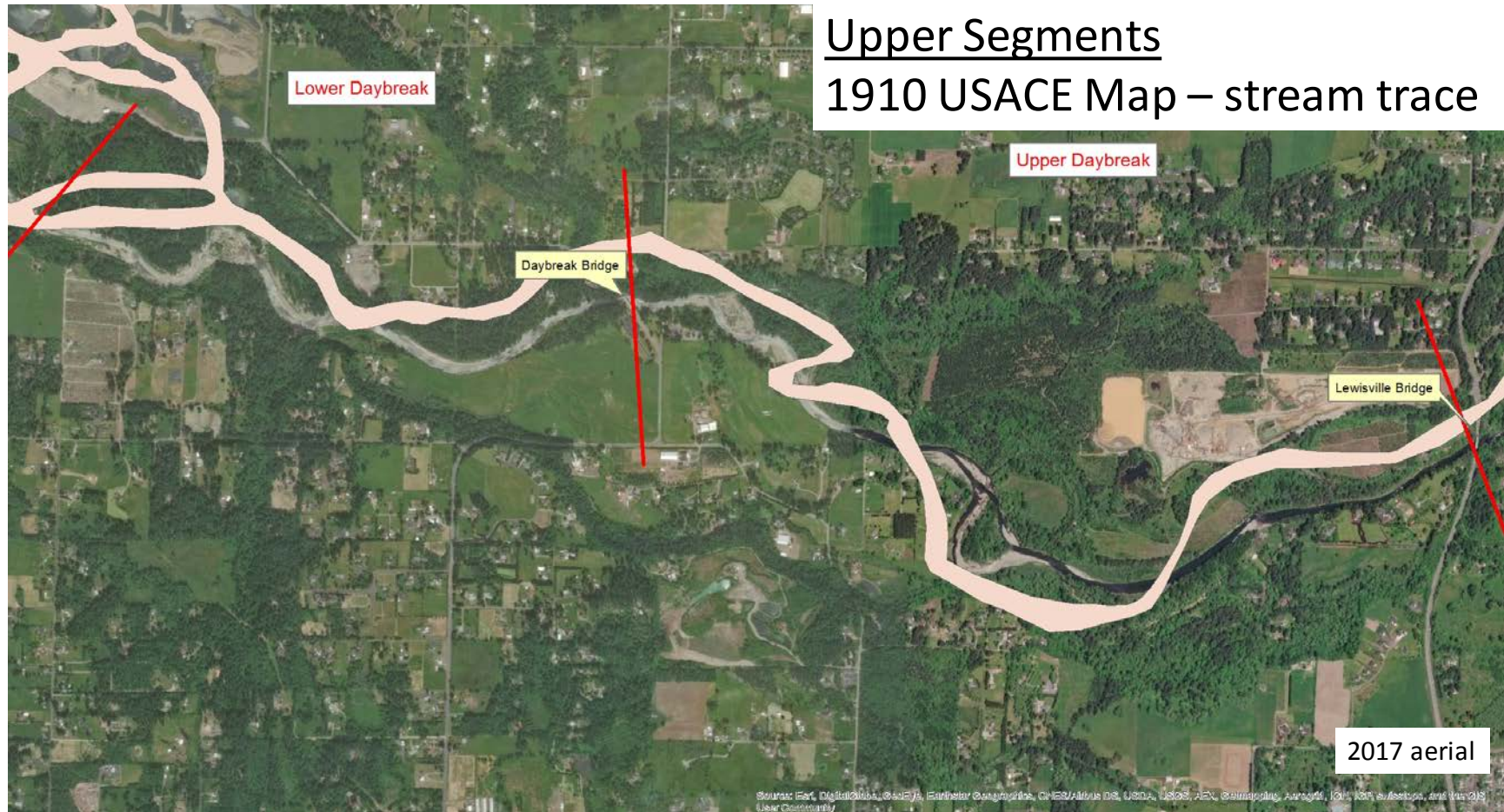
Appendix A. Historical Maps and Air Photos

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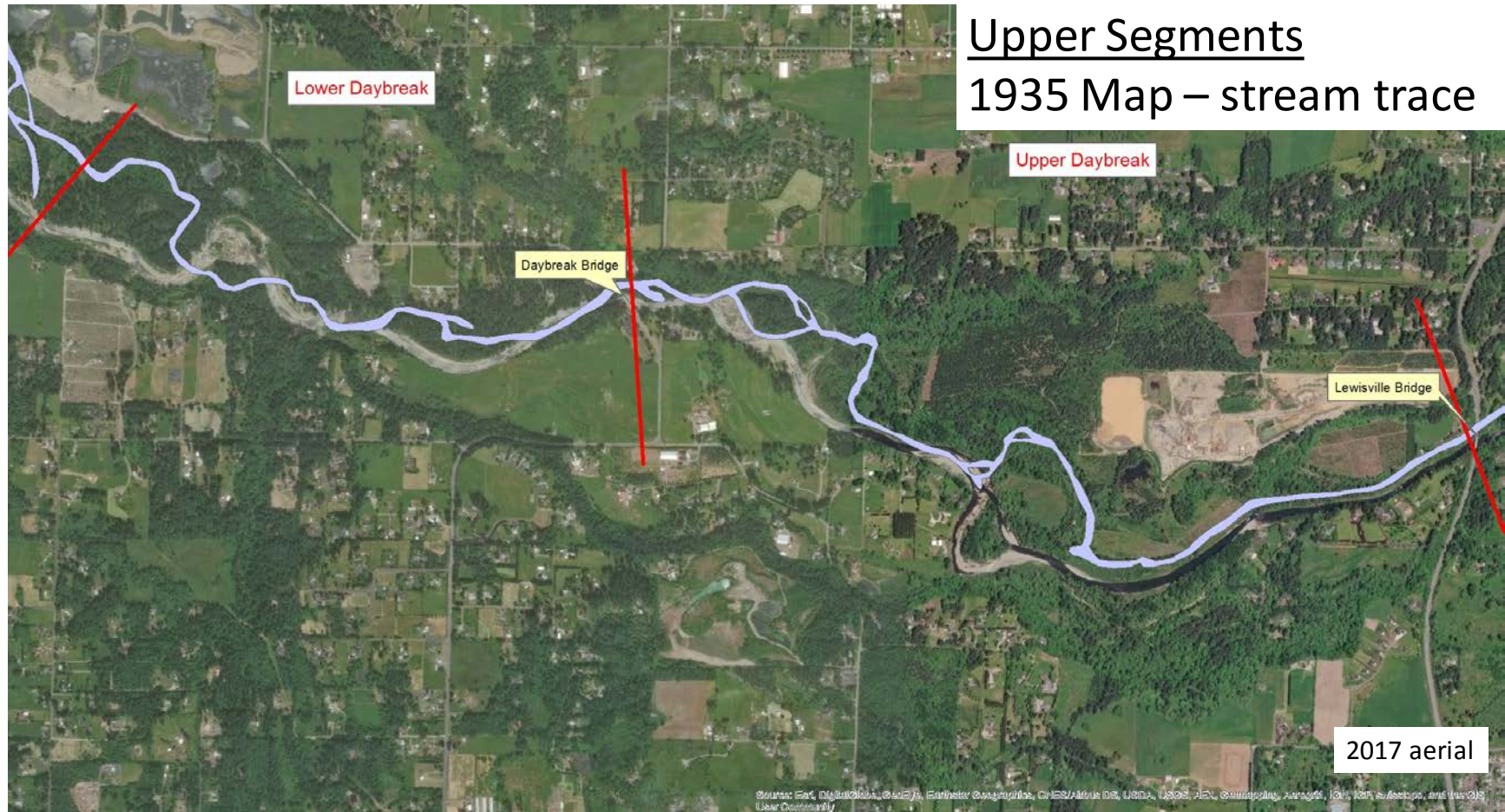
Upper Segments

1910 USACE Map – stream trace

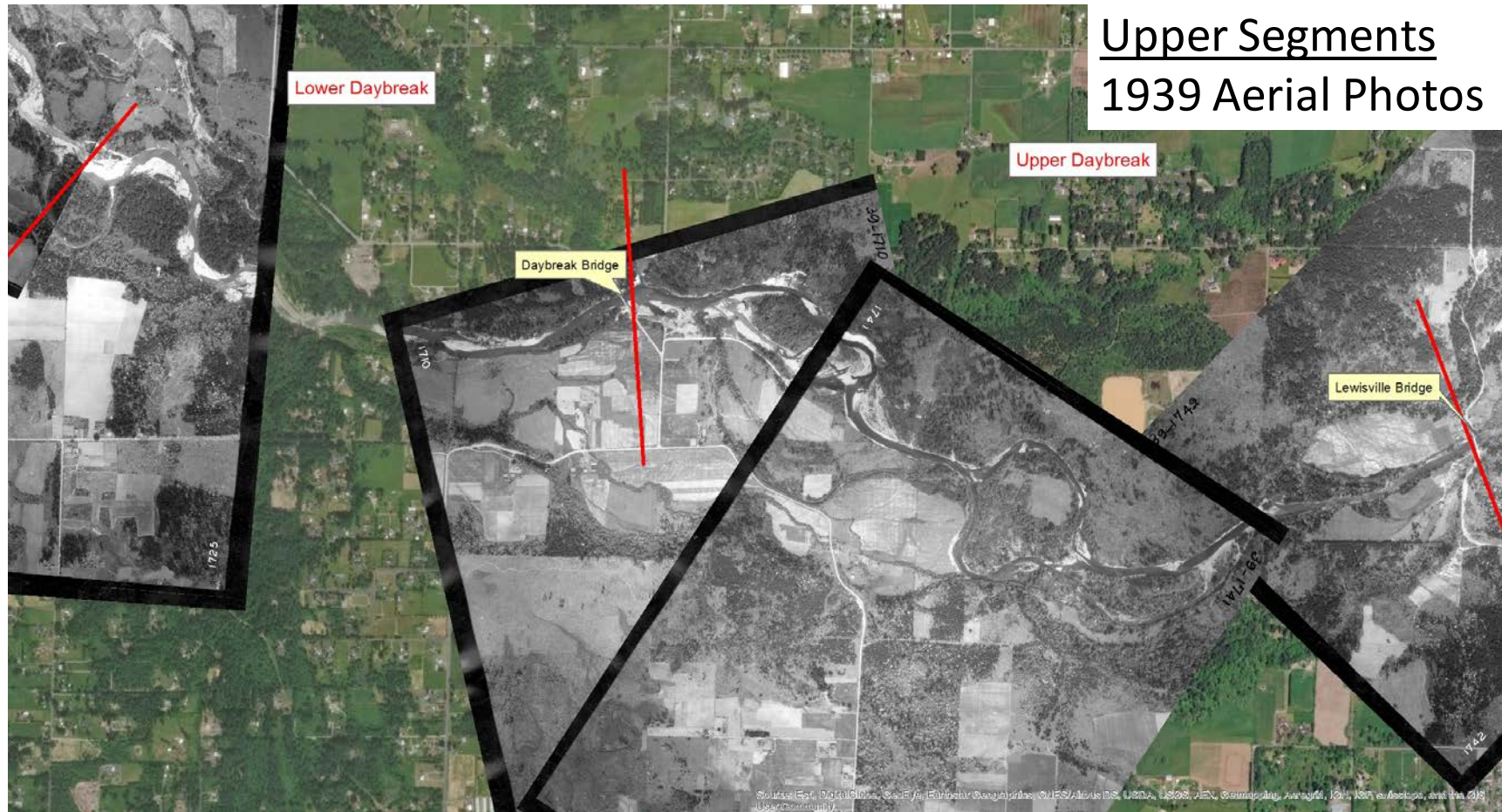


Upper Segments

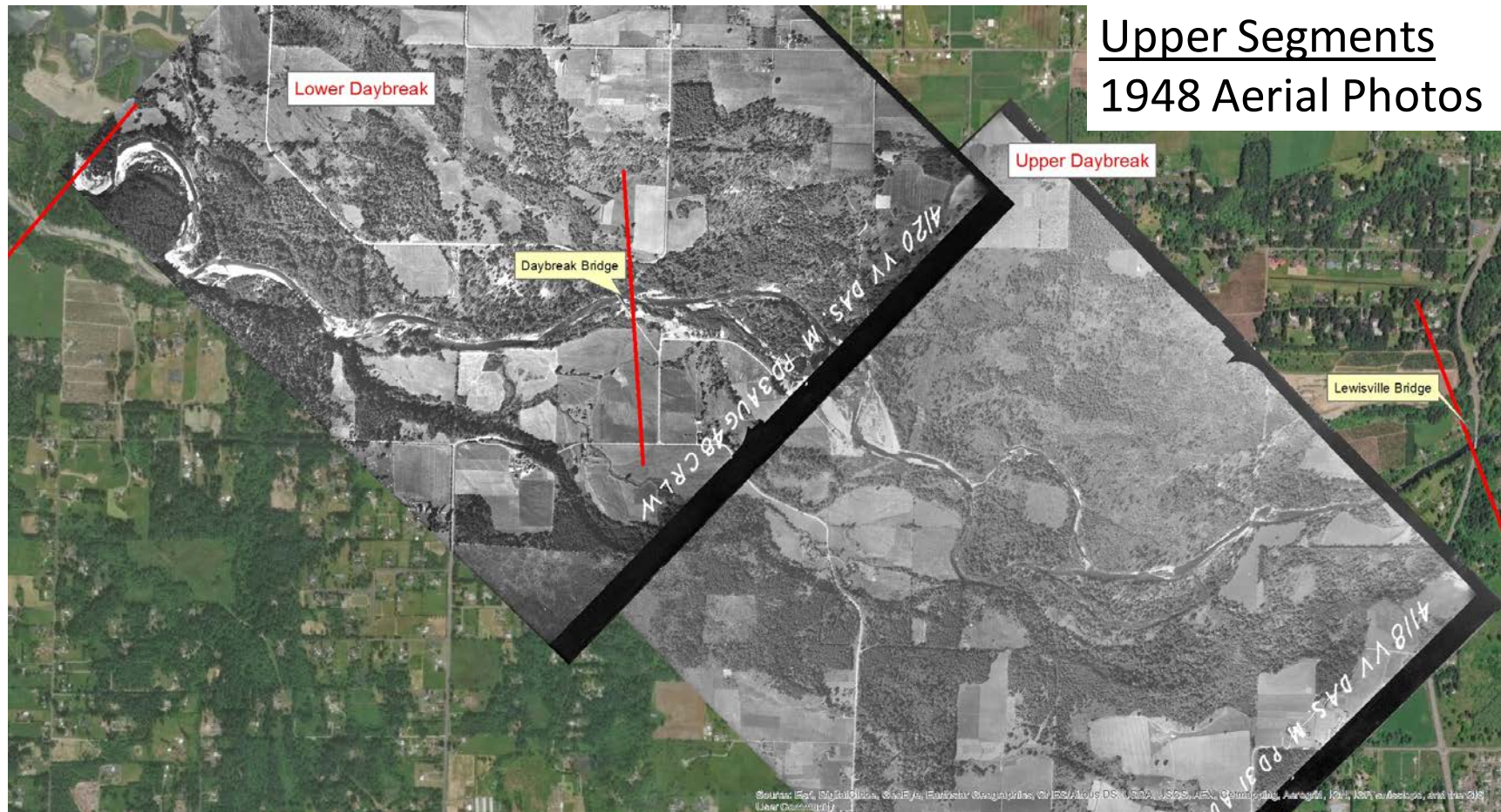
1935 Map – stream trace



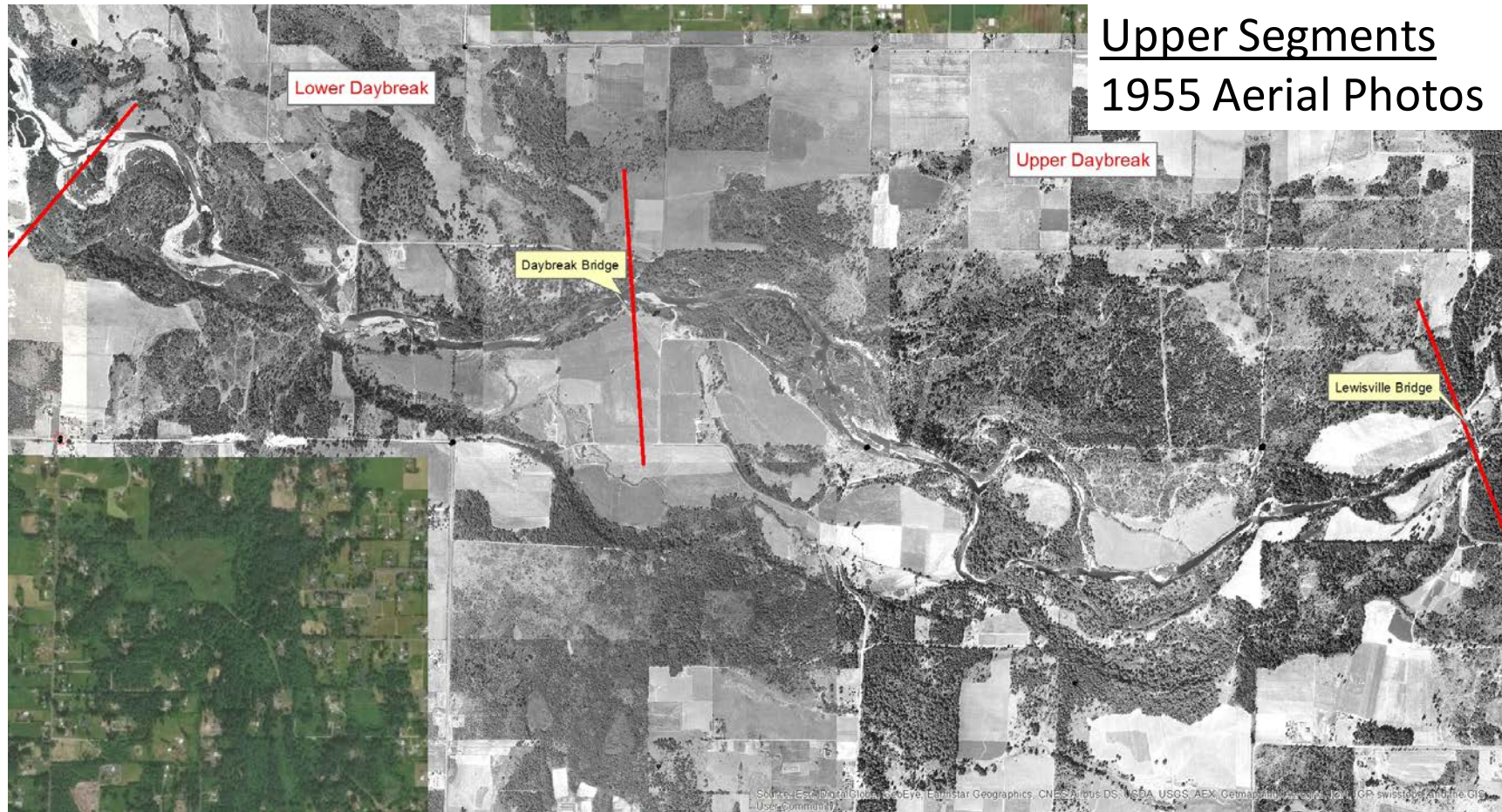
Upper Segments 1939 Aerial Photos



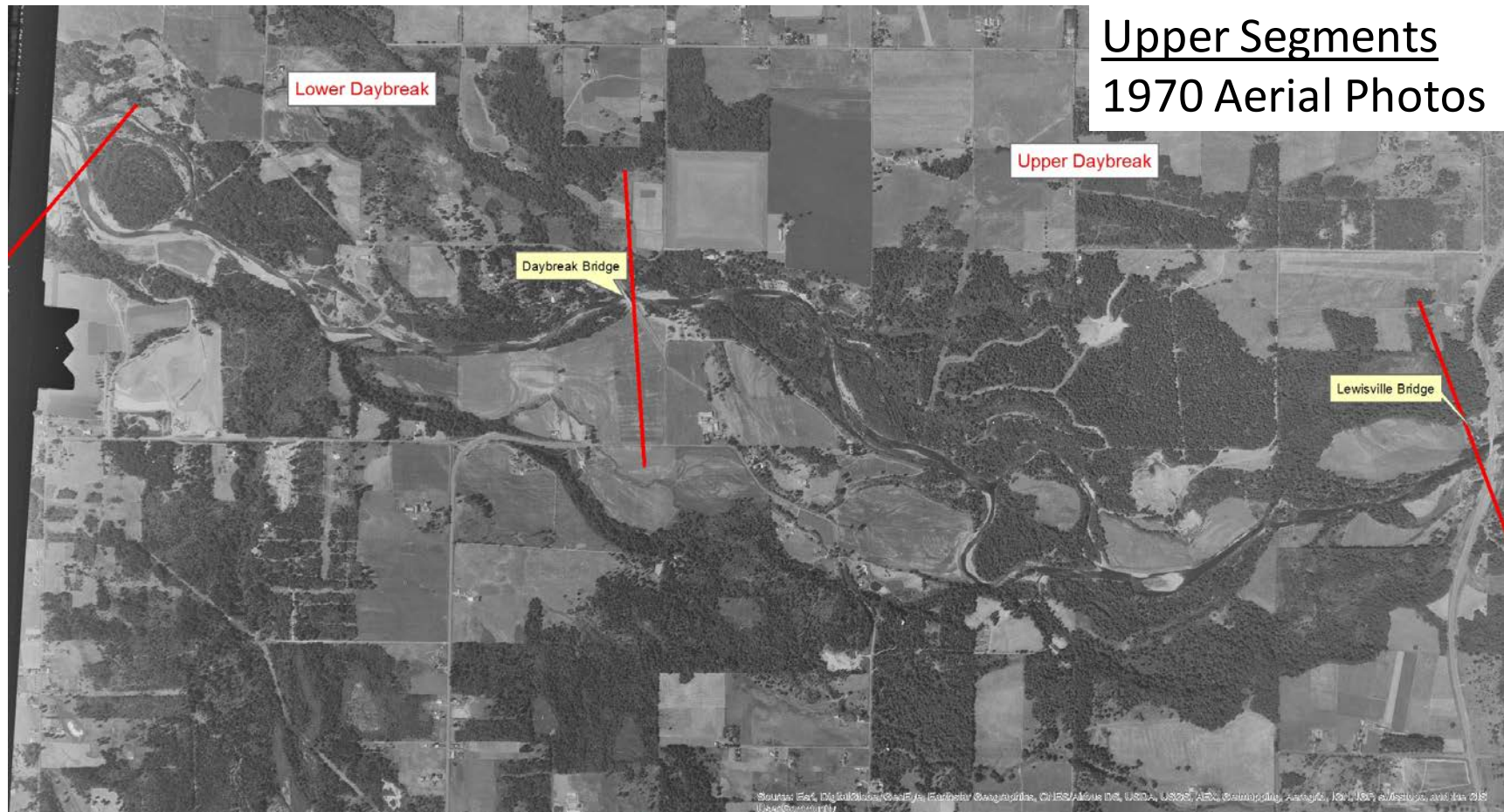
Upper Segments 1948 Aerial Photos



Upper Segments 1955 Aerial Photos



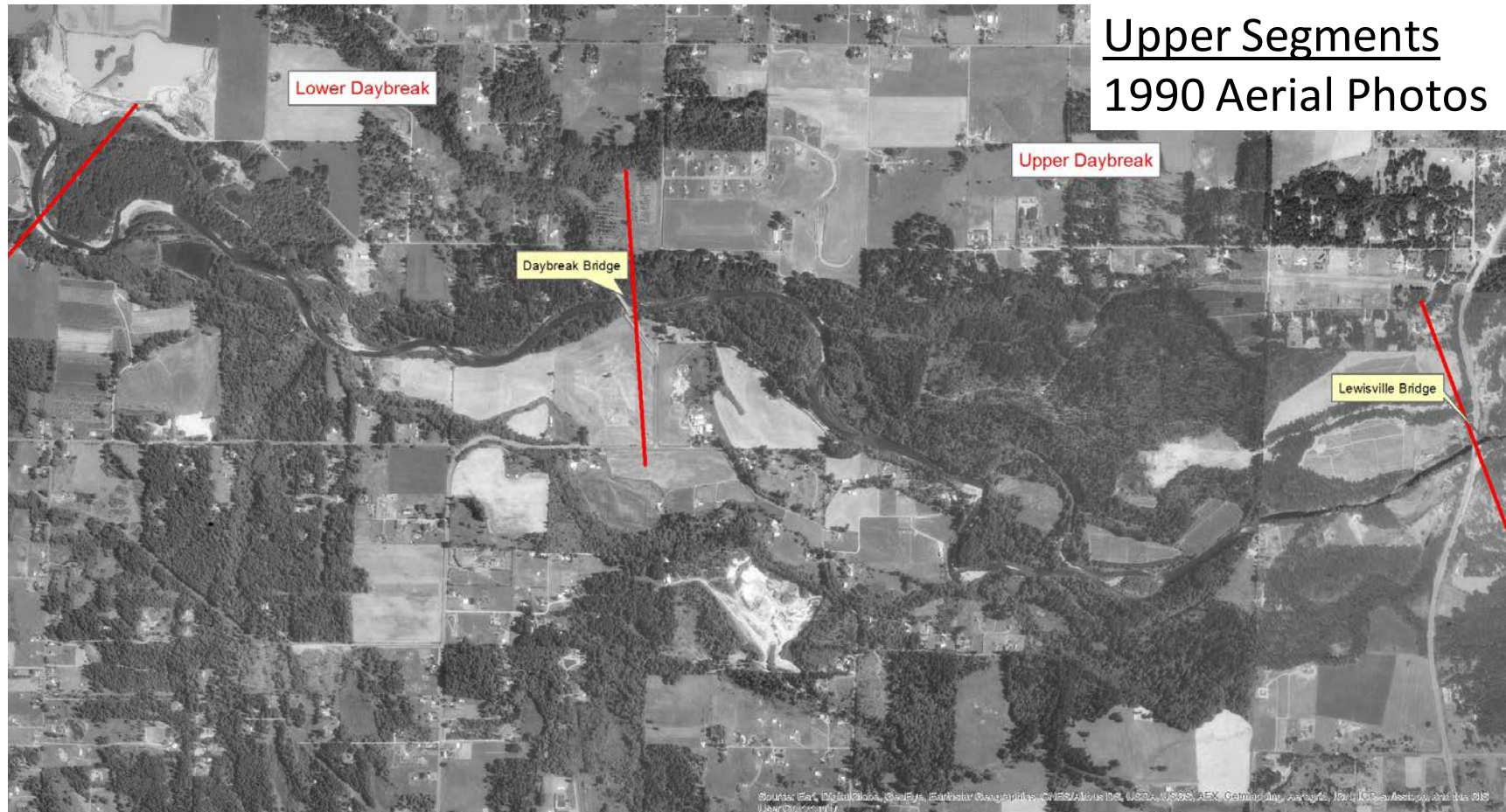
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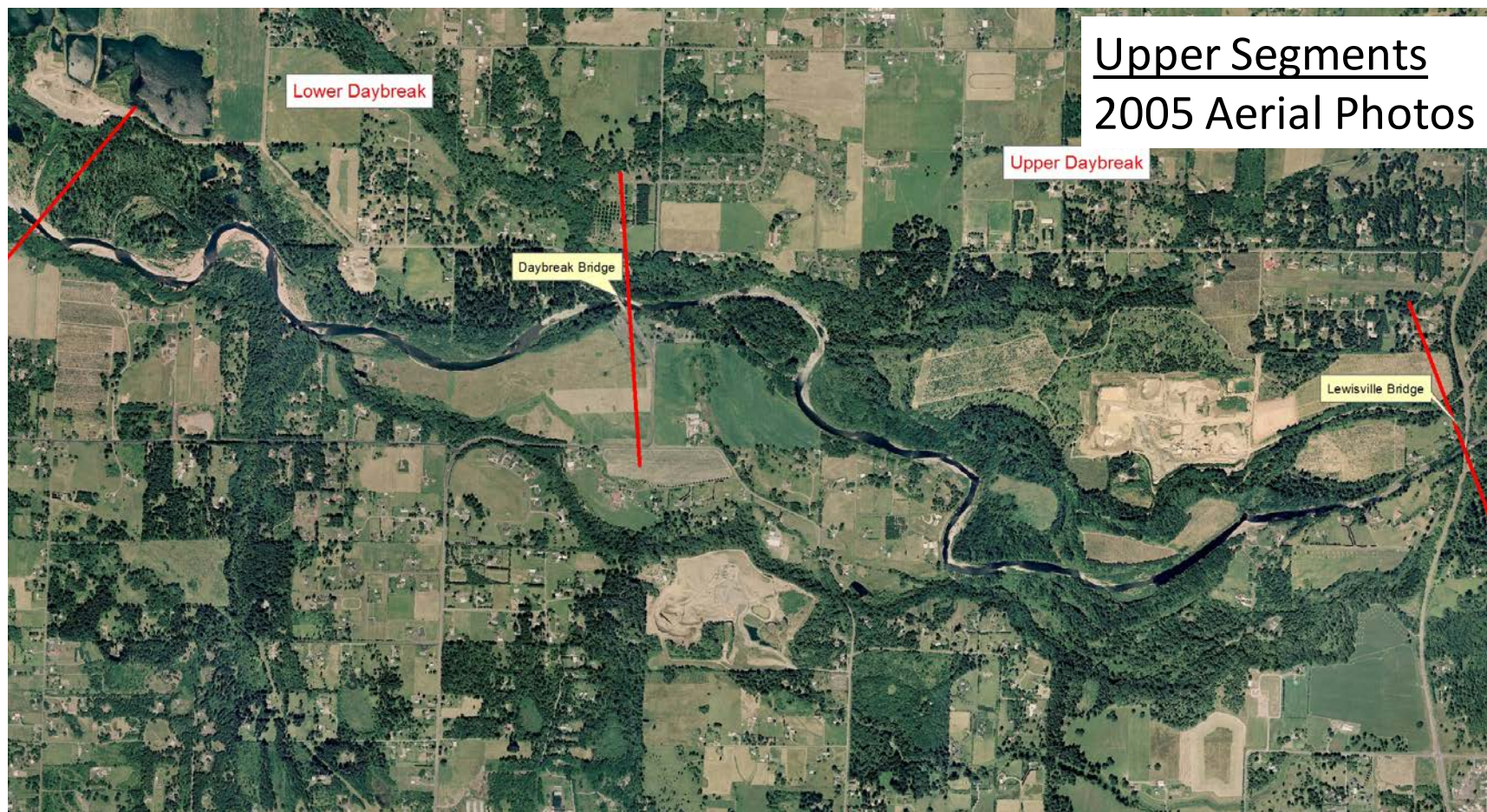


Upper Segments 1975 Aerial Photos



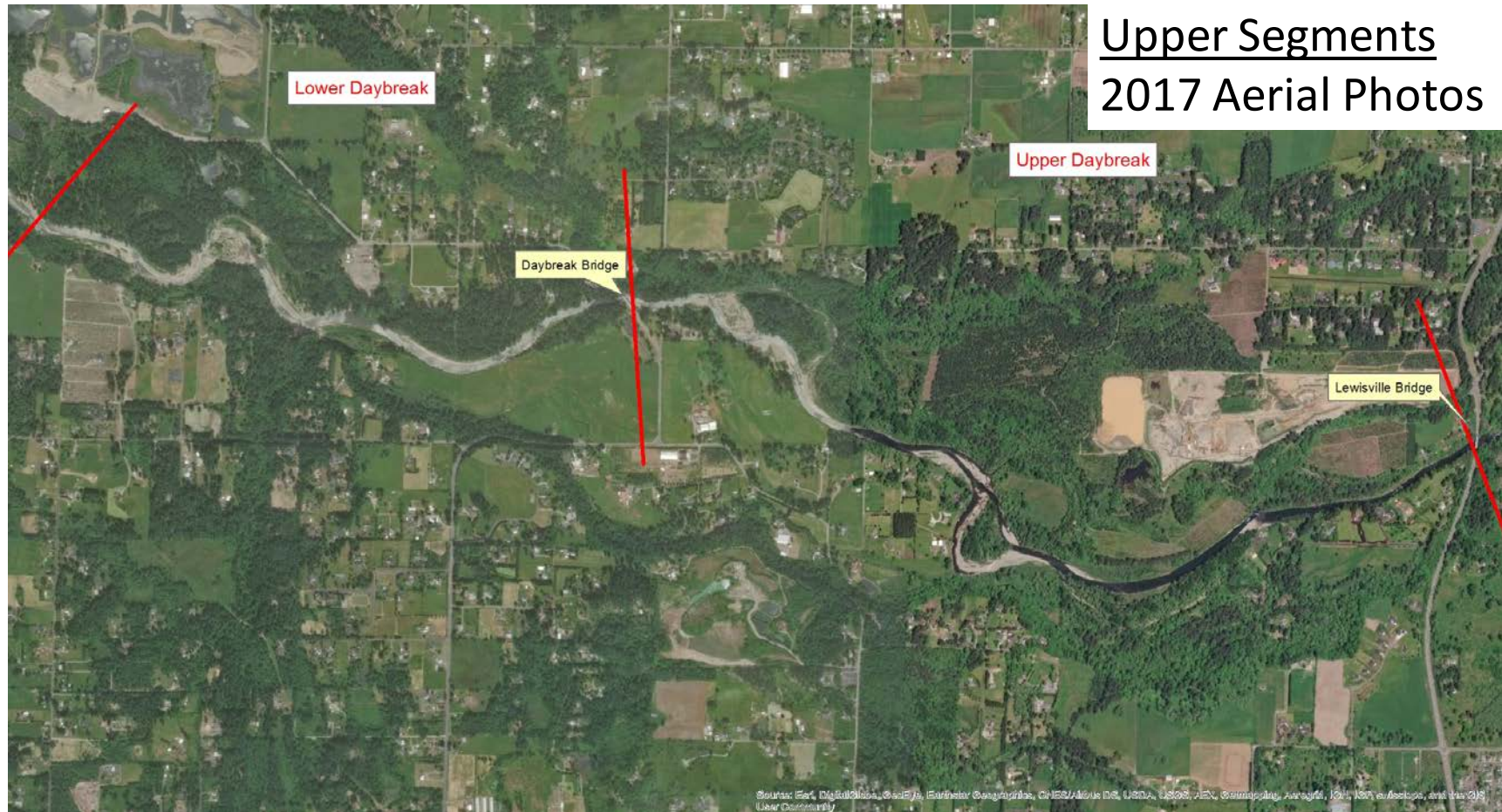
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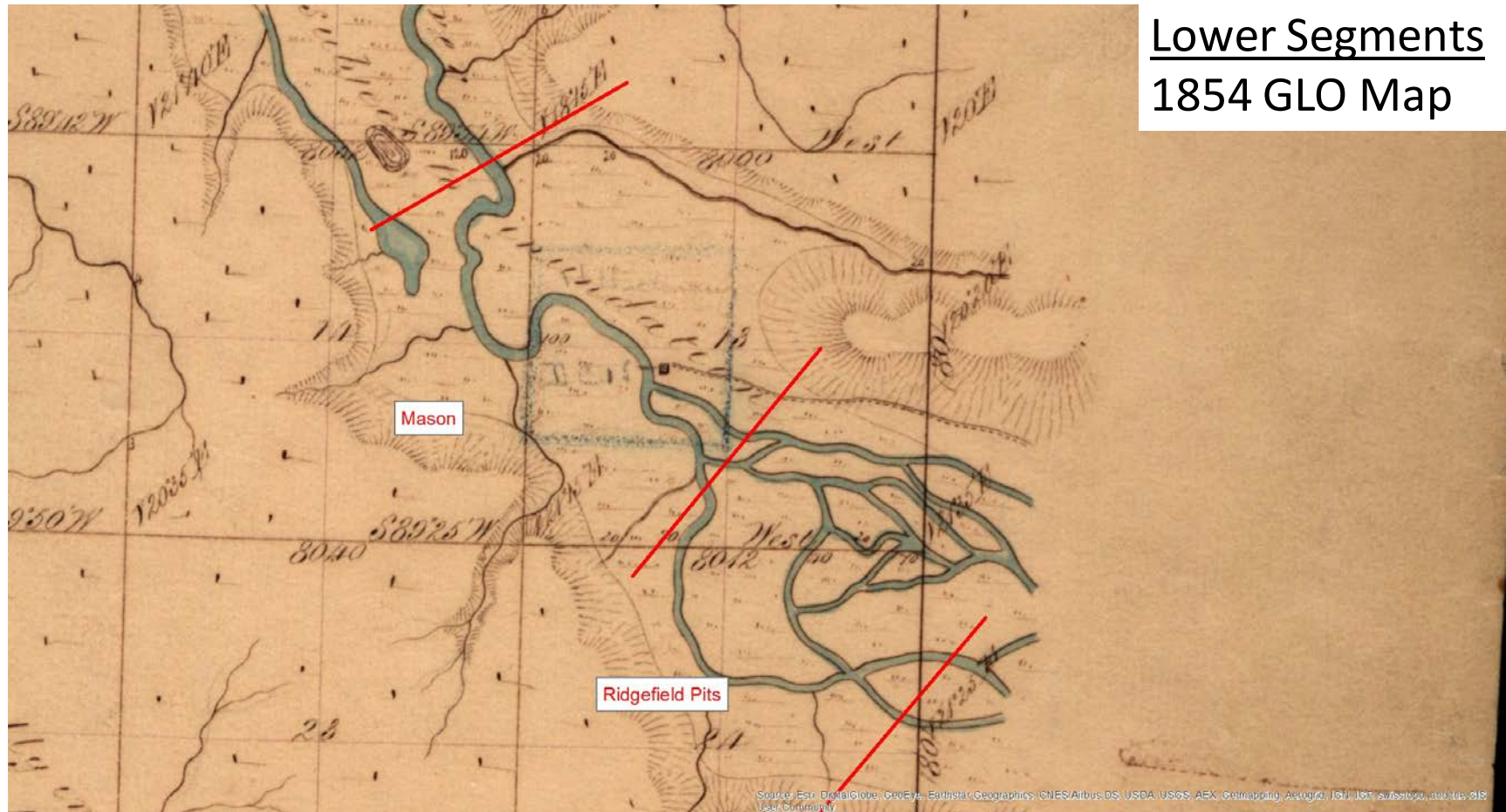


Upper Segments 2005 Aerial Photos

Upper Segments 2017 Aerial Photos

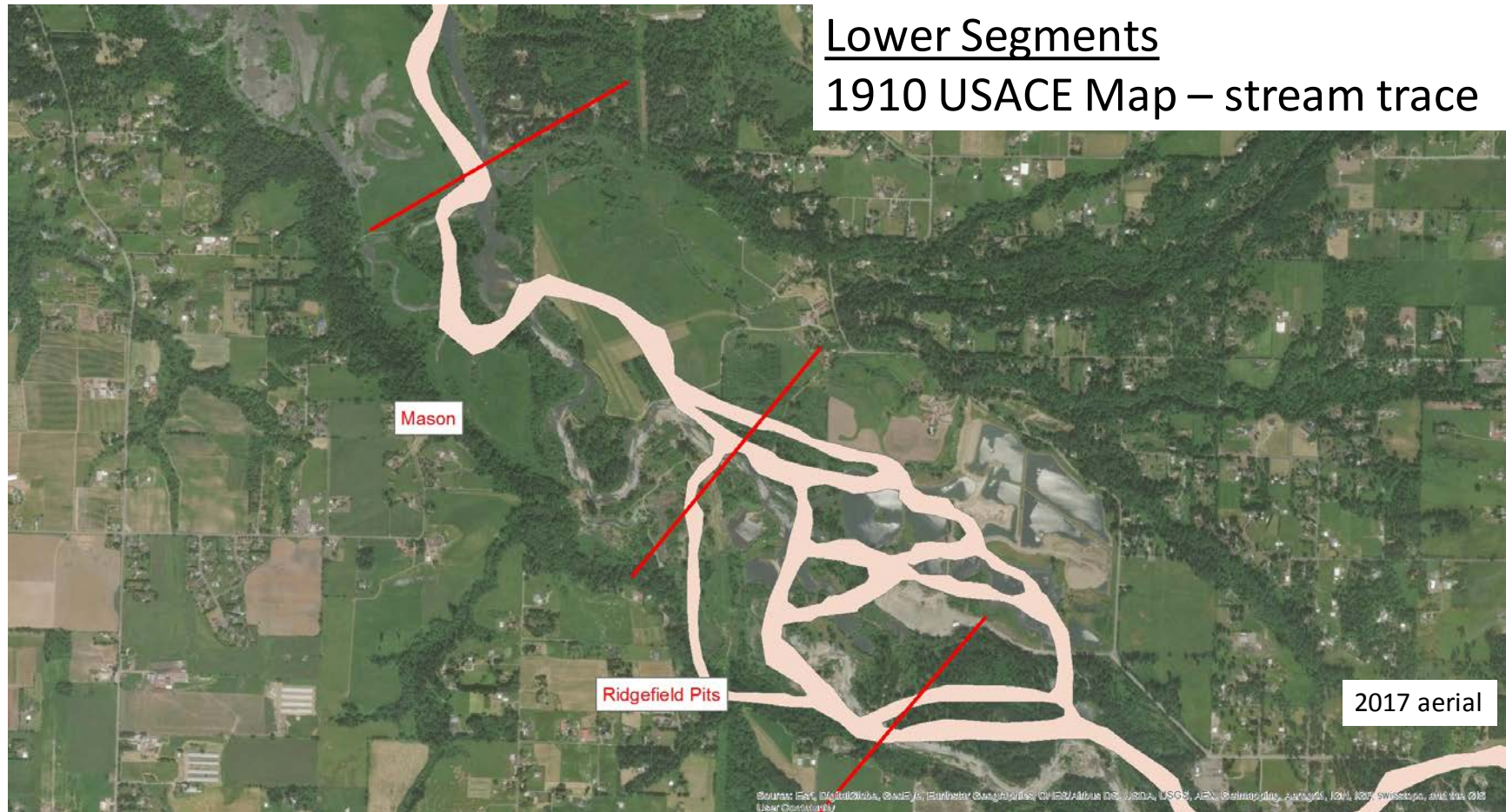


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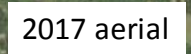


Lower Segments

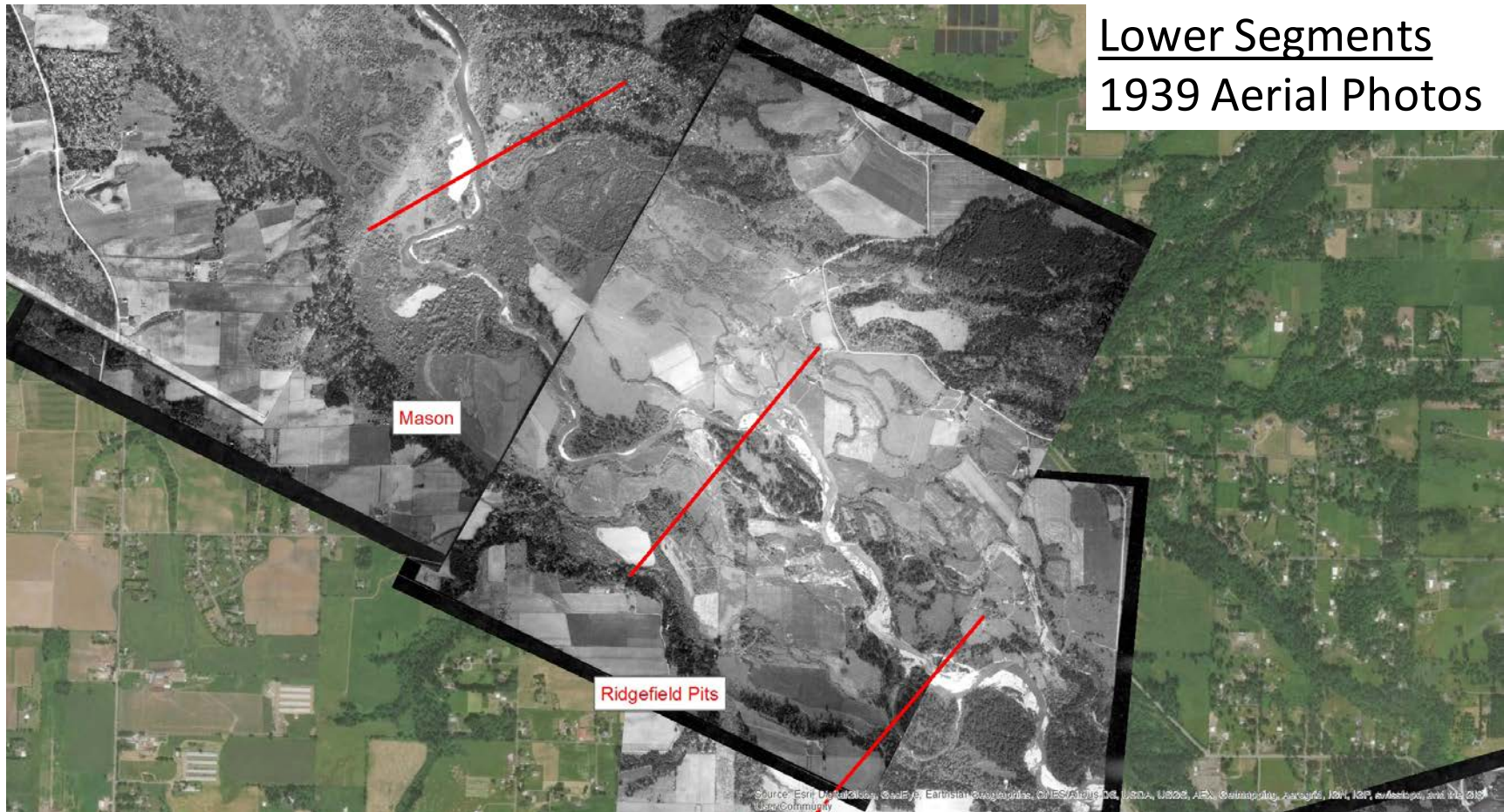
1910 USACE Map – stream trace



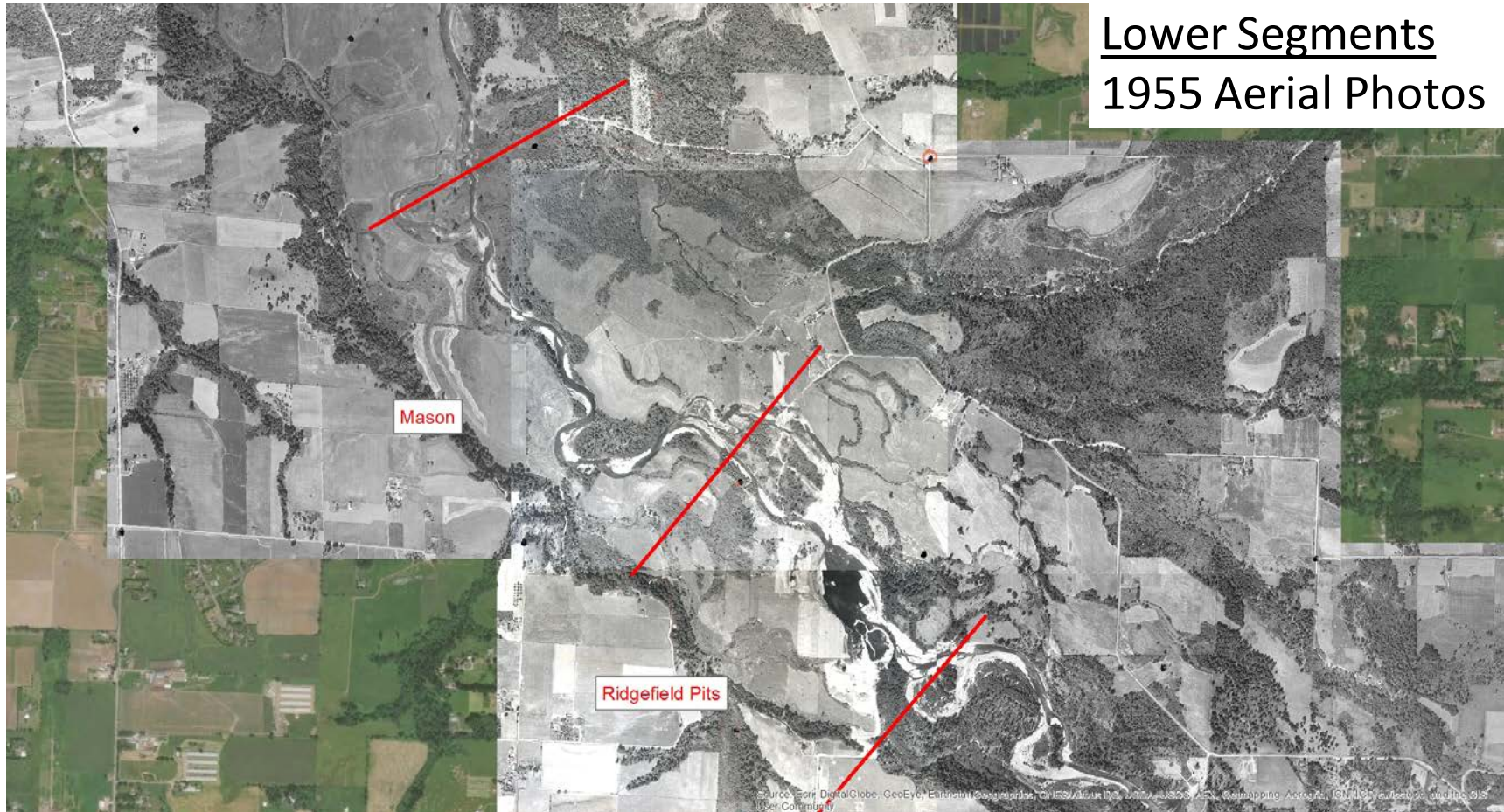
1935 Map – stream trace



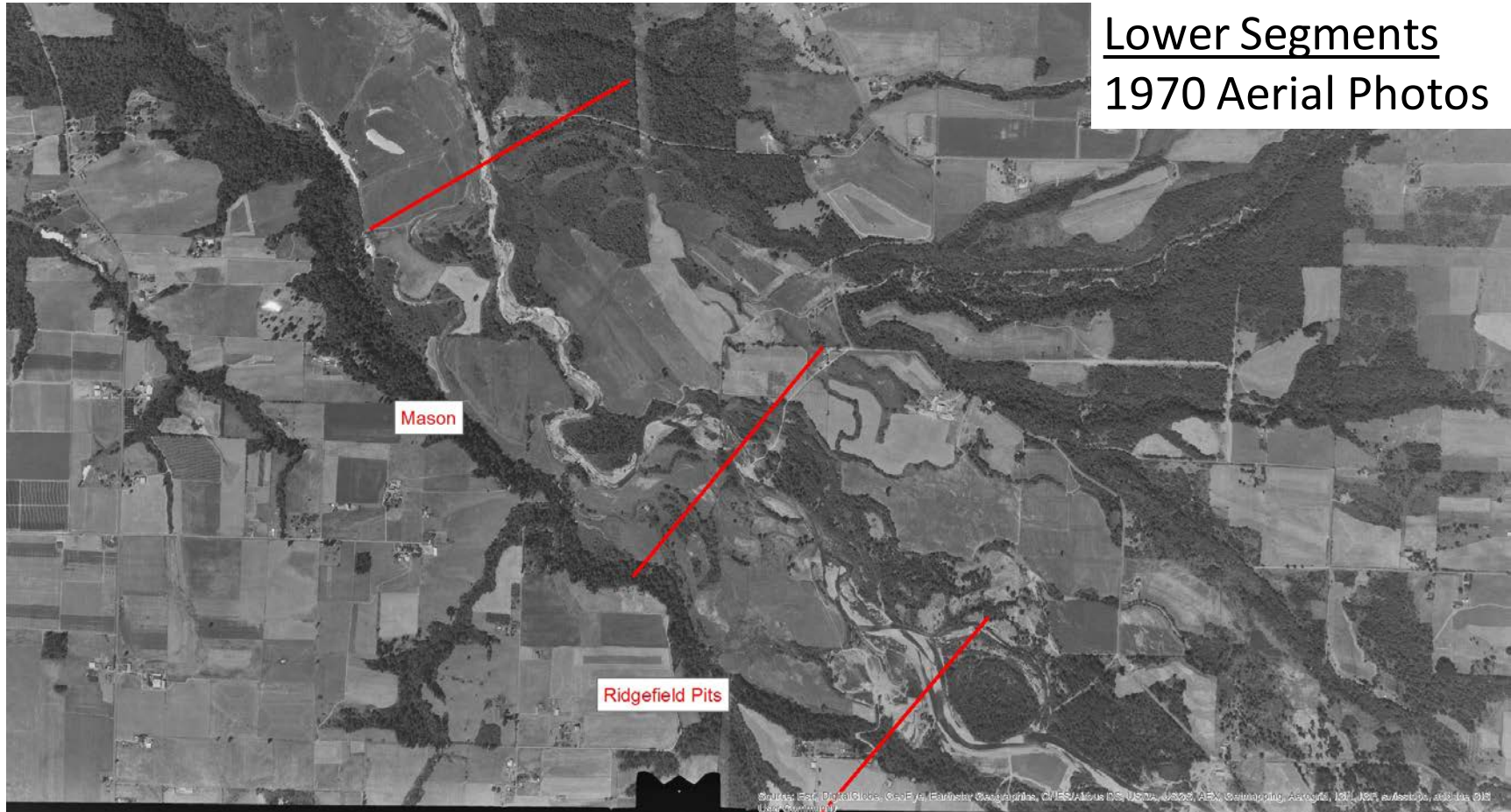
Lower Segments 1939 Aerial Photos



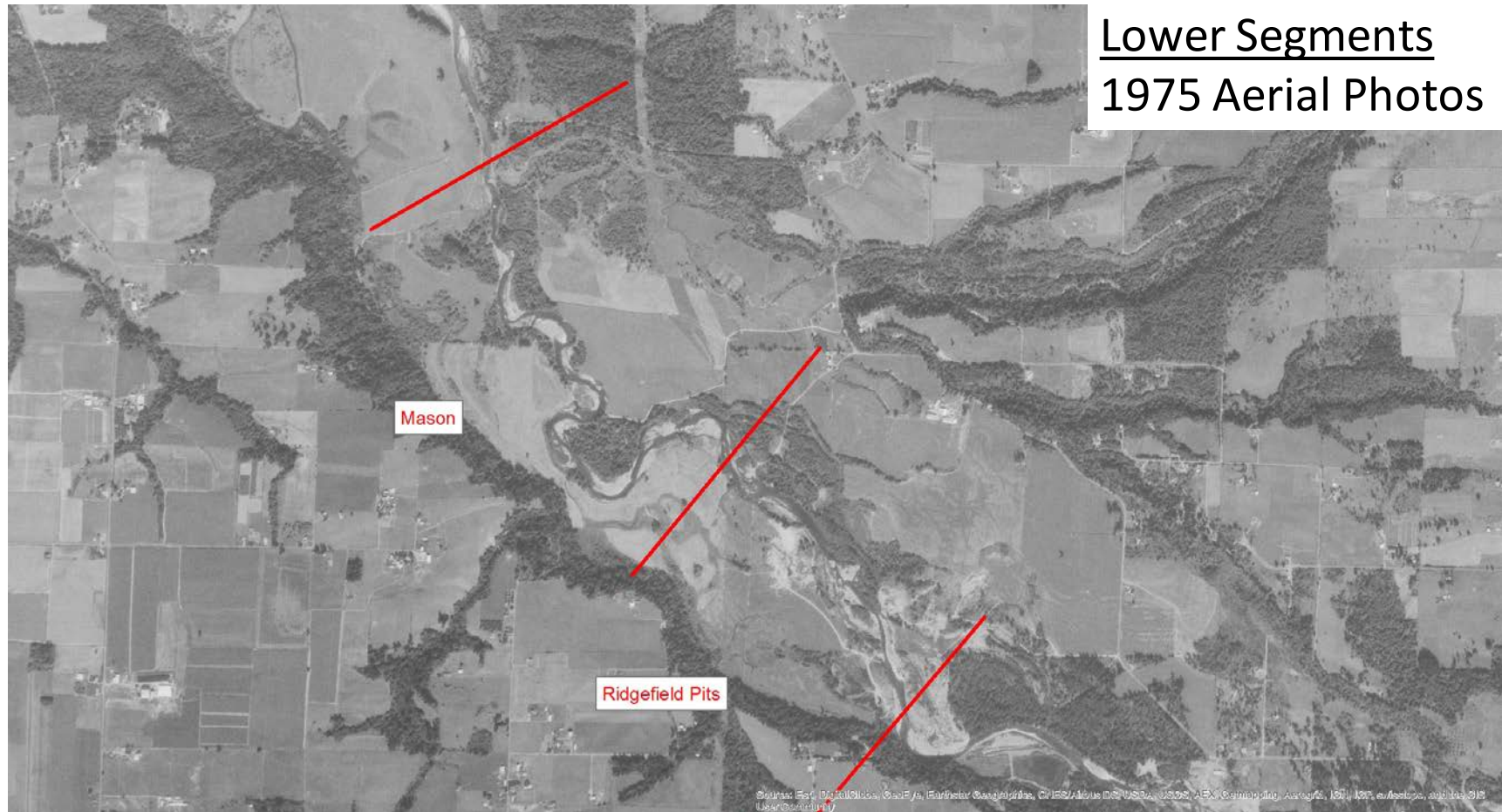
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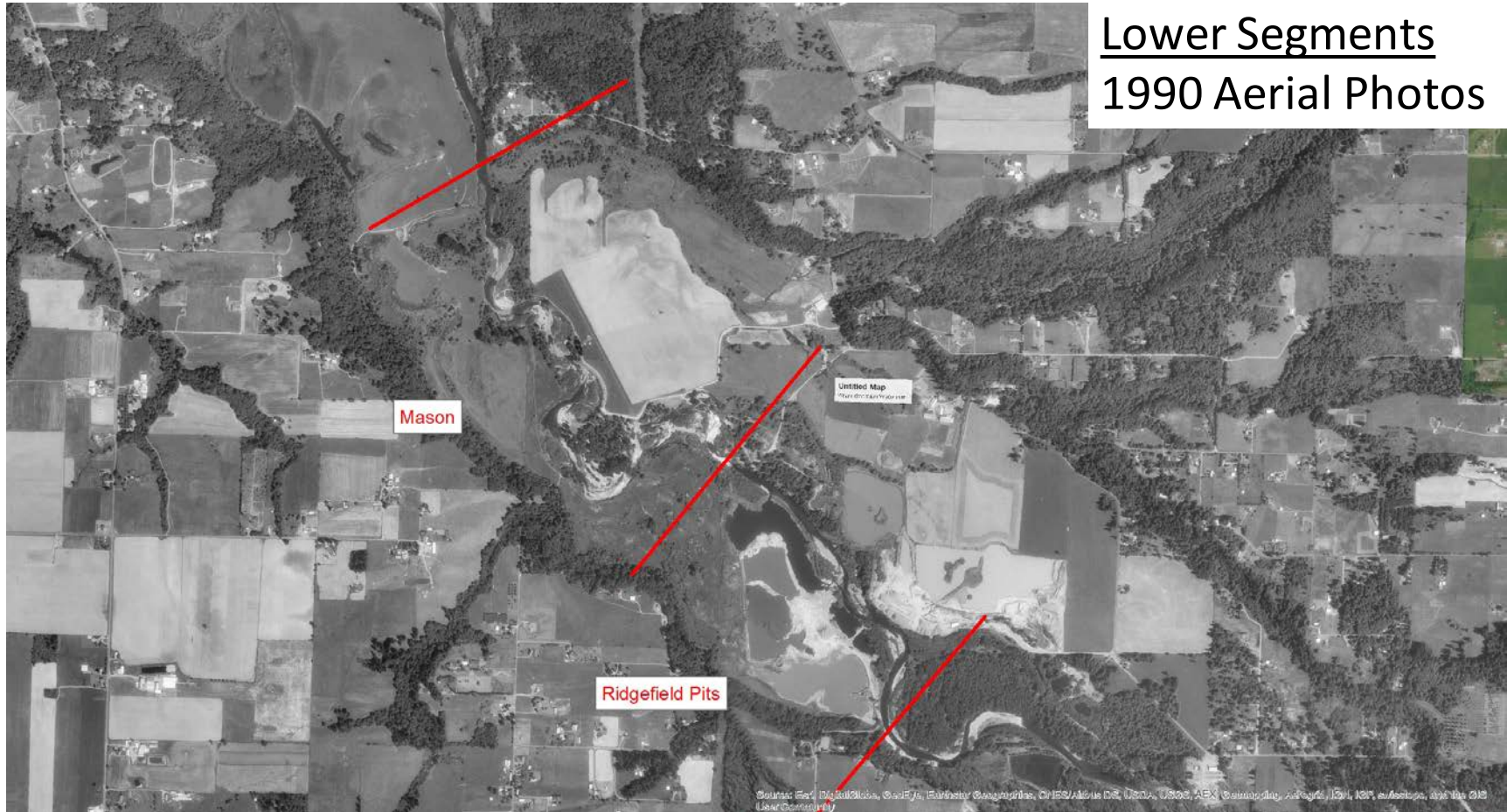
Lower Segments 1970 Aerial Photos



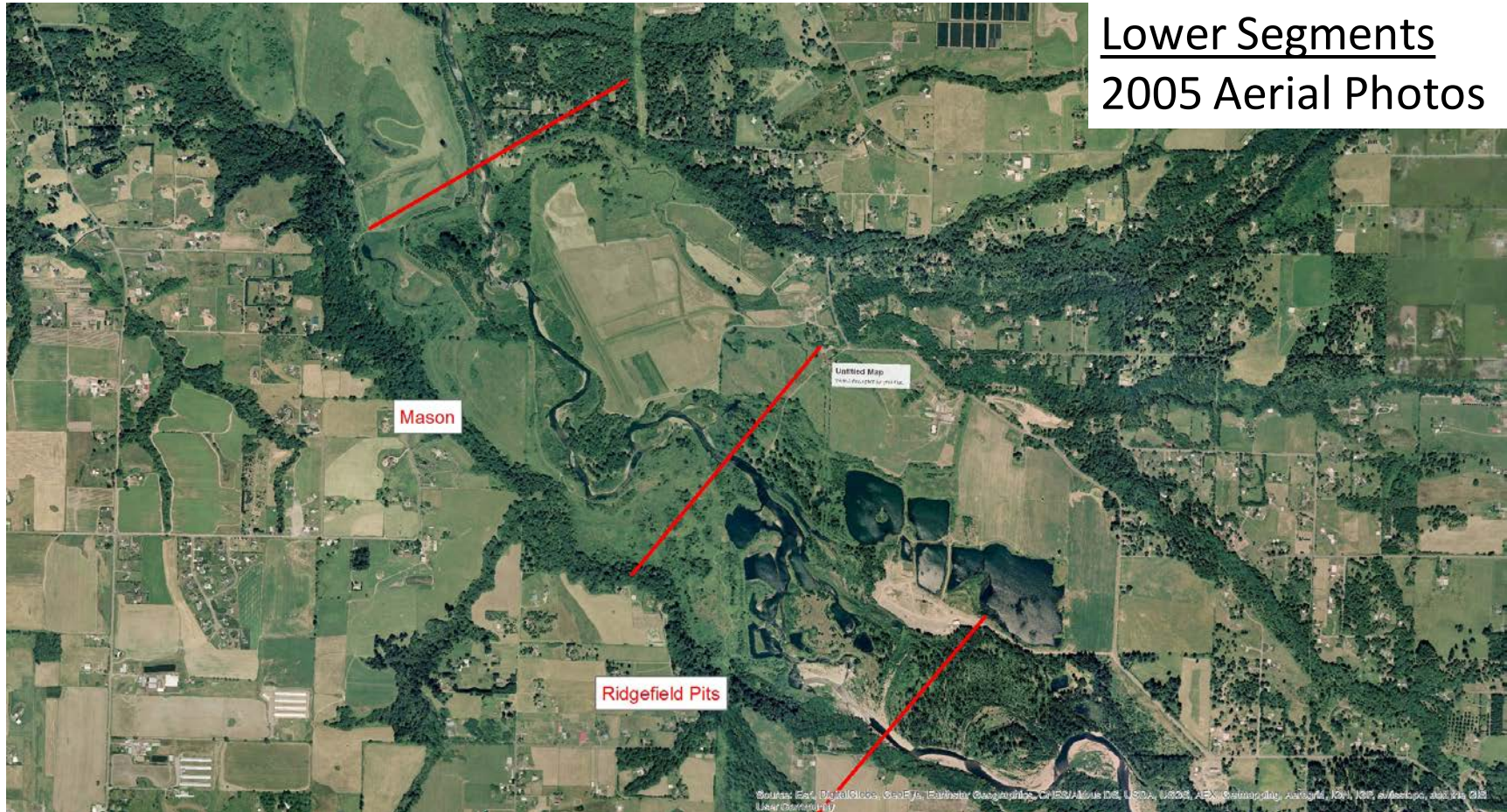
Lower Segments 1975 Aerial Photos



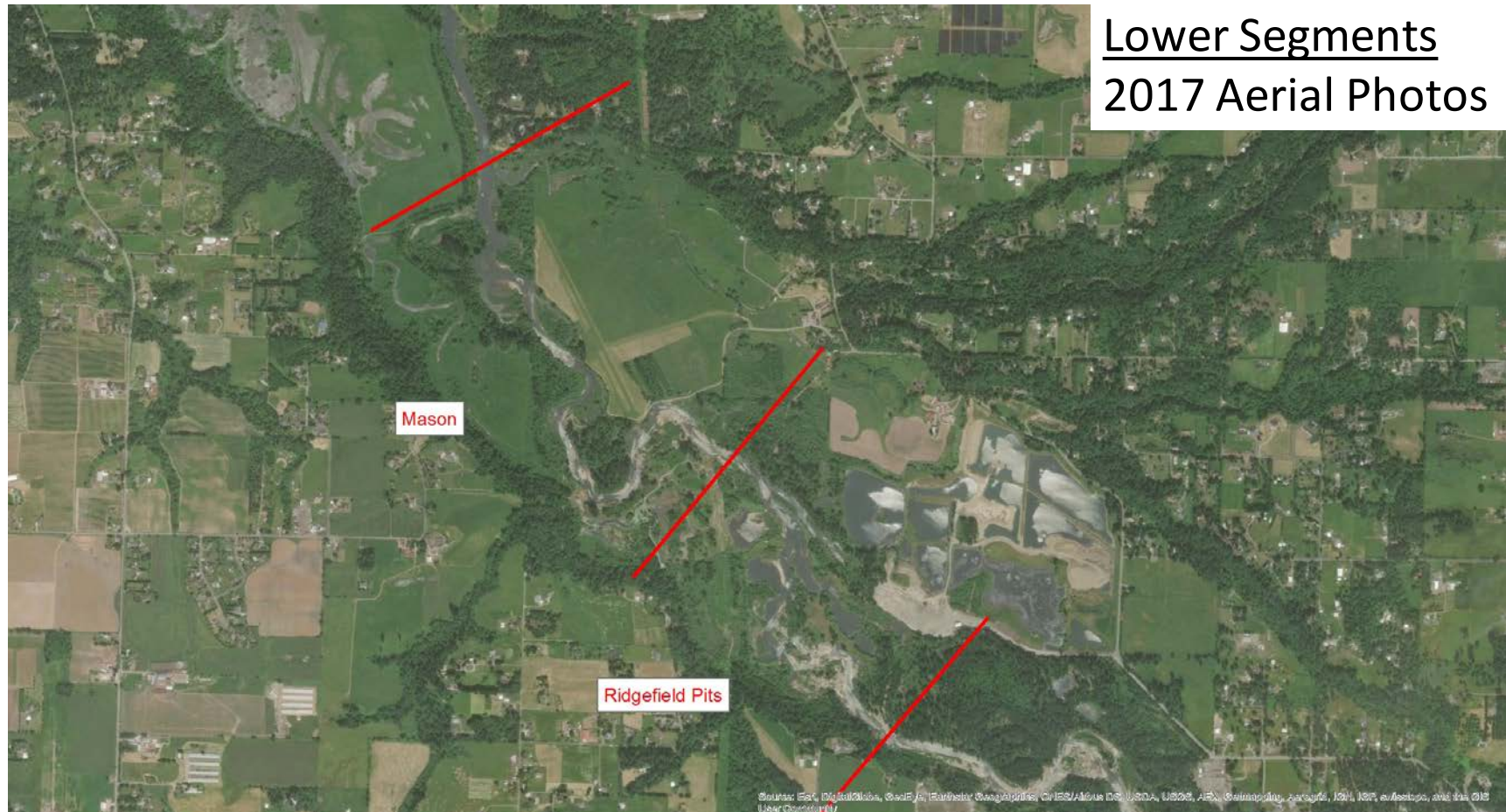
Lower Segments 1990 Aerial Photos



Lower Segments 2005 Aerial Photos



Lower Segments 2017 Aerial Photos

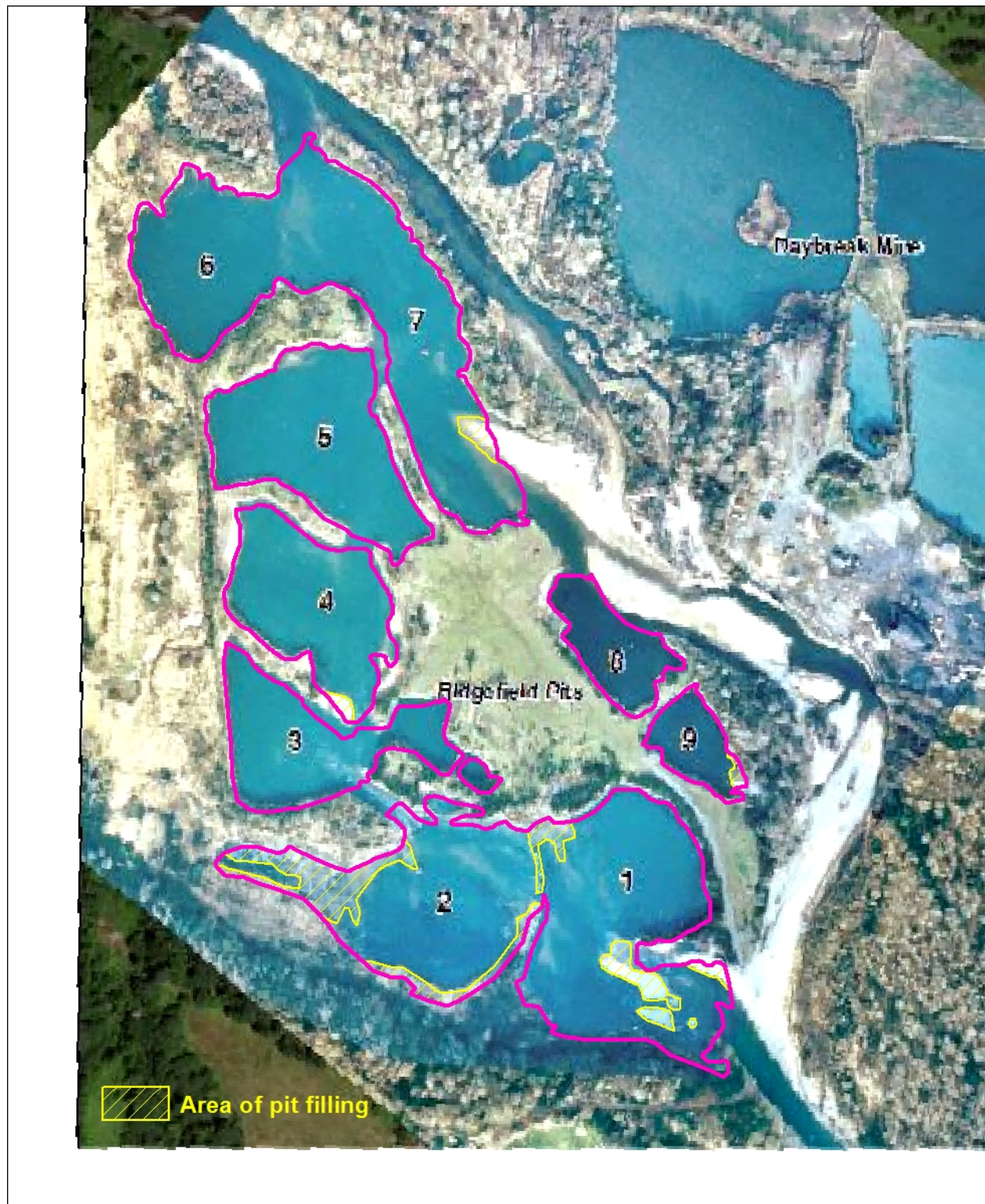


Appendix B. Air Photo Series of Pit Filling

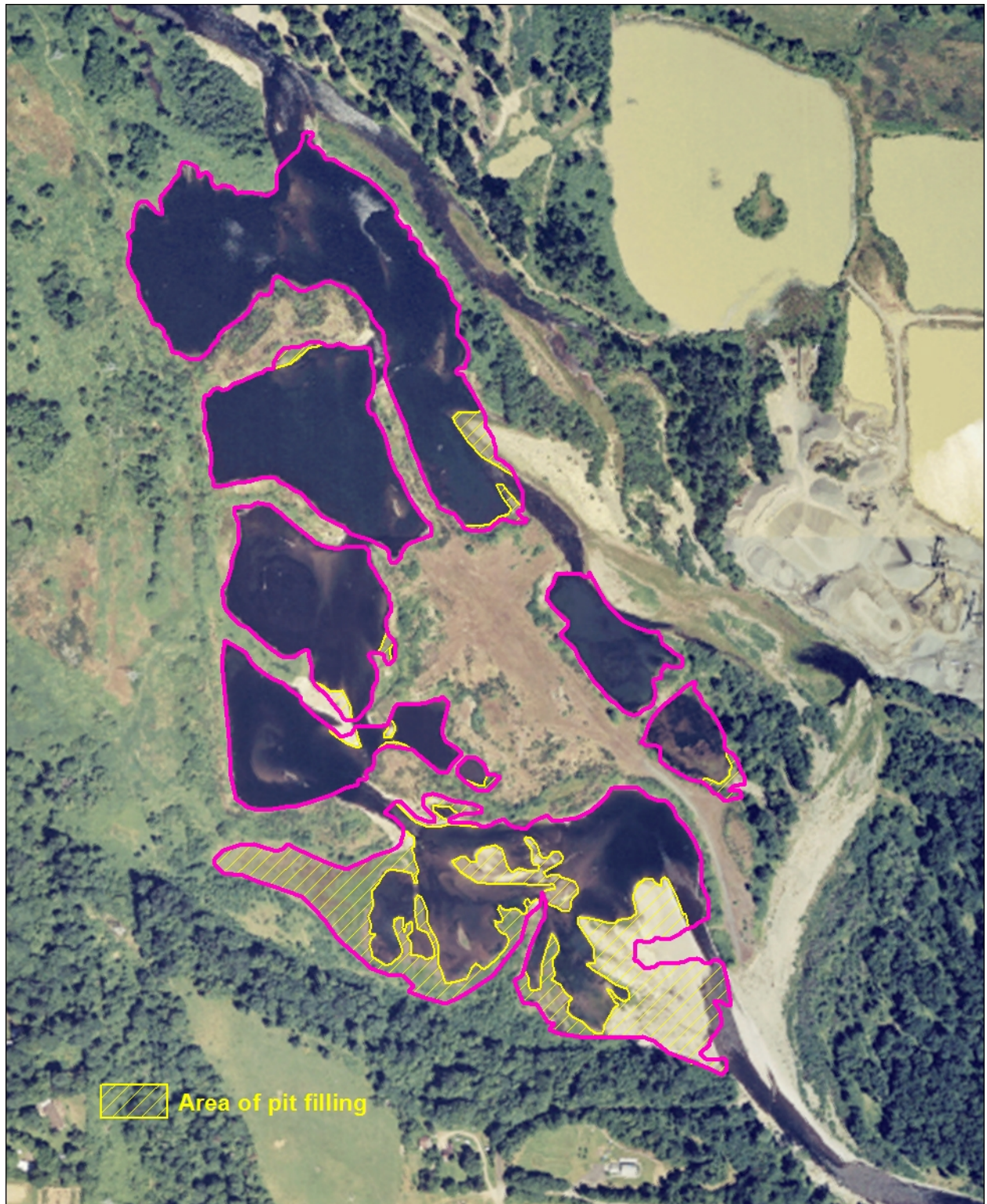
1994



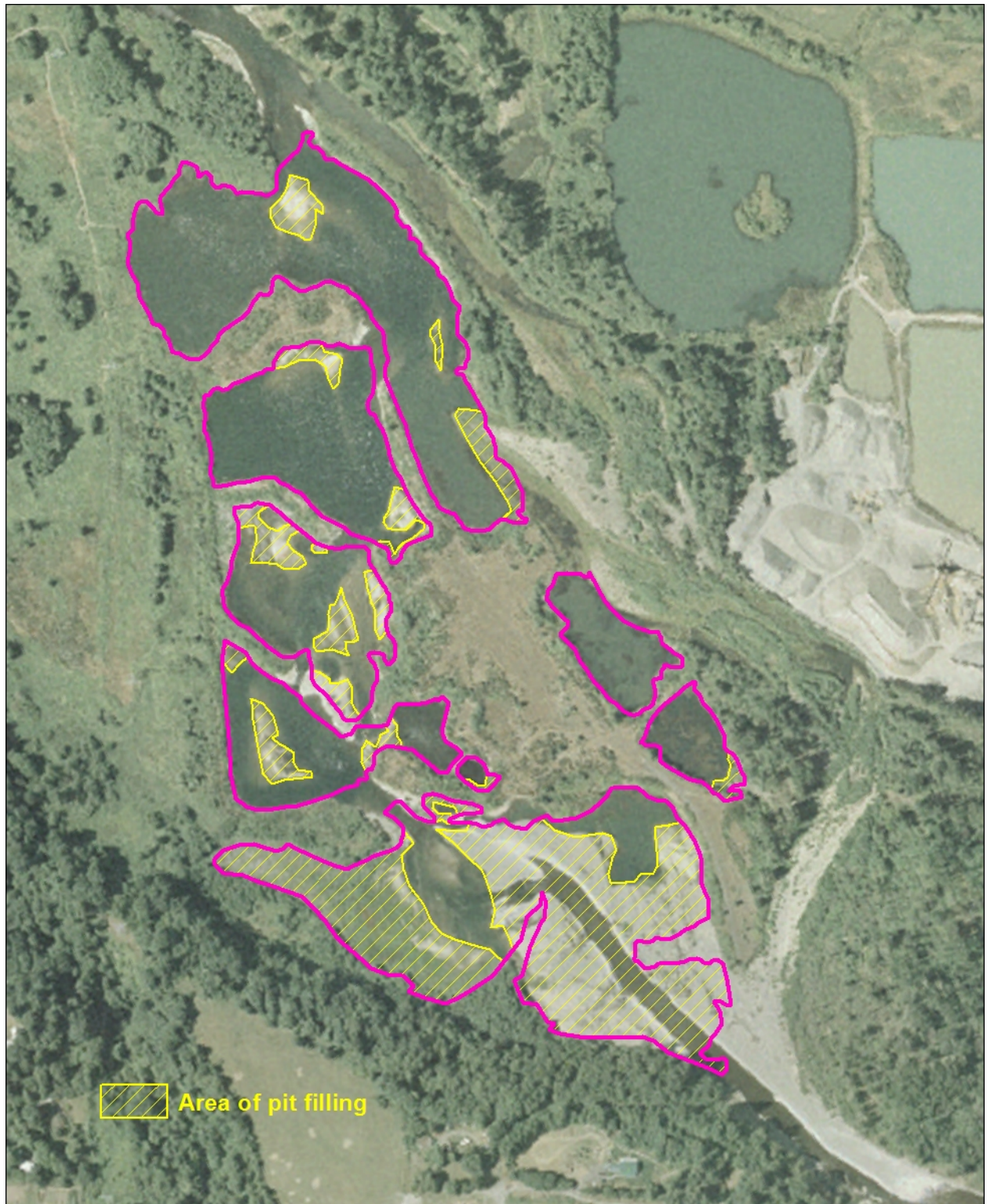
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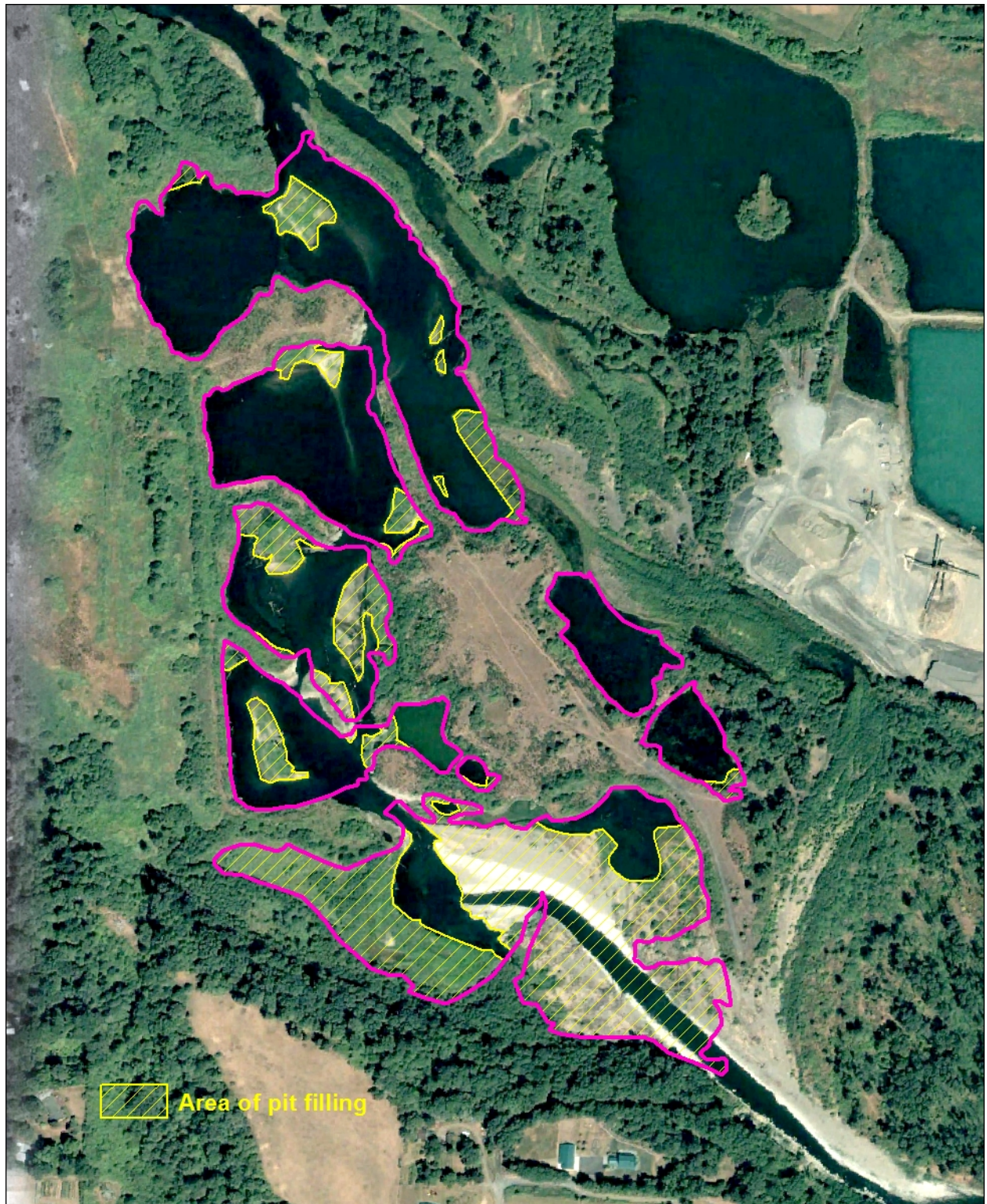
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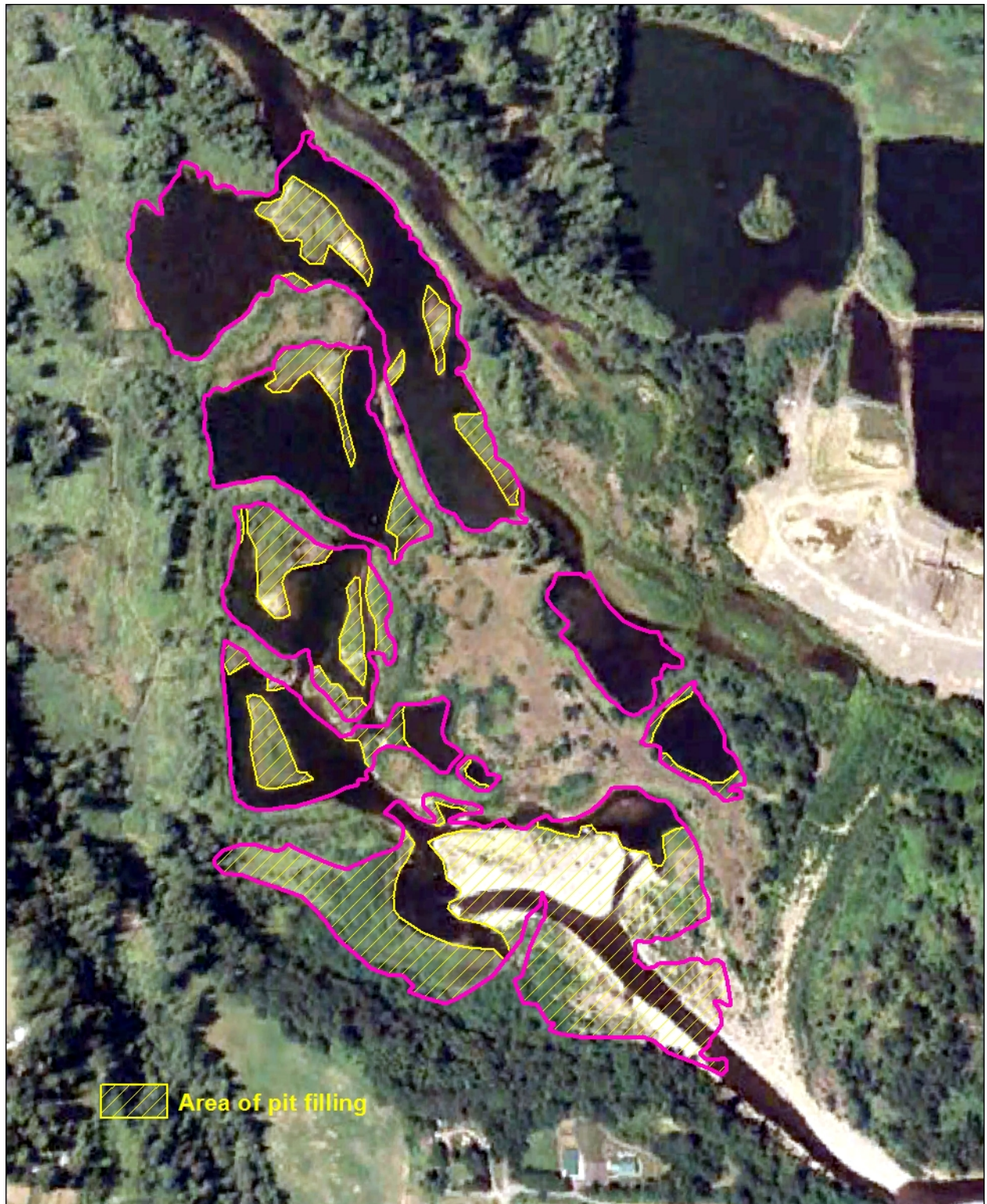
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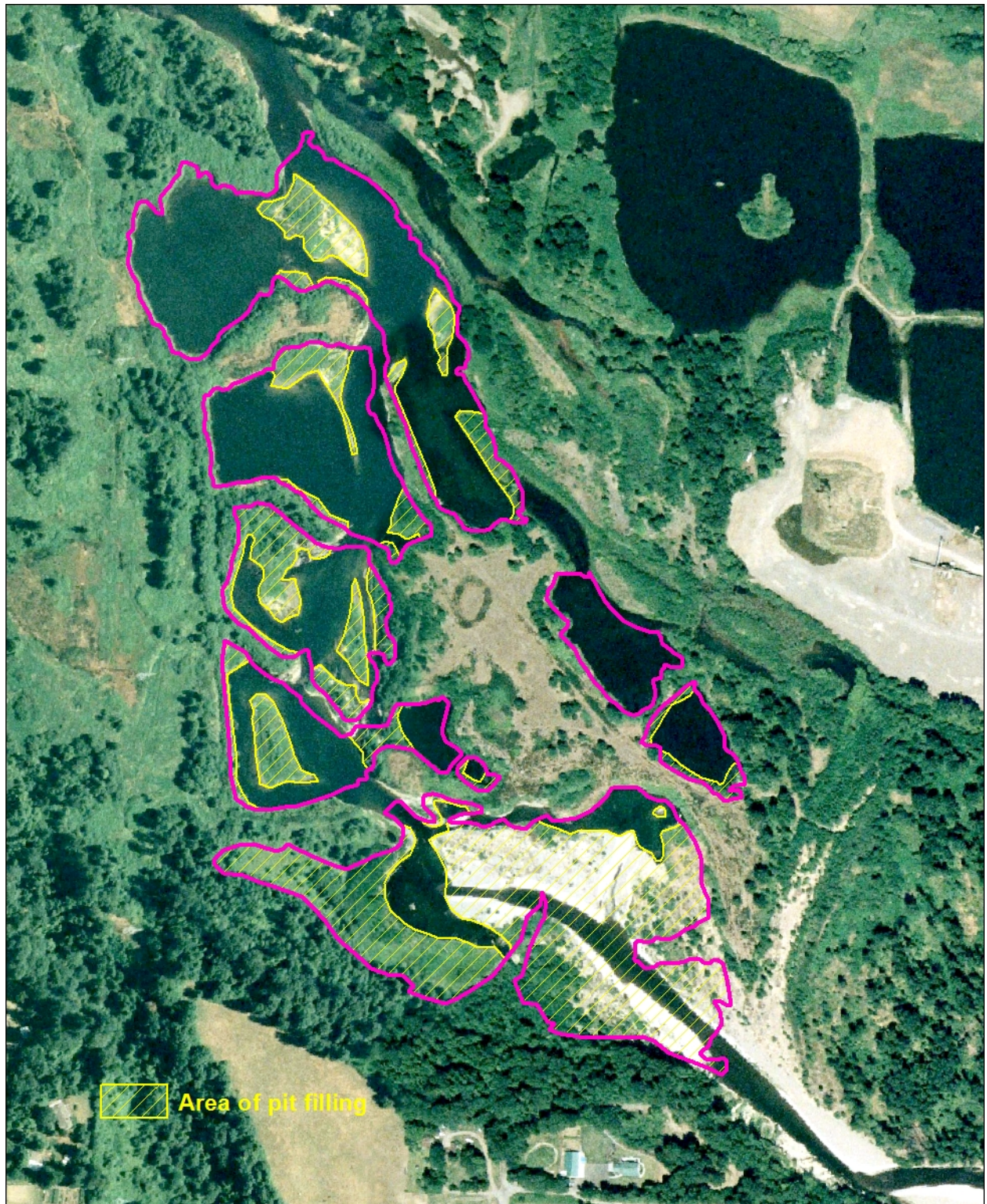
2003



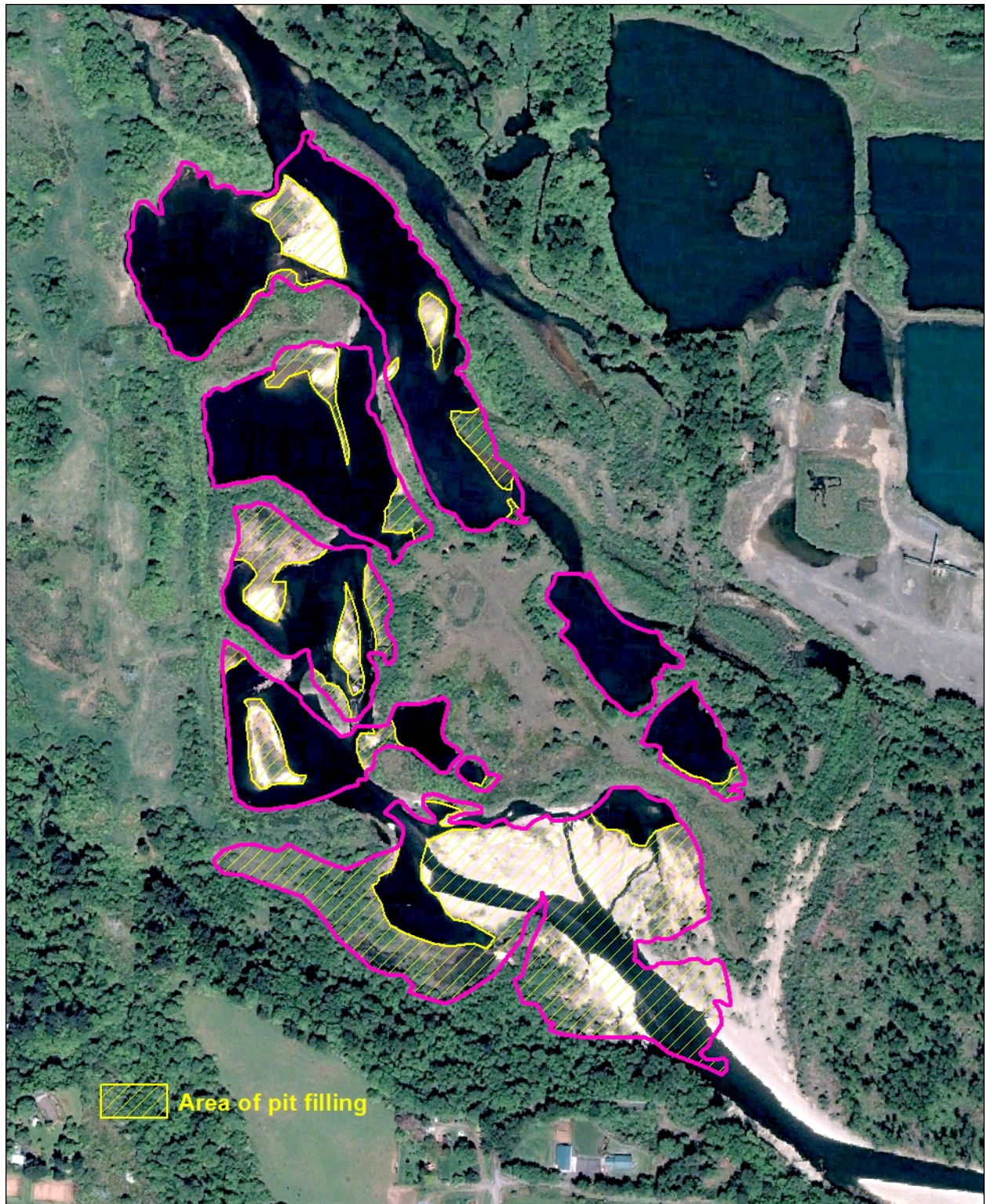
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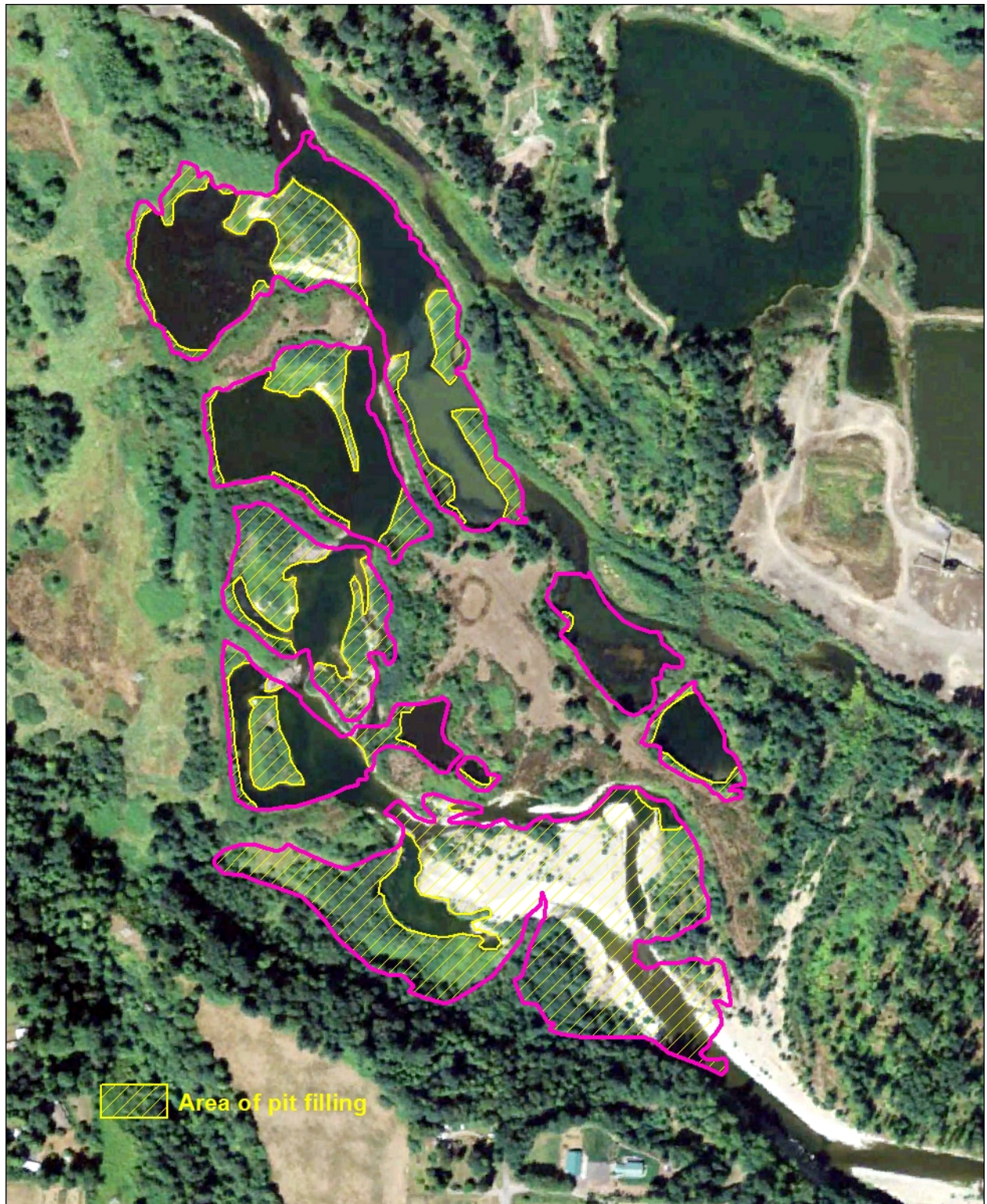
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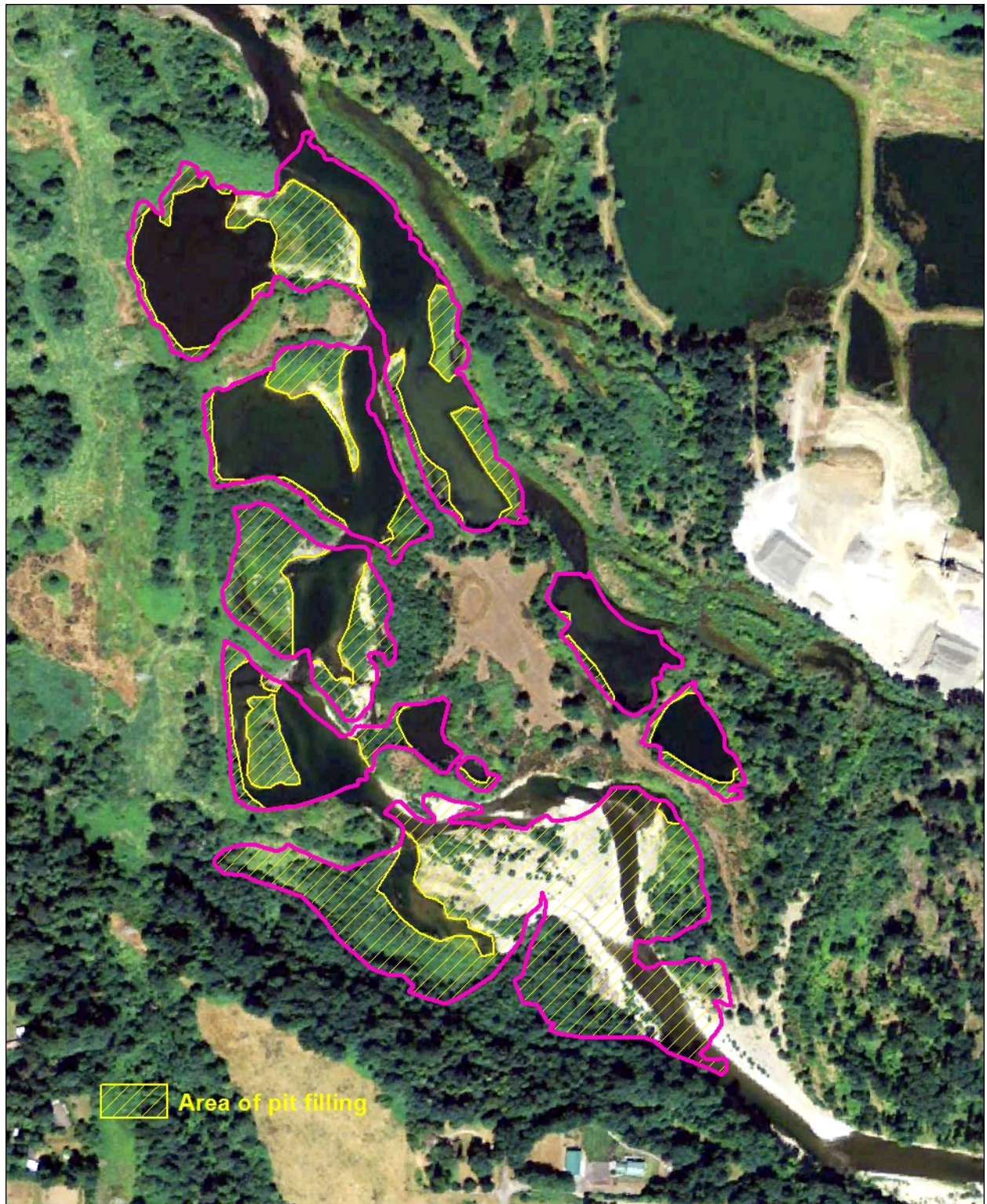
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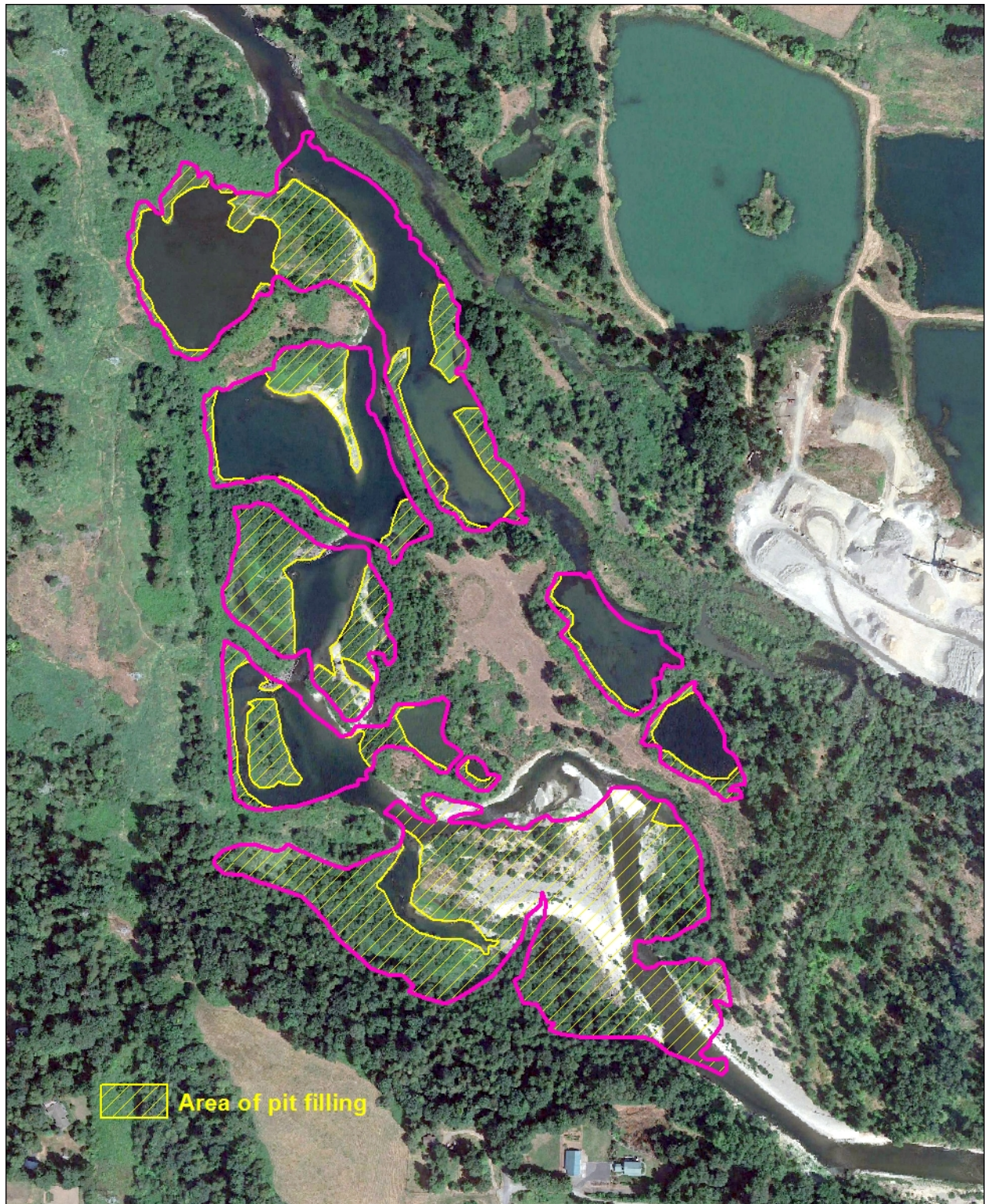
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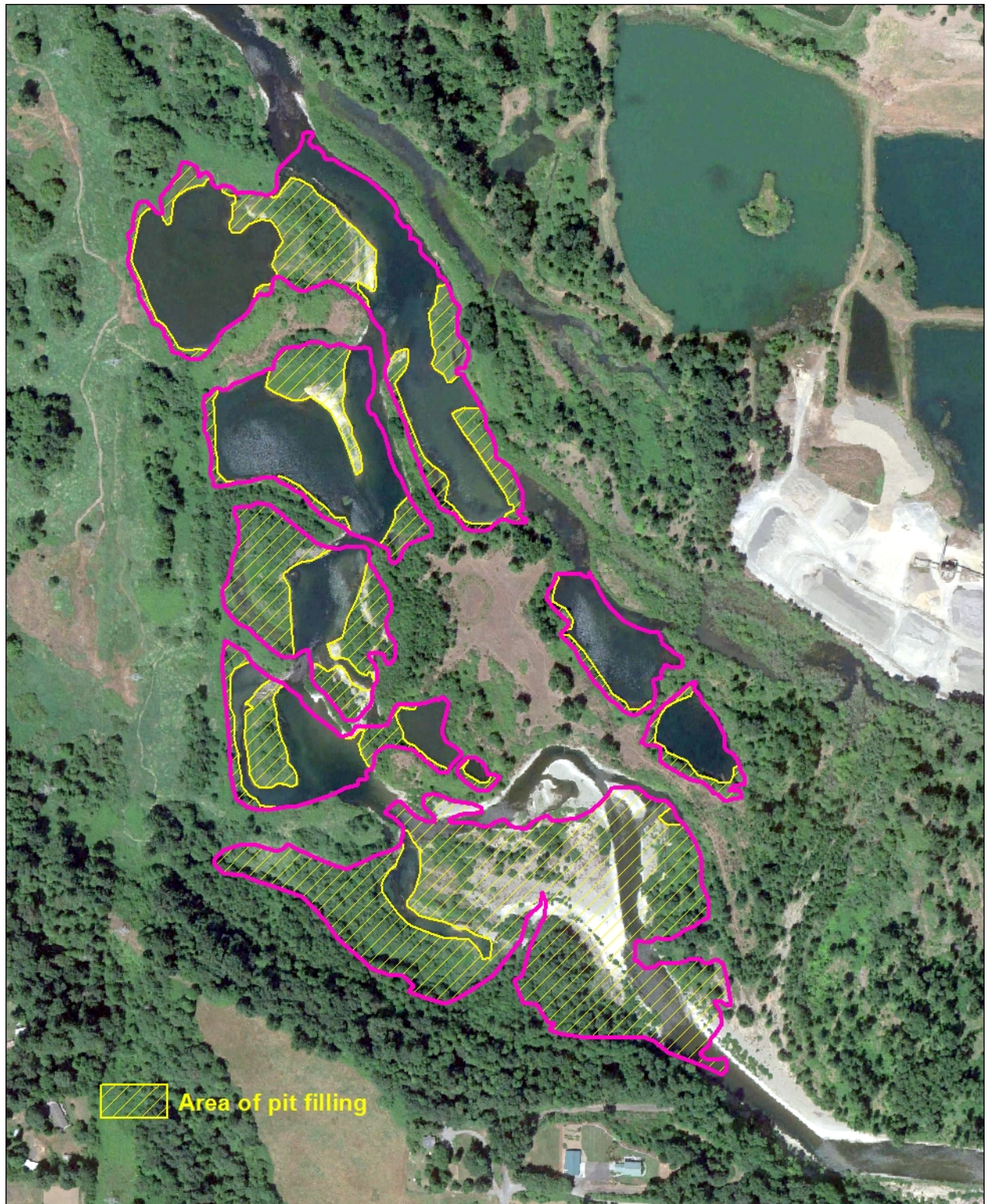
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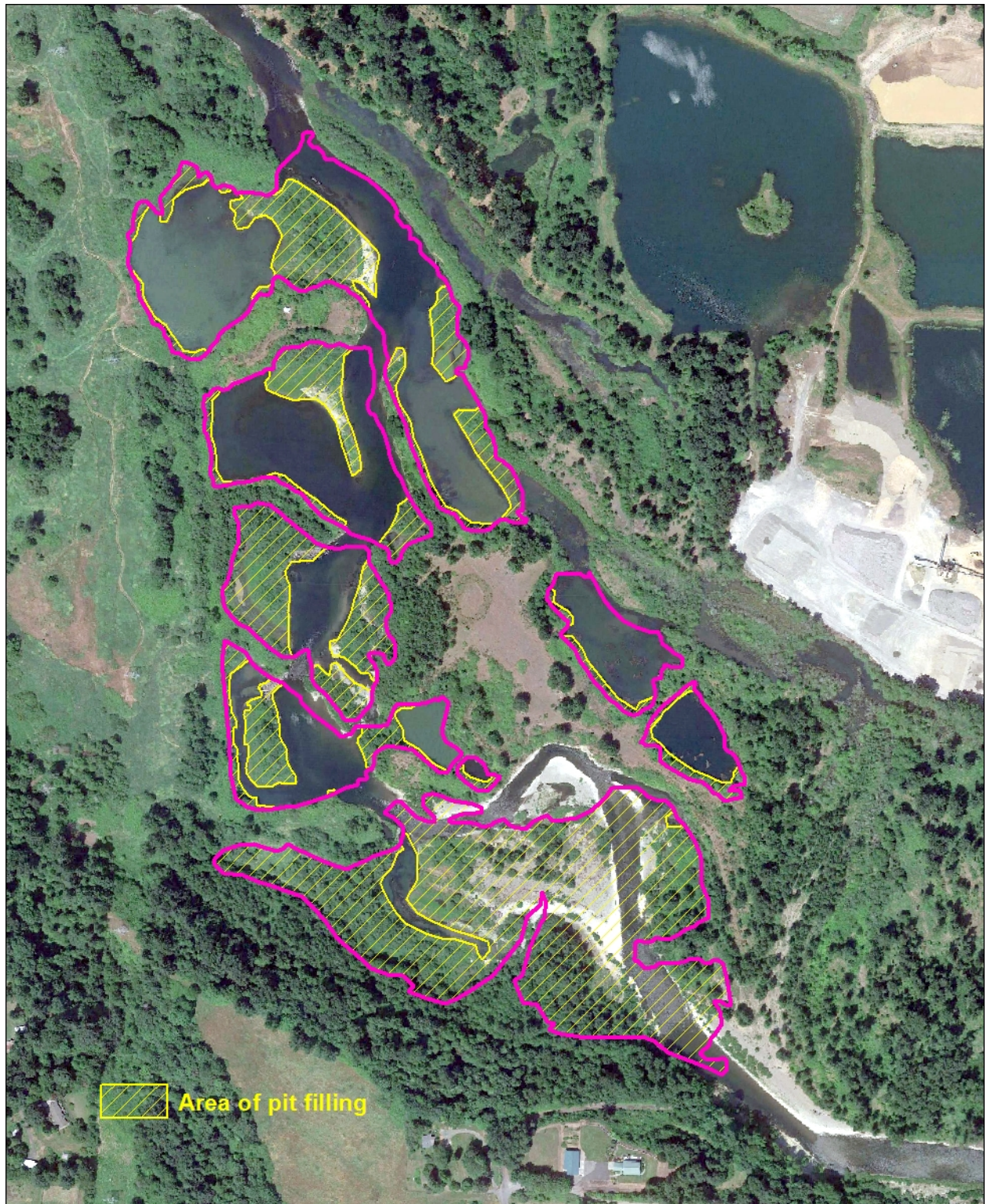
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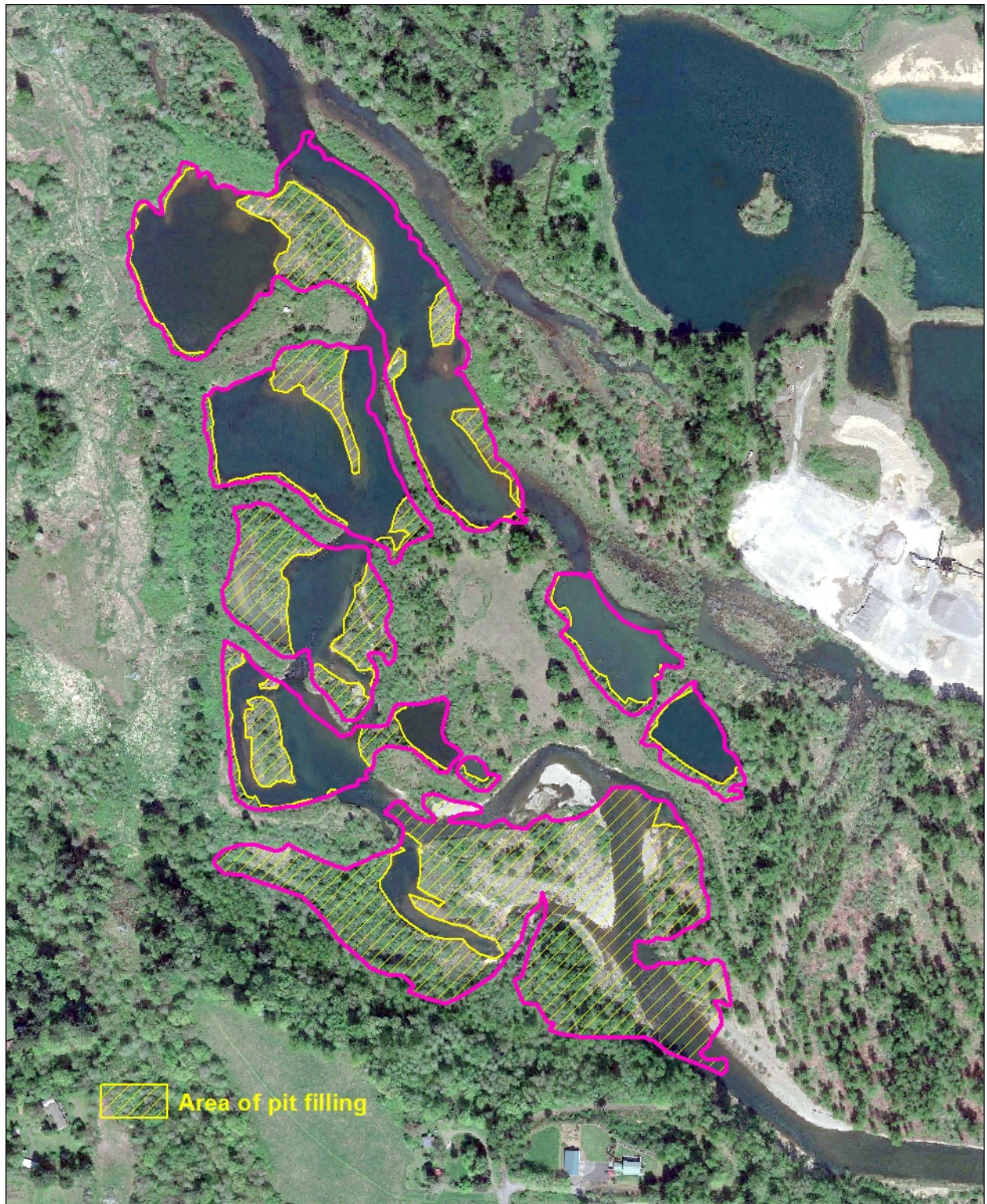
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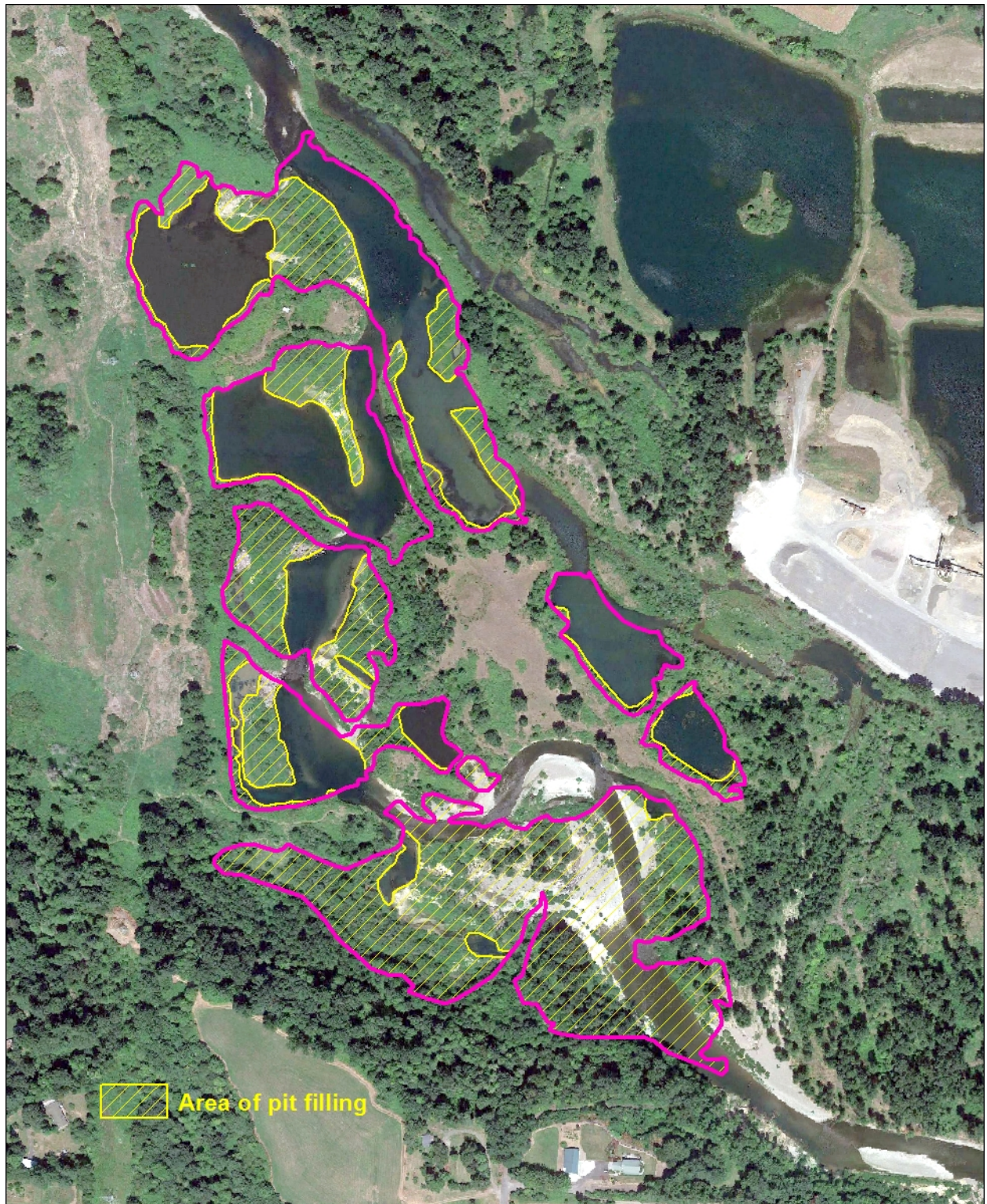
2014



2015



2016



2017



2018



C. Hydraulic Modeling

continues on next page

East Fork Lewis River Ridgefield Pits Restoration

Basis of Design Report Preliminary Design:
Attachment 3 – Hydraulic Model Analysis



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1.1 OVERVIEW

LCEP developed a 2D hydrodynamic model using the Tuflow FV modeling engine (Tuflow FV 2020, 2013) developed by the University of Queensland in Australia (and currently owned by British Maritime Technologies) to evaluate surface hydraulics along the East Fork Lewis River (EFLR) and its floodplain throughout the project site. The model is an upstream extension of an original model that was calibrated and applied as part of the EFLR La Center Wetlands project. The hydraulic model was used to evaluate existing hydraulic conditions and aid in the selection of preferred restoration design alternatives. Hydraulic model outputs also provide input to sediment and water quality modules used to evaluate geomorphic changes and water temperatures (see main report sections 2.5 and 2.6, respectively). A summary of the modelling process and model results are presented here. The model uses a metric coordinate system (UTM) and thus simulation results are output in metric units accordingly. Conversion to Imperial units has been done in this report where it is convenient and useful for the reader, however many of the data plots do retain metric units.

1.2 MODEL EXTENT AND ELEVATION DATA SOURCES

The model extent is shown in Figure 1. We derived model grid elevations from 2010 U.S Army Corps of Engineers LiDAR; 2018 bathymetric soundings collected by Inter-Fluve (see main report Attachment #1); 2018 RTK-based topo/bathy points collected by Inter-Fluve and LCEP (see main report Attachment #1); and 2018 UAV-derived imagery collected by LCEP.



Figure 1. Hydrodynamic model grid, illustrating model extent and upstream/downstream boundary forcing locations.

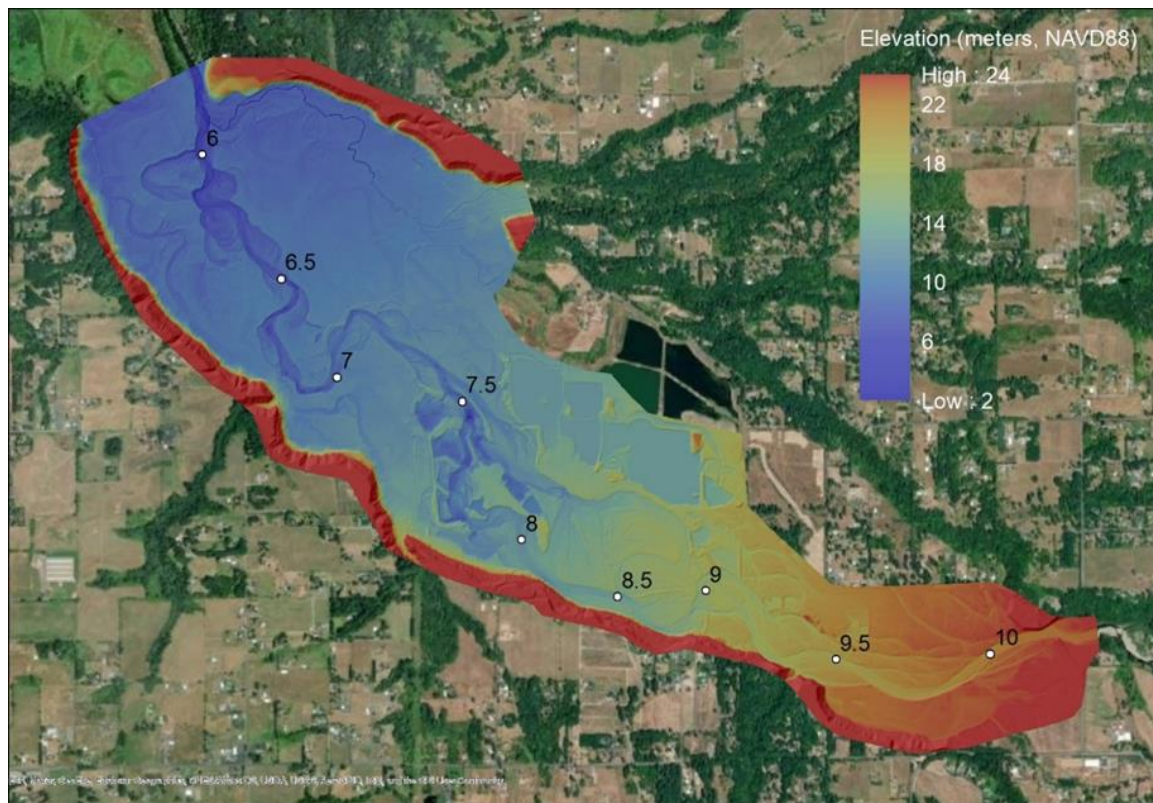


Figure 2. Hydrodynamic model topography in meters. Markers indicate EFLR miles.

Changes in river planform are occurring rapidly in the Project reach, and survey data collected for the model may no longer be accurate in some areas. Figure 2 illustrates the extent of change that has occurred between 2010 (when Corps of Engineers LiDAR data was collected) and 2017 near River Mile 8, where a significant northward migration of the river channel can be seen. It is recommended that for these areas especially, and possibly the entire reach, a new elevation survey be conducted for future design phases to ensure that the model and design surfaces reflect current conditions.



Figure 2. Change in river planform at river mile 8 between 2010 (indicated by the yellow line) and 2017 (shown in image).

1.3 MODEL BOUNDARIES AND BOUNDARY CONDITION FORCING

Model forcing is applied at the upstream boundary near river mile 10 (just upstream of Daybreak Park) and at the downstream boundary near river mile 6 (just downstream of the Mason Creek confluence). EFLR discharge is applied at the upstream boundary, with corresponding river stage applied at the downstream boundary. A range of discharge values have been applied in steady state simulations, covering the approximate 1,2,5,10 and 100-year flood recurrence interval magnitudes (Table 1) and lower flows covering the summer-fall base flow period. Downstream stage values corresponding to each discharge value are obtained from a stage-discharge relationship that was established using the earlier, calibrated model developed for a downstream project at La Center Wetlands. Figure 3 shows predicted stage at the upstream boundary of that model (which corresponds to the downstream boundary of the Ridgefield Pits model) for the range of discharge values that were applied, and the resulting stage-discharge curves (for overbank and in-channel flow separately) that were derived. Figure 4 shows the extent and overlap of the earlier La Center Wetlands model and the Ridgefield Pits model.

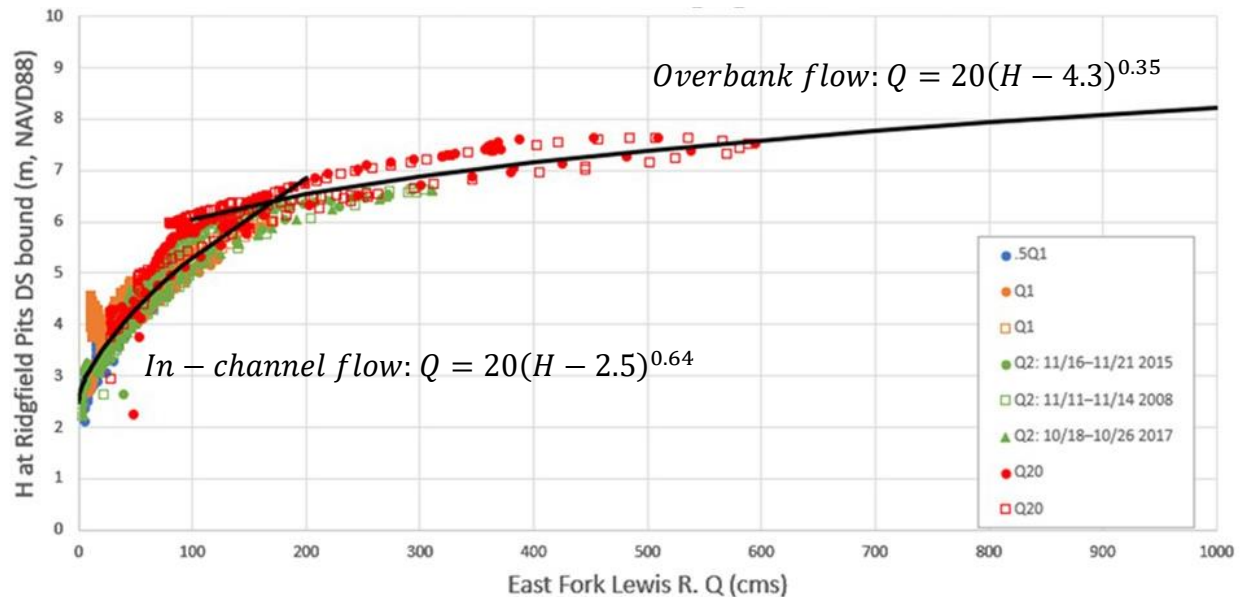


Figure 3. Established stage (H) - discharge (Q) relationship between upstream flow and downstream water level for the Ridgefield Pits model, obtained from outputs of downstream La Center Wetlands model simulations.

Table 1. Steady-state discharge values in cubic feet per second (cfs) that have been applied at the project upstream boundary for hydraulic and temperature modeling.

Discharge (Q), cfs	Applied Models	Note	Discharge (Q), cfs	Applied Models	Note
35	Hydraulic/Temp.	approx. lowest flow recorded	5,000	Hydraulic	approx. Q ₁
80	Hydraulic/Temp.		10,000	Hydraulic	approx. Q ₂
150	Hydraulic/Temp.		15,000	Hydraulic	approx. Q ₁₀
500	Hydraulic		22,000	Hydraulic	Approx. Q ₅₀
1,000	Hydraulic		28,000	Hydraulic	Approx. Q ₅₀₀
3,000	Hydraulic	approx. bankfull			

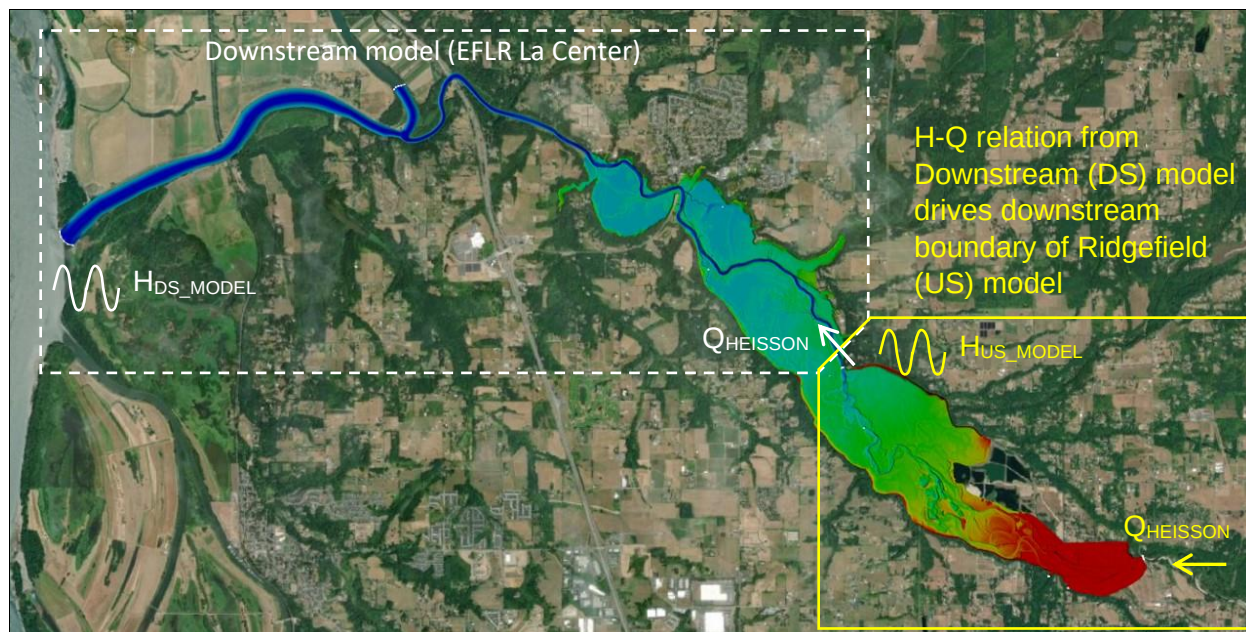


Figure 4. Full extent and overlap of the downstream La Center Wetlands and upstream Ridgefield Pits hydrodynamic models.

1.4 EXISTING CONDITIONS (EC) CHANNEL GEOMETRY

Longitudinal bed profiles and channel cross section profiles of the main channel in the Existing Condition (EC) model surface are shown in Figures 5 and 6. Metric profiles output directly from the model surface are shown in Figure 5 while imperial unit profiles have been included as Figure 6, for interested users and for direct comparison to other studies. Average slope of the project reach above the Ridgefield Pits is ~ 0.00364 . Average slope through the Ridgefield Pits Reach decreases to ~ 0.00167 . Large variations in depth occur through this section, which are indicative of both limited resolution of the bathymetric data source as well as gravel pits in various stages of recovery from accumulation of sediment over the past several decades.

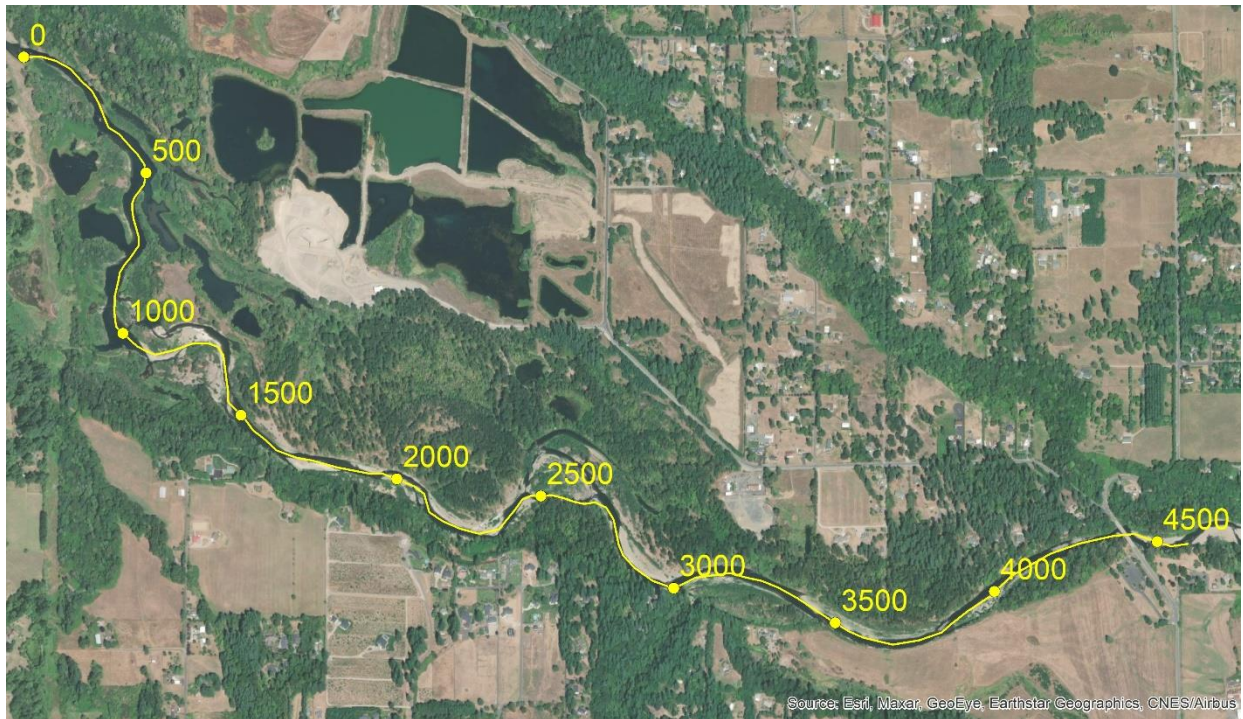


Figure 5a. Longitudinal track along main EFLR channel used to generate bed profile shown in Figure 4b. Metric units.

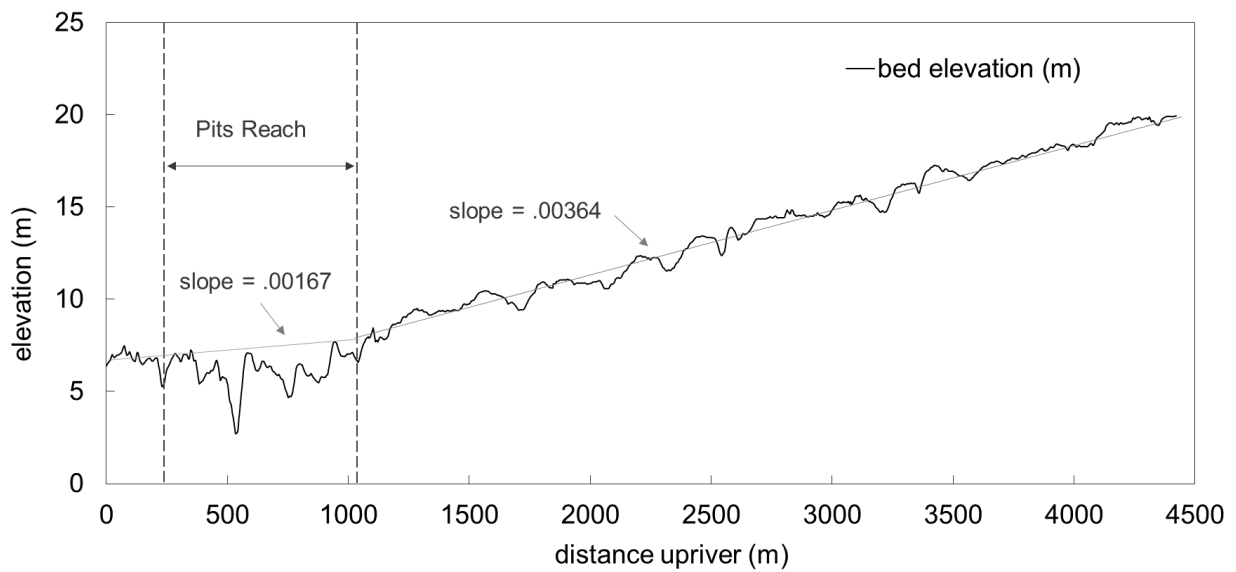


Figure 5b. Longitudinal bed profile of main EFLR channel along track shown in Figure 4a, derived from the EC model surface. Metric units.

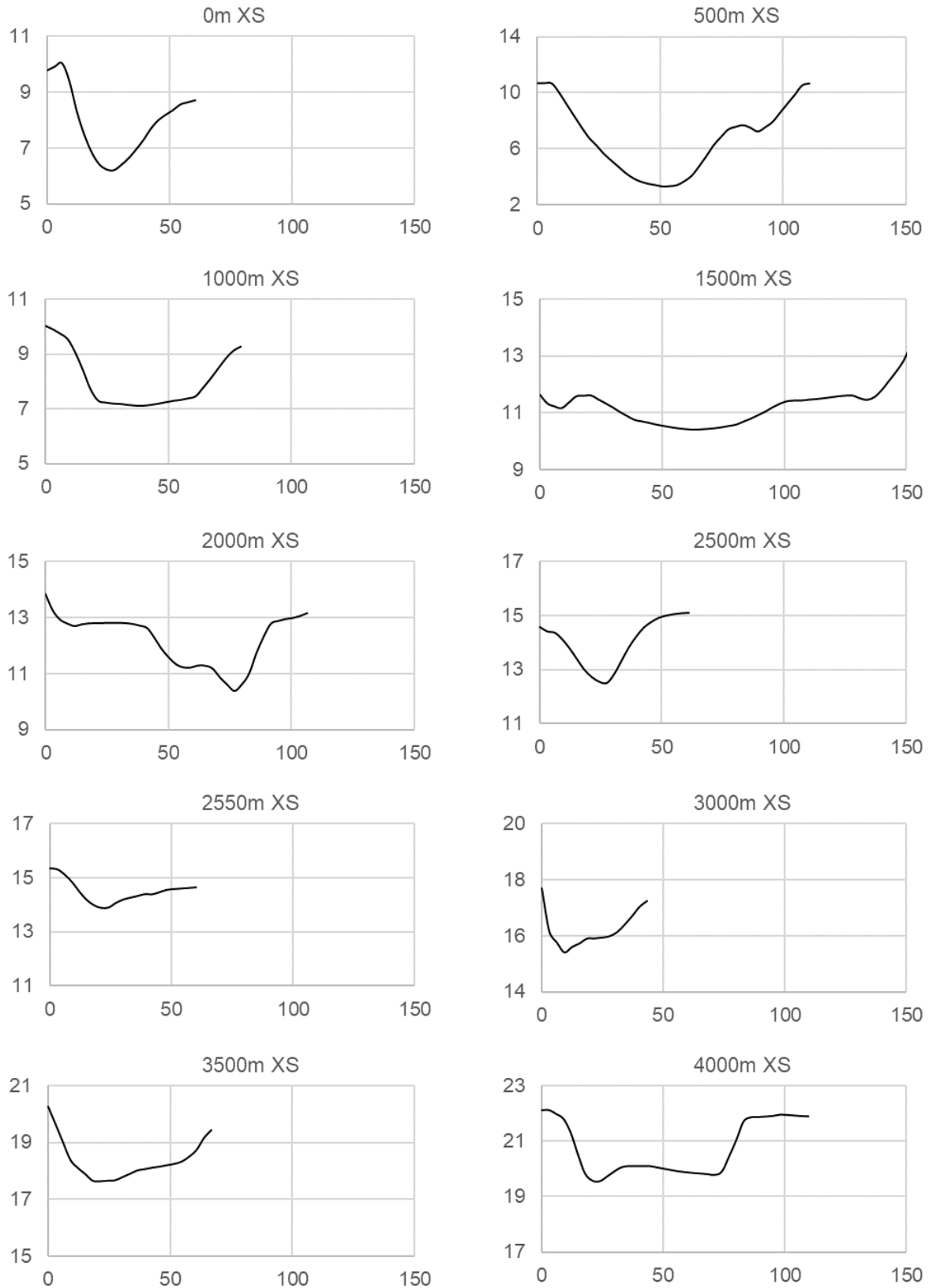


Figure 5c. EFLR main channel cross sections at point locations shown in Figure 4a, derived from the EC model surface. For all plots: X axis = distance along cross section in meters; Y axis = elevation in meters.

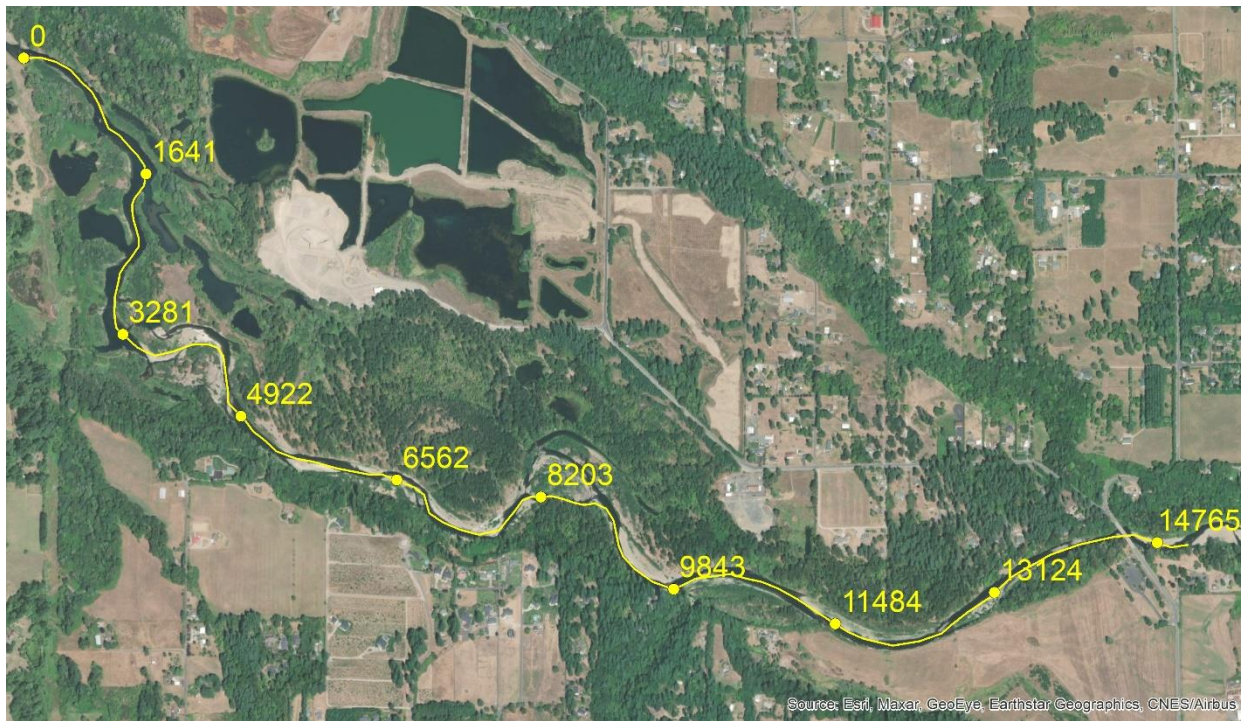


Figure 6a. Longitudinal track along main EFLR channel used to generate bed profile shown in Figure 5b. Imperial units.

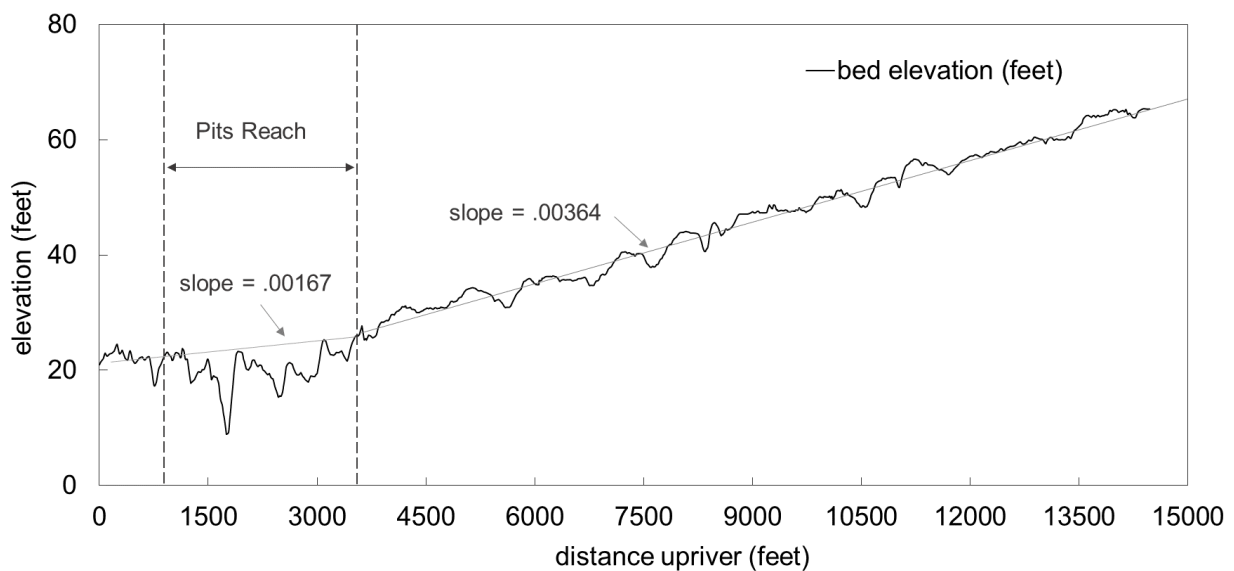


Figure 6b. Longitudinal bed profile of main EFLR channel along track shown in Figure 5a, derived from the EC model surface. Imperial units

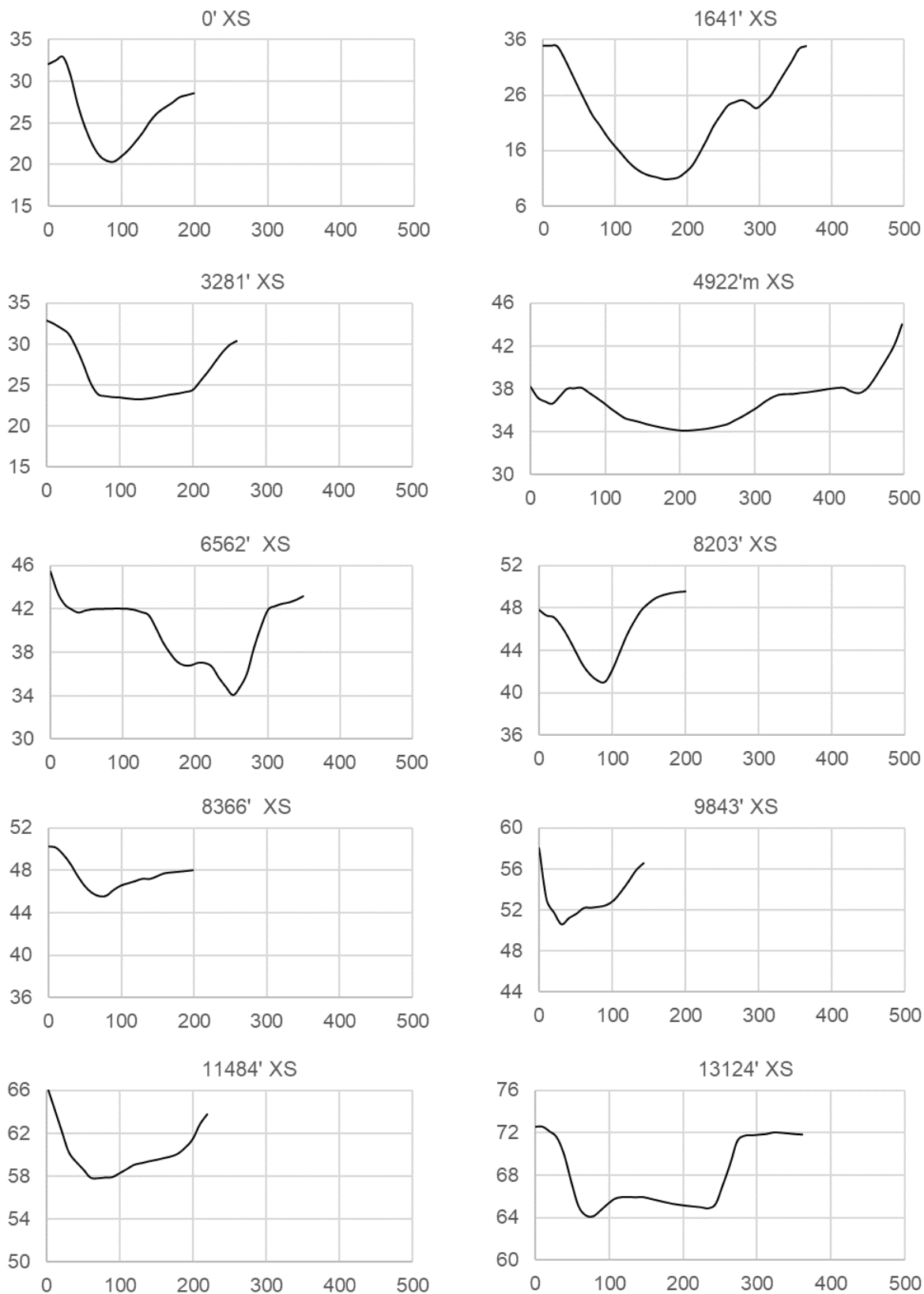


Figure 6c. EFLR main channel cross sections at point locations shown in Figure 5a, derived from the EC model surface. For all plots: X axis = distance along cross section in feet; Y axis = elevation in feet.

1.5 MODEL SURFACE COMPOSITION AND MANNING’S FRICTION COEFFICIENTS

Bed friction momentum terms are calculated in the TufLOW 2D hydraulic model using a Manning’s roughness coefficient, η , specified for the bed surface material. The surface materials and assigned Manning’s values that are used in the model are shown in Table 2. Values were estimated using the USGS Guide for Selecting Manning’s Roughness Coefficients for Natural Channels and Flood Plains (Arcement and Schneider, 1989) as well as values applied in the calibrated Downstream La Center model. The East Fork Lewis River channel takes on many different bed forms through the project area, ranging from a surface armored with large cobble throughout some sections to finer sands and gravels in slower flowing, lower gradient reaches, particularly through the Ridgefield Pits.

Table 2. Surface materials used in the hydraulic model, and their assigned Manning’s η values.

Surface Material	Assigned Manning’s η value
High-gradient straight channel, armored	.03
Low-gradient straight channel, armored	.032
Low-gradient straight channel, no armor	.028
Low-gradient winding channel, armored	.04
Low-gradient winding channel, no armor	.035
Deep pools, gravel pits	.04
Sand (floodplain)	.025
Grasslands (floodplain)	.038
Light shrub (floodplain)	.05
Dense shrub/forest (floodplain)	.06
Gravel shoals	.045
Bare, compacted (floodplain)	.025

1.6 MODEL GRID RESOLUTION

TufLOW FV is a flexible mesh modeling engine that allows for a varied grid size throughout the model domain. This allows for higher resolution modeling in areas that require it due to small-scale topographic variations, whereas in other areas with greater spatial homogeneity a larger grid size can be used, thereby minimizing the number of grid cells and associated processing time. The model developed for the Ridgefield Project reach uses a fixed cell size of approximately 5 square meters throughout the areas where restoration alternatives were evaluated. While not as computationally efficient as the variable size solution discussed above, this was done to keep the model grid consistent for the different channel geometries that were evaluated, thereby eliminating the potential for any grid biases when comparing simulation results for these different alternatives. This is most important regarding performance of the morpho-dynamic module used to evaluate sediment transport, which is discussed in Section 2.5 and Attachment #4 of the main report. The 5-meter cell size was selected as a balance between resolving the minimum channel widths to be modeled while keeping the grid to a reasonable size based on the available computing power. Figure 7 shows the model grid cells within the Ridgefield Pits reach, for the EC and the initial multi-thread hybrid alternative that was evaluated.

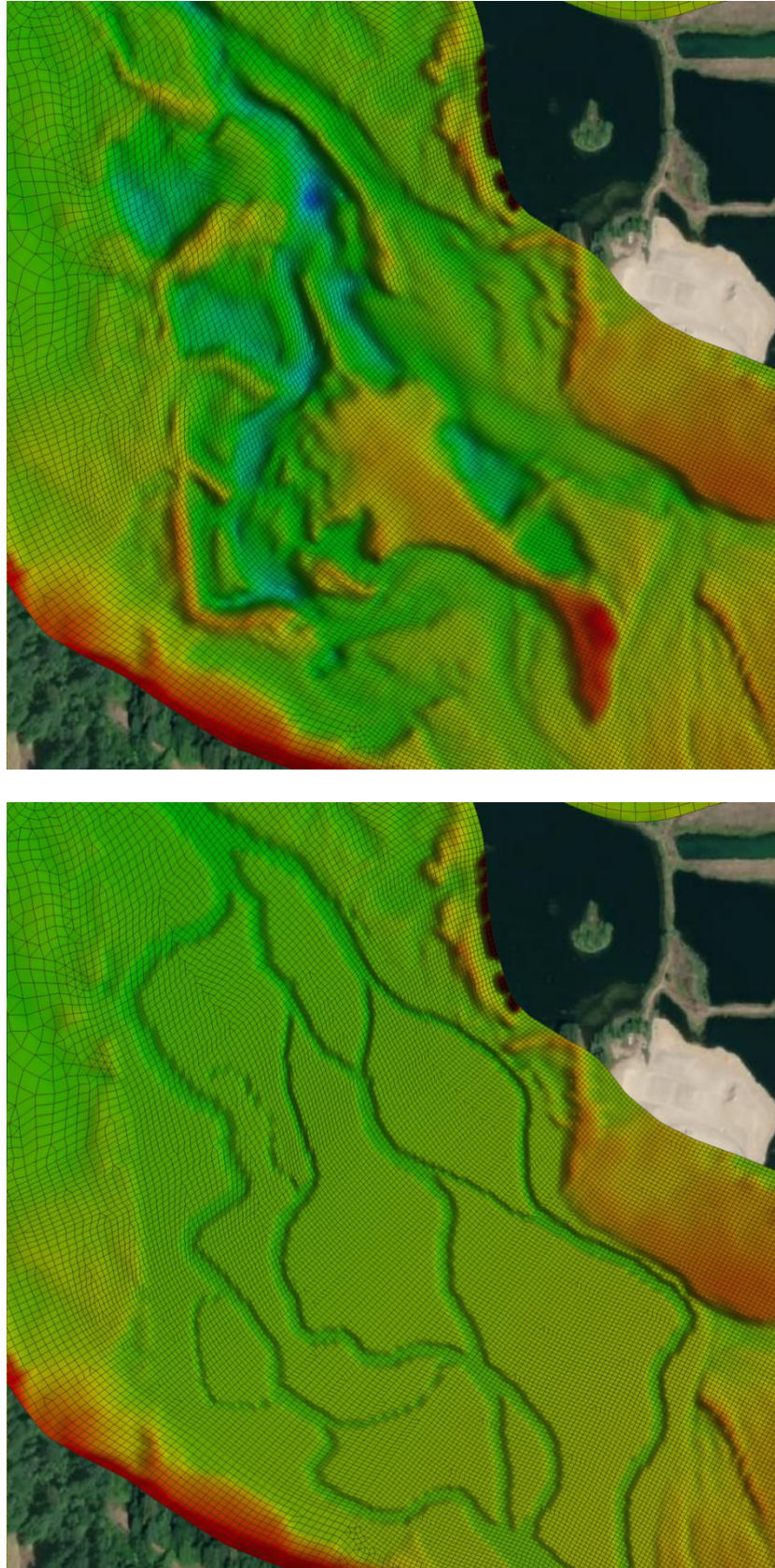


Figure 7. Model grid illustrating the grid cell resolution and fixed cell size in the vicinity of the Ridgefield Pits reach. Top: EC. Bottom: initial multi-thread Alternative 3.

1.7 MODEL SIMULATIONS COMPLETED

The hydraulic model was run for the range of flows listed in Table 1, for the EC and selected restoration alternatives that include significant changes to channel geometries and resulting hydraulics. From the list of developed alternatives in described in Section 3.1 of the main report, those which were modeled are listed in Table 3.

Table 3. Restoration Alternatives for which hydraulic modeling was applied to evaluate performance.

Restoration Alternative
¹ Alternative 1 – No action; passive recovery of Pits Reach (EC)
² Alternative 2 – Relocate main channel within Pits Reach into pre-avulsion channel location (single-thread)
³ Alternative 3 – Full pits re-grade (multi-thread channel network)
⁴ Alternative 5 – Mill-Manley confluence high-flow channel.

Alternative 1. This is the EC. Simulations results are compared to those for other Alternatives in the Ridgefield Pits reach, which include Alternatives 2 and 3. Performance of each is weighed against the Goals and Objectives included in Section 4.1 of the main report.

Alternative 2. This modeling is still in progress. The design team did not initially intend to model this Alternative based on the low score it received during the initial screening process, however the TOG has expressed additional interest in reviewing the results. The team is currently working to generate the results and compare to those for the EC and Alternative 3.

Alternative 3. The design team modeled two separate Alternative 3 multi-thread channel networks. The initial layout consisted of several channels of varied size with crossing paths. The second layout consisted of a 3-channel ‘hybrid’ network which included alcoves in existing areas. This iterative process is discussed in Section 4.2.1 of the main report and ultimately the ‘hybrid’ layout was selected as the preferred for the reasons discussed within. Model results shown in this section are included for the 3-channel hybrid alternative only.

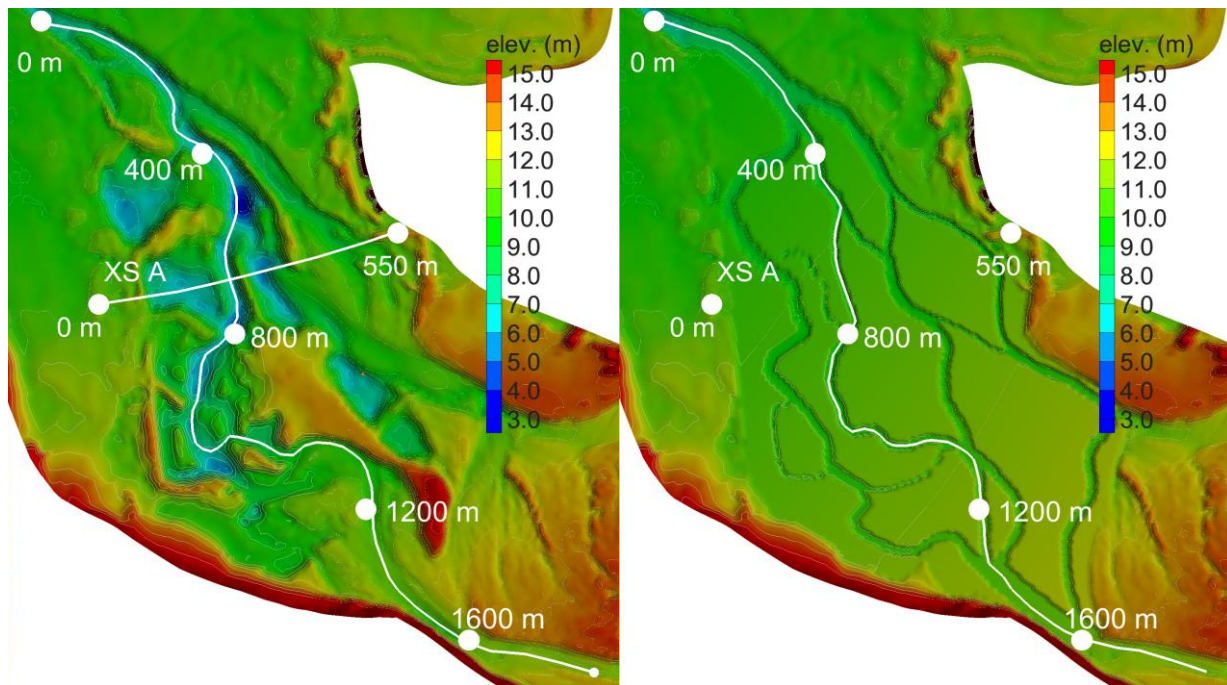
Alternative 5. Multiple restoration concepts were proposed at the Mill-Manley confluence however the overflow channel was the only one that involved significant channel re-work requiring hydraulic model evaluation. Results were compared to the EC, to evaluate the capacity for high flows delivered by the overflow channel to the confluence zone to create adequate scour to remove sand and gravels that typically deposit in this area and reduce available cold-water habitat.

1.8 MODEL RESULTS: ALTERNATIVES 1 AND 3 (EC COMPARED TO MULTI-THREAD)

- Alternative 3 channel geometry

Channel profiles for the EC and iterations of the Alternative 3 multi-thread are shown in Figure 9, for the respective longitudinal and cross-sectional profiles shown in Figure 8. Evolution of the Alternative 3 channel configuration was guided by the following design objectives, as discussed in Section 4.2.1 of the main report: maintaining an acceptable cut-fill balance; the desired bankfull flow; the desired number of channels as determined by the Technical Oversight Group.

The amount of external fill required (i.e. the amount of fill that would need to be imported to the site to fill the Ridgefield Pits and grade the floodplain to the desired slope) was reduced from ~400,000 cy to ~44,000 cy through the iteration process. This was accomplished by lowering the overall elevation and adjusting the longitudinal slope of the floodplain through the Ridgefield Pits reach, as can be seen in Figure 9. In going from the initial multi-thread surface to the initial 3-channel hybrid (Fig. 8 top right to bottom left) a net cut (i.e. material needing to be removed from the site) of 72,000 cy resulted. The floodplain elevation was then raised back up slightly, resulting in the revised 3-channel hybrid surface (i.e. the proposed Alternative 3 surface, as shown in Fig. 8, bottom right) with a net fill of ~44,000 cy. This was considered an acceptable cut-fill balance for the current design level and will be further adjusted as necessary during final design.



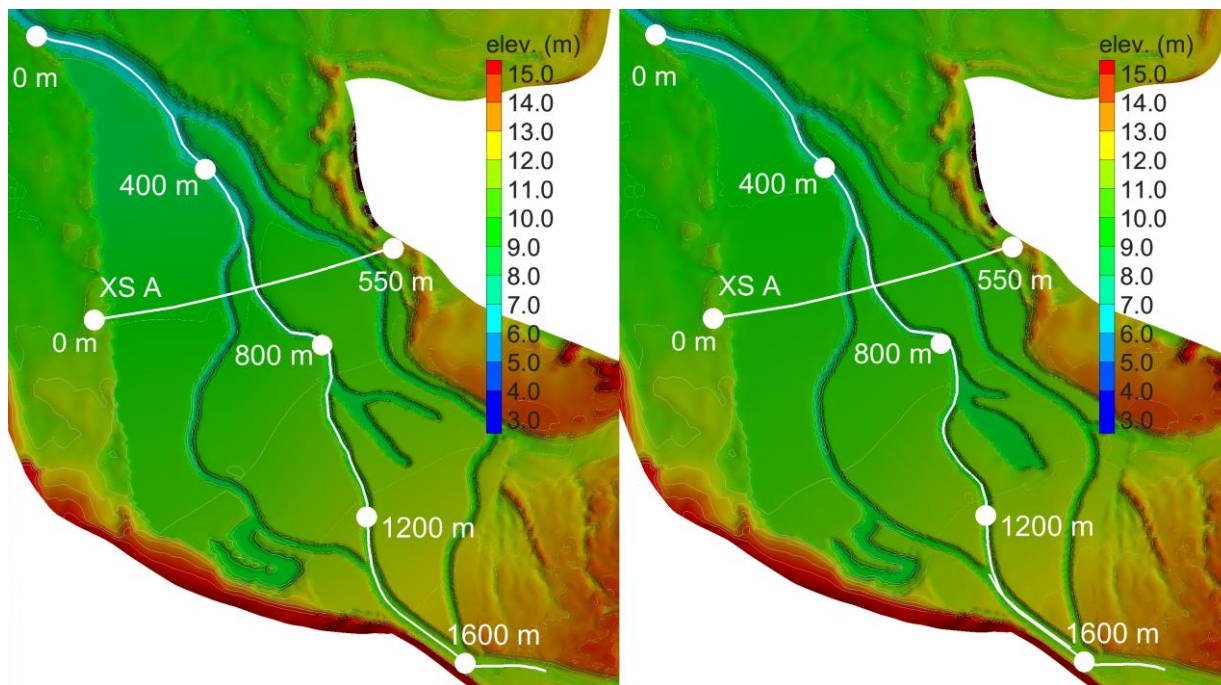
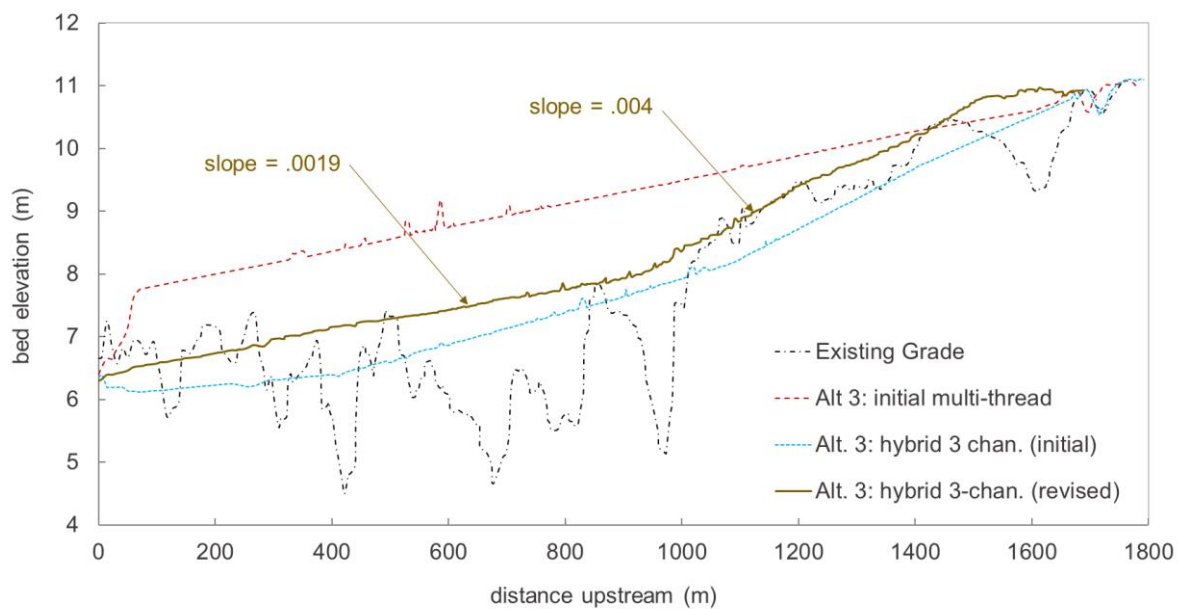


Figure 8. Model topography and elevation profile paths for the EC and Alternative 3 multi-thread iterations. Top Left: EC; Top Right: initial multi-thread; Bottom Right: initial 3-channel hybrid; Bottom Left: revised 3-channel hybrid. Respective longitudinal and cross-sectional elevation profiles are shown in Figure 9 below.



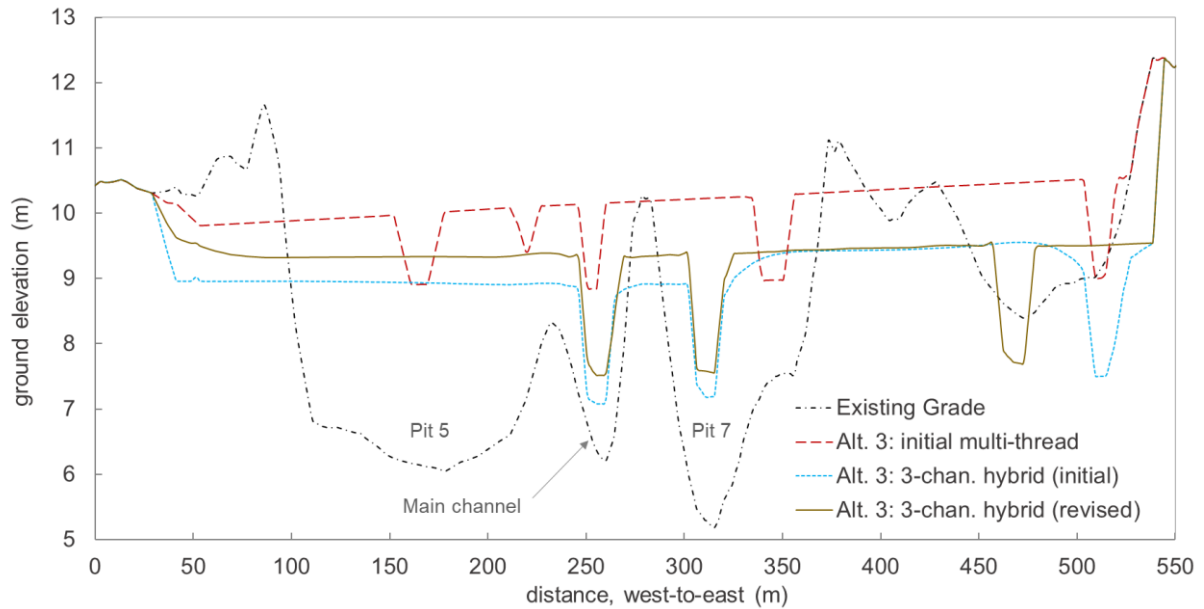


Figure 9. Model elevation profiles along the profile paths shown in Figure 8 above. Top: longitudinal profiles for selected channels; Bottom: cross-sectional profiles along cross section A (XS A in Figure 7).

Longitudinal bed slope of the Alt3 hybrid 3-channel network is close to that of the EC channel. Both exhibit a grade break at approximately 1,000m upstream, with higher slope upstream (0.0036 for the EC, versus 0.004 for Alt.3) and lower slope downstream (0.0017 for the EC versus 0.0019 for Alt. 3) of the break. Maintaining this existing floodplain grade helps to optimize the cut fill balance for the Alt. 3 design and allows preservation of intact, high elevation vegetation that currently exists upstream of the grade break.

Geometries (channel widths and depths) for the Alt. 3 hybrid 3-channel network were determined using standard Manning's calculations for trapezoidal channels, based on the desired bankfull depth of 1.8 m (5.9') and approximate bankfull flow of 2,600 cfs for the project reach (see Section 4.2.1 of the main report). Measured values for channel geometry parameters taken from the model surfaces are shown in Table 4 below, along with calculated bankfull flow, flow velocity, width-to-depth ratio, and shear stress values. For the Alt. 3 hybrid 3-channel preferred alternative shown in the left column, measured values differed slightly from targeted design values because of limitations imposed by the model grid cell size (~5 meters). Channel parameters for the EC model are also included in Table 4 for comparison. The EC consists of a single channel through most of the Ridgefield Pits reach.

For the given parameters, channel overtopping is predicted to occur at 1,267 cfs for the Alt. 3 hybrid 3-channel design, which corresponds to an upstream discharge of 3,801 cfs ($3 \times 1,267$ cfs) entering the project reach. This value is higher than the initial design guideline of 2,600 cfs. Modeling time constraints did not allow for a further revision of channel geometry to reduce the bankfull flow to the targeted value during the present design phase, and so this will be done in later phases when the channel layouts are looked at in greater detail.

Results of the trapezoidal channel calculations shown in Table 4 suggest improvements in hydraulic conditions for the preferred Alternative 3 compared to the EC. These include reduced

channel velocities and reduced shear stress at the bankfull condition, as well as reduced channel width to depth ratios which should improve temperature performance at lower flows, by maintaining greater water depths (except for in the Ridgefield Pits proper, where water depths are currently high at all flows).

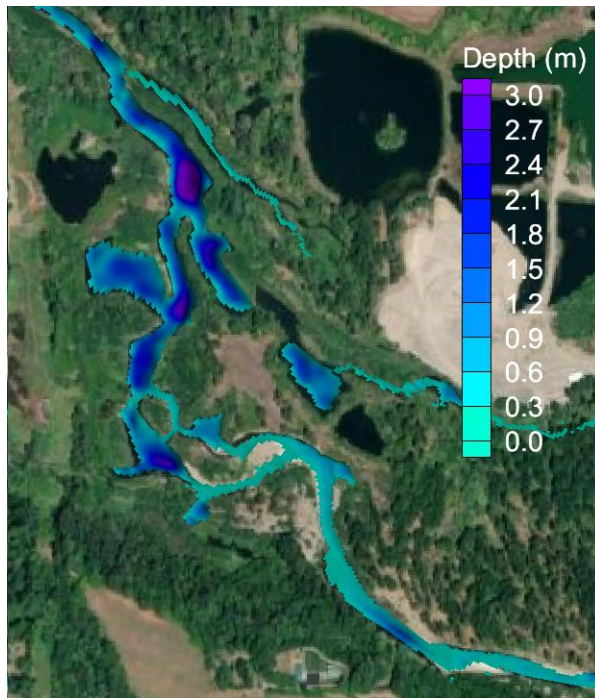
Table 4. Channel geometry parameters and associated bankfull flow, flow velocity, and shear stress calculated using Manning's trapezoidal channel formula, for the Alternative 3 hybrid 3-channel model and the EC model.

	Alternative 3 hybrid 3-channel network, individual channel parameters	EC, single channel parameters
Channel bottom width (m / ft.)	9.0 / 29.5	36 / 118.1
Side slope (x/y)	3	4.5
Manning's n -value	0.035	0.035
Chan slope, upstream section	0.004	0.0036
Chan slope, downstream section	0.0019	0.0017
Flow Depth (m / ft.)	1.75 / 5.7	2.7 / 8.9
Channel top width (m / ft.)	19.4 / 63.6	60.3 / 197.8
Flow conveyance area (m^2 / ft^2)	24.9 / 268.4	130.0 / 1399.4
Wetted perimeter (m / ft.)	20.1 / 65.8	60.9 / 199.8
Hydraulic Radius (m / ft.)	1.2 / 4.1	2.1 / 7.0
Bottom Width/Depth ratio	5.1	13.3
Calculated flow velocity, upstream section (m/s / ft./s)	2.1 / 6.9	2.8 / 9.3
Calculated flow velocity, downstream section (m/s / ft./s)	1.4 / 4.7	2.0 / 6.4
Calculated bankfull flow, Q, upstream section (m^3/s / $ft.^3/s$)	52 / 1,839	369.5 / 13,048
Calculated bankfull flow, Q, downstream section (m^3/s / $ft.^3/s$)	35.9 / 1,267	253.9 / 8,967
Calculated Shear stress, upstream section (N/m^2 / $pd./ft.^2$)	48.7 / 1.0	75.4 / 1.6
Calculated Shear stress, downstream section (N/m^2 / $pd./ft.^2$)	23.1 / 0.5	35.6 / 0.7

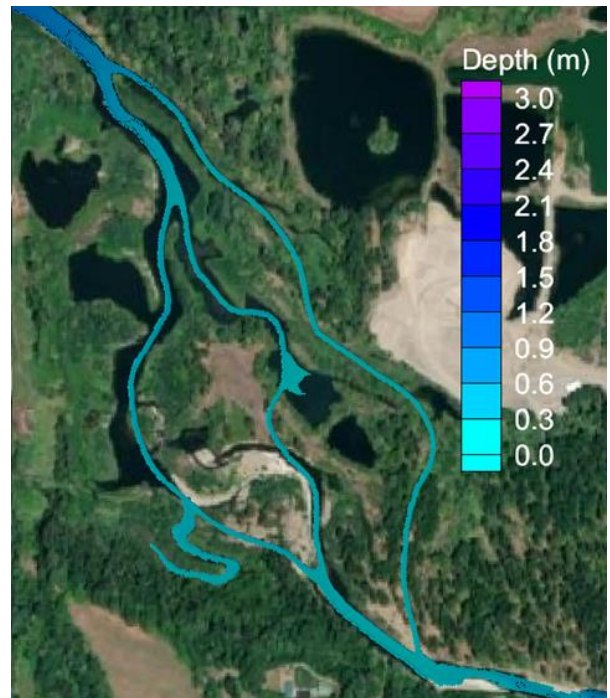
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- Model steady-state simulation outputs: Water Depth

Steady-state simulation water depth profiles are shown in Figure 10 for the EC and Alternative 3 hybrid 3-channel network model surfaces. Channel depths and flows for the individual channels of the Alt.3 hybrid 3-channel network are shown in Table 5 for input flows less than and up to the design bankfull flow. Depths for the EC model are not included because water depth is highly variable throughout the Ridgefield Pits reach, making comparison to the Alt 3 results difficult.

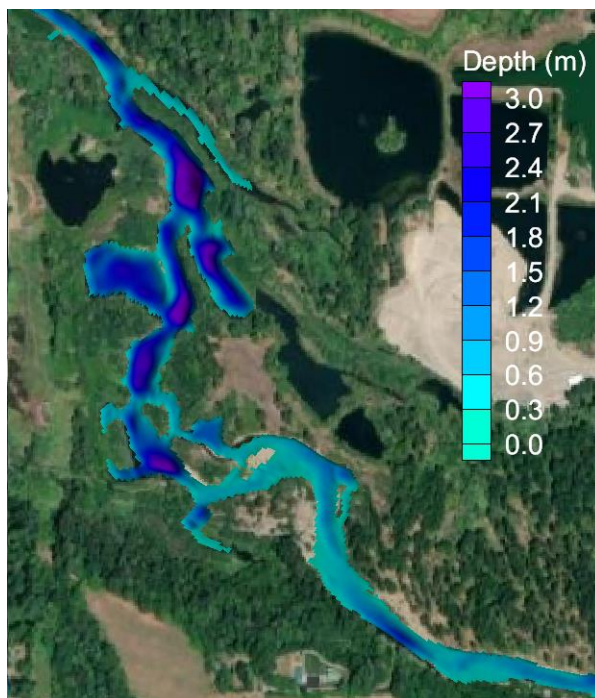
EC, Q = 35 cfs



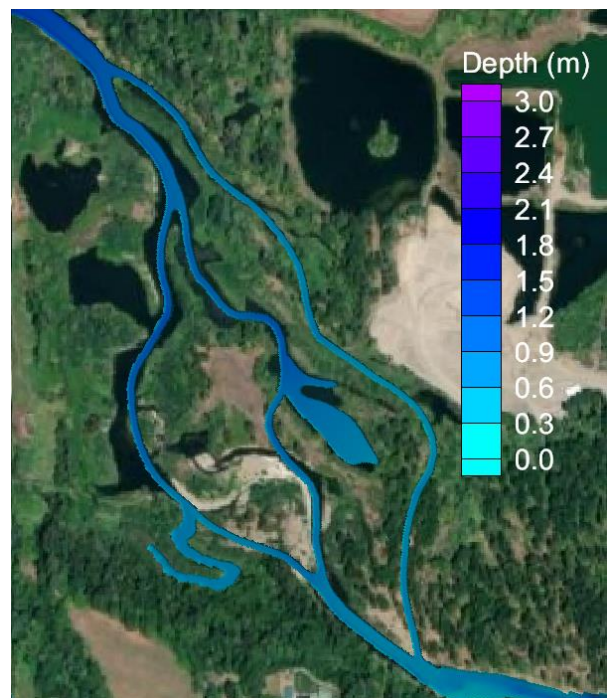
Alt 3, Q = 35 cfs



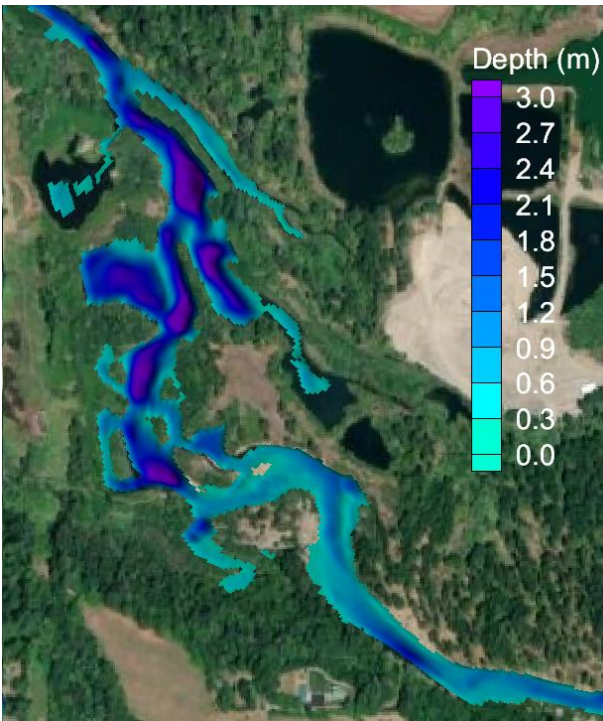
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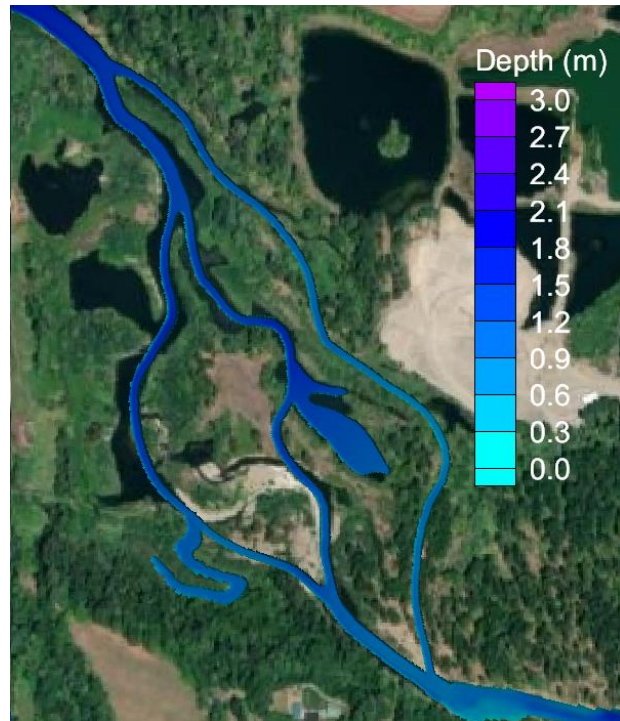
Alt 3, Q = 500 cfs



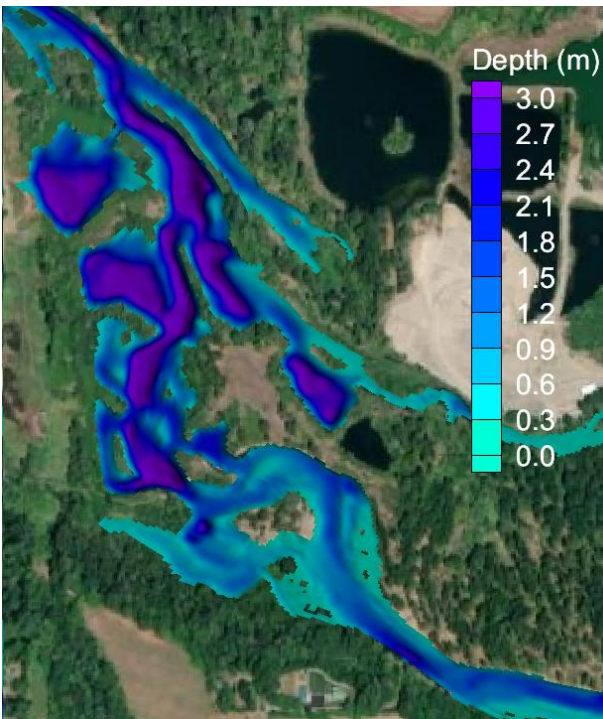
EC, Q = 1,000 cfs



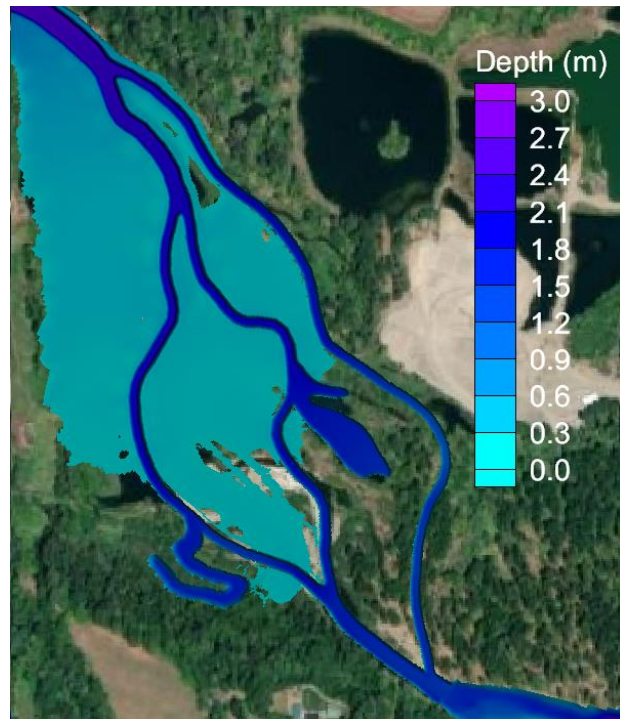
Alt 3, Q = 1,000 cfs



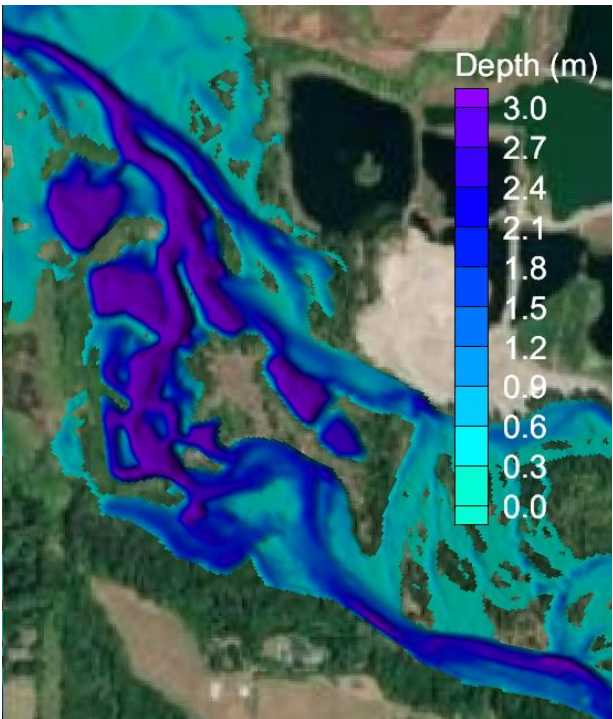
EC, Q = 3,000 cfs



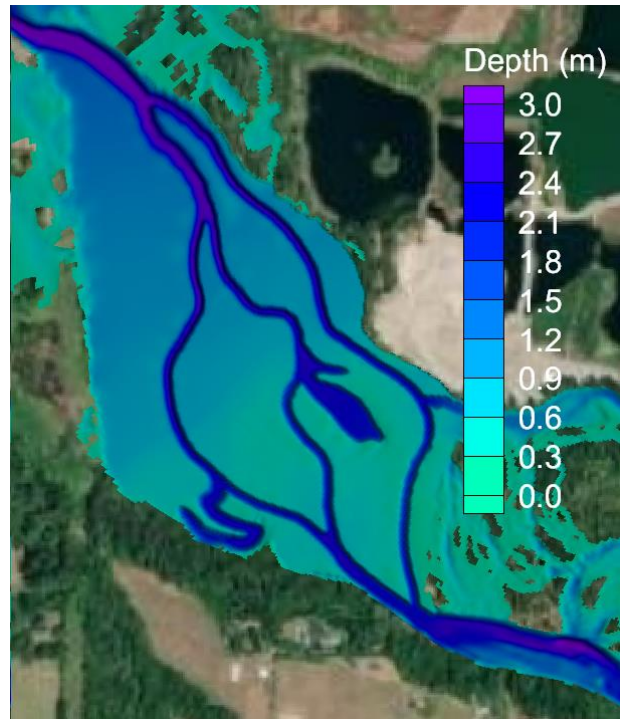
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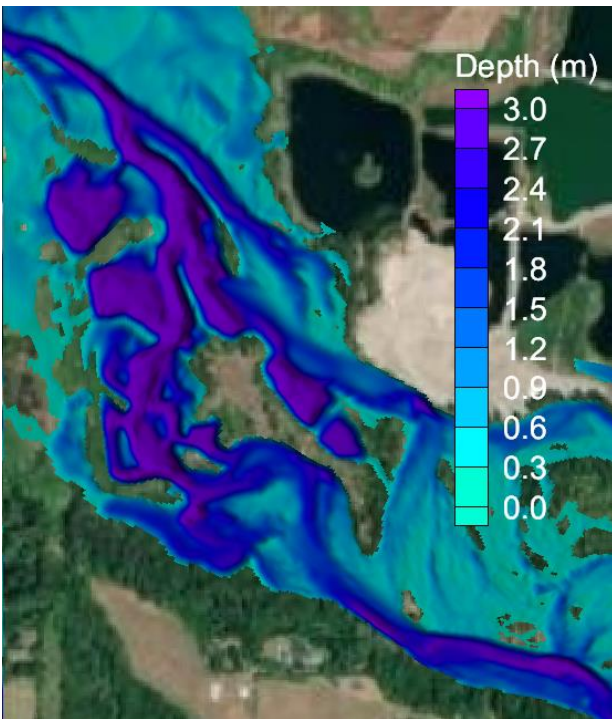
EC, Q = 10,000 cfs



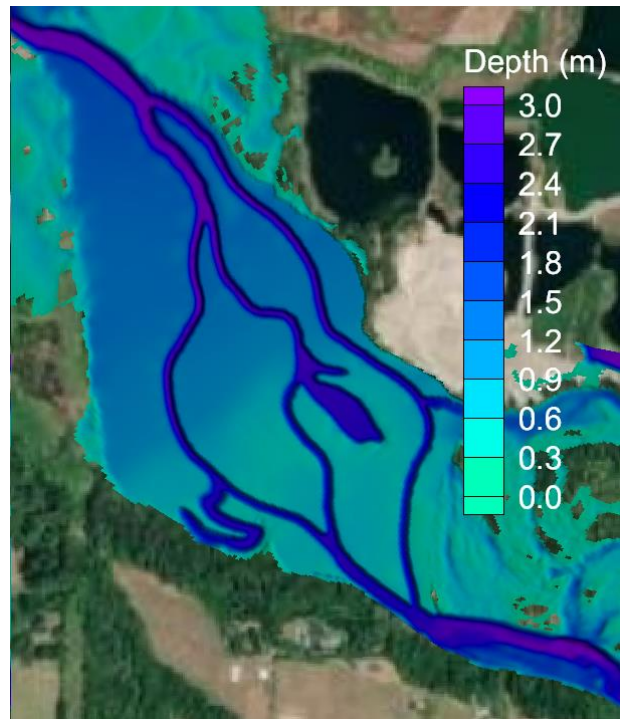
Alt 3, Q = 10,000 cfs



EC, Q = 15,000 cfs



Alt 3, Q = 15,000 cfs



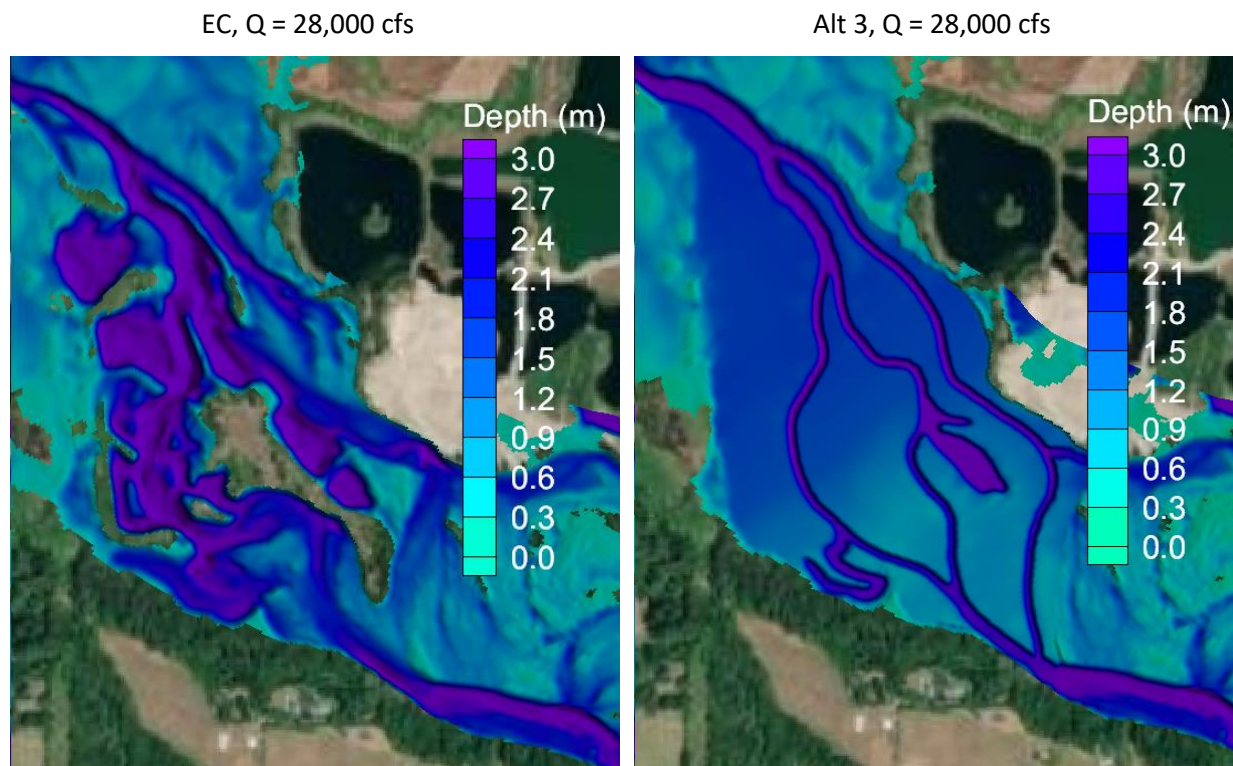


Figure 10. Water depth plots for model steady-state simulations covering the full range of ELFR discharge values: base flow – 500-year flood event. Left column: depths for the EC model. Right column: depths for the 3-channel hybrid Alternative model.

Table 5. Minimum and maximum water depths, and relative flow magnitudes, for the individual channels of the Alt. 3 hybrid 3-channel network. Values are included for the minimum simulated input flow of 35 cfs, up to the approximate design bankfull flow of 3,000 cfs.

	@ Q = 35 cfs	@ Q = 500 cfs	@ Q = 1,000 cfs	@ Q = 3,000 cfs
West channel min./max. depth (ft)	0.42 / 0.9	1.45 / 3.2	2.0 / 4.6	3.9 / 6.6
Middle channel min./max. depth (ft)	0.2 / 0.5	1.7 / 3.0	3.0 / 4.1	4.9 / 6.2
East channel min./max. depth (ft)	0.2 / 0.4	1.2 / 2.0	1.7 / 3.2	3.5 / 6.1
West Channel flow (cfs) / % of total flow	17 / 50%	199 / 40%	400 / 40%	1,208 / 40%
Middle channel flow (cfs) / % of total flow	10 / 29%	183 / 36%	370 / 37%	1,035 / 35%
East channel flow (cfs) / % of total flow	8 / 21%	118 / 24%	230 / 23%	872 / 29%

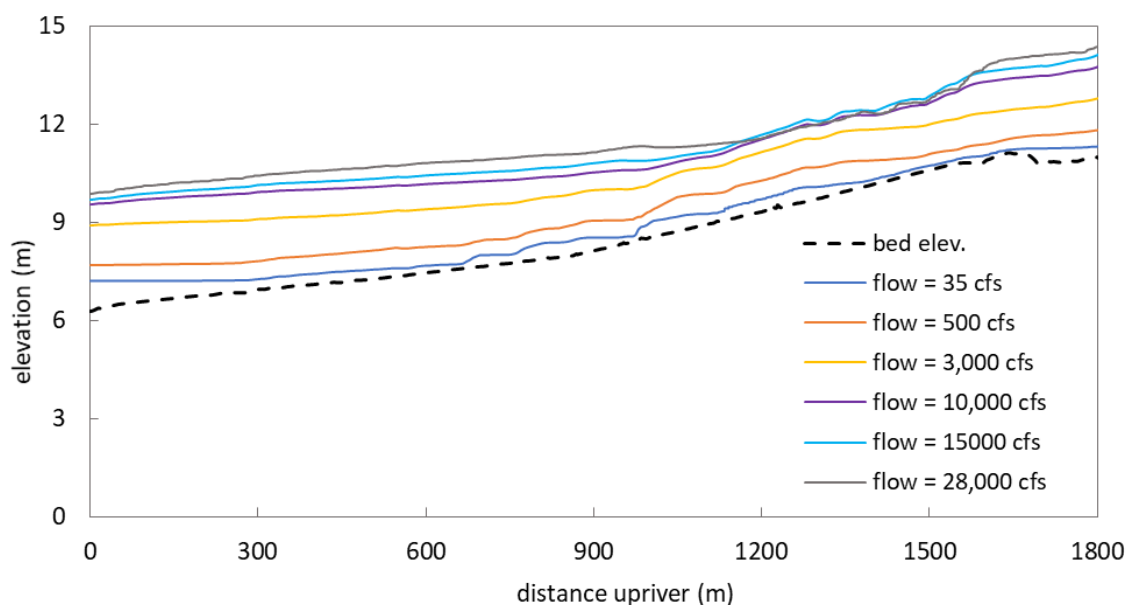
As illustrated in Table 5, flow is not evenly distributed between the individual channels in the Alt. 3 hybrid 3-channel network. Most flow (and resulting greater water depth) is concentrated in the western channel, with the middle and eastern channels receiving successively less flow. The effect is most pronounced at the lowest input flow of 35 cfs, with flows evening out somewhat as the input flow increases to the approximate bankfull design flow. The uneven distribution may be due

in part to a slight westward tilt of the floodplain surface, which is evident in the cross-sectional bed profile seen in Figure 9 above. Channel geometries may be adjusted in future design phases however some amount of flow concentration may be desirable, to maintain greater water depth in at least one of the channels during low-flow periods.

Filling of the pits with material, proposed in the Alternative, results in significant decrease in water depth throughout the pits reach. Currently, under the EC, water depths exceed 15 feet in some of the Ridgfield Pits even under the lowest flow conditions. At bankfull, depths exceed 25 feet in many areas. Alternative 3 channel depths range from 0.3 feet at the minimum input base flow of 35 cfs, up to 6.6 feet at just over bankfull flow of 3,000 cfs.

Model simulations for Alternative 3 show the channel banks overflowing at the 3,000 cfs input flow level, consistent with the design goal of 2,600 cfs. We did not run a simulation at the design bankfull input of 2,600 cfs, however water depths for the 3,000 cfs simulation are in the range of 6.1–6.5 feet. This being slightly higher than the design bankfull elevation of 5.9 feet indicates that the banks are overtopping at flows close to what was targeted in the design. It was noted earlier that channel overtopping as calculated by the Manning's trapezoidal channel formulas was predicted to occur at 3,801 cfs, which is somewhat higher than what the model results show. Discrepancies may be due to two factors: 1) inability of the model cell resolution to fully capture exact channel dimensions; and 2) a lack of field observations to fully calibrate and validate the model over the full range of input flow. Calibration and validation will be done prior to future design phases and design parameters will be adjusted accordingly.

Longitudinal water surface plots through the Ridgfield Pits reach for the steady-state simulations are shown in Figure 11. These illustrate the reduction in water depths for the Alternative 3 multi-thread channel network (Fig. 11, top) relative to the EC (Fig. 10, bottom). Water surface slopes are also generally reduced for the Alternative, particularly at flows less than or equal to the bankfull flow, resulting in reduced erosive potential (shear stress) and current velocity through the reach.



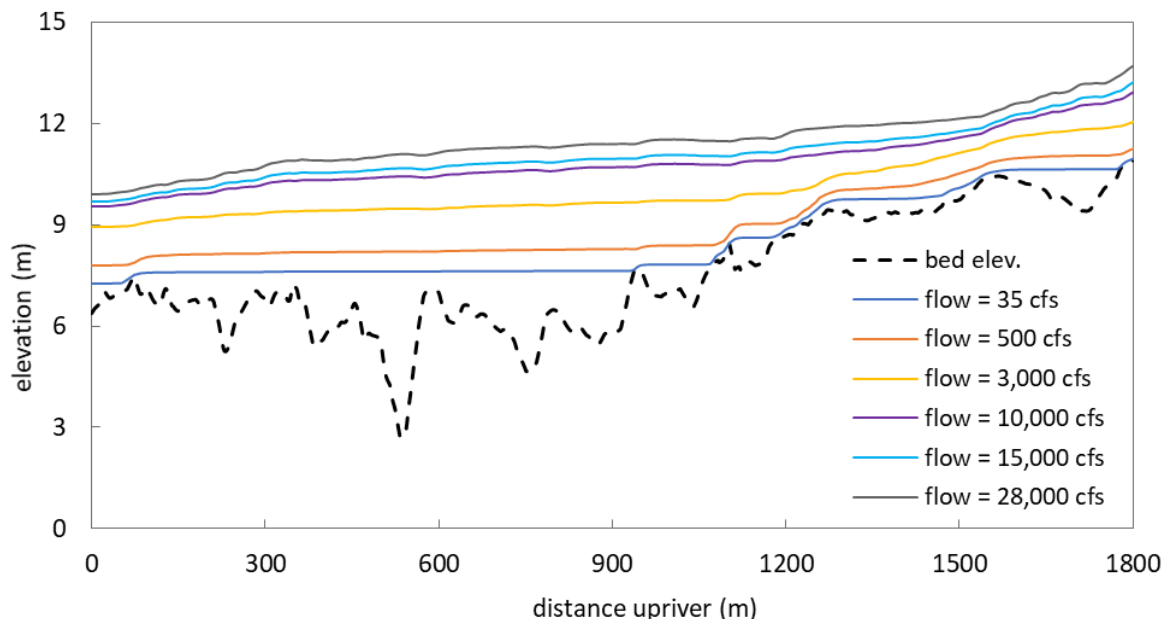


Figure 11. Longitudinal water surface profiles through the Ridgefield Pits reach for the steady-state model simulations. Top: Alternative 3 hybrid 3-channel network (middle channel). Bottom: EC.

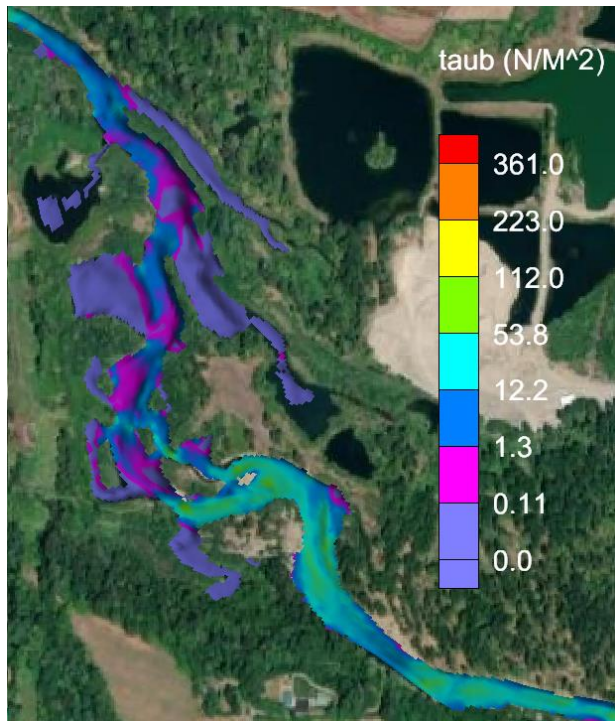
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- Model steady-state simulation outputs: Bed shear stress (τ_b)

Steady-state simulation bed shear stress (τ_b) profiles are shown in Figure 12 for the EC and Alternative 3 hybrid 3-channel network model surfaces. Plots are included for higher flow conditions only, as erosive conditions are not present at flows less than approximately 1,000 cfs. Plots are binned according to critical shear stress values (τ_c) required to move various grain size, as shown in Table 6. For example, in areas colored pink, sand (0.0625–2.0 mm grain size) and finer sediments would be transported under the given flow condition. In areas colored green, small cobble (64–128 mm grain size) and finer materials would be transported, etc.

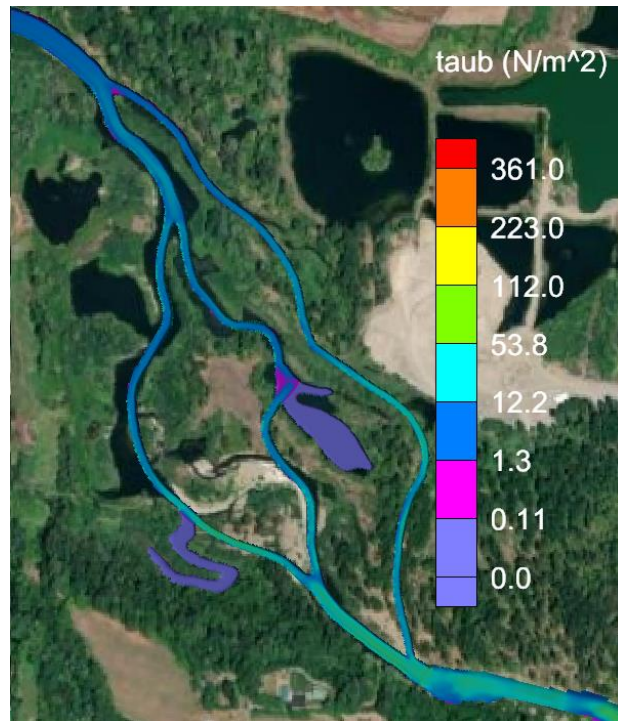
Table 6. Grain diameters and associated critical shear stress values. Source: USGS Scientific Investigations Report 2008-5093 (<https://pubs.usgs.gov/sir/2008/5093/table7.html>)

Particle class	Range of particle diameters		Critical bed shear stress (τ_c) (N/m ²)
	mm	inches	
Large Cobble	128 – 256	5 – 10	112 – 223
Small Cobble	64 – 128	2.5 – 5	53.8 – 112
Coarse Gravel	16 – 64	0.6 – 2.5	12.2 – 53.8
Fine Gravel	2 – 16	0.1 – 0.6	1.3 – 12.2
Sand	0.0625 – 2	0.0025 – 0.1	0.11 – 1.3
Silt and Fines	0 – 0.0625	0.0000 – 0.0025	0 – 0.11

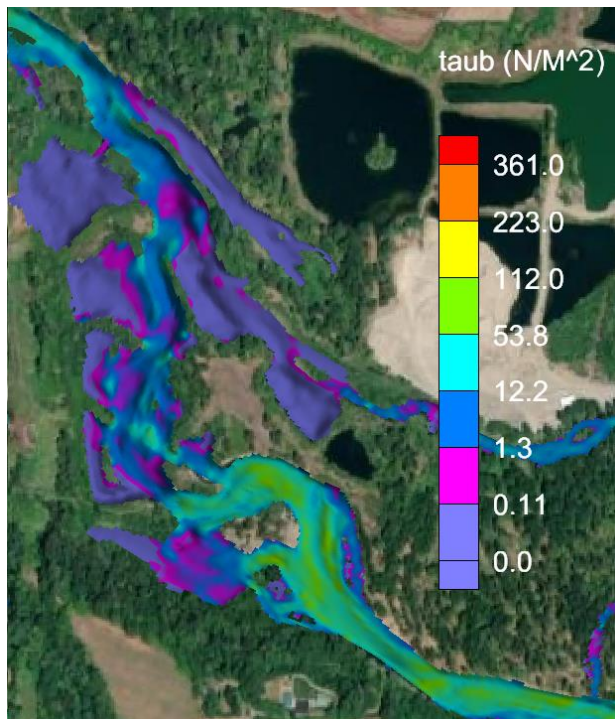
EC, Q = 1,000 cfs



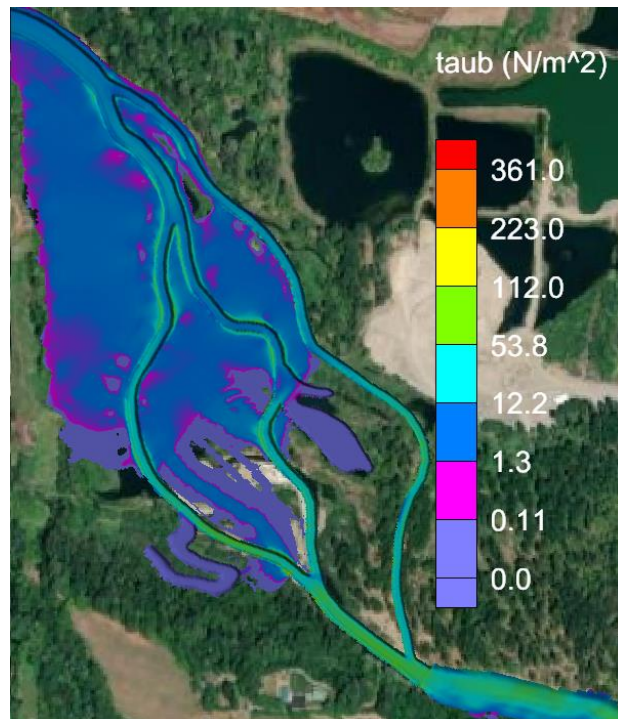
Alt 3, Q = 1,000 cfs



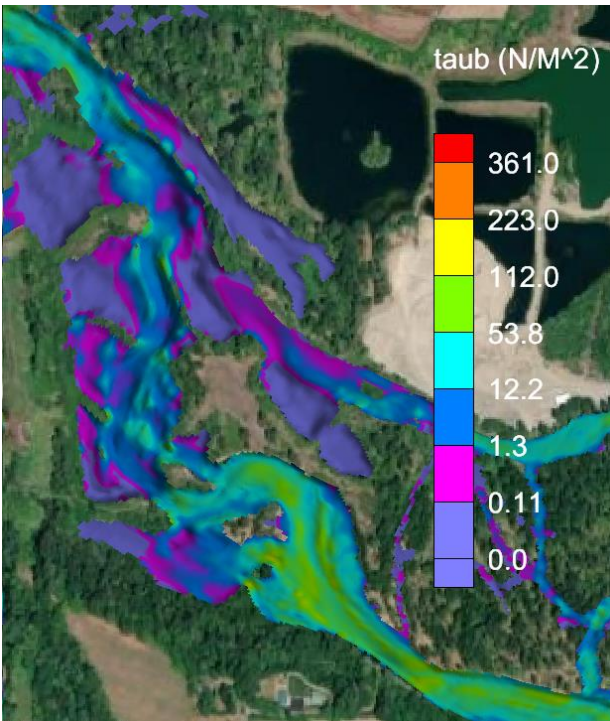
EC, Q = 3,000 cfs



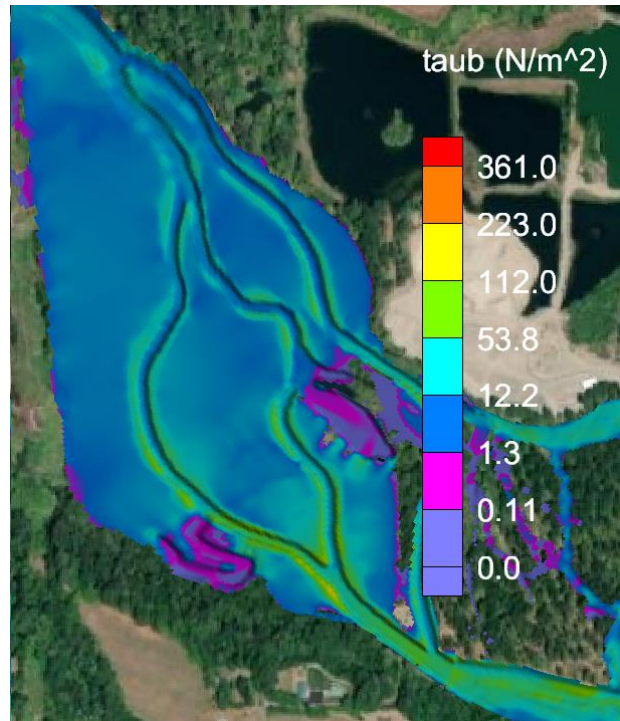
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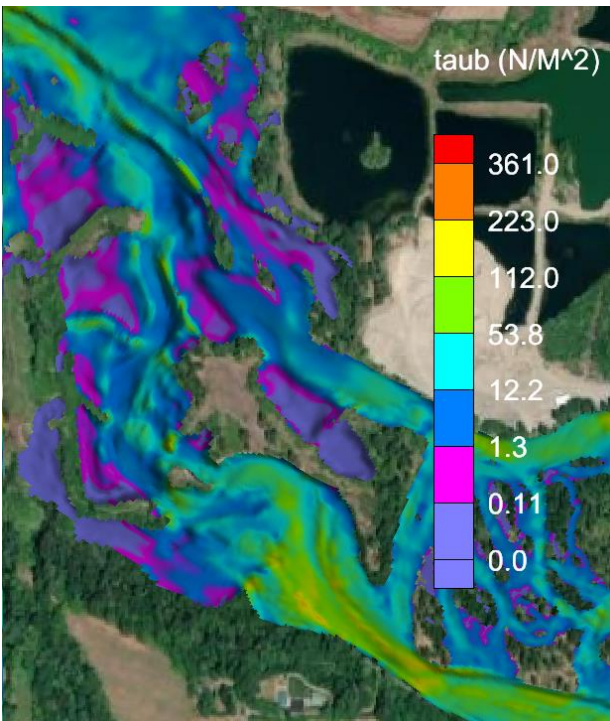
EC, Q = 5,000 cfs



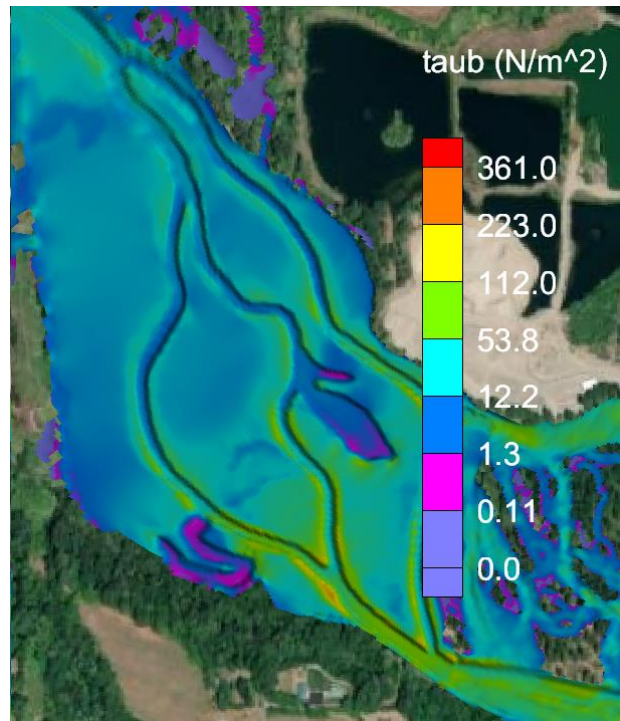
Alt 3, Q = 5,000 cfs



EC, Q = 10,000 cfs



Alt 3, Q = 10,000 cfs



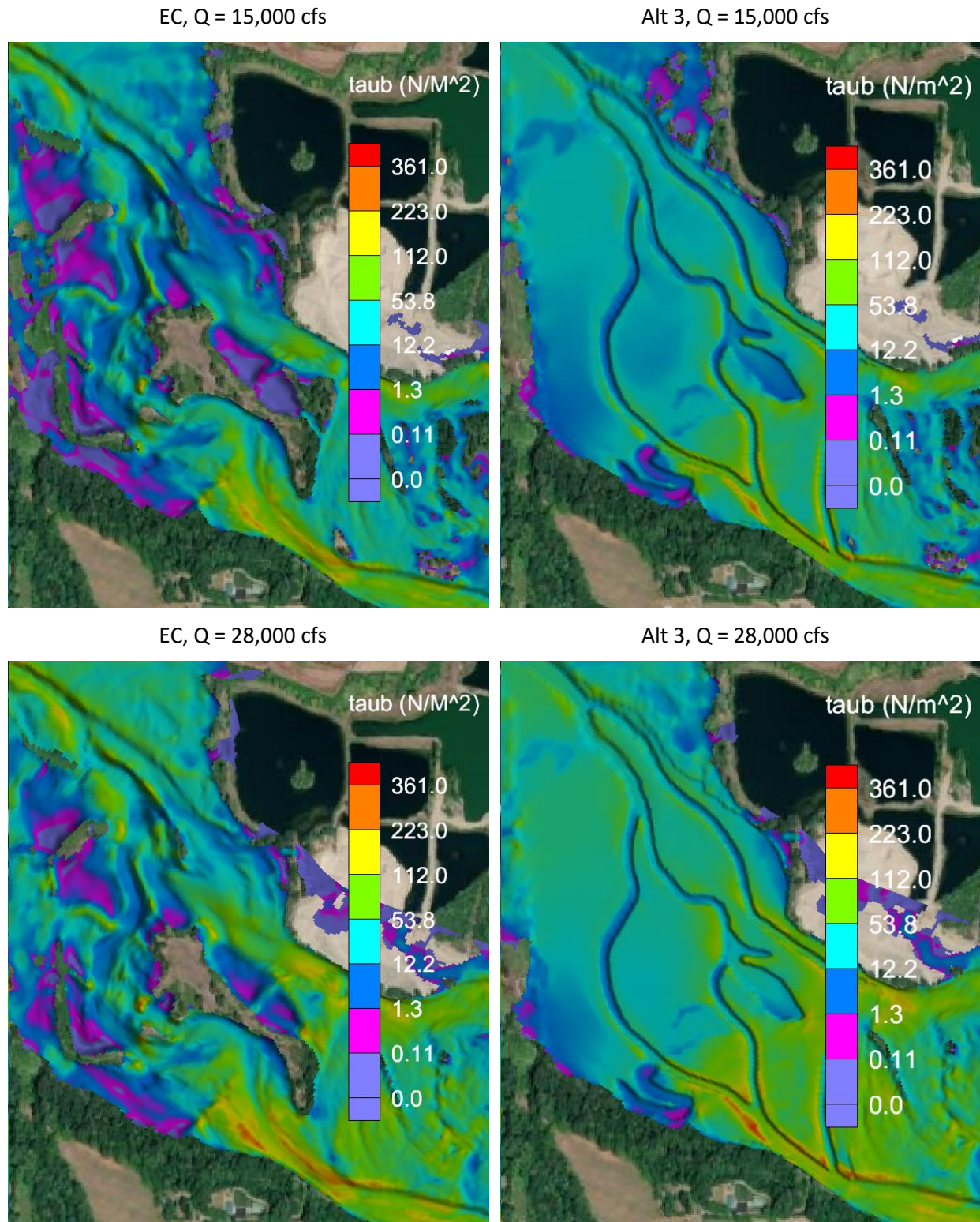


Figure 11. Bed shear (τ_b) plots for model steady-state simulations covering the range of higher ELFR discharge values from 1,000 cfs up to the 500-year flood event. Left column: τ_b for the EC model. Right column: τ_b for the 3-channel hybrid Alternative model.

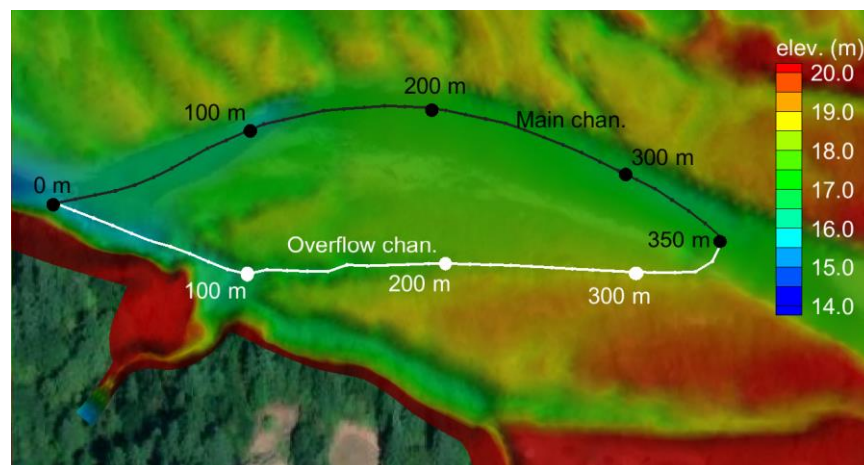
Plots in Figure 11 show a general reduction of channel bed shear stress values at the upstream end of the Ridgefield Pits reach for the Alternative 3 hybrid multi-thread compared to the EC, at bankfull, 1-year (~5,000 cfs) and 2-year (~10,000 cfs) input flows. This reduction should increase channel stability in this portion of the reach, which has shown significant channel instability throughout the past several years. Over this same flow range, low-shear areas currently present in the deep pits are eliminated in the Alternative model. Combined with more uniform shear stresses overall for the Alternative model, at magnitudes large enough to move gravels, sediment transport through the reach is expected to improve significantly compared to the EC.

1.9 MODEL RESULTS: ALTERNATIVE 5

Multiple restoration concepts were proposed at the Mill-Manley confluence however the overflow channel was the only one that involved significant channel re-work requiring hydraulic model evaluation. The objective of creating the Alternative 5 overflow channel is to increase flow to the Mill/Manley confluence zone during high flow events to induce scour of sand and gravel material that currently concentrates here and degrades cold water habitat conditions. This Alternative was proposed early in the TOG process, however due to various factors identified in subsequent meetings its potential effectiveness was called into question. These factors include: 1) increased sediment load from Mill Creek due to upper watershed impacts; 2) risk of impacting existing cold water habitat in the beaver ponds at the Manley Creek confluence; and 3) risk of increasing erosion along the severely eroded south bank immediately downstream of Mill Creek. Despite the decision to no longer pursue this Alternative the TOG requested the modeling to proceed, and so results are included here.

- Alternative 5 channel geometry

Channel profiles for the Existing Condition (EC) and iterations of the Alternative 5 overflow channel are shown in Figure 13, for the respective longitudinal profiles shown in Figure 12 for the overflow and main channels. A second iteration of the overflow channel was created after model results for the first iteration did not result in increasing scour at the confluence zone (see results below).



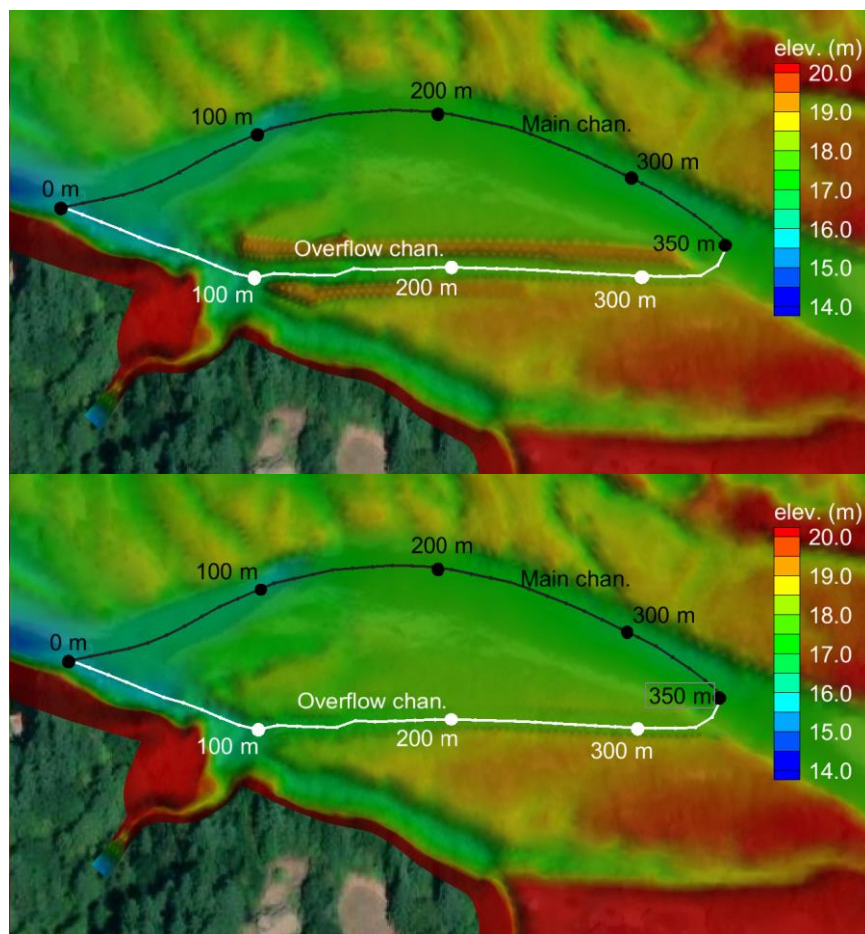


Figure 13. Model topography and longitudinal elevation profile paths for the EC and Alternative 5 overflow channel at the Mill/Manley confluence zone. Top: EC; Middle: initial Alt. 5 overflow channel; Bottom: Alt. 5 overflow channel, 2nd iteration. Respective longitudinal elevation profiles are shown in Figure 13 below.

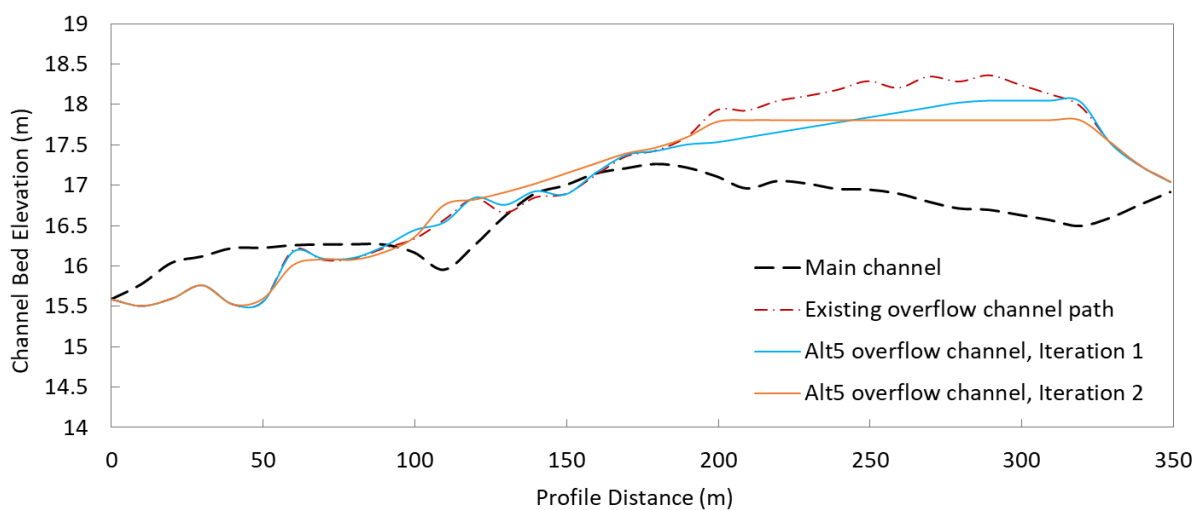


Figure 13. Model elevation profiles along the longitudinal profile paths shown in Figure 12 above.

- Model steady-state simulation outputs: Bed shear stress (τ_b)

Steady-state simulation bed shear stress profiles are shown in Figure 14 for the EC and Alternative 5 overflow channel model surfaces, over the input flow magnitudes of interest. Plots are binned according to the same critical shear stress values required to move various grain size, as were described above in Table 6. Relative difference in bed shear between the overflow channel model and the EC model are shown in Figure 15. Yellow, red, and orange shades indicate an increase in bed shear for the overflow channel condition whereas blue shades indicate a decrease, relative to the EC. The area enclosed by the white circle encompasses the Mill/Manley confluence area of interest. The objective of Alternative 5 is to increase bed shear in this zone during the flow period of interest, to promote sediment scour and maintain water depths that are suitable for use by salmonids seeking thermal refuge.

The initial overflow channel was modeled with berms to help concentrate flow in the channel. Model results showed no advantage with these structures present, with bed shear values decreasing relative to the EC (Fig. 15, left side images). These berms were removed, and the overflow channel was re-graded, for the 2nd and final iteration (see profiles in Fig. 13). Bed shear values for this final iteration show a slight increase in the zone of interest relative to the EC (Fig 15, right side images), however increased scour potential is also introduced further upstream in the overflow channel, which could potentially deliver additional sediment to the confluence zone. Bed shear does not show any increase along eroding EFLR bank immediately downstream of the Mill/Manley confluence zone, however this was not studied in detail for this analysis since this Alternative has been deemed generally unfavorable by the TOG.

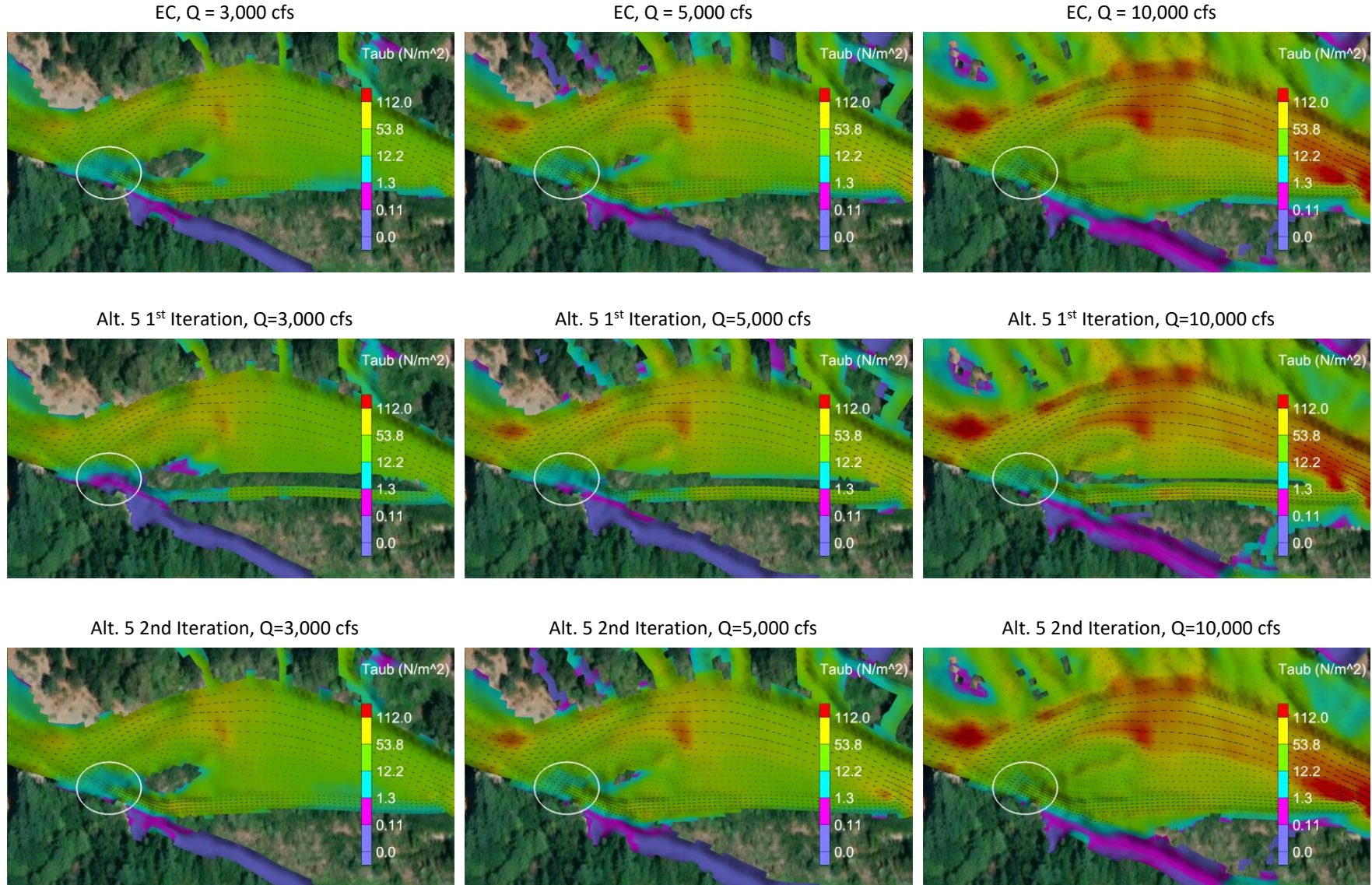


Figure 14. Bed shear (τ_b) plots for model steady-state simulations covering the typical winter EFLR flows up to the approximate 2-year flood event. Left column: τ_b for the EC model. Middle column: τ_b for the Alt 5. Model, initial iteration. Right column: τ_b for the Alt 5. Model, final iteration.

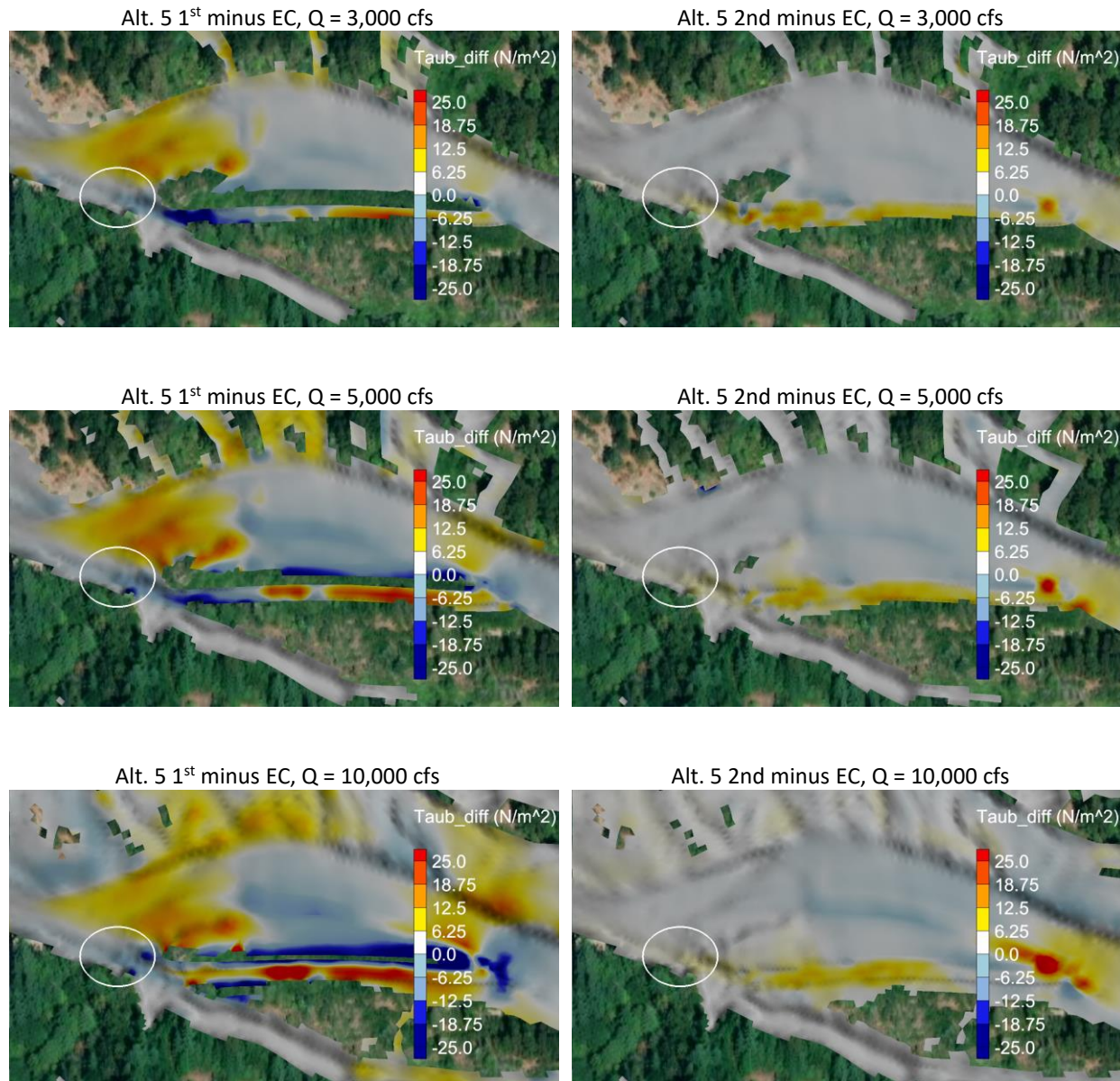


Figure 15. Bed shear (τ_b) difference plots for model steady-state simulations covering the typical winter EFLR flows up to the approximate 2-year flood event. Left column: τ_b (Alt. 5 iteration 1) - τ_b (EC). Right column: τ_b (Alt. 5 iteration 2) - τ_b (EC).

1.10 HYDRAULIC MODELING SUMMARY AND NEXT STEPS

The Ridgefield Pits hydraulic model was used to help evaluate restoration Alternative 3 – within the Ridgefield Pits reach proper, and restoration Alternative 5 – the proposed overflow channel upstream of the Mill/Manley confluence with the EFLR. The model also serves as input for extended analyses of sediment transport and water temperature, using add-on modules within the Tuflow modeling package. These analyses are described in Sections 2.5 and 2.6 of the main report, although sediment modeling has not been fully completed at this time. Inputs to the Ridgefield Pits model were derived from an initial model covering the entire EFLR downstream of the project reach, that

was developed for the La Center Wetlands restoration project. That model was fully calibrated and validated, however this process has not yet been completed for the Ridgefield Pits model because required field observations are still being collected.

Model simulations of the preferred restoration Alternative 3 for the Ridgefield Pits reach generally show improved hydraulic conditions for the 3-channel hybrid network relative to the Existing Condition (EC). Bed shear and water surface profiles suggest improved sediment transport and channel stability through this reach for the 3-channel network. Currently, the reach shows significant channel instability, and a continued lack of sediment conveyance, as the reach continues to slowly adjust to the 1996 channel avulsion event. Bankfull flow occurrence as predicted by the model is somewhat less than what was predicted by channel calculations for the given channel design parameters. This is expected, as the model is not fully calibrated, and the model grid cell resolution is limited in the ability to fully resolve the relatively small channel widths incorporated in the design. Further grid refinements, and model calibration, will be incorporated into the next design phase to resolve these issues.

Model simulations of the overflow channel proposed in Alternative 5 at the Mill/Manley confluence did not show a significant improvement over the EC, relevant to the restoration objective of promoting scour at this confluence zone. A minor increase in bed shear was obtained after some refinement of the channel geometry, however increased bed shear upstream, as well as other potential concerns associated with this action that were expressed by the TOG, have generally deemed this restoration alternative unfavorable.

1.11 REFERENCES

- Arcement, G.J., V.R. Schneider. 1989. Guide for selecting Manning's roughness coefficients for natural channels and flood plains. U.S. Geological Survey Water-Supply Paper 2339.
- Inter-Fluve, Lower Columbia Estuary Partnership. 2014. East Fork Lewis River La Center Wetlands Floodplain Restoration Preliminary Design Report. Prepared for the Lower Columbia Fish Recovery Board.
- Tuflow FV Flexible Mesh Modeling. 2020. [Tuflow FV User Manual](#), Build 2020.02. Hydrodynamic Modeling Engine.
- Tuflow FV Flexible Mesh Modeling. 2013. [Tuflow FV Science Manual](#).
- Wood Rogers Inc. 2015. Lewis River East Fork Tuflow FV Model QC/QA Review. Prepared for the Lower Columbia Estuary Partnership.

D. Sediment Sampling

continues on next page

East Fork Lewis River Ridgefield Pits Restoration

Basis of Design Report Preliminary Design:
Attachment 4 – Sediment Sampling & Analysis



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1.1 SEDIMENT SAMPLING

1.1.1 Overview

To characterize the EFLR channel bed and bank composition throughout the project reach a sediment sampling survey was completed in October 2018. Photo points were used to interpret bank composition, while Wohlman pebble counts were done for random transects at selected channel bed surface and subsurface, as well as floodplain locations. Depth of refusal measurements were also taken in Ridgefield Pits # 4, 5, and 7, to characterize the bottom composition and estimate water depths. The sampling plan is illustrated in Figure 1.

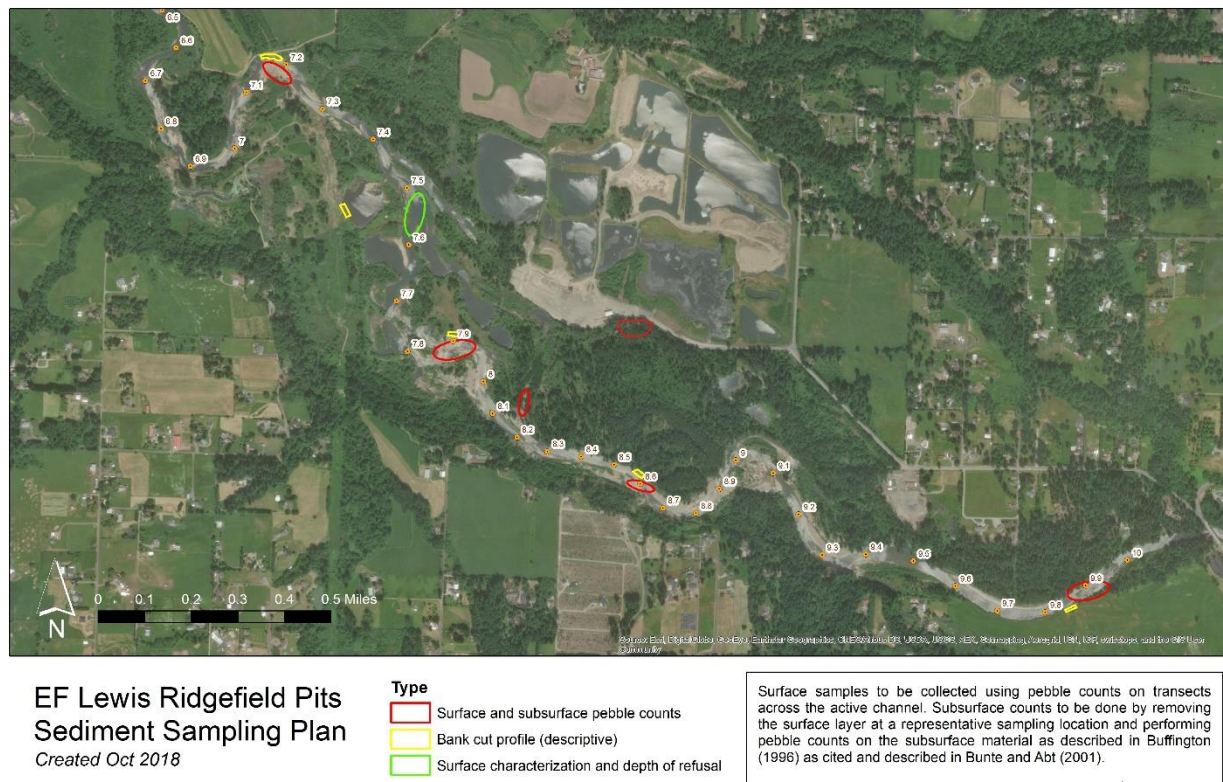


Figure 1. Sediment sampling plan for the project reach.

1.1.2 Sediment sampling results

A complete analysis of the collected sediment data is included as Appendix A of this attachment. The images in Figure 2 provide a summary of results at representative locations.

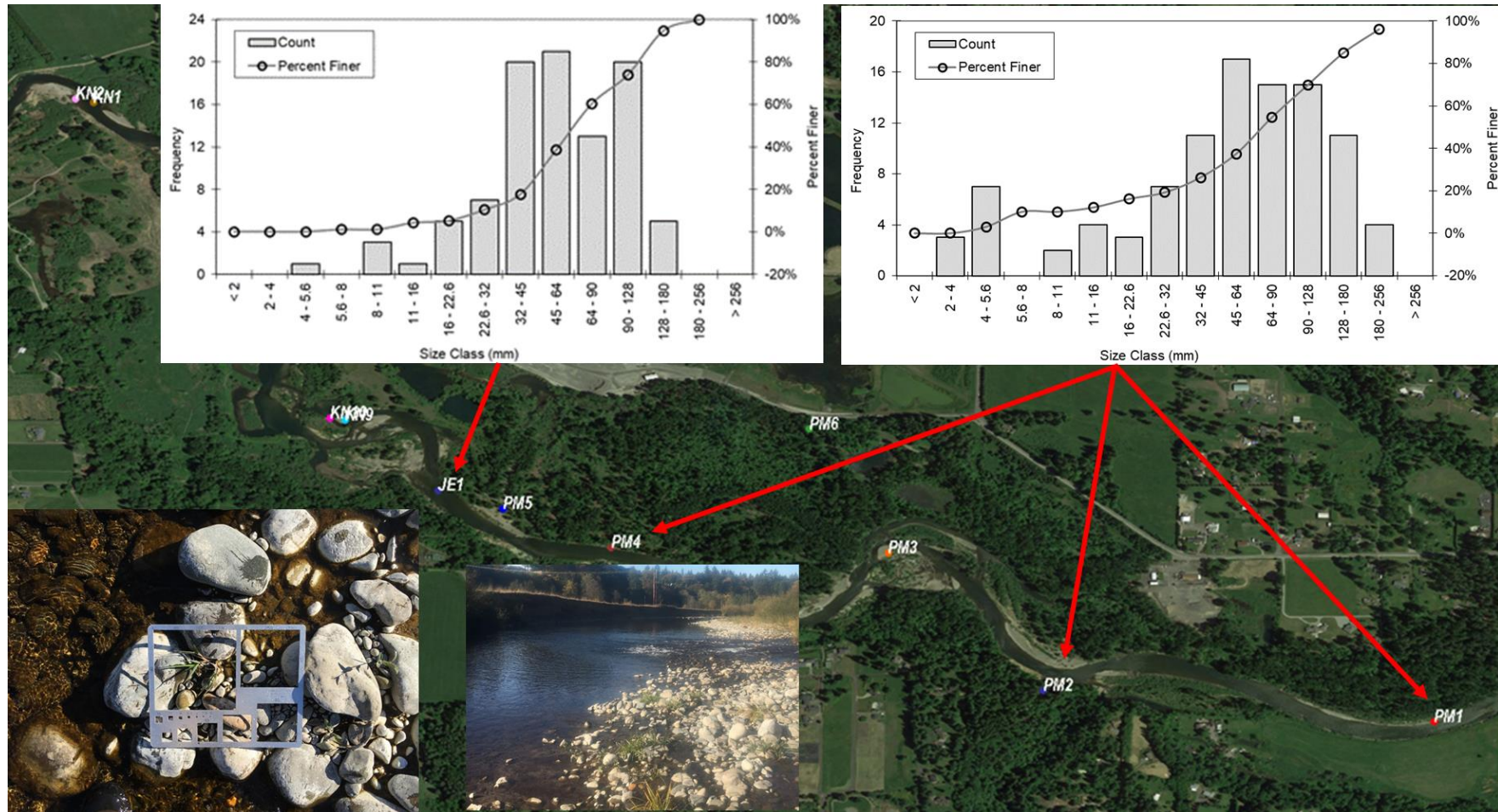


Figure 2a. Grain size analysis at selected locations at the bed surface. The plot on the right is for location PM4, however PM1 and PM2 were similar (see Appendix A of this attachment for complete results). Note large cobbles present in these surface layers in the photos, which act to armor the underlying bed from erosion.

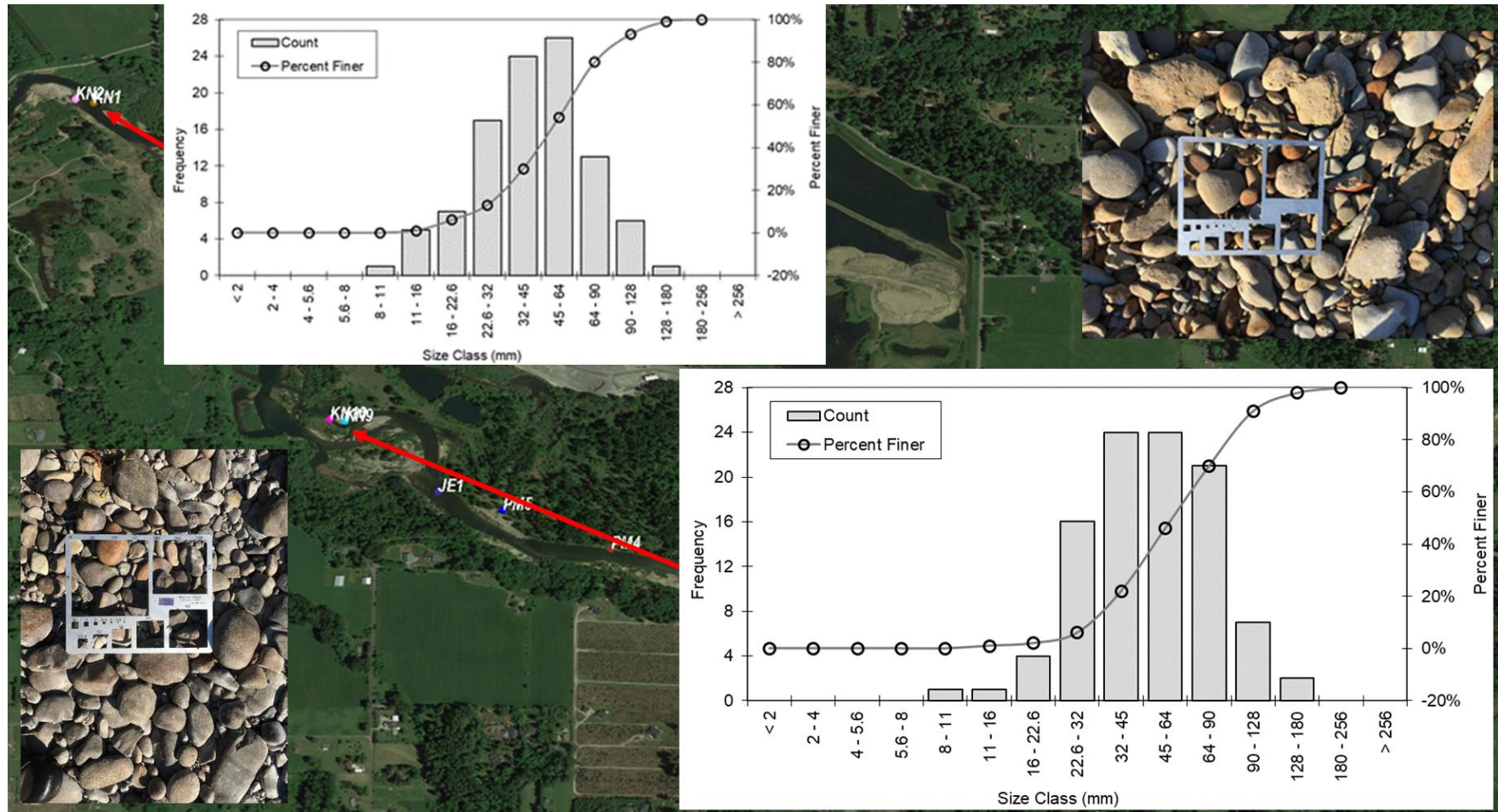


Figure 2b. Grain size analysis at additional bed surface locations. Note large cobbles present in these surface layers in the photos, which act to armor the underlying bed from erosion.

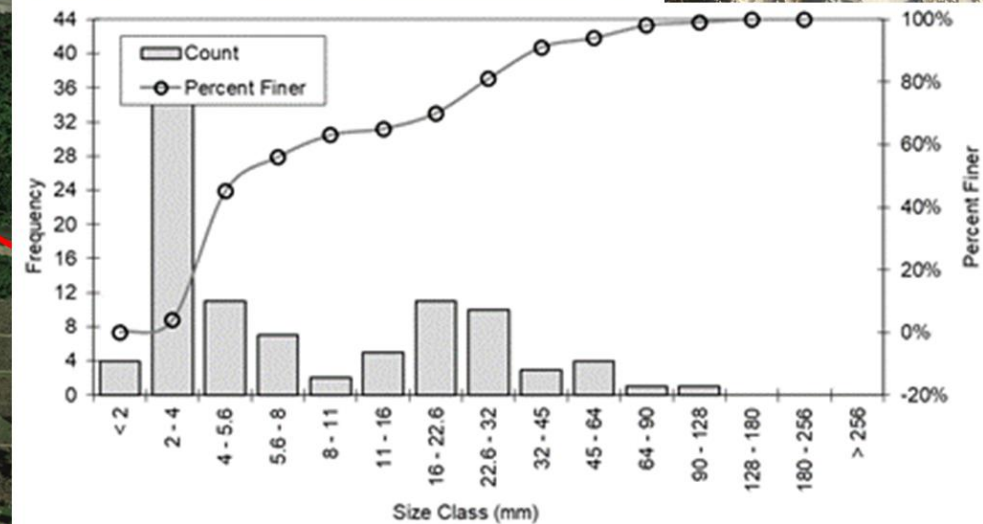
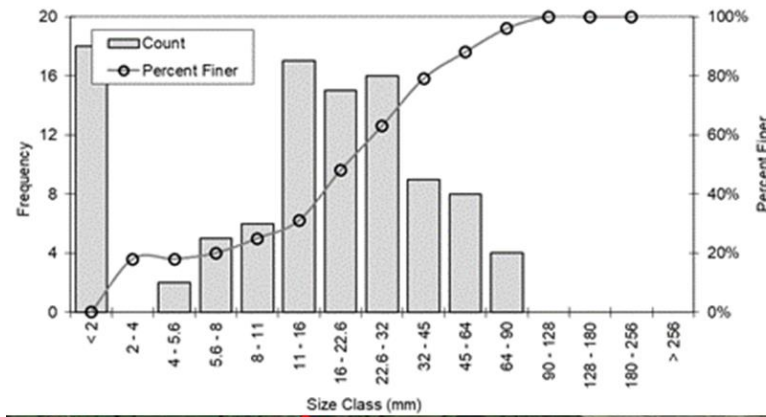


Figure 2c. Grain size analysis at selected bed sub-surface locations. Note finer materials present here, under the overlying armored surface layer with larger cobbles.

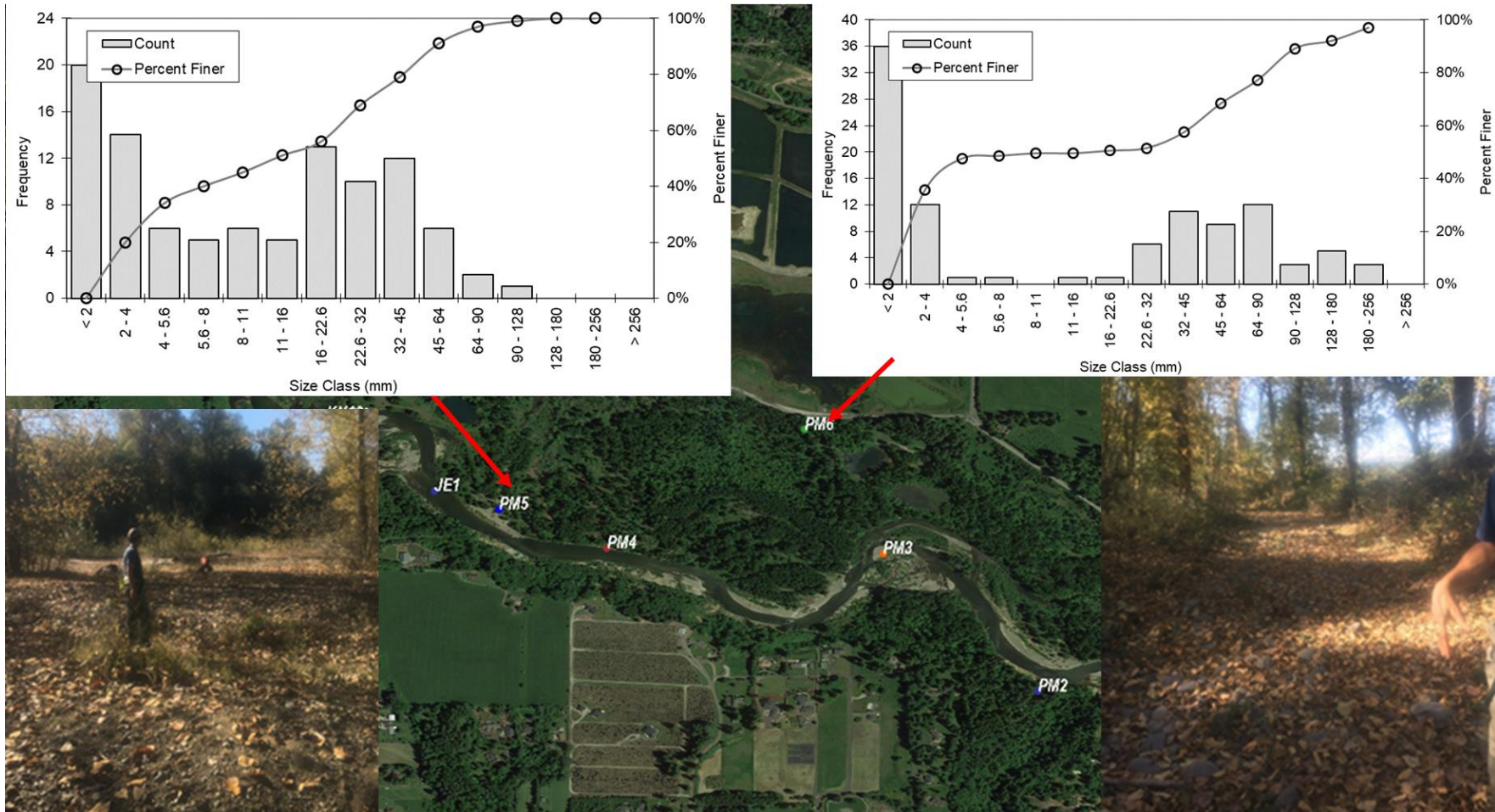


Figure 2d. Grain size analysis at selected floodplain locations.



Figure 2e. Vertical bank profiles at selected EFLR mainstem locations.

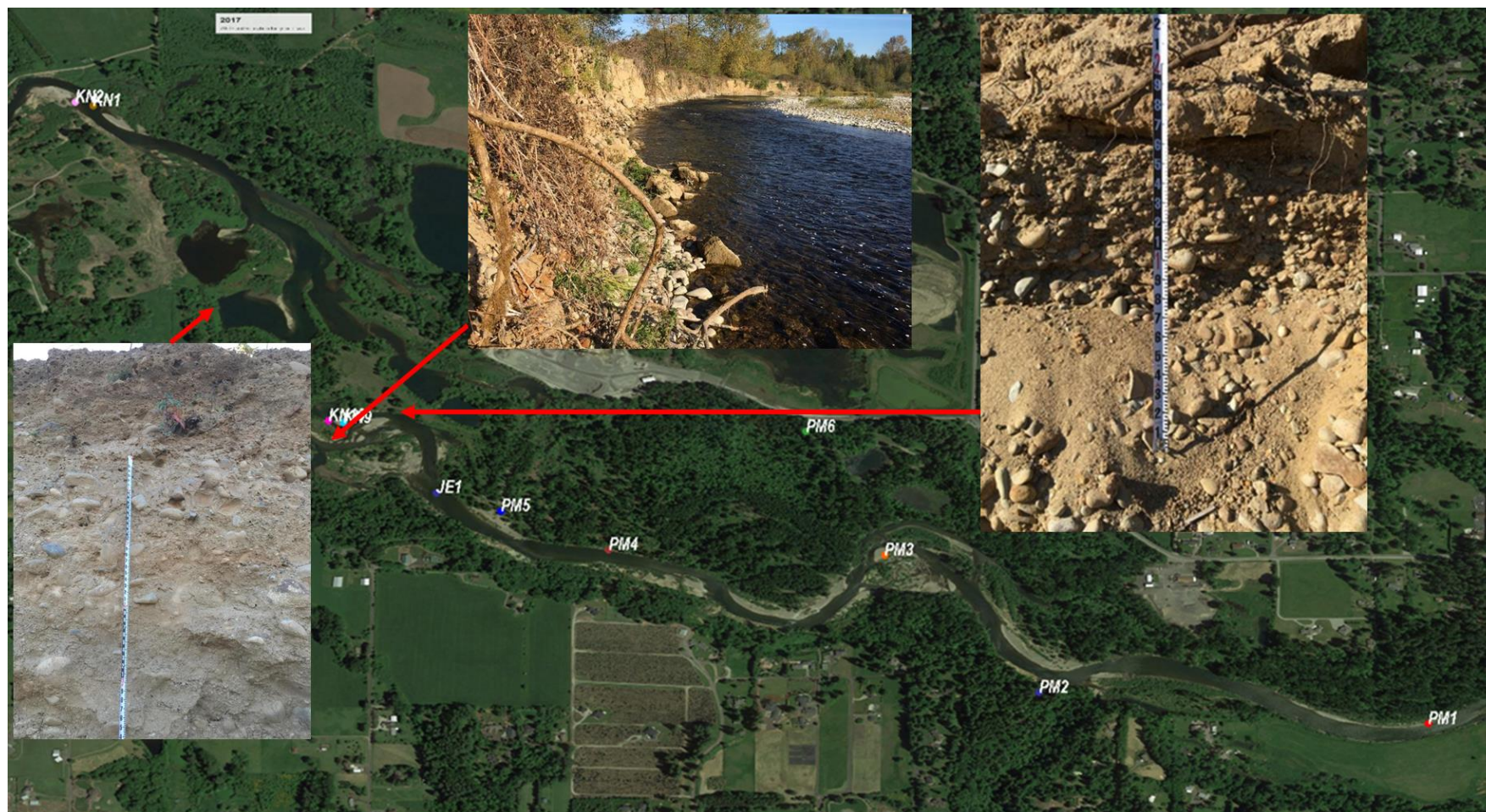
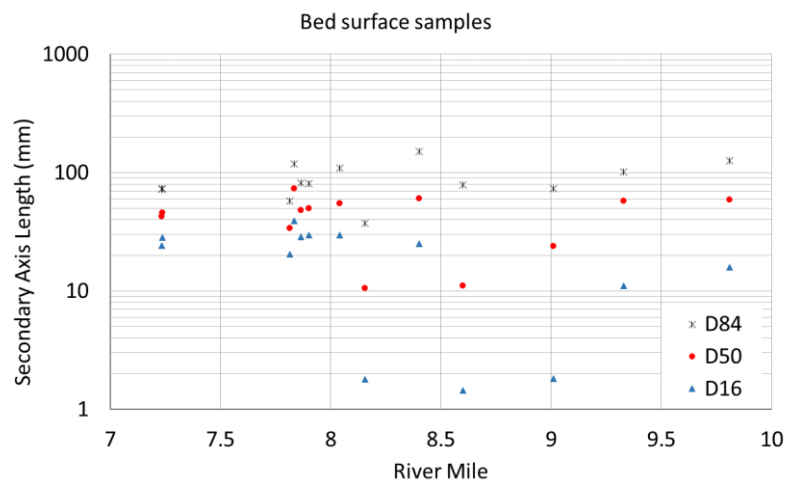


Figure 2f. Vertical bank profiles at additional EFLR mainstem locations.

Grain size distribution for all pebble count locations sampled is summarized in Table 1 and Figure 2. In general, grain size distribution was consistent throughout the project reach (Table 2) for both bed surface and sub-surface. The surface layer consists mostly of coarse gravel and cobble, with very little fine sediment. This ‘armored’ layer acts to shield the underlying (sub-surface) channel bed from erosion over much of the flow regime. Subsurface sediments show a bi-modal distribution, with a significant fine grain component consisting of sands up to ~4 mm and an additional component of coarse gravels and cobble similar to the surface layer. Floodplain composition is similar to that of the channel subsurface. Photos taken of channel banks in exposed locations (Figs. 2e and 2f) show two general patterns of vertical bank profile characteristic of the project reach. The first is a single, consolidated bank layer of mixed sand, gravel, and cobble, with grain size generally decreasing with increased height. The second, and most dominant, profile consists of this same initial mixed grain size layer, with an overlying fine layer of consolidated silts.

Table 1. Grain size analysis summary for all sampling locations, with overall mean and median values for D_{16} , D_{50} , and D_{84} .

Location	Bed sub-surface			Bed surface		
	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)
PM1 (RM 9.8)	2.9	6.3	16.4	15.8	59	125.9
PM2 (RM 9.3)				11.0	57.7	100.9
PM3 (RM 9.0)				1.8	24.0	73.4
PM4 (RM 8.4)	2.6	4.7	24.4	25.1	60.7	150.2
PM5 (RM 8.2)	2.0	3.8	17.1	1.8	10.5	37.4
PM6 (RM 8.6)				1.4	11.0	78.8
KN1 (RM 7.2)				24.3	42.8	72.0
KN2 (RM 7.2)	4.0	11.2	22.2	28.4	45.7	73.5
KN5 (RM 7.8)				20.4	34.0	57.4
KN6 (RM 7.8)	7.7	14.1	29.7			
KN7 (RM 7.9)				29.8	50.1	80.4
KN8 (RM 7.9)	2.8	16.9	39.2			
KN9 (RM 7.9)				28.5	48.2	81.3
KN10 (RM 7.8)				39.3	73	118.1
JE1 (RM 8.0)				29.8	55.0	108.3
Mean	3.7	9.5	24.8	19.8	44.0	89.0
Median	2.9	8.8	23.3	24.3	48.2	80.4



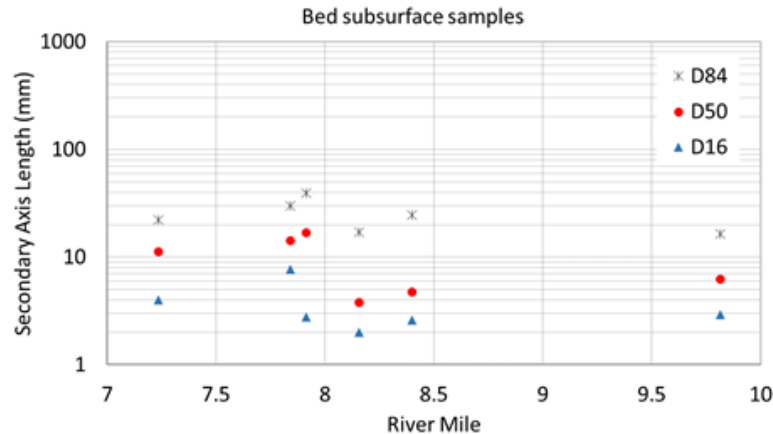


Figure 3. Grain size distribution by river mile. Top: bed surface samples. Bottom: bed sub-surface samples.

1.2 SEDIMENT TRANSPORT AND MORPHO-DYNAMIC MODELING

1.2.1 Overview and setup

A morpho-dynamic sediment transport model with the capability to dynamically adjust bed elevations in response to hydraulically forced movement of bed and suspended load materials was developed to help characterize current transport conditions and inform the restoration alternatives that were assessed using the hydraulic model. The model used is included in the Tuflow FV modelling package (Tuflow 2020b), as an add-on module to the hydraulic modeling engine (Tuflow 2020a, 2013). Figure 3 illustrates the basic module capabilities and function. Multiple bed layers and sediment fractions within each layer can be defined to capture vertical variations in grain size distribution. Bed interaction between the surface and lower layers is included to mimic bed surface armoring effects, such as are present in the project reach. Several bedload and suspended load transport models are available for use within the module. For bedload we applied the Meyer-Peter-Muller equation, applicable to gravel bed rivers, and for suspended load applied the Mehta erosion and deposition model. Full model setup is complex and beyond the scope of this document, with numerous parameters that must be defined for transport, deposition, and erosion rates, bed layer composition, and sediment input rates. Setup is summarized in Tables 3 and 4. A complete description of the Tuflow Sediment Transport module can be found in Tuflow 2020b.

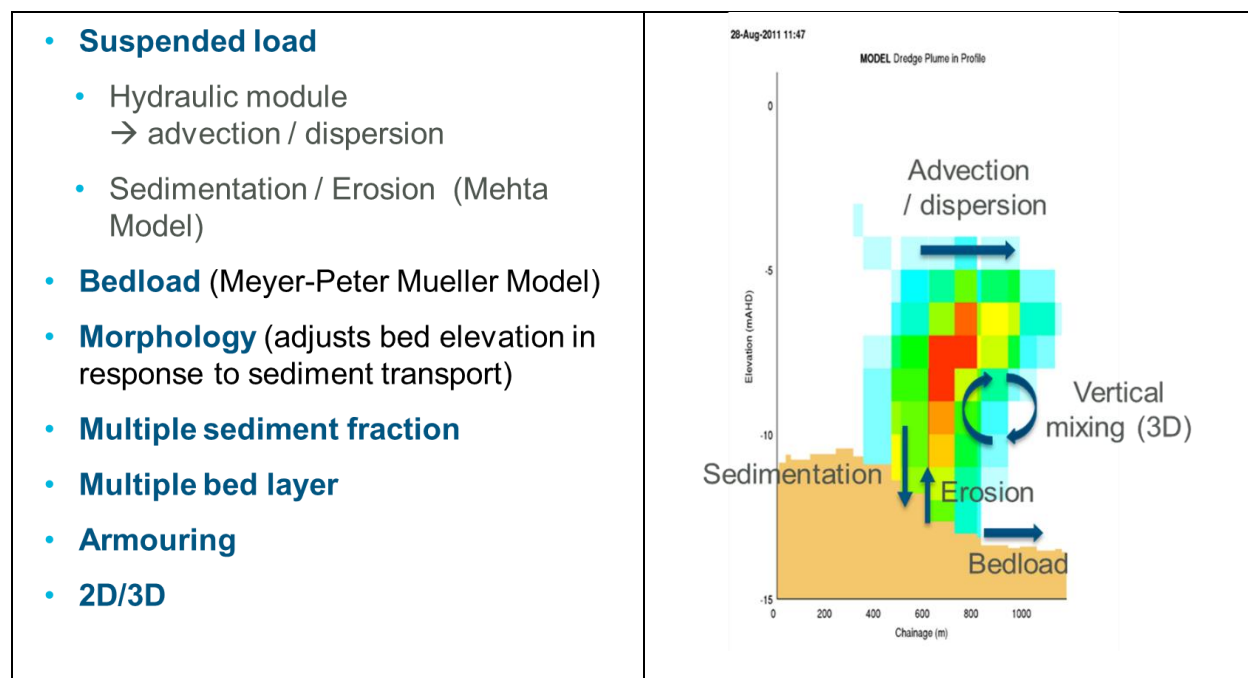


Figure 3. Capabilities and general functionality of the Tuflow FV morpho-dynamic sediment module.

Table 2 - Sediment transport and morpho-dynamic model setup: transport parameter assignments.

Model Parameter	Selected Option/Input	Notes
Sediment Fraction	Based on bed material (see Table 5)	Sediment makeup of a specific layer within the bed. Each layer can have varying amounts of sediment types.
Sediment Layers	Based on bed material (see Table 5)	Any bed material can have a single, or multiple, layers.
Bed roughness	Nikuradse bed roughness height, k_s	Fixed bed roughness height specified.
Bed shear model	Default	Selected the default option.
Settling model	Constant w_s	Constant settling velocity defined by the settling parameters.
Deposition model	Unhindered (w_s)	Deposition rate based on settling velocity and susp. sed. concentration.
Erosion model	Mehta	Corresponding stage based on HQ relation.
Bed load model	Meyer-Peter-Mueller (MPM)	Applicable for gravel bed rivers.
Critical stress model	None	Built into the MPM model
Sediment Input concentrations (mg/L)	Bedload: zero gradient Suspended load: TBD	Constant input supply.

Table 3 - Sediment transport and morpho-dynamic model setup: bed composition.

Material	# of layers	Layer Material Composition
Higher gradient armored channel bed	2	Layer 1: 0.15m thick armor layer with 22% med-coarse gravels ($D_{50} = 25$ mm), 48% very coarse gravel ($D_{50} = 50$ mm), 30% small-medium cobbles ($D_{50} = 100$ mm). Layer 2: 10 m thick underlying sand/gravel layer with 63% sand ($D_{50} = 2$ mm), 28% med-coarse gravels ($D_{50} = 25$ mm), 7% very coarse gravel ($D_{50} = 50$ mm), 2% small-medium cobbles ($D_{50} = 100$ mm)
Gravel pits, and lower - gradient channel through pits	2	Layer 1: 0.5 m thick layer of finer materials with 82% silt ($D_{50} = 0.05$ mm); 18% sand (0.2mm) Layer 2: 5 m thick underlying sand/gravel layer with 63% sand ($D_{50} = 2$ mm), 28% med-coarse gravels ($D_{50} = 25$ mm), 7% very coarse gravel ($D_{50} = 50$ mm), 2% small-medium cobbles ($D_{50} = 100$ mm)
Floodplain	2	Layer 1: 0.5 m thick sand/gravel layer with 63% sand ($D_{50} = 2$ mm), 28% med-coarse gravels ($D_{50} = 25$ mm), 7% very coarse gravel ($D_{50} = 50$ mm), 2% small-medium cobbles ($D_{50} = 100$ mm) Layer 2: 10 m thick underlying sand/gravel layer with 63% sand ($D_{50} = 2$ mm), 28% med-coarse gravels ($D_{50} = 25$ mm), 7% very coarse gravel ($D_{50} = 50$ mm), 2% small-medium cobbles ($D_{50} = 100$ mm)

1.2.2 Sediment Transport Modeling Summary and Next Steps

Objectives of sediment transport modeling for this project include comparing transport rates, changes in bedform, and channel stability of the Existing Condition to those of the proposed restoration alternatives; and informing the design of a preferred alternative that will achieve improved overall transport conditions relative to the Existing Condition. Because the model was being developed concurrently with the Technical Oversight Group process, its use in helping to identify and define the restoration alternatives was limited.

To date LCEP has run a limited set of sediment transport simulations for the Existing Conditions model. A significant effort was expended testing the sensitivities of the model to changes in various bedload and transport parameters and their associated coefficients, as well as other elements of the model setup and simulation process. We have found results to be sensitive to changes in the underlying model grid. This presented challenges when updates to the grid were necessary to accommodate various iterations of design alternatives. Due to the required time to setup and run these models, we were not able to complete simulations for the latest grid revisions, including the Existing Condition, and restoration Alternatives 2 (the single thread channel) & 3 (the preferred alternative three channel network) for the Ridgefield Pits reach, in time for this report.

LCEP is currently in the process of refining model surfaces for Alternatives 2 & 3. We were able to compare water temperature performance for these (see Section 2.6 of the main report and Attachment 5), however channel geometries have not been optimized for higher flow conditions where sediment transport occurs. This step will be completed early in the next design phase, after which we will run the transport model and compare results for the preferred Alternative 3 and the Existing Condition, and for Alternatives 2 and 3 at the behest of the Technical Oversight Group, who have requested this additional analysis.

1.3 REFERENCES

Tuflow FV Flexible Mesh Modeling. 2020a. [Tuflow FV User Manual](#), Build 2020.02. Hydrodynamic Modeling Engine.

Tuflow FV Flexible Mesh Modeling. 2020b. [Tuflow FV User Manual](#), Build 2020.01. Sediment Transport and Particle Tracking Modules.

Tuflow FV Flexible Mesh Modeling. 2013. [Tuflow FV Science Manual](#).

1.4 APPENDIX A – SEDIMENT SAMPLING SURVEY RESULTS

Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	PK/Matt	Personnel
PM1	Identifier / Unit		Location		
	Longitudinal Description (<i>Pool, Riffle, Bend, Crossing, etc.</i>)		Latitude or Northing		
Sub-surface	Sample Type: Surface or Sub-surface		Longitude or Easting		
	Dominant / Subdominant Substrate		Waypoint		



Notes

Text

Photo

Photo

PM1_Subsurface.jpg



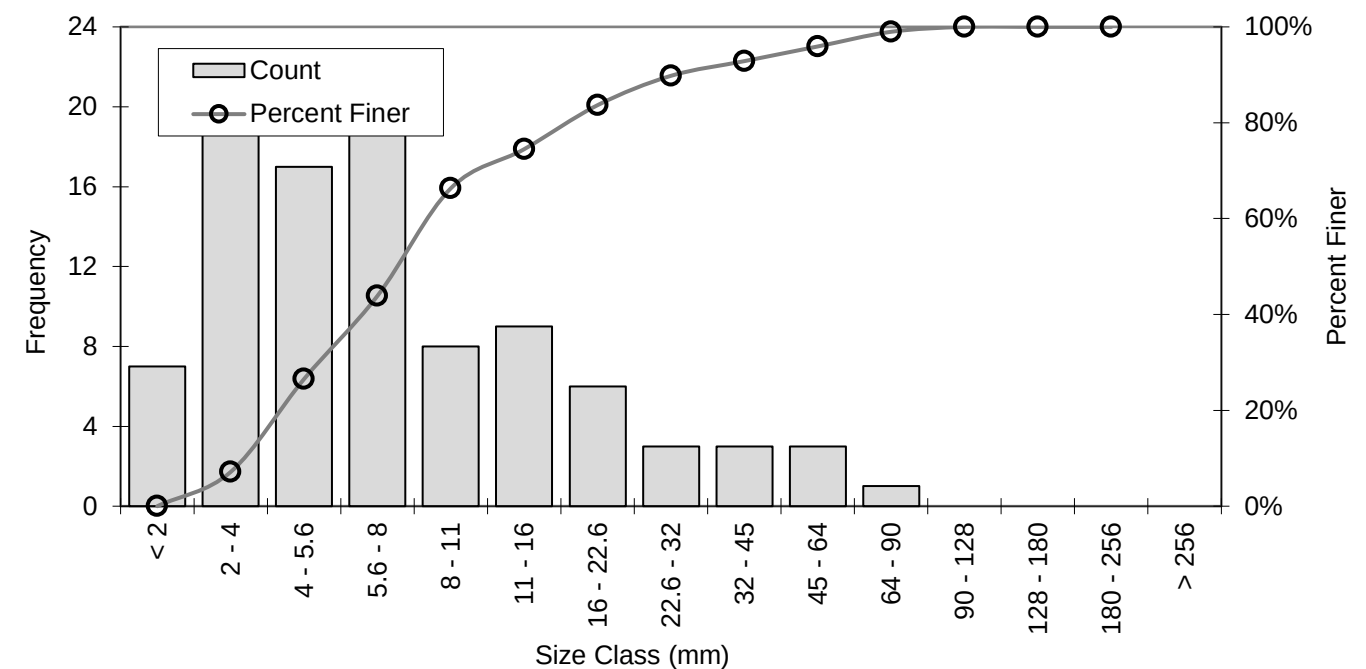
Distribution Statistic Points (Percent Finer)

D_{16}	2.9	mm
D_{50}	6.3	mm
D_{84}	16.4	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2	7	0%
Very Fine Gravel	2 - 4	19	7%
Fine Gravel	4 - 5.6	17	27%
Fine Gravel	5.6 - 8	22	44%
Medium Gravel	8 - 11	8	66%
Medium Gravel	11 - 16	9	74%
Coarse Gravel	16 - 22.6	6	84%
Coarse Gravel	22.6 - 32	3	90%
Very Coarse Gravel	32 - 45	3	93%
Very Coarse Gravel	45 - 64	3	96%
Small Cobble	64 - 90	1	99%
Small Cobble	90 - 128		100%
Large Cobble	128 - 180		100%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		98	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	PK/Matt	Personnel
PM4	Identifier / Unit		Location		
Main Channel Pool Tailout	Longitudinal Description (Pool, Riffle, Bend, Crossing, etc.)	45.816039	Latitude or Northing		
Sub-surface	Sample Type: Surface or Sub-surface	-122.618059	Longitude or Easting		
	Dominant / Subdominant Substrate		Waypoint		



Notes

Text

Photo

PM4_Subsurface.jpg



Photo

PM4Subsurface_SurfaceDownstream.jpg



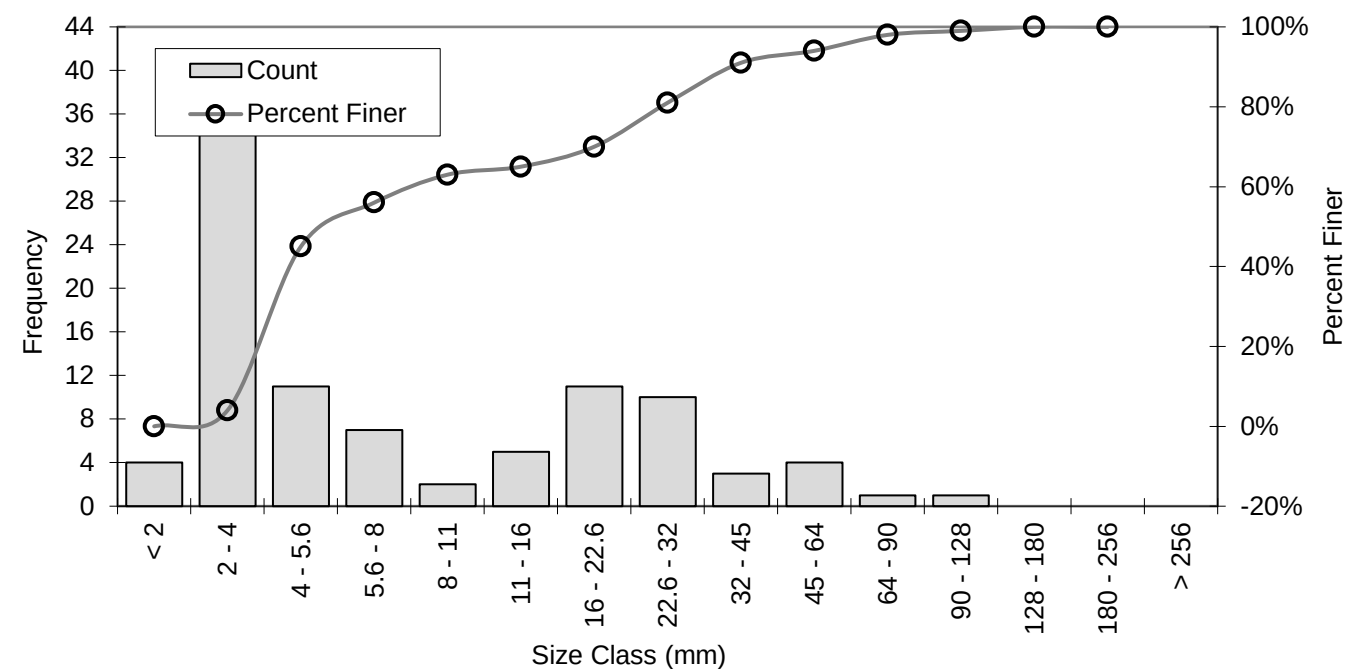
Distribution Statistic Points (Percent Finer)

D_{16}	2.6	mm
D_{50}	4.7	mm
D_{84}	24.4	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2	4	0%
Very Fine Gravel	2 - 4	41	4%
Fine Gravel	4 - 5.6	11	45%
Fine Gravel	5.6 - 8	7	56%
Medium Gravel	8 - 11	2	63%
Medium Gravel	11 - 16	5	65%
Coarse Gravel	16 - 22.6	11	70%
Coarse Gravel	22.6 - 32	10	81%
Very Coarse Gravel	32 - 45	3	91%
Very Coarse Gravel	45 - 64	4	94%
Small Cobble	64 - 90	1	98%
Small Cobble	90 - 128	1	99%
Large Cobble	128 - 180		100%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		100	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	PK/Matt	Personnel
PM5	Identifier / Unit		Location		
Secondary Channel - Floodplain	Longitudinal Description (<i>Pool, Riffle, Bend, Crossing, etc.</i>)	45.817369	Latitude or Northing		
Sub-surface	Sample Type: Surface or Sub-surface	-122.622199	Longitude or Easting		
	Dominant / Subdominant Substrate		Waypoint		



Notes

Text

Photo

PM5_Subsurface.jpg

Photo



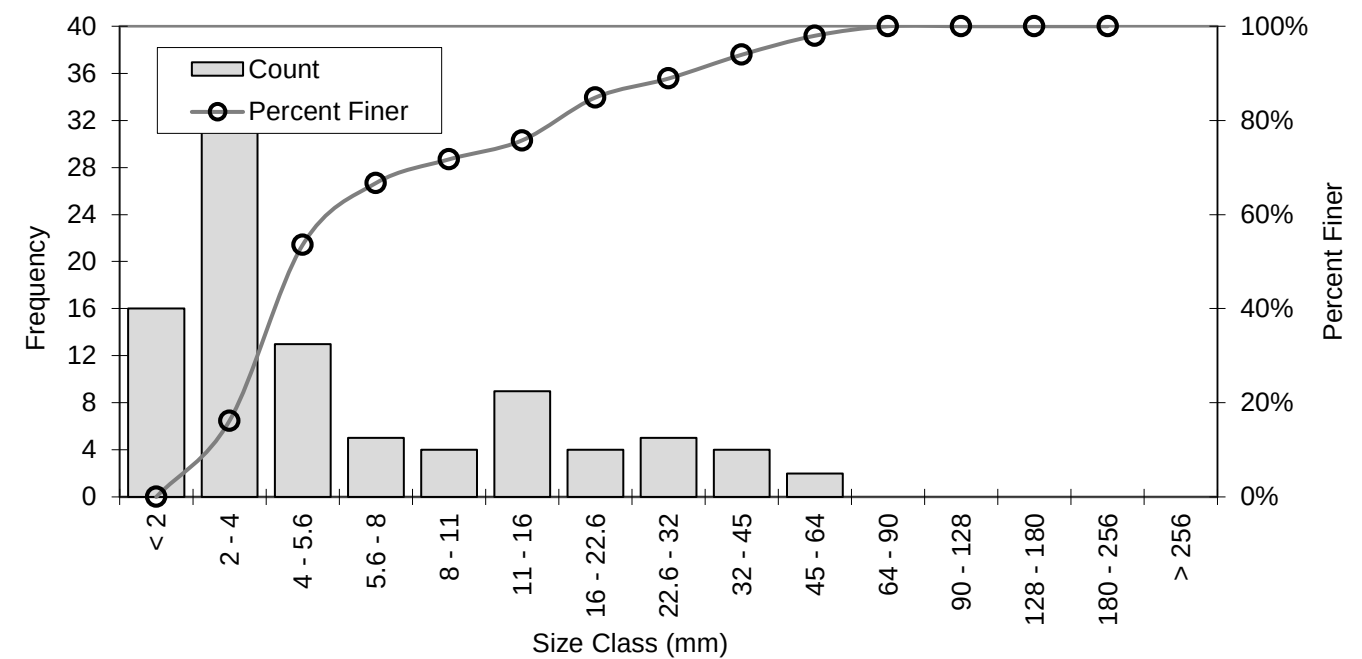
Distribution Statistic Points (Percent Finer)

PM5	2.0	mm
D ₅₀	3.8	mm
D ₈₄	17.1	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2	16	0%
Very Fine Gravel	2 - 4	37	16%
Fine Gravel	4 - 5.6	13	54%
Fine Gravel	5.6 - 8	5	67%
Medium Gravel	8 - 11	4	72%
Medium Gravel	11 - 16	9	76%
Coarse Gravel	16 - 22.6	4	85%
Coarse Gravel	22.6 - 32	5	89%
Very Coarse Gravel	32 - 45	4	94%
Very Coarse Gravel	45 - 64	2	98%
Small Cobble	64 - 90		100%
Small Cobble	90 - 128		100%
Large Cobble	128 - 180		100%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		99	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	PK/Matt	Personnel
PM1-Surface	Identifier / Unit		Location		
Main Channel Bar Deposit	Longitudinal Description (<i>Pool, Riffle, Bend, Crossing, etc.</i>)	45.811971	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.598658	Longitude or Easting		
	Dominant / Subdominant Substrate		Waypoint		



Notes

Photo PM1_SurfaceDownstream.jpg



Photo PM1_SurfaceUpstream.jpg



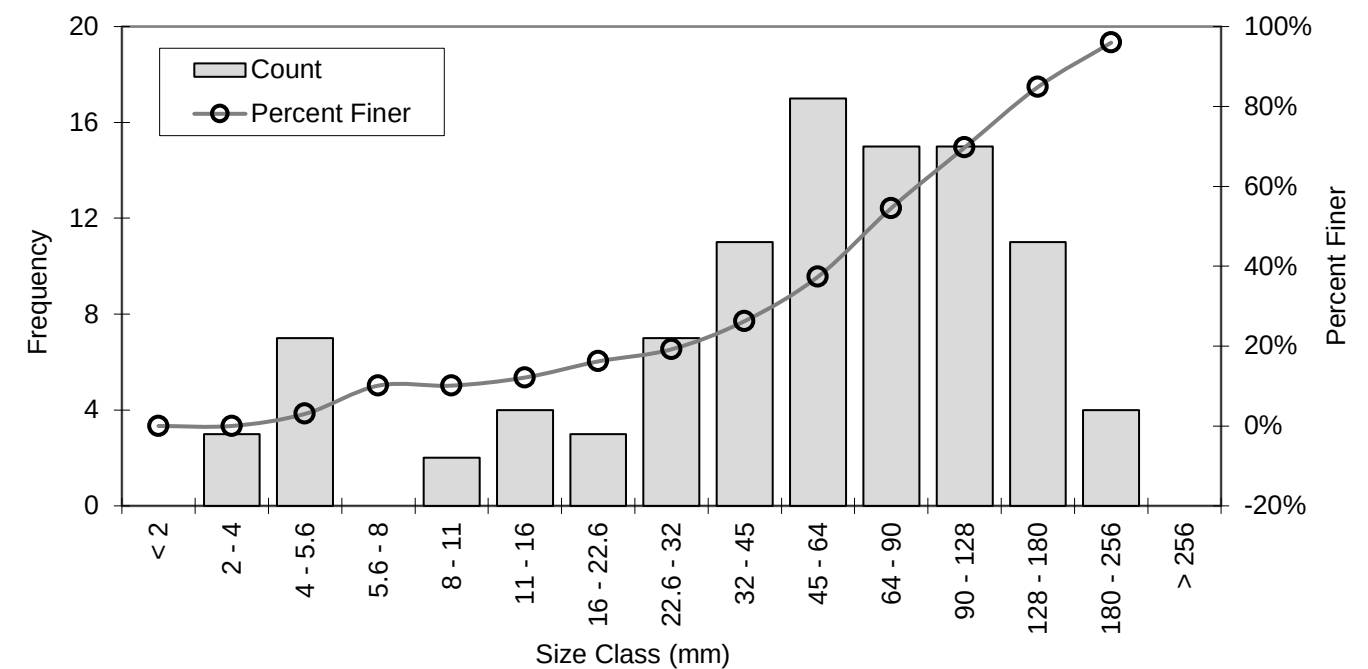
Distribution Statistic Points (Percent Finer)

<i>PM5</i>	15.8	mm
<i>D</i> ₅₀	59.0	mm
<i>D</i> ₈₄	125.9	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2		0%
Very Fine Gravel	2 - 4	3	0%
Fine Gravel	4 - 5.6	7	3%
Fine Gravel	5.6 - 8		10%
Medium Gravel	8 - 11	2	10%
Medium Gravel	11 - 16	4	12%
Coarse Gravel	16 - 22.6	3	16%
Coarse Gravel	22.6 - 32	7	19%
Very Coarse Gravel	32 - 45	11	26%
Very Coarse Gravel	45 - 64	17	37%
Small Cobble	64 - 90	15	55%
Small Cobble	90 - 128	15	70%
Large Cobble	128 - 180	11	85%
Small Boulders	180 - 256	4	96%
Boulders	> 256		100%
Total		99	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	PK/Matt	Personnel
PM2-Surface	Identifier / Unit		Location		
Main Channel Bar Deposit / Pool Tailout	Longitudinal Description (Pool, Riffle, Bend, Crossing, etc.)	45.81276	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.608541	Longitude or Easting		
	Dominant / Subdominant Substrate		Waypoint		



Notes

Main channel braided section

Photo PM2_SurfaceReference.jpg



Photo PM2_SurfaceUpstream.jpg



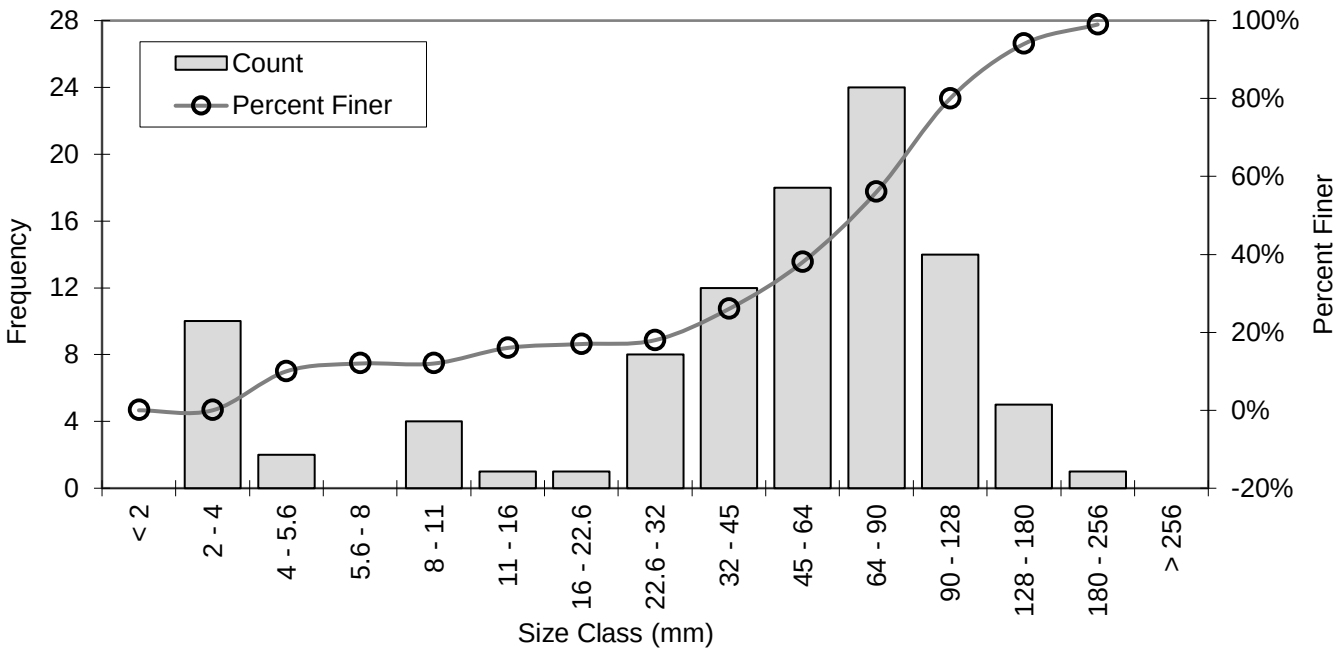
Distribution Statistic Points (Percent Finer)

PM5	11.0	mm
D ₅₀	57.7	mm
D ₈₄	100.9	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2		0%
Very Fine Gravel	2 - 4	10	0%
Fine Gravel	4 - 5.6	2	10%
Fine Gravel	5.6 - 8		12%
Medium Gravel	8 - 11	4	12%
Medium Gravel	11 - 16	1	16%
Coarse Gravel	16 - 22.6	1	17%
Coarse Gravel	22.6 - 32	8	18%
Very Coarse Gravel	32 - 45	12	26%
Very Coarse Gravel	45 - 64	18	38%
Small Cobble	64 - 90	24	56%
Small Cobble	90 - 128	14	80%
Large Cobble	128 - 180	5	94%
Small Boulders	180 - 256	1	99%
Boulders	> 256	0	100%
Total		100	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	PK/Matt	Personnel
PM3-Surface	Identifier / Unit		Location		
Main Channel Bar Deposit	Longitudinal Description (<i>Pool, Riffle, Bend, Crossing, etc.</i>)	-122.612459 45.8	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.612459 45.8	Longitude or Easting		
	Dominant / Subdominant Substrate		Waypoint		



Notes

Text

Photo

PM3_SurfaceSandReference.jpg



Photo

PM3_SurfaceUpstream.jpg



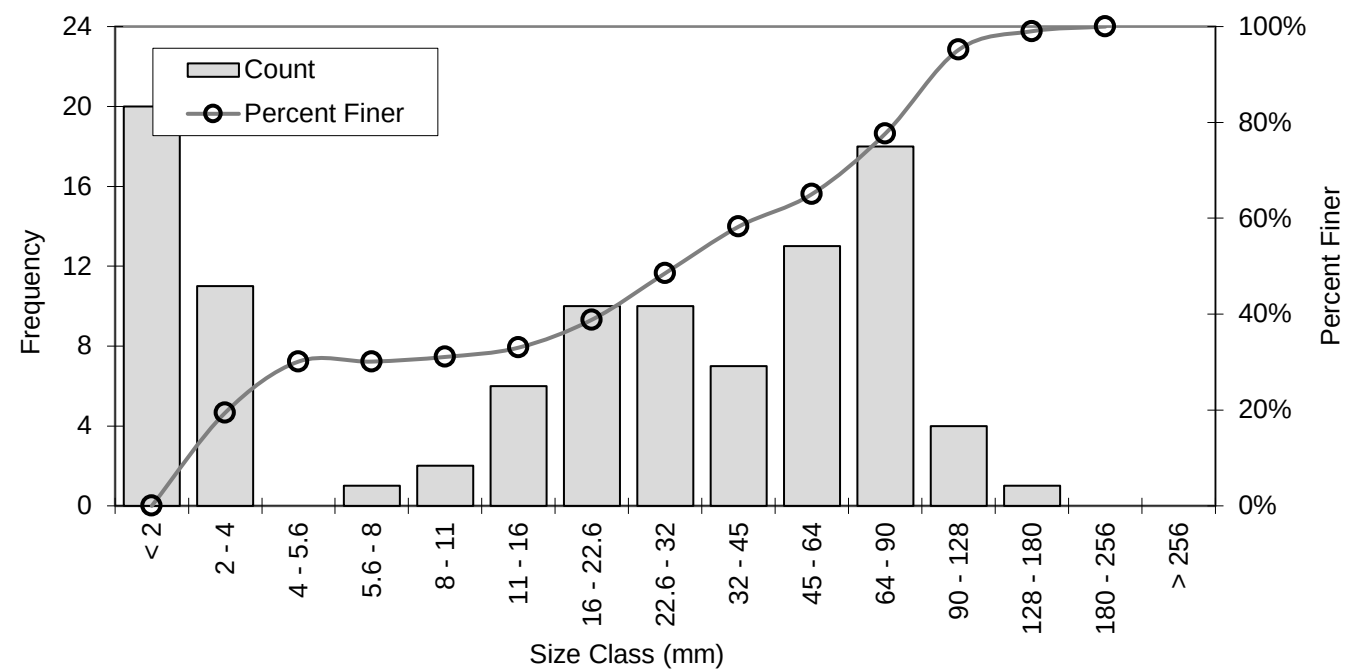
Distribution Statistic Points (Percent Finer)

<i>PM5</i>	1.8	mm
<i>D</i> ₅₀	24.0	mm
<i>D</i> ₈₄	73.4	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2	20	0%
Very Fine Gravel	2 - 4	11	19%
Fine Gravel	4 - 5.6		30%
Fine Gravel	5.6 - 8	1	30%
Medium Gravel	8 - 11	2	31%
Medium Gravel	11 - 16	6	33%
Coarse Gravel	16 - 22.6	10	39%
Coarse Gravel	22.6 - 32	10	49%
Very Coarse Gravel	32 - 45	7	58%
Very Coarse Gravel	45 - 64	13	65%
Small Cobble	64 - 90	18	78%
Small Cobble	90 - 128	4	95%
Large Cobble	128 - 180	1	99%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		103	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	PK/Matt	Personnel
PM4-Surface	Identifier / Unit		Location		
Main Channel Pool Tailout	Longitudinal Description (Pool, Riffle, Bend, Crossing, etc.)	45.816382	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.619471	Longitude or Easting		
	Dominant / Subdominant Substrate		Waypoint		



Notes

Text Photo Photo PM4Subsurface_SurfaceDownstream.jpg

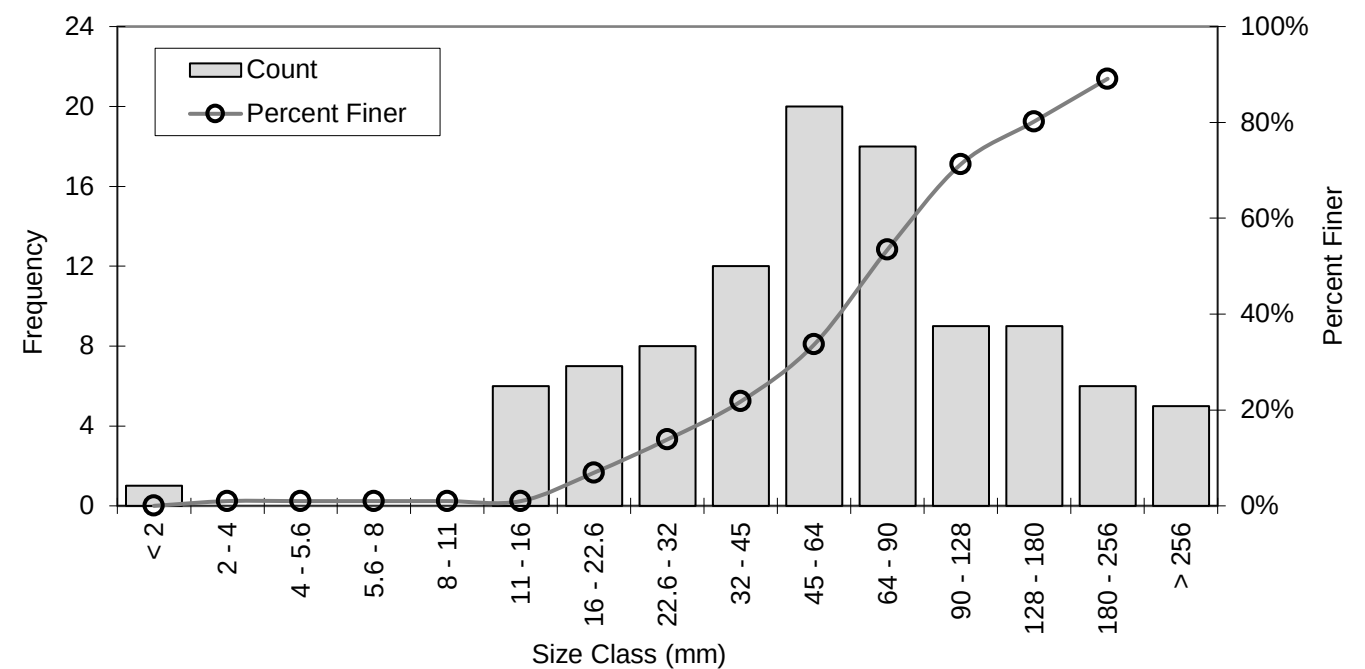
Distribution Statistic Points (Percent Finer)

PM5	25.1	mm
D ₅₀	60.7	mm
D ₈₄	150.2	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2	1	0%
Very Fine Gravel	2 - 4		1%
Fine Gravel	4 - 5.6		1%
Fine Gravel	5.6 - 8		1%
Medium Gravel	8 - 11		1%
Medium Gravel	11 - 16	6	1%
Coarse Gravel	16 - 22.6	7	7%
Coarse Gravel	22.6 - 32	8	14%
Very Coarse Gravel	32 - 45	12	22%
Very Coarse Gravel	45 - 64	20	34%
Small Cobble	64 - 90	18	53%
Small Cobble	90 - 128	9	71%
Large Cobble	128 - 180	9	80%
Small Boulders	180 - 256	6	89%
Boulders	> 256	5	95%
Total		101	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	PK/Matt	Personnel
PM5-Surface	Identifier / Unit		Location		
	Longitudinal Description (<i>Pool, Riffle, Bend, Crossing, etc.</i>)		Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface		Longitude or Easting		
	Dominant / Subdominant Substrate		Waypoint		



Notes

Text

Photo PM5_SurfaceDownstream.jpgPhoto PM5_SurfaceUpstream.jpg

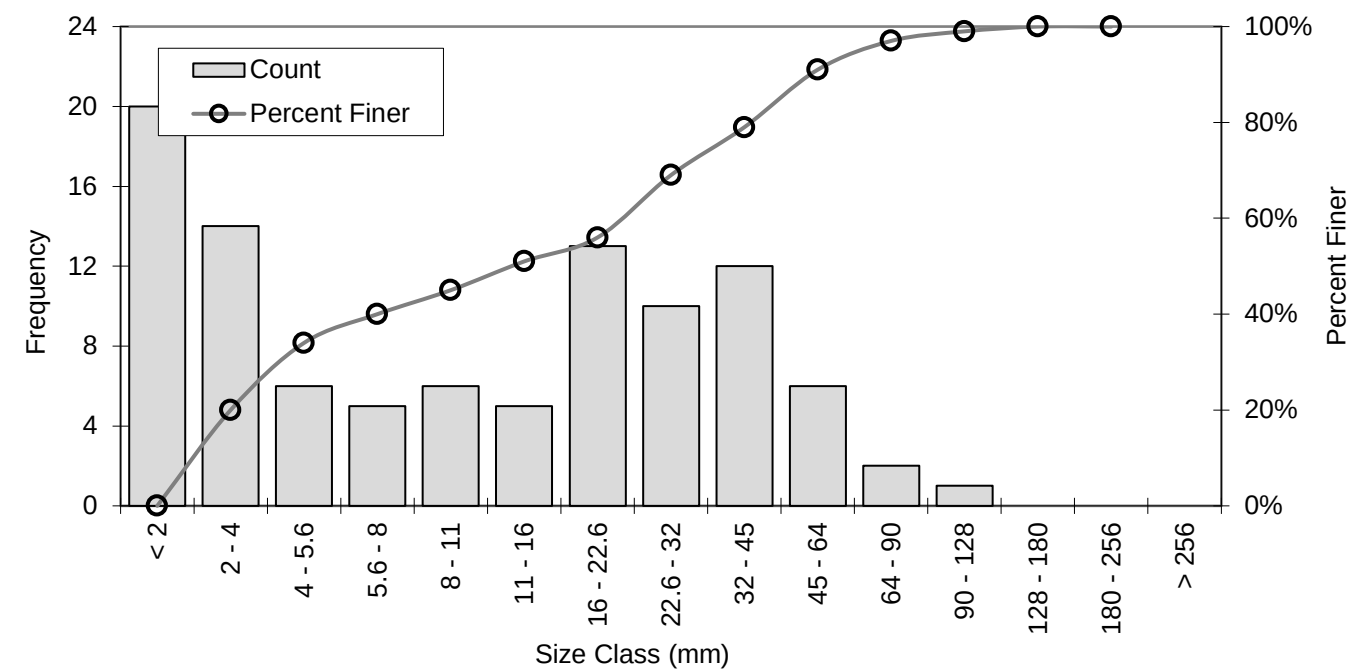
Distribution Statistic Points (Percent Finer)

PM5	1.8	mm
D ₅₀	10.5	mm
D ₈₄	37.4	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2	20	0%
Very Fine Gravel	2 - 4	14	20%
Fine Gravel	4 - 5.6	6	34%
Fine Gravel	5.6 - 8	5	40%
Medium Gravel	8 - 11	6	45%
Medium Gravel	11 - 16	5	51%
Coarse Gravel	16 - 22.6	13	56%
Coarse Gravel	22.6 - 32	10	69%
Very Coarse Gravel	32 - 45	12	79%
Very Coarse Gravel	45 - 64	6	91%
Small Cobble	64 - 90	2	97%
Small Cobble	90 - 128	1	99%
Large Cobble	128 - 180		100%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		100	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	PK/Matt	Personnel
PM6-Surface	Identifier / Unit		Location		
Secondary Channel	Longitudinal Description (<i>Pool, Riffle, Bend, Crossing, etc.</i>)	45.819391	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.614461	Longitude or Easting		
	Dominant / Subdominant Substrate		Waypoint		



Notes

Text

Photo PM6Surface_Downstream.jpgPhoto PM6Surface_Upstream.jpg

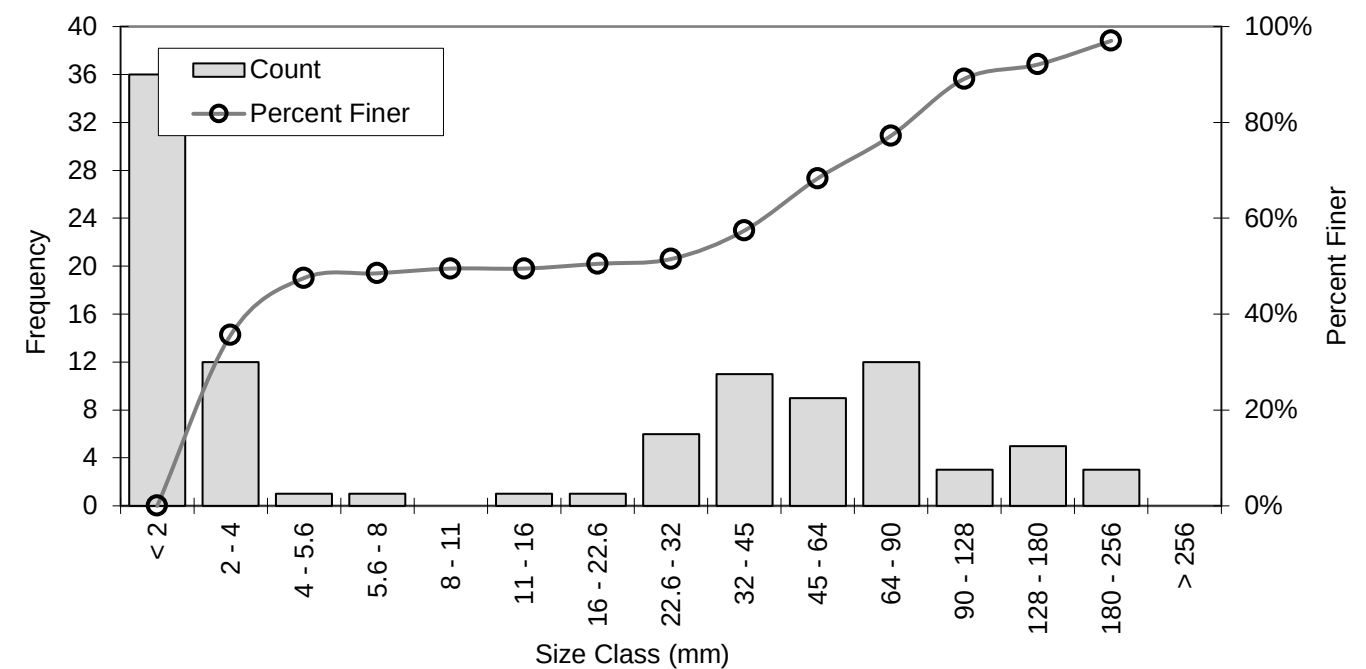
Distribution Statistic Points (Percent Finer)

<i>PM5</i>	1.4	mm
<i>D</i> ₅₀	11.0	mm
<i>D</i> ₈₄	78.8	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2	36	0%
Very Fine Gravel	2 - 4	12	36%
Fine Gravel	4 - 5.6	1	48%
Fine Gravel	5.6 - 8	1	49%
Medium Gravel	8 - 11	1	50%
Medium Gravel	11 - 16	1	50%
Coarse Gravel	16 - 22.6	1	50%
Coarse Gravel	22.6 - 32	6	51%
Very Coarse Gravel	32 - 45	11	57%
Very Coarse Gravel	45 - 64	9	68%
Small Cobble	64 - 90	12	77%
Small Cobble	90 - 128	3	89%
Large Cobble	128 - 180	5	92%
Small Boulders	180 - 256	3	97%
Boulders	> 256		100%
Total		101	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	KM / Niko	Personnel
KN2	Identifier / Unit		Location		
Gravel Bar	Longitudinal Description (<i>Pool, Riffle, Bend, Crossing, etc.</i>)	45.827759	Latitude or Northing		
Sub-surface	Sample Type: Surface or Sub-surface	-122.633011	Longitude or Easting		
Gravel / Cobble	Dominant / Subdominant Substrate		Waypoint		



Notes

Photo [field_4-20181018-181420.jpg](#)



Photo [field_12-20181018-182302.jpg](#)



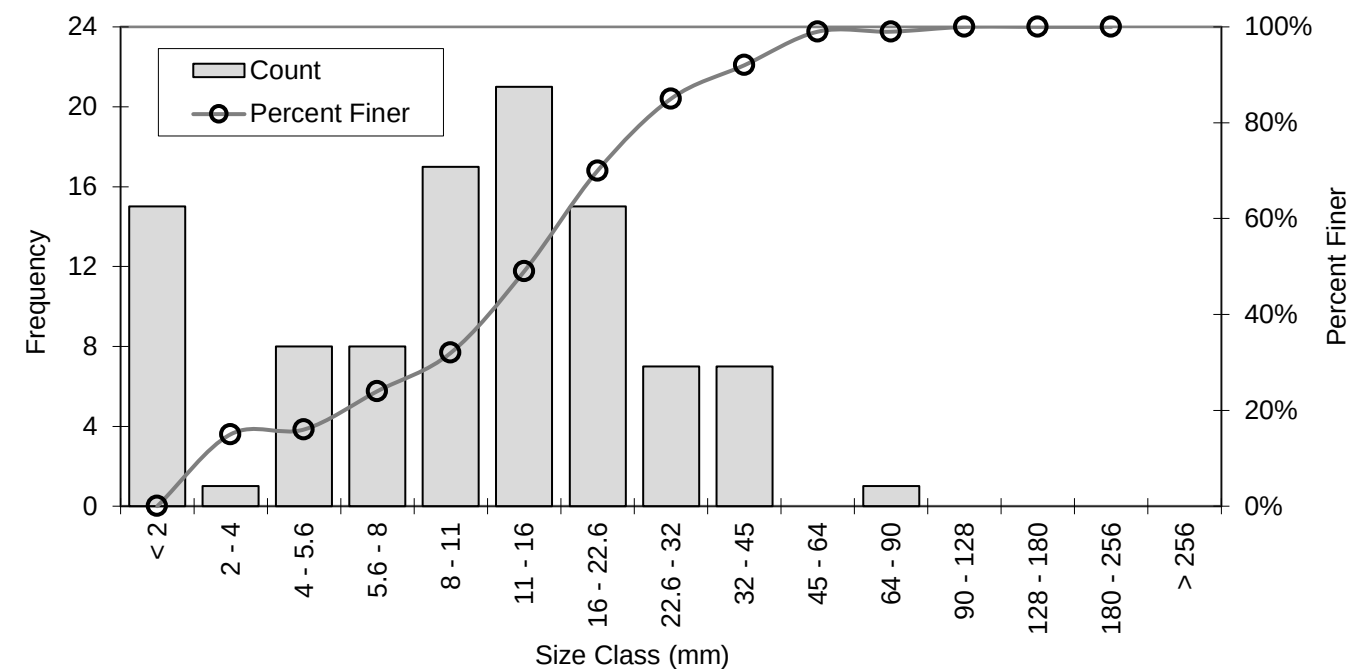
Distribution Statistic Points (Percent Finer)

D_{16}	-70.1	mm
D_{50}	#DIV/0!	mm
D_{84}	-326.0	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2	15	0%
Very Fine Gravel	2 - 4	1	15%
Fine Gravel	4 - 5.6	8	16%
Fine Gravel	5.6 - 8	8	24%
Medium Gravel	8 - 11	17	32%
Medium Gravel	11 - 16	21	49%
Coarse Gravel	16 - 22.6	15	70%
Coarse Gravel	22.6 - 32	7	85%
Very Coarse Gravel	32 - 45	7	92%
Very Coarse Gravel	45 - 64		99%
Small Cobble	64 - 90	1	99%
Small Cobble	90 - 128		100%
Large Cobble	128 - 180		100%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		100	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	KM / Niko	Personnel
KN6	Identifier / Unit		Location		
Bar Deposit	Longitudinal Description (<i>Pool, Riffle, Bend, Crossing, etc.</i>)	45.819065	Latitude or Northing		
Sub-Surface	Sample Type: Surface or Sub-surface	-122.626668	Longitude or Easting		
Gravel / Sand	Dominant / Subdominant Substrate		Waypoint		



Notes

Thin armor layer, lots of sand

Photo KN6subcount_armor_removed_pre_mix.JPG



Photo KN6subcount_armor_removed_post_mix.JPG



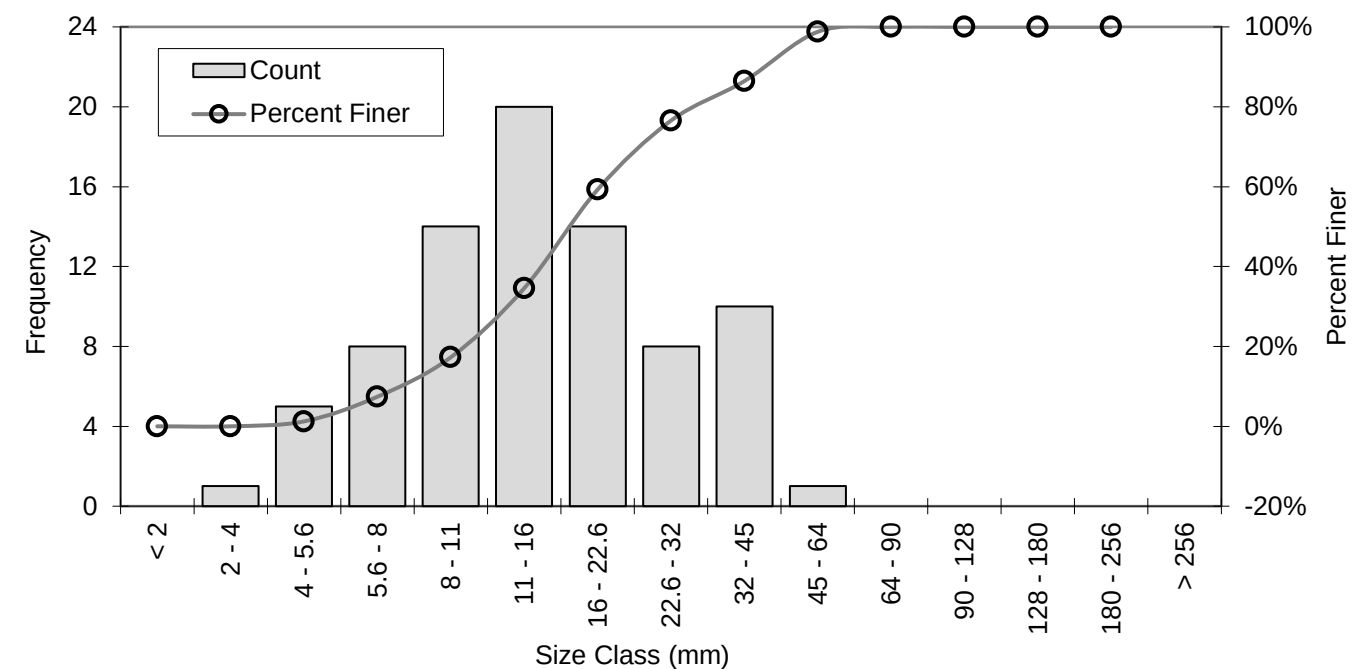
Distribution Statistic Points (Percent Finer)

D_{16}	7.7	mm
D_{50}	14.1	mm
D_{84}	29.7	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2		0%
Very Fine Gravel	2 - 4	1	0%
Fine Gravel	4 - 5.6	5	1%
Fine Gravel	5.6 - 8	8	7%
Medium Gravel	8 - 11	14	17%
Medium Gravel	11 - 16	20	35%
Coarse Gravel	16 - 22.6	14	59%
Coarse Gravel	22.6 - 32	8	77%
Very Coarse Gravel	32 - 45	10	86%
Very Coarse Gravel	45 - 64	1	99%
Small Cobble	64 - 90		100%
Small Cobble	90 - 128		100%
Large Cobble	128 - 180		100%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		81	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	KM / Niko	Personnel
KN8	Identifier / Unit		Location		
	Longitudinal Description (<i>Pool, Riffle, Bend, Crossing, etc.</i>)	45.819694	Latitude or Northing		
Sub-Surface	Sample Type: Surface or Sub-surface	-122.625368	Longitude or Easting		
Gravel / Sand	Dominant / Subdominant Substrate		Waypoint		



Notes

Lots of fine sand mixed with gravel and cobble

Photo KN8subcount_armor_layer.JPG



Photo KN8subcount_armor_removed_pre_mix



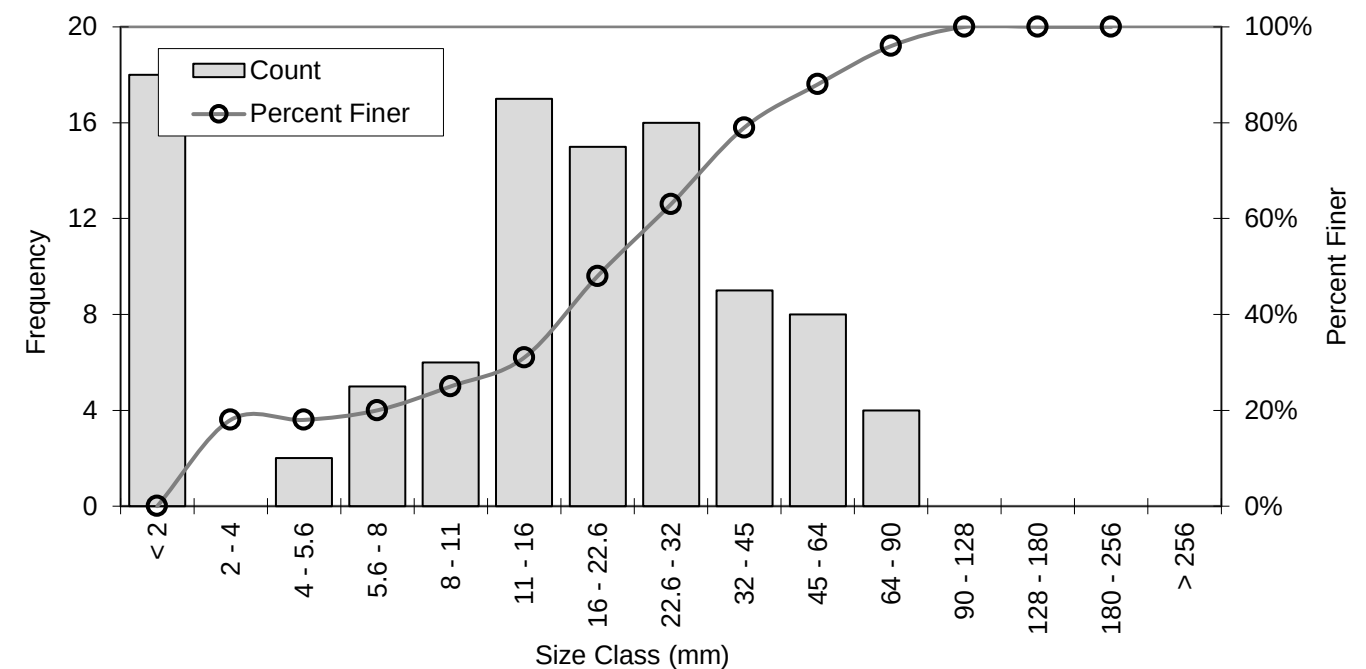
Distribution Statistic Points (Percent Finer)

D_{16}	2.8	mm
D_{50}	16.9	mm
D_{84}	39.2	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2	18	0%
Very Fine Gravel	2 - 4	0	18%
Fine Gravel	4 - 5.6	2	18%
Fine Gravel	5.6 - 8	5	20%
Medium Gravel	8 - 11	6	25%
Medium Gravel	11 - 16	17	31%
Coarse Gravel	16 - 22.6	15	48%
Coarse Gravel	22.6 - 32	16	63%
Very Coarse Gravel	32 - 45	9	79%
Very Coarse Gravel	45 - 64	8	88%
Small Cobble	64 - 90	4	96%
Small Cobble	90 - 128		100%
Large Cobble	128 - 180		100%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		100	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	KM / Niko	Personnel
KN1	Identifier / Unit		Location		
Riffle	Longitudinal Description (Pool, Riffle, Bend, Crossing, etc.)	45.827668	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.632556	Longitude or Easting		
Gravel / Cobble	Dominant / Subdominant Substrate		Waypoint		



Notes

Diagonal riffle transects, redds upstream in tailout, riffle not in high flow main energy line, pebble count all in water

Photo [field_6-20181018-180552.jpg](#)

Photo [field_5-20181018-175149.jpg](#)



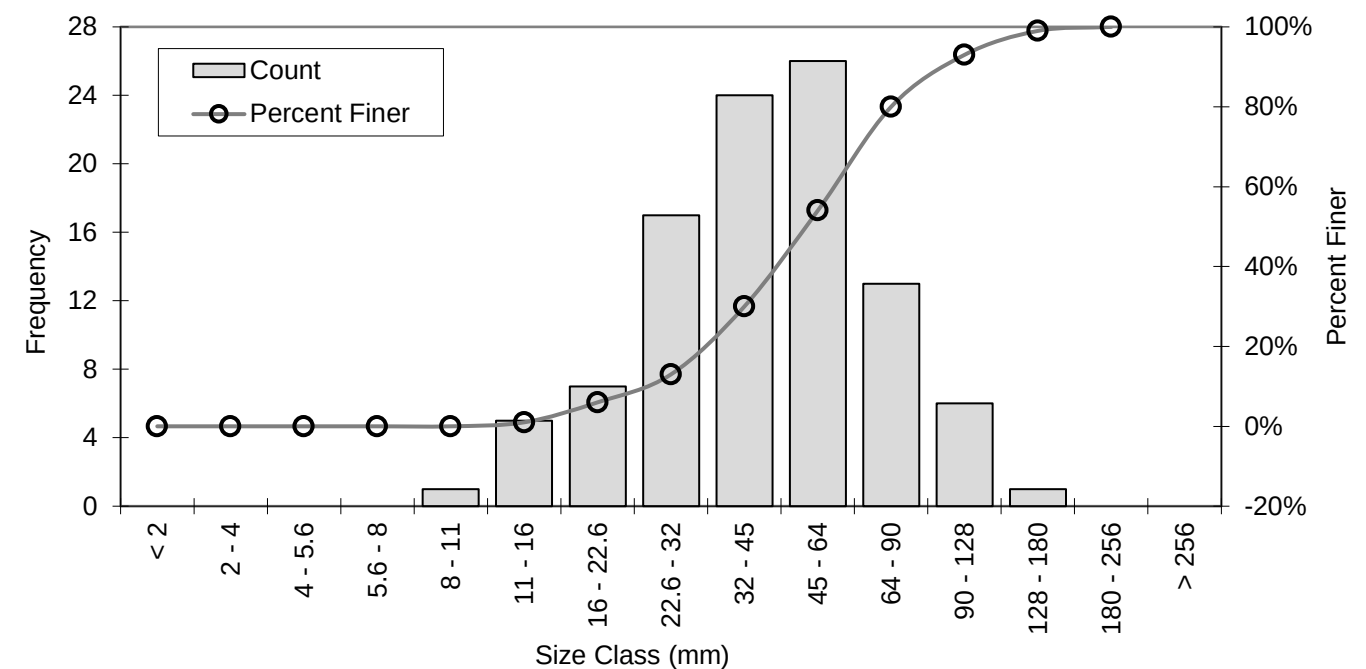
Distribution Statistic Points (Percent Finer)

D_{16}	24.3	mm
D_{50}	42.8	mm
D_{84}	72.0	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2		0%
Very Fine Gravel	2 - 4		0%
Fine Gravel	4 - 5.6		0%
Fine Gravel	5.6 - 8		0%
Medium Gravel	8 - 11	1	0%
Medium Gravel	11 - 16	5	1%
Coarse Gravel	16 - 22.6	7	6%
Coarse Gravel	22.6 - 32	17	13%
Very Coarse Gravel	32 - 45	24	30%
Very Coarse Gravel	45 - 64	26	54%
Small Cobble	64 - 90	13	80%
Small Cobble	90 - 128	6	93%
Large Cobble	128 - 180	1	99%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		100	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	KM / Niko	Personnel
KN2	Identifier / Unit		Location		
Gravel Bar	Longitudinal Description (Pool, Riffle, Bend, Crossing, etc.)	45.827759	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.633011	Longitude or Easting		
Gravel / Cobble	Dominant / Subdominant Substrate		Waypoint		



Notes

Text

Photo field_4-20181018-181420.jpg

Photo



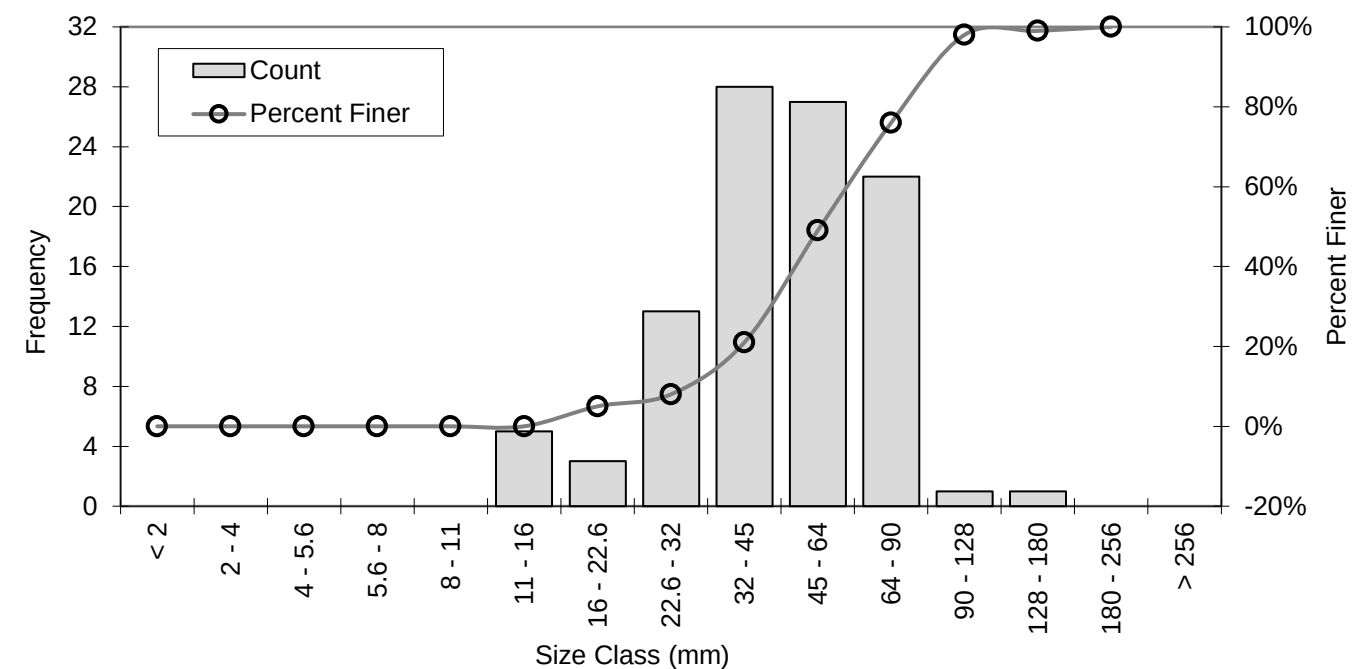
Distribution Statistic Points (Percent Finer)

D_{16}	28.4	mm
D_{50}	45.7	mm
D_{84}	73.5	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2		0%
Very Fine Gravel	2 - 4		0%
Fine Gravel	4 - 5.6		0%
Fine Gravel	5.6 - 8		0%
Medium Gravel	8 - 11		0%
Medium Gravel	11 - 16	5	0%
Coarse Gravel	16 - 22.6	3	5%
Coarse Gravel	22.6 - 32	13	8%
Very Coarse Gravel	32 - 45	28	21%
Very Coarse Gravel	45 - 64	27	49%
Small Cobble	64 - 90	22	76%
Small Cobble	90 - 128	1	98%
Large Cobble	128 - 180	1	99%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		100	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	KM / Niko	Personnel
KN5	Identifier / Unit		Location		
Riffle / Bar Deposit	Longitudinal Description (Pool, Riffle, Bend, Crossing, etc.)	45.819065	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.626668	Longitude or Easting		
Gravel / Cobble	Dominant / Subdominant Substrate		Waypoint		



Notes

Narrow riffle with bar, just above entrance to a pit. Sand dune above bar on downstream side. River mile 7.8.

Photo

KN5surfcount_Ref.JPG



Photo

KN5_transect_W.JPG



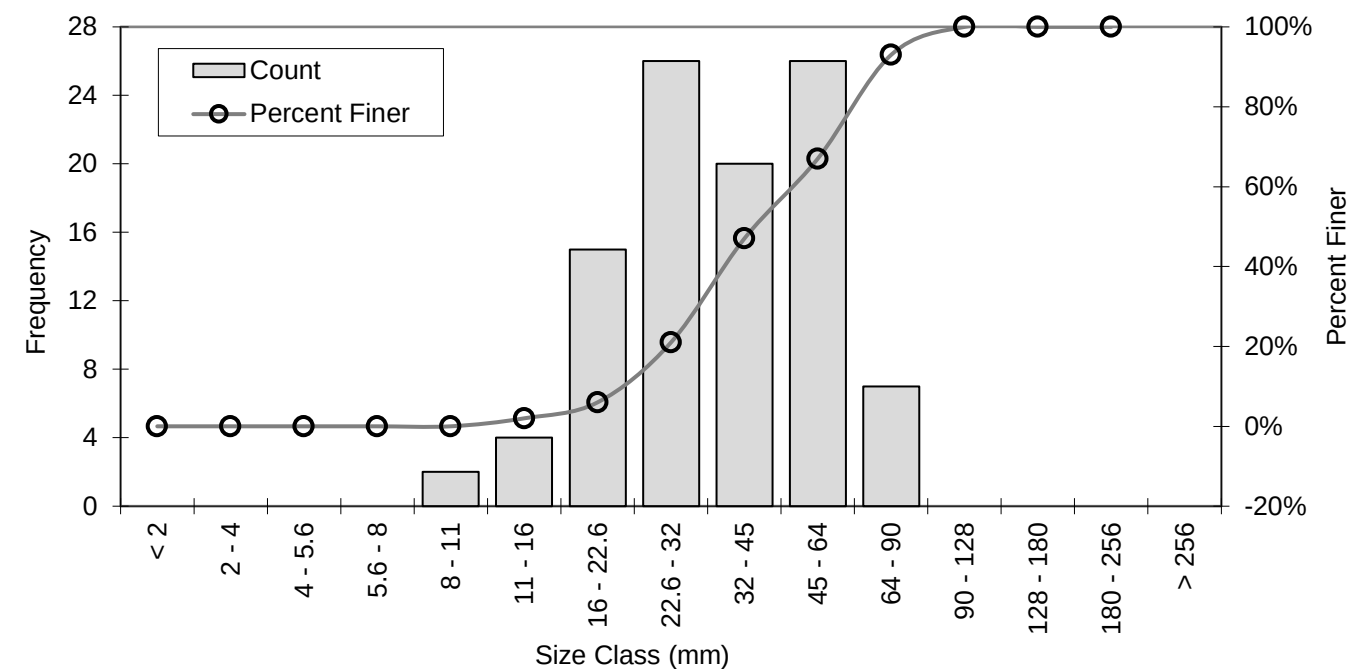
Distribution Statistic Points (Percent Finer)

D_{16}	20.4	mm
D_{50}	34.0	mm
D_{84}	57.4	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2		0%
Very Fine Gravel	2 - 4		0%
Fine Gravel	4 - 5.6		0%
Fine Gravel	5.6 - 8		0%
Medium Gravel	8 - 11	2	0%
Medium Gravel	11 - 16	4	2%
Coarse Gravel	16 - 22.6	15	6%
Coarse Gravel	22.6 - 32	26	21%
Very Coarse Gravel	32 - 45	20	47%
Very Coarse Gravel	45 - 64	26	67%
Small Cobble	64 - 90	7	93%
Small Cobble	90 - 128		100%
Large Cobble	128 - 180		100%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		100	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	KM / Niko	Personnel
KN7	Identifier / Unit		Location		
	Longitudinal Description (Pool, Riffle, Bend, Crossing, etc.)	45.819694	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.625368	Longitude or Easting		
Cobble / Gravel	Dominant / Subdominant Substrate		Waypoint		



Notes

Mid-channel bar deposit in the middle of a floodplain expansion adjacent to riffle, upstream of recent avulsion. Several adult salmon spawning in the riffle.

Photo KN7surfcount_Ref.JPG

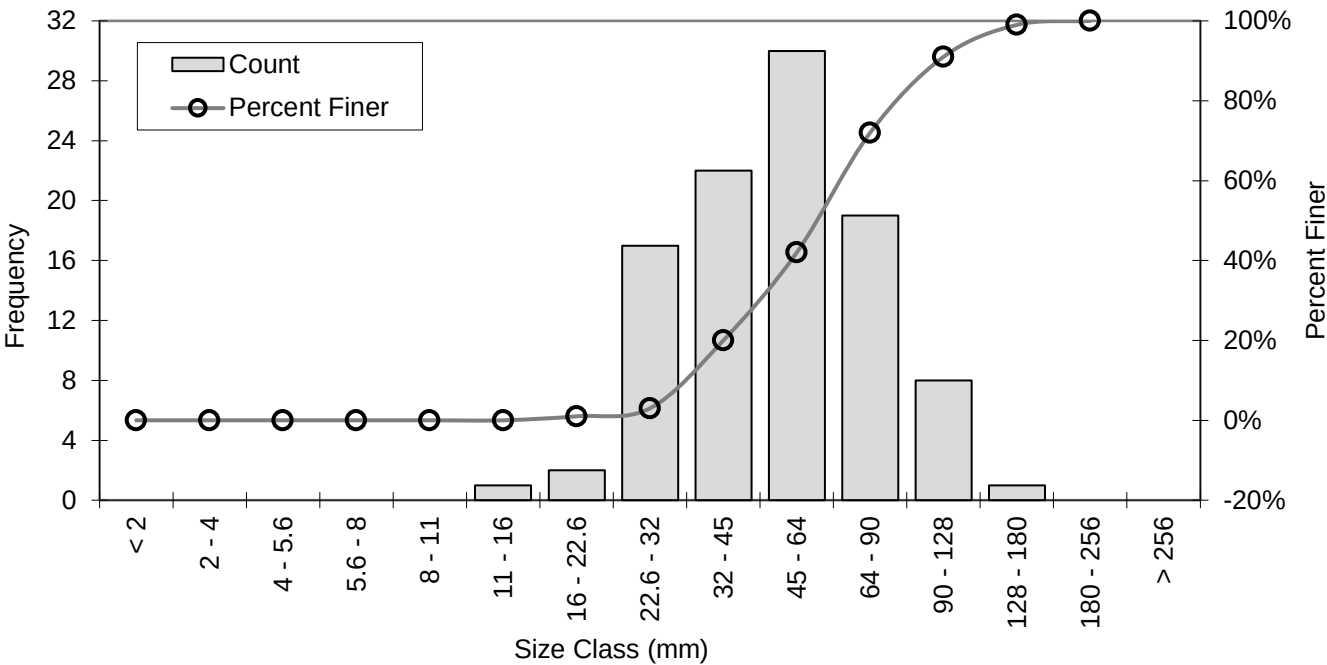


Photo KN7_transect_W.JPG



Distribution Statistic Points (Percent Finer)			
D_{16}	29.8	mm	
D_{50}	50.1	mm	
D_{84}	80.4	mm	
Assumes a linear interpolation			

Pebble Count Data			
Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2		0%
Very Fine Gravel	2 - 4		0%
Fine Gravel	4 - 5.6		0%
Fine Gravel	5.6 - 8		0%
Medium Gravel	8 - 11		0%
Medium Gravel	11 - 16	1	0%
Coarse Gravel	16 - 22.6	2	1%
Coarse Gravel	22.6 - 32	17	3%
Very Coarse Gravel	32 - 45	22	20%
Very Coarse Gravel	45 - 64	30	42%
Small Cobble	64 - 90	19	72%
Small Cobble	90 - 128	8	91%
Large Cobble	128 - 180	1	99%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		100	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	KM / Niko	Personnel
KN9	Identifier / Unit		Location		
Riffle / Bar Deposit	Longitudinal Description (Pool, Riffle, Bend, Crossing, etc.)	45.81962	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.626196	Longitude or Easting		
Cobble / Gravel	Dominant / Subdominant Substrate		Waypoint		



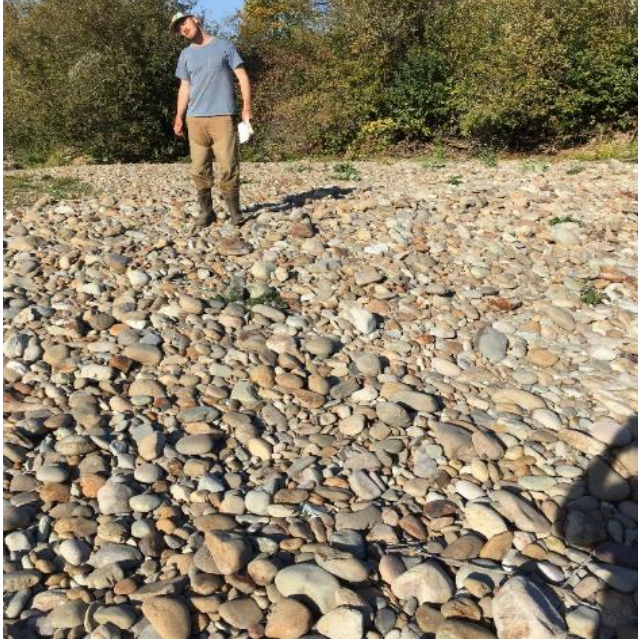
Notes

Just bar, no riffle. Last riffle on main channel below pits

Photo KN9surfcount_Ref.JPG

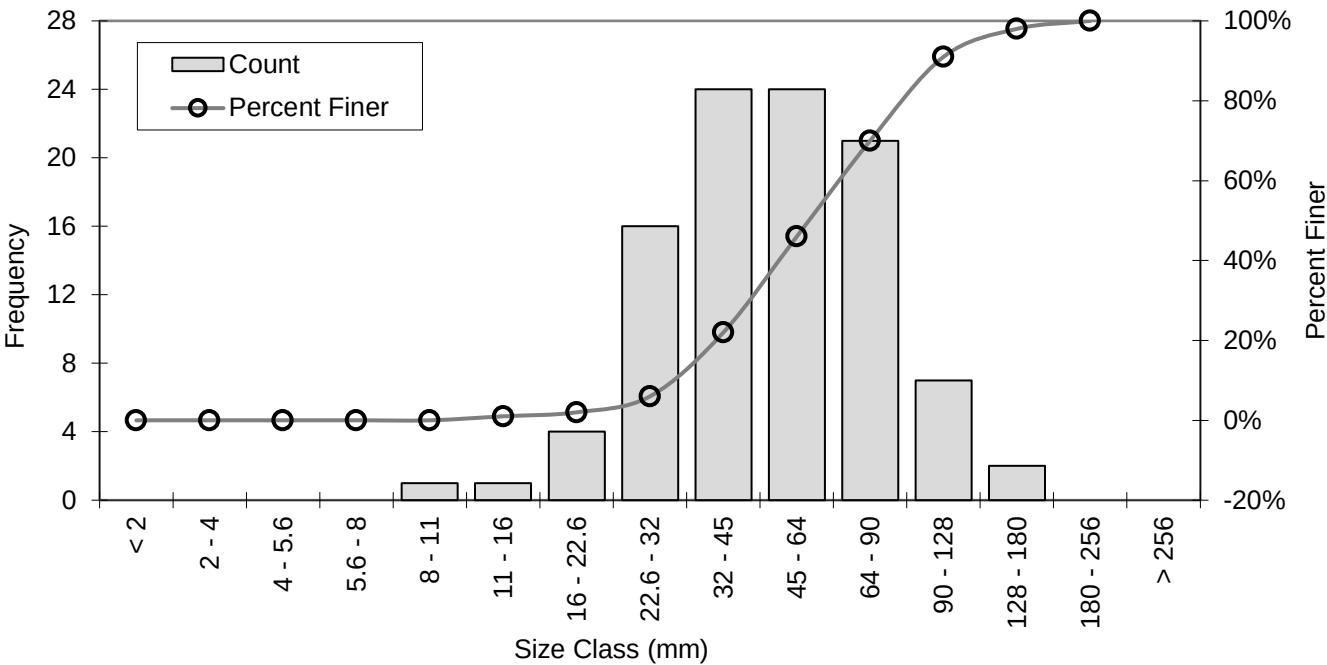


Photo KN9_transect_N.JPG



Distribution Statistic Points (Percent Finer)			
D_{16}	28.5	mm	
D_{50}	48.2	mm	
D_{84}	81.3	mm	
Assumes a linear interpolation			

Pebble Count Data			
Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2		0%
Very Fine Gravel	2 - 4		0%
Fine Gravel	4 - 5.6		0%
Fine Gravel	5.6 - 8		0%
Medium Gravel	8 - 11	1	0%
Medium Gravel	11 - 16	1	1%
Coarse Gravel	16 - 22.6	4	2%
Coarse Gravel	22.6 - 32	16	6%
Very Coarse Gravel	32 - 45	24	22%
Very Coarse Gravel	45 - 64	24	46%
Small Cobble	64 - 90	21	70%
Small Cobble	90 - 128	7	91%
Large Cobble	128 - 180	2	98%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		100	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	KM / Niko	Personnel
KN10	Identifier / Unit		Location		
Riffle / Bar Deposit	Longitudinal Description (<i>Pool, Riffle, Bend, Crossing, etc.</i>)	45.819665	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.62658	Longitude or Easting		
Gravel / Cobble	Dominant / Subdominant Substrate		Waypoint		



Notes

Transect crosses riffle goes up slope of bar, stops below top. New main channel alignment at downstream end of deltaic deposit

Photo

KN10_transect_E.JPG



Photo

KN10surfcount_Ref.JPG



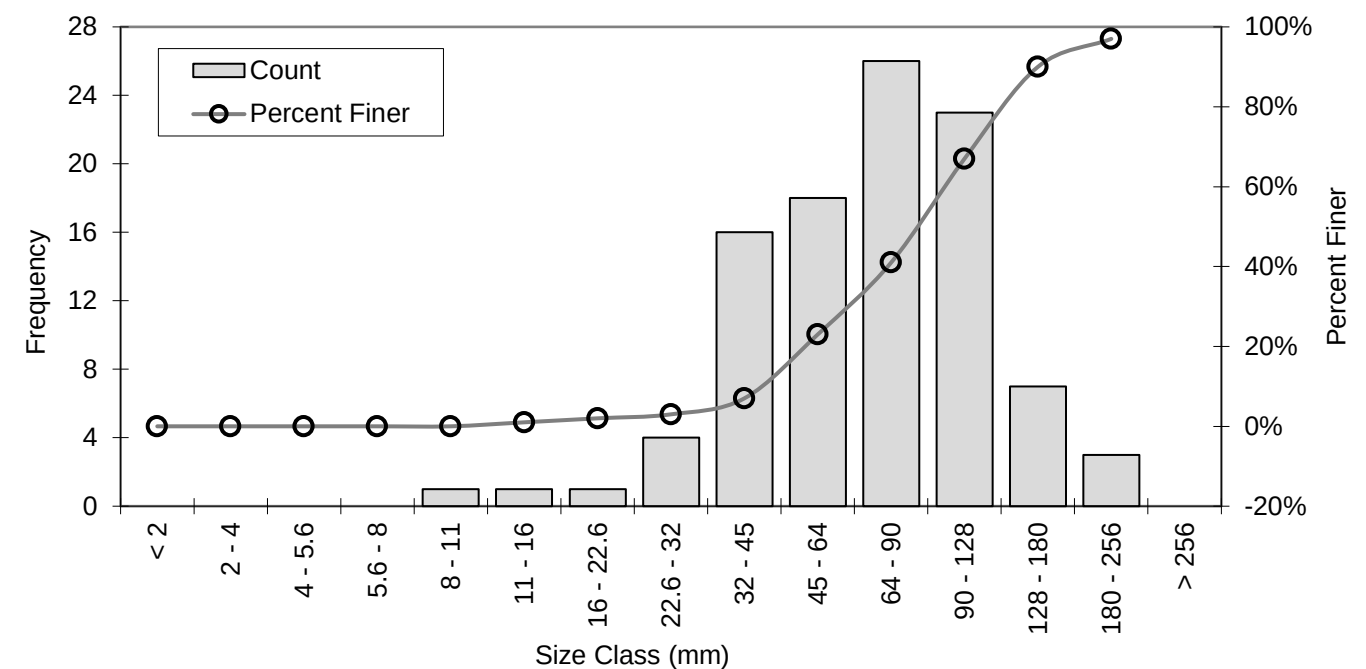
Distribution Statistic Points (Percent Finer)

D_{16}	39.3	mm
D_{50}	73.0	mm
D_{84}	118.1	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2		0%
Very Fine Gravel	2 - 4		0%
Fine Gravel	4 - 5.6		0%
Fine Gravel	5.6 - 8		0%
Medium Gravel	8 - 11	1	0%
Medium Gravel	11 - 16	1	1%
Coarse Gravel	16 - 22.6	1	2%
Coarse Gravel	22.6 - 32	4	3%
Very Coarse Gravel	32 - 45	16	7%
Very Coarse Gravel	45 - 64	18	23%
Small Cobble	64 - 90	26	41%
Small Cobble	90 - 128	23	67%
Large Cobble	128 - 180	7	90%
Small Boulders	180 - 256	3	97%
Boulders	> 256		100%
Total		100	



Sediment Grain Size Analysis

EF Lewis River	Stream	10/18/2018	Date	KM / Niko	Personnel
JE1	Identifier / Unit		Location		
Riffle	Longitudinal Description (Pool, Riffle, Bend, Crossing, etc.)	45.817832	Latitude or Northing		
Surface	Sample Type: Surface or Sub-surface	-122.623838	Longitude or Easting		
Cobble / Gravel	Dominant / Subdominant Substrate		Waypoint		



Notes

Coarse inundated riffle/bar unit, large redd upstream in tailout

Photo

field_6-20181018-215000.jpg



Photo

field_4-20181018-214854.jpg



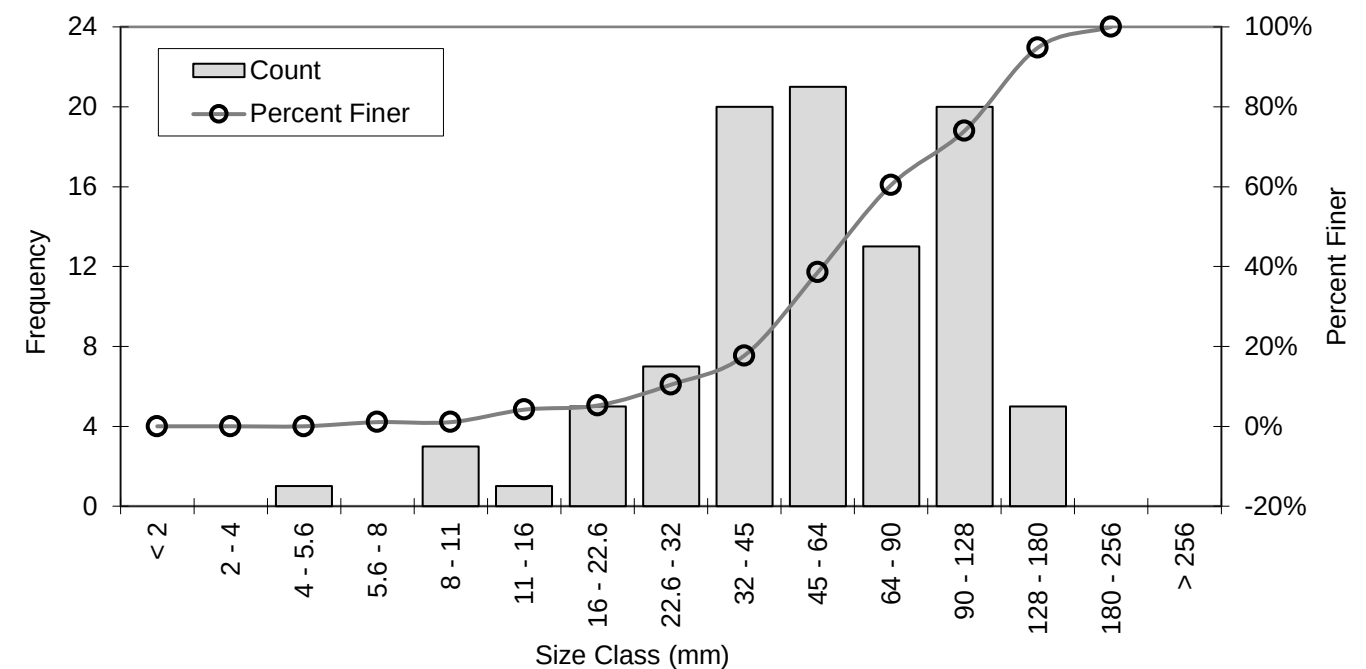
Distribution Statistic Points (Percent Finer)

D_{16}	29.8	mm
D_{50}	55.0	mm
D_{84}	108.3	mm

Assumes a linear interpolation

Pebble Count Data

Class (Wentworth)	Size Class (mm)	Count	Percent Finer
Sand	< 2		0%
Very Fine Gravel	2 - 4		0%
Fine Gravel	4 - 5.6	1	0%
Fine Gravel	5.6 - 8		1%
Medium Gravel	8 - 11	3	1%
Medium Gravel	11 - 16	1	4%
Coarse Gravel	16 - 22.6	5	5%
Coarse Gravel	22.6 - 32	7	10%
Very Coarse Gravel	32 - 45	20	18%
Very Coarse Gravel	45 - 64	21	39%
Small Cobble	64 - 90	13	60%
Small Cobble	90 - 128	20	74%
Large Cobble	128 - 180	5	95%
Small Boulders	180 - 256		100%
Boulders	> 256		100%
Total		96	



Bank Profile

EF Lewis River	Stream	10/18/2018	Date	JE	Personnel
BP1	Identifier / Unit	45.819611	Location		
		-122.626694	Latitude or Northing		
			Longitude or Easting		
			Waypoint		

Notes: Outside of bend in new avulsion at the top of the pits reach



Profile Range (ft)	Description
4-14	nd /gravel with cobble
0-4	sand/gravel with cobble at surface

Photo field_6-20181018-220730.jpg



Photo field_4-20181018-220649.jpg



Bank Profile					
EF Lewis River		Stream	10/18/2018	Date	JE
BP2		Identifier / Unit		Location	Personnel
Notes: Outside of bend in new avulsion at the top of the pits reach, Upstream of BP1			45.819466	Latitude or Northing	
			-122.626459	Longitude or Easting	
				Waypoint	

Profile Range (ft)	Description
2-12	silt/sand w cobble and gr
0-2	cobble
4:1 slope of cobble at toe	

Photo field_5-20181018-221420.jpg



Photo field_6-20181018-221448.jpg



Photo field_4-20181018-221352.jpg



Bank Profile

EF Lewis River	Stream	10/18/2018	Date	JE	Personnel
BP3	Identifier / Unit	45.819741	Location		
Notes:		-122.625944	Latitude or Northing		
			Longitude or Easting		
			Waypoint		



Profile Range (ft)	Description
12-13	Fines / Gravel / Sand
9-12	Sand / Silt
5-9	Silt / Sand
0-5	Alluvium

Photo field_5-20181018-221856.jpg



Photo field_12-20181018-222201.jpg



Bank Profile

EF Lewis River	Stream	10/18/2018	Date	JE	Personnel
BP4	Identifier / Unit	45.819796	Location		
Notes:		-122.625783	Latitude or Northing		
			Longitude or Easting		
			Waypoint		



	Photo	field_4-20181018-222838.jpg	Photo	field_6-20181018-223331.jpg
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Profile Range (ft)	Description
9.5-11	soil
7-9.5	silt / sand
4.5-7	gravel / silt / cobble
3.5-4.5	Cobble w/ gravel (old riffle?)
2-3.5	Alluvium
0-2	Alluvium (red from iron)



Photo field_12-20181018-223342.jpg



Bank Profile					
EF Lewis River		Stream	10/18/2018	Date	JE
BP5		Identifier / Unit	45.818971	Location	Personnel
Notes:			-122.625728	Latitude or Northing	
				Longitude or Easting	
				Waypoint	



Profile Range (ft)	Description
4-7	Sand / Silt
0-4	Gravel / Sand

Photo field_4-20181018-224851.jpg



Photo field_6-20181018-224930.jpg



Photo field_5-20181018-224913.jpg



Bank Profile				
EF Lewis River		Stream	10/18/2018	Date
BP-KN3		Identifier / Unit	45.827254	Location
Notes:			-122.632613	Latitude or Northing
				Longitude or Easting
				Waypoint



		Photo	field_5-20181018-184741.jpg
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Profile Range (ft)	Description
5-6	soil
0-5	alluvium

Photo field_4-20181018-184732.jpg



Bank Profile			
EF Lewis River	Stream	10/18/2018	Date
BP-KN4	Identifier / Unit	45.819796	Location
Notes:		-122.625783	Latitude or Northing
			Longitude or Easting
			Waypoint
		JE	Personnel



Profile Range (ft)	Description
5.5-7	soil
1-5.5	silt / sand w/ some cobble
0-1	alluvium

Photo field_4-20181018-185426.jpg



Photo field_5-20181018-185436.jpg



Bank Profile

EF Lewis River	Stream	10/18/2018	Date	JE	Personnel
PM1-Bank	Identifier / Unit	45.811775	Location		
Notes: Upper layer- all fines including sands and clays. Visual estimate of D50= 2.8 cm			Latitude or Northing		
Middle layer - fines and gravels. Visual estimate of D50 is 22cm (likely bimodal dist.)-	Toe	-122.598443	Longitude or Easting		
zone- gravels (coarser than middle layer)	Unconsolidated		Waypoint		



Profile Range (ft)	Description
6.5	upper layer- fines
3	middle layer- fines and gravels
6.5	toe- gravels

Photo PM1_Bank_1.jpg



Photo PM1_Bank_Close_LowerSubstrate.jpg



Photo PM1_Bank_Downstream.jpg



Bank Profile

EF Lewis River	Stream	10/18/2018	Date	Paul / Matt	Personnel
PM4-Bank	Identifier / Unit		Location		
Notes: top layer- all fines including sands and clays. Visual estimate of D50= 2.8 cm		45.815699	Latitude or Northing		
bottom layer - gravels. Visual estimate of D50 is 22cm (likely bimodal dist.)		-122.616793	Longitude or Easting		
cause for brown layer?			Waypoint		
		Oxidation			
		Unconsolidated			

Profile Range (ft)	Description
1.5- 2	Top Layer- fines
3	Bottom Layer- gravels and fines

Photo

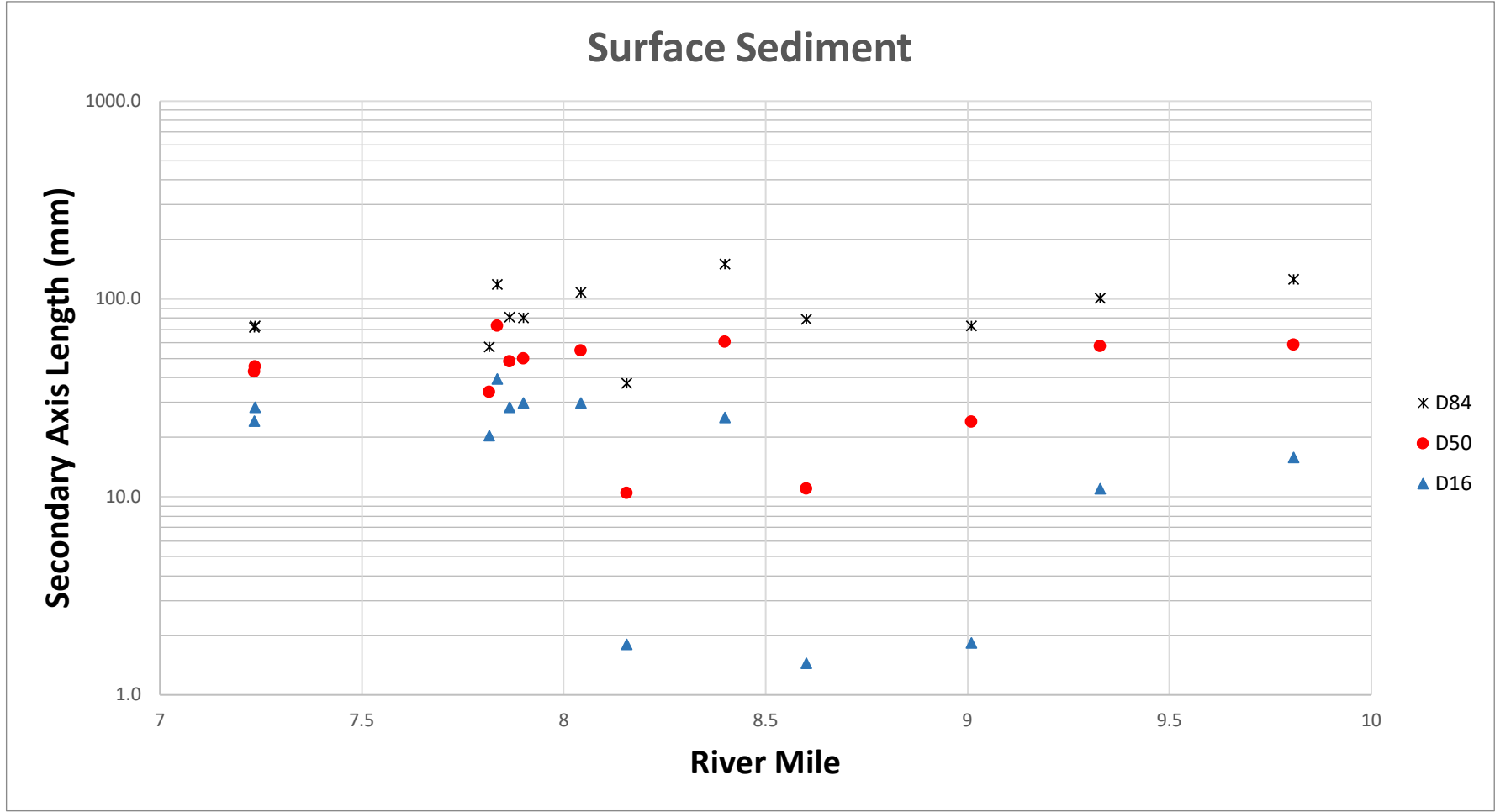
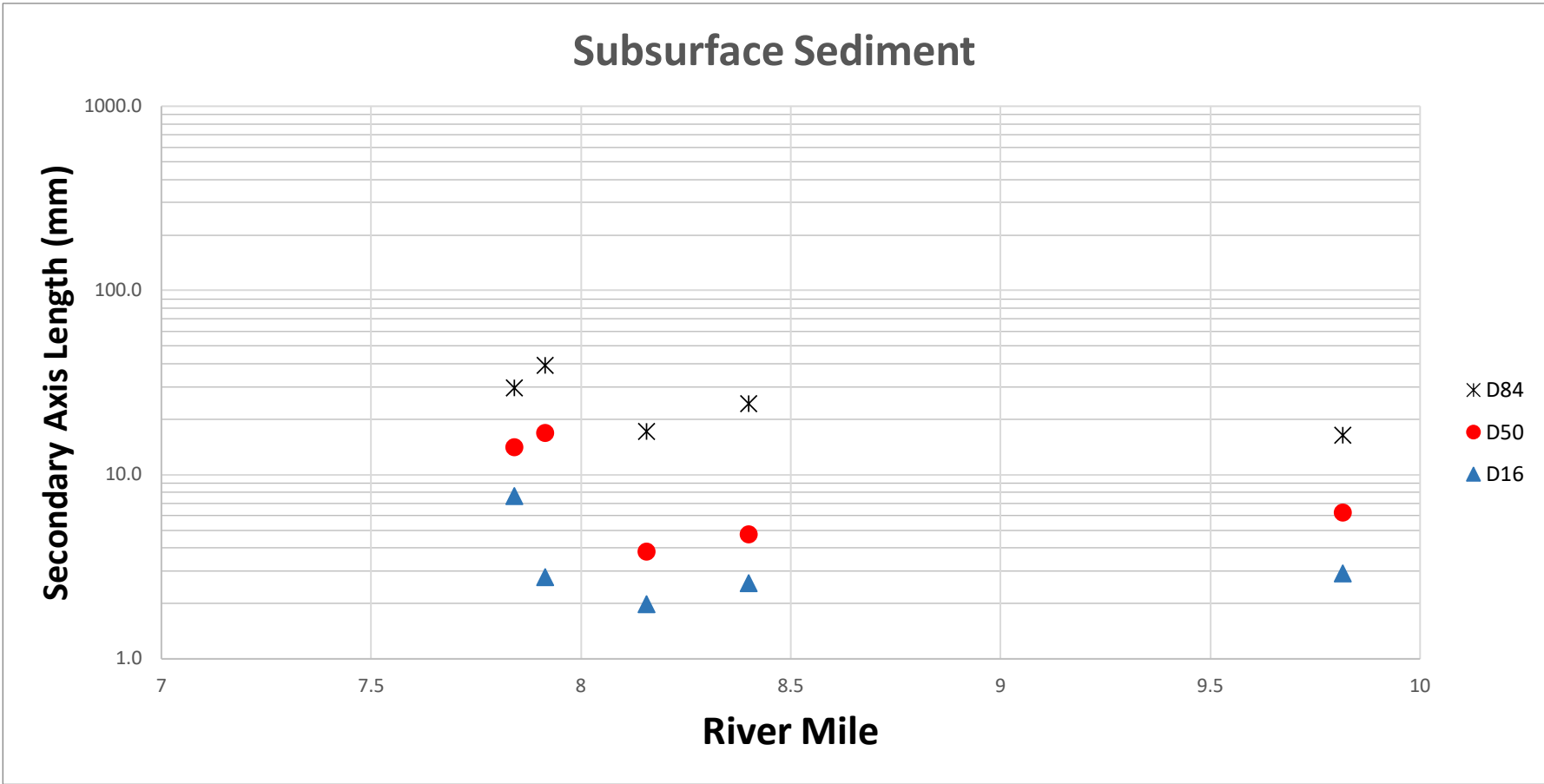


Photo

PM4Bank_1.jpg



Type	Sample ID	D16	D50	D84	RM
Sub-surface	PM1		2.9	6.3	16.4
Sub-surface	PM4		2.6	4.7	24.4
Sub-surface	PM5		2.0	3.8	17.1
Sub-surface	KN2		-70.1	#DIV/0!	-326.0
Sub-Surface	KN6		7.7	14.1	29.7
Sub-Surface	KN8		2.8	16.9	39.2
Surface	PM1-Surface		15.8	59.0	125.9
Surface	PM2-Surface		11.0	57.7	100.9
Surface	PM3-Surface		1.8	24.0	73.4
Surface	PM4-Surface		25.1	60.7	150.2
Surface	PM5-Surface		1.8	10.5	37.4
Surface	PM6-Surface		1.4	11.0	78.8
Surface	KN1		24.3	42.8	72.0
Surface	KN2		28.4	45.7	73.5
Surface	KN5		20.4	34.0	57.4
Surface	KN7		29.8	50.1	80.4
Surface	KN9		28.5	48.2	81.3
Surface	KN10		39.3	73.0	118.1
Surface	JE1		29.8	55.0	108.3
	KN3				7.265151515
	KN4				7.271969697



E. Water Temperature Modeling

continues on next page

East Fork Lewis River Ridgefield Pits Restoration

Basis of Design Report Preliminary Design:
Attachment 5 – Water Temperature Analysis



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1.1 OVERVIEW

This section describes water temperature characteristics of the EFLR mainstem above and through the Project reach, based on information collected by Washington Department of Ecology (DOE) (Carey & Bilhimer 2009, McCarthy 2018) and LCEP (Quantum Spatial 2020, LCEP 2018). Information is focused on the summer months from approximately July through mid-September, when low flows combined with maximum atmospheric heating elevate mainstem water temperatures to levels that exceed critical temperature thresholds for salmonid health (16-20°C as defined by various agencies for various criteria). Following this baseline temperature characterization, we present results of modeling we completed to help assess factors influencing the current temperature profile, and predicted performance of restoration alternatives #2 and #3, the respective single channel and hybrid 3-channel networks through the Ridgefield Pits section (Pits reach) of the Project reach.

1.2 BASELINE TEMPERATURE CHARACTERISTICS BASED ON FIELD OBSERVATIONS

1.2.1 EFLR upstream of Project reach

Carey and Bilhimer (2009) and LCEP/Quantum Spatial (2020) both observed a significant warming of the mainstem EFLR during the summer, beginning at approximately river mile (RM) 26 and continuing downstream to the upstream extent of the Project reach at RM 10. The trend is illustrated in Figure 1, which shows continuous water temperature observations between RM 10 and RM 21 recorded by Hobo temperature loggers during the 2020 LCEP study. Contributing factors are discussed in various DOE reports and elsewhere, but the relevance for this project is that water temperature is already significantly degraded when EFLR flow reaches the site. This presents significant challenges to reducing stream temperatures to levels acceptable to salmonids through proposed restoration actions.

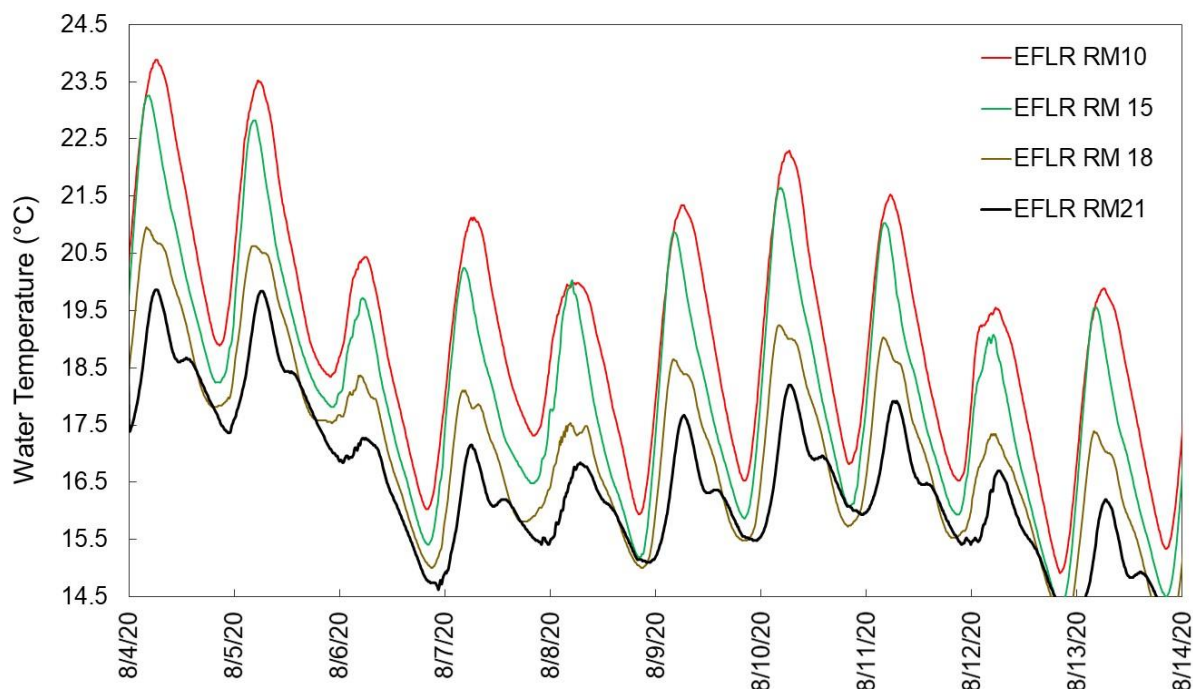


Figure 1. EFLR water temperature between RM 10 and 21, recorded during the LCEP 2020 FLIR study.

1.2.2 EFLR through Project reach

Due to its highly dynamic nature, including frequently shifting channels, areas of hyporheic flow, surface/groundwater exchange, and ongoing adjustment to the 1996 gravel pit avulsions, the Project reach exhibits a dynamic and complex water temperature profile accordingly. Carey and Bilhimer (2009) noted a transition point at approximately RM 9 where the EFLR shifts from losing flow upstream to gaining flow downstream of this location because of groundwater interaction. In the upstream losing reach a portion of surface streamflow was shown to be lost to the ground, primarily through a large gravel bar which the river meandered around at the time of the study but is now largely cut off as the main channel has assumed a more direct path. In the downstream gaining reach from RM 9 to 7.3, groundwater was presumed to be introduced, potentially cooling the river. Monitoring locations and frequency were too sparse, however, to provide conclusive evidence for groundwater introduction at any specific location within the mainstem. The authors also acknowledged that the transition to a more ponded and channel through the Ridgefield Pits could also be a contributing factor to the temperature drop that they noted.

Results from LCEP's 2020 water temperature study (Quantum Spatial 2020) are shown in Figure 2 for the Project reach. For this study, LCEP contracted Quantum Spatial to conduct an airborne thermal infrared (TIR) survey of EFLR surface water temperature on August 11, 2020. Advantages of this technique include the ability to observe water temperature over a large spatial area at high spatial resolution. Because the data is all collected over a relatively short time frame of 30 minutes or less, temperature response to atmospheric heating or cooling during the data acquisition period is largely eliminated, allowing a more or less 'instantaneous' snapshot of temperature differences over the entire survey area. A technical report for the Quantum survey (Quantum Spatial 2020) is available from LCEP, and a complete analysis of the results will be included in the upcoming report for the LCFRB-funded LCEP East Fork Lewis River Thermal Assessment study, for which the survey was flown.

The most notable feature of the thermal infrared data is a significantly cooler temperature signal detected through the Pits reach, from roughly RM 7.8 to RM 7.2. Temperature in this section is as much as 2°C cooler than what was measured upstream and downstream. This difference may be a result of two factors: 1) introduction of colder groundwater into the mainstem in the vicinity of the Ridgefield Pits, which would be consistent with Cary and Bilhimer's (2009) characterization of this area as a gaining reach; and 2) a moderating effect of this deeper section of the mainstem on atmospheric heating and cooling effects. Additional monitoring and modeling done by LCEP that is described below suggest that the latter may be primarily responsible. Downstream of RM 7.2 (roughly the downstream end of the Project reach) water temperature is seen to increase again, and within a mile is roughly equivalent to what was measured in the Project reach upstream of the Ridgefield Pits.

The thermal infrared data does not indicate any change in temperature in the vicinity of the gravel bar at RM 9, where Carey and Bilhimer (2009) described the mainstem losing nearly 10 cfs of flow

underground across the prominent gravel bar located here, which they then claimed re-entered the mainstem as colder water shortly downstream of this feature. It is possible that this is no longer occurring, due to a meander cutoff that formed in years after the study and now routes most flow to the south of the bar rather than meandering around it to the north. It is also possible that a significant amount of flow is still being lost through the gravel bar and is re-surfacing further downstream, or in off-channel locations.

LCEP collected additional temperature data for the mainstem EFLR during the summers of 2018 and 2020 (Figure 3 and Table 1). This data was collected by Onset Hobo data loggers deployed at selected locations across the Project reach. Data collected in 2020 was used to calibrate the airborne thermal infrared data collected by Quantum Spatial.

Observation of the 2018 data immediately downstream and upstream of the Ridgefield Pits (Fig. 3 top, RM 7.2 and 8 respectively) shows significantly reduced diurnal fluctuation, and slightly higher overall average temperature downstream compared to upstream. The smaller diurnal temperature swing observed downstream may be the result of the large volume of deep, slow-moving water through the Pits reach acting to slow the rate of atmospheric heating and cooling, relative to shallower and faster-moving sections of the mainstem. This moderating effect would explain the differences in instantaneous temperatures measured at the two locations shown in Table 1: a slower rate of overnight cooling keeps water temperatures in the Pits reach higher than those upstream during the morning hours; during the late morning the shallower upstream reach begins to heat faster, and by mid-day temperatures are roughly equal at the two locations; heating continues at a faster rate upstream during the afternoon, and by late afternoon temperature at the upstream location is higher than downstream. Thermal infrared measurements recorded by Quantum were collected in late afternoon, and thus the pattern observed in that data is consistent with this explanation.

Several previous studies have noted potential groundwater recharge of the mainstem in the Pits reach (Cary & Bilheimer 2009; Daybreak Mine Habitat Conservation Plan 2003; McFarland and Morgan; 1996). We did not attempt to measure groundwater inputs as part of this design effort, and thus cannot estimate its relative contribution to temperature patterns noted in the Pits reach in LCEP temperature monitoring studies. Because of the volume of groundwater that would likely be required to influence the large volume of water in the Reach, we suspect that the moderation of temperatures seen the Pits reach is predominantly due to reduced atmospheric heating and cooling, with a potential smaller contribution from groundwater acting to locally cool areas. Average temperature at the downstream end of the reach was noted to be higher compared to upstream in the LCEP study (20.3 versus 19.8 °C), suggesting that groundwater inputs, if occurring, may have been small at least for the 2018 summer that was monitored. Groundwater inputs may vary from year to year based on climate patterns.

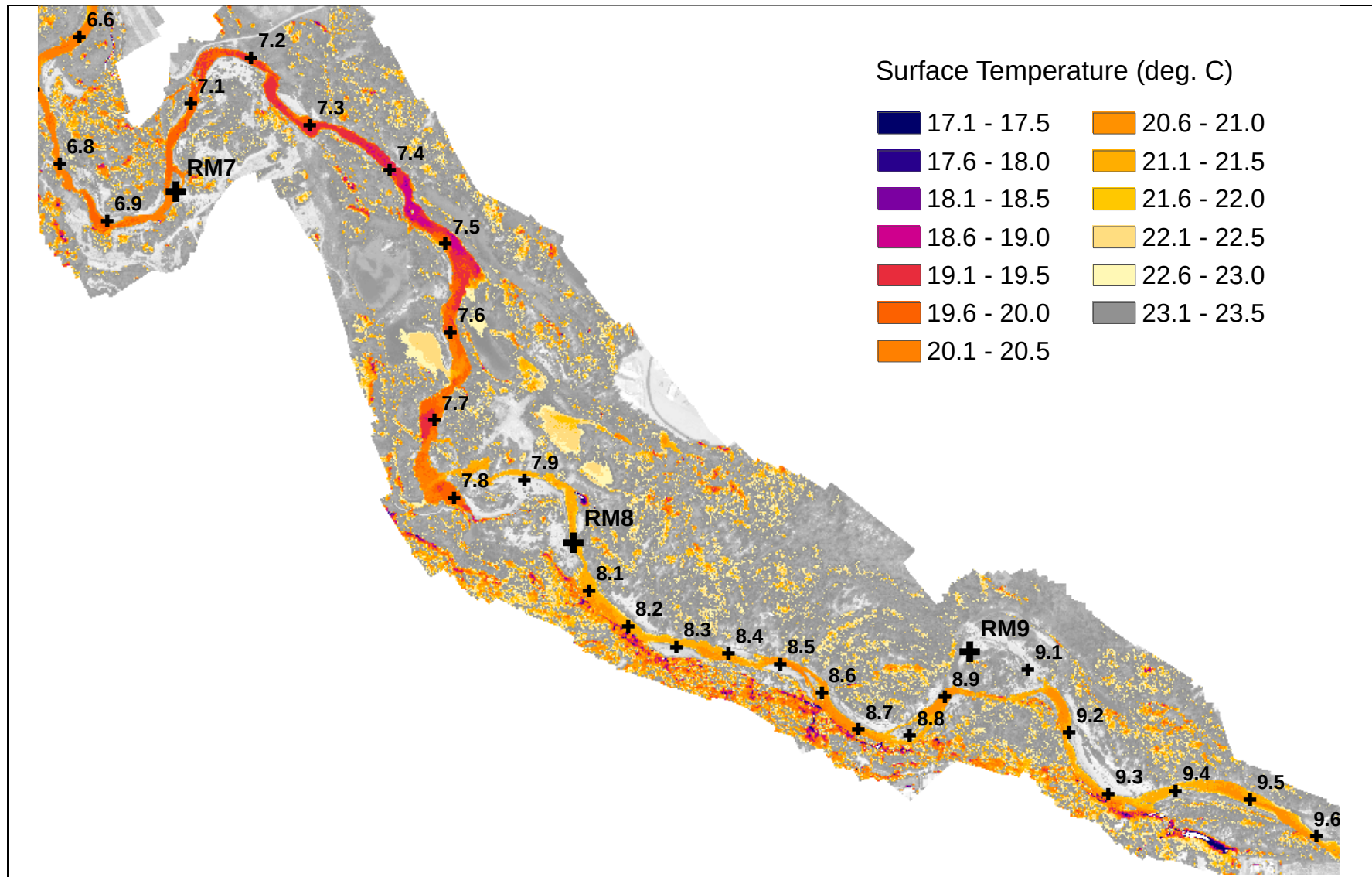
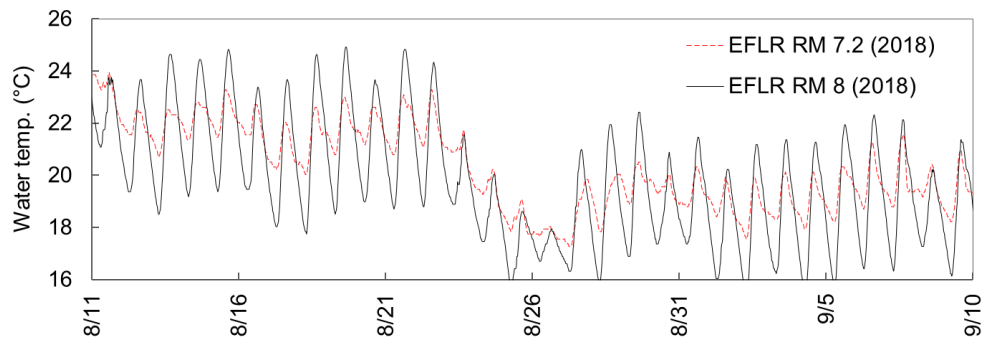
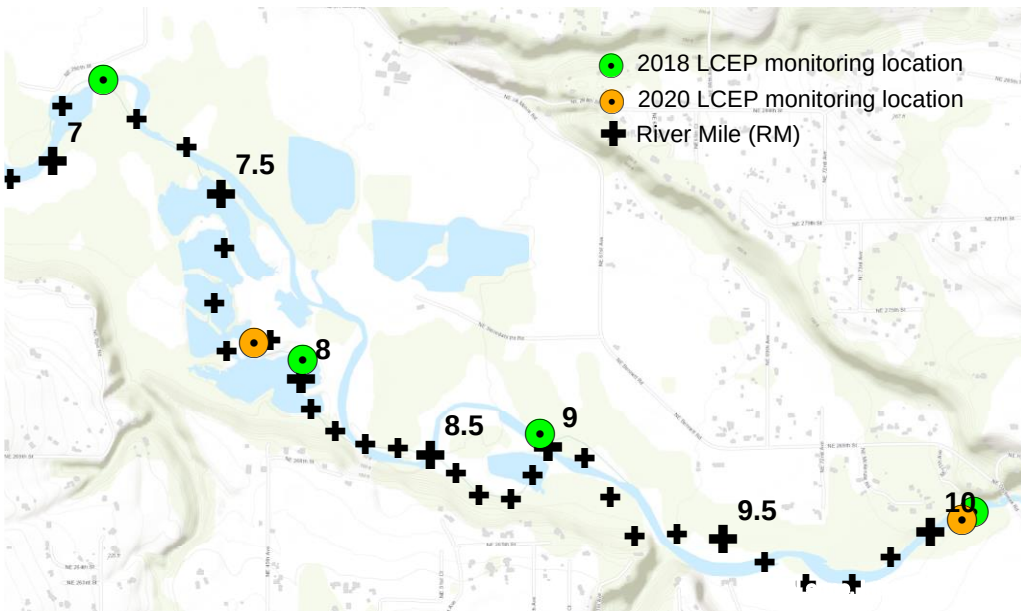
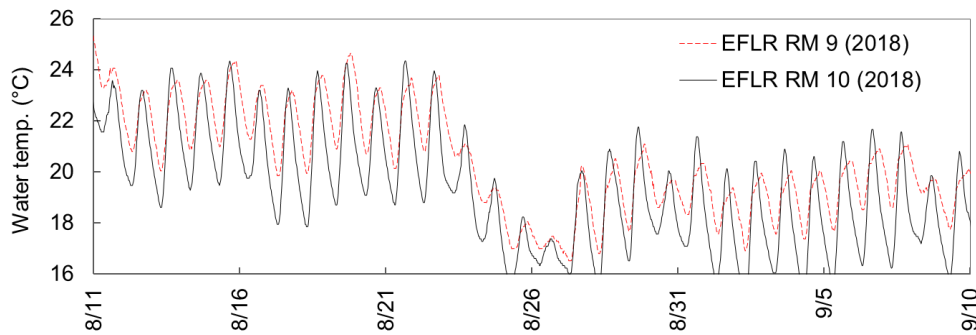


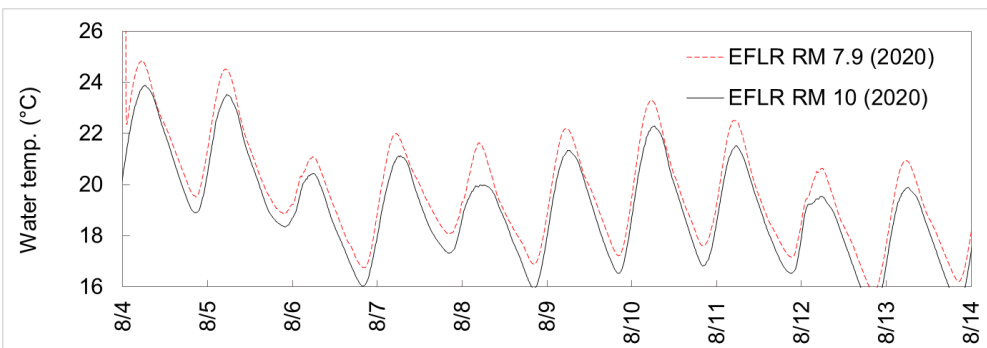
Figure 2. Surface water temperature of mainstem EFLR through the Project Reach, recorded by thermal infrared remote sensing on August 11, 2020 at 3:30 pm PST. Note: most of the small cold-indicated patches along the bottom (south) margin and other small spots elsewhere outside of the mainstem are shaded land areas and should be disregarded.



Mean values
 RM 6.2: 19.9
 RM 7.2: 20.3
 RM 8: 19.8



RM 9: 20.4
 RM 10: 19.3



RM 7.9: 19.8
 RM 10: 19.1

Figure 3. LCEP EFLR mainstem temperature monitoring locations and corresponding results for summers 2018 and 2020.

Table 1. Instantaneous water temperatures recorded at 9:00, 12:00, and 17:00 hours immediately downstream (RM 7.2) and upstream (RM 8.0) of the Ridgefield Pits during a selected one-week period in 2018.

		09:00 hrs. on:						
Location		8/12/18	8/13/18	8/14/18	8/15/18	8/16/18	8/17/18	8/18/18
RM 7.2		21.7	21.1	21.7	21.9	21.6	20.5	20.5
RM 8.0		19.8	19.3	19.9	20.1	19.6	18.1	18.7
		12:00 hrs. on:						
Location		8/12/18	8/13/18	8/14/18	8/15/18	8/16/18	8/17/18	8/18/18
RM 7.2		22.4	22.1	22.4	23.1	22.4	21.4	22.0
RM 8.0		22.1	22.2	22.3	22.9	21.7	21.4	22.0
		17:00 hrs. on:						
		8/12/18	8/13/18	8/14/18	8/15/18	8/16/18	8/17/18	8/18/18
RM 7.2		22.1	22.3	22.6	22.8	22.1	21.7	22.1
RM 8.0		23.2	24.4	24.3	24.4	23.1	23.2	24.1

1.2.3 Off-channel areas within Project reach

In addition to the mainstem EFLR, the Project reach includes other sources of surface water including side channels and off-channel areas in the floodplain, inundated gravel pits including the Ridgefield Pits, and the Mill and Manley creek tributary inputs. LCEP monitored water temperature at several of these during summer 2018, including previously known cold water locations, using deployed Onset Hobo data loggers and Pendant temperature loggers. Monitoring locations and corresponding results are shown in Figure 4, with location symbol colors corresponding to average daily maximum temperatures for the deployment period from late July – early September. Analysis of these results, some of which can offer additional insight into temperature patterns observed in the Pits reach of the mainstem, is as follows:

- Location T2. Off-channel area where former gravel pit #2, which has almost filled in after the 1996 avulsion, was located. The consistently cold temperature, with minimal diurnal variation, indicates the likely presence of groundwater intrusion.
- Location T3A - Side channel flowing through former gravel pit #3 which has largely filled in after the 1996 avulsion. Flow through this channel out of the mainstem has been increasing in recent years as the river continues to respond to the avulsion. As a result, the temperature profile is nearly identical to what is observed at location WSE3 (the mainstem monitoring location at RM 8, discussed above). This is illustrated in Figure 5a below.
- Location T5. Ridgefield Pit #5, which remains largely unfilled after the 1996 avulsion. The consistently warm temperature indicates a lack of groundwater intrusion into this pit. Water depth is up to 15 feet deep in some areas and we presume that the corresponding large volume of water moderates atmospheric heating and cooling and is thus responsible for the minimal

diurnal temperature variation observed in the plot. If true this would be consistent with what we presume is also happening in the Pits reach of the mainstem, as discussed in Section 1.2.2 above, where that relatively large volume of water is likely moderating mainstem heating and cooling. Although they are hydrologically connected the very different temperature signals observed in the mainstem and Pit #5 suggests limited mixing between the two, and thus it is unlikely that Pit #5 is influencing mainstem EFLR water temperature. This is somewhat supported by the LCEP 2020 TIR data, however since those measurements are limited to surface water it cannot be stated with absolute certainty.

- Location T6. Ridgefield Pit #6, which remains largely unfilled after the 1996 avulsion. Thermal performance is nearly identical to what was observed, and described above, for Ridgefield Pit #5. This is expected as the two share very similar physical and geomorphic characteristics, the major difference being that Pit #6 is typically minimally connected to the mainstem throughout the summer. The fact that Pit #5, with its more frequent hydrologic connection to the mainstem, shares nearly identical thermal properties to the disconnected Pit #6 supports the conclusion that there is limited interaction between the EFLR mainstem and Pit #5.
- Location T7. Ridgefield Pit #7, which remains mostly unfilled after the 1996 avulsion but has seen some fine sediment accumulation and is shallower and smaller in volume relative to the other pits. Thermal performance is similar to what was observed downstream of the mainstem at RM 7.2 (described above in Section 1.2.2), but with a larger diurnal variation that is mostly expressed in the daytime heating portion of the cycle. This is illustrated in Figure 5b below. The close relationship between the two temperature profiles suggests mixing between the two water bodies, and the increased daytime heating in Pit 7 could be explained by its shallower, more stagnant water and reduced volume relative to the mainstem. The surface of Pit #7 sits at a lower elevation relative to that of Pit #8 during the summer, and thus it receives a very small amount of surface water from the higher pit through the narrow berm/beaver dam complex that separates the two. Pit #8, described below, is considerably cooler than Pit #7, however it does not appear that its surface water contribution is large enough to produce any cooling in Pit #7, at least during the period of record for our monitoring.
- Location T8. Ridgefield Pit #8, which remains unfilled, and largely disconnected from the mainstem EFLR except for a very small surface water contribution through Pit #7, as described above. Pit #8 connects to a series of off-channel wetlands and side channels at its upstream end. This entire network appears to be fed by groundwater consistently throughout the summer, as illustrated by the consistently cold and minimally varying temperature profile shown in Figure 4.
- Location 9. Ridgefield Pit #9, which remains disconnected from the mainstem EFLR. Surface water connection to the remaining hydrologic network within the Project reach appears minimal as well. Thermal performance is similar to Pit #8, but temperature is roughly 2 degrees higher, suggesting a smaller groundwater presence within Pit #9. The slightly increased diurnal

variation seen in Pit #9 relative to Pit #8 would also be consistent with that assumption but could also be influenced by the overall shallower depth, smaller volume, and lack of surface water connection exhibited by Pit #9.

- Locations T11 and T12. Side channel adjacent to the large gravel bar at RM 9, where Carey and Bilhimer estimated significant loss (~10 cfs) of surface water from the mainstem to groundwater, through this feature. If still occurring a portion of this groundwater may be re-surfacing in this side channel, which would explain the relatively cold temperature profiles observed here. Both locations show a slightly increasing temperature trend throughout the period of record, which would be consistent with a decreasing volume of groundwater loss and re-expression associated with decreasing EFLR mainstem flows as summer progresses.
- Location T13. Mill/Manley creeks confluence. This location had the coldest water of all the locations monitored, primarily due to the contribution from Mill Creek. Other studies by DOE have shown Manley Creek to be warmer, however the beaver pond complex that is present at its downstream end immediately upstream of the confluence zone remains relatively cold throughout the summer, as is illustrated in the LCEP TIR data.

It is worth noting that although several surface water locations off the mainstem have been observed to be cooler than the mainstem, likely due to groundwater intrusion, most of these areas remain disconnected from the mainstem at typical low summer EFLR flows when elevated temperatures are of most concern. This disconnection may serve to preserve these cold-water areas, but it also means that during these times fish in the mainstem would not be able to access these areas for thermal refuge. This refuge would only be provided to fish that entered these areas prior to the disconnection occurring. Hydraulic modeling provides us with an estimate of the flow magnitudes required to establish these connections, but until the model is fully calibrated, we cannot provide exact values. In general, though, most areas are likely to remain disconnected at flows less than ~80 cfs, roughly the long-term average daily flow for the month of August (USGS Heisson gage monthly flow statistics).

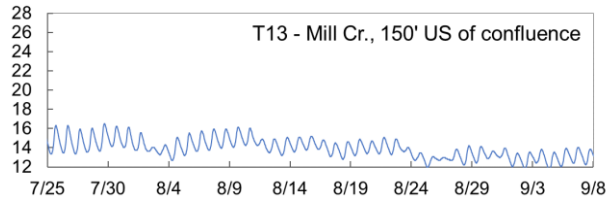
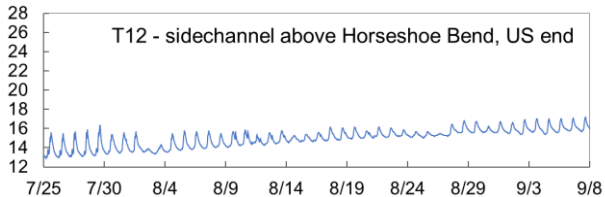
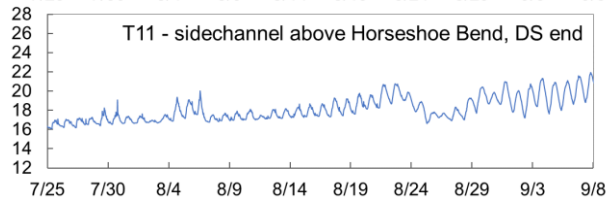
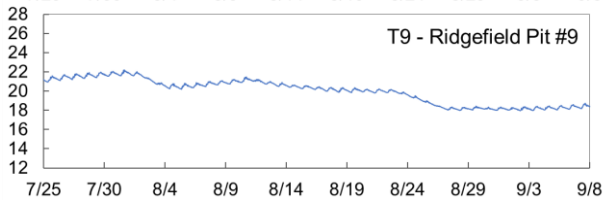
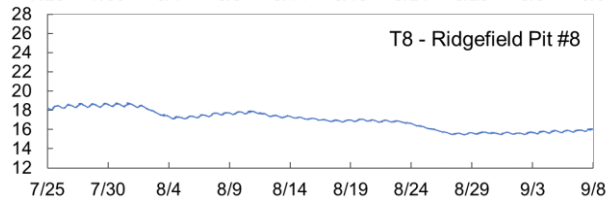
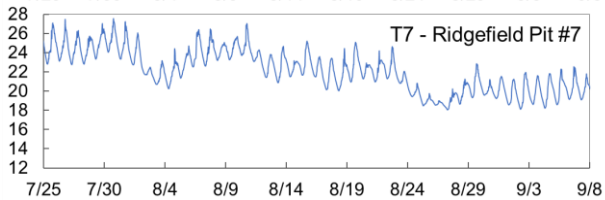
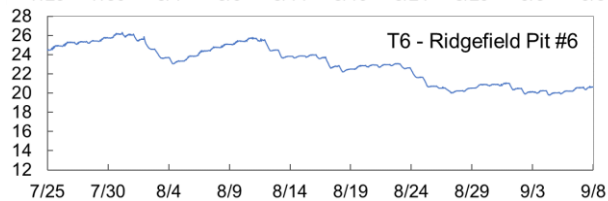
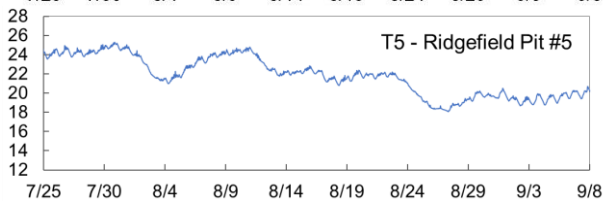
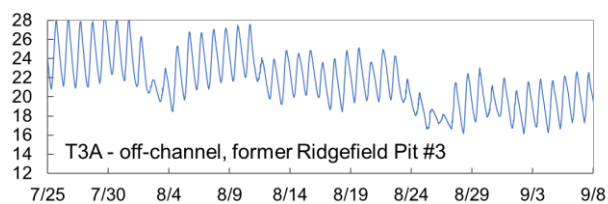
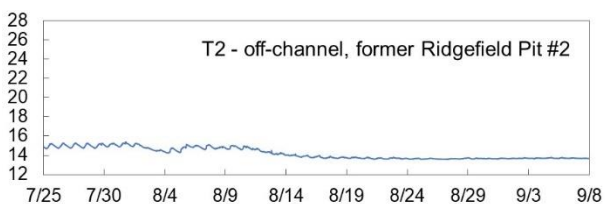
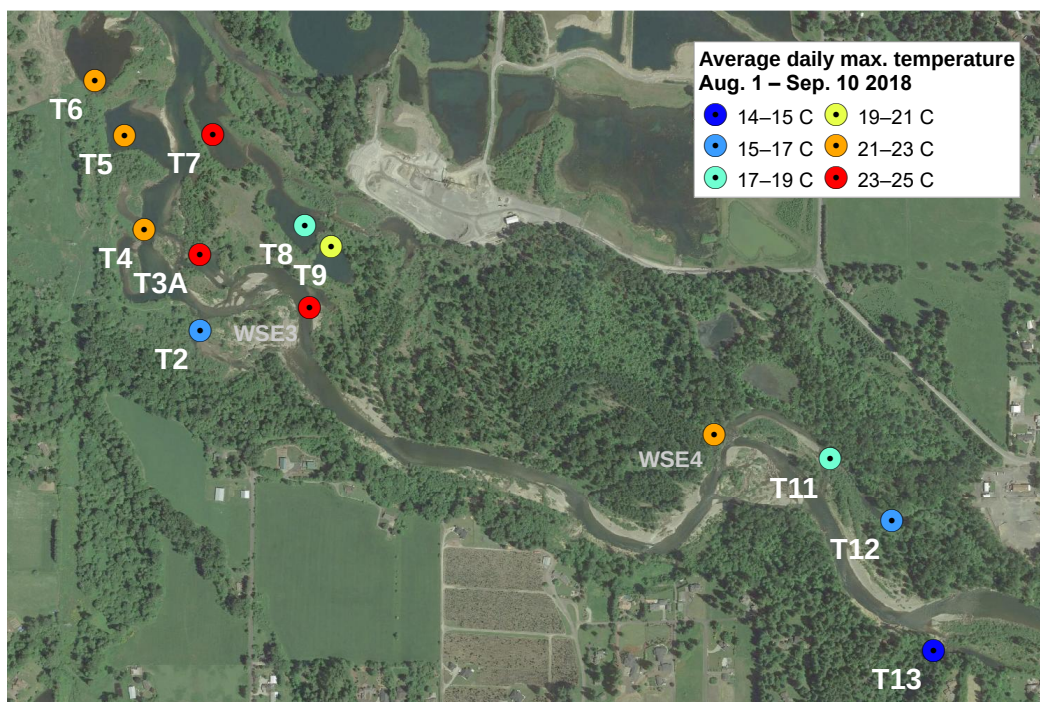


Figure 4. LCEP off-channel temperature monitoring locations and corresponding results for summer 2018. Note WSE3, WSE4, and T4 are mainstem locations and thus not included in results presented here.

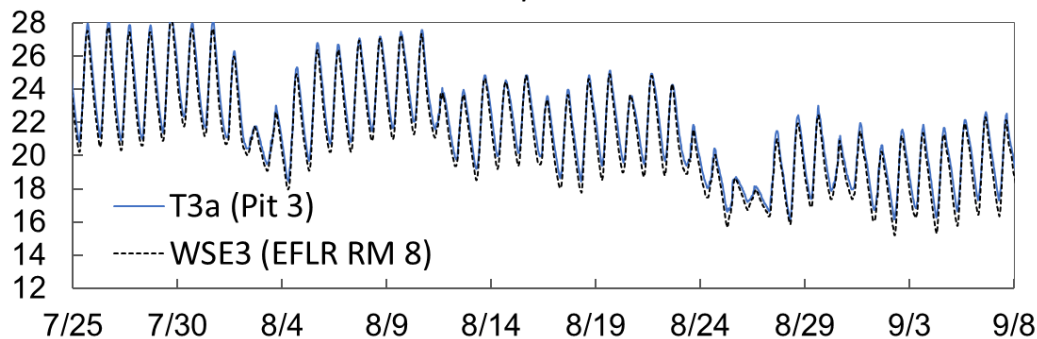


Figure 5a. Comparison of water temperature monitored by LCEP at Pit #3 with that of the EFLR mainstem measured at RM 8, during summer 2018.

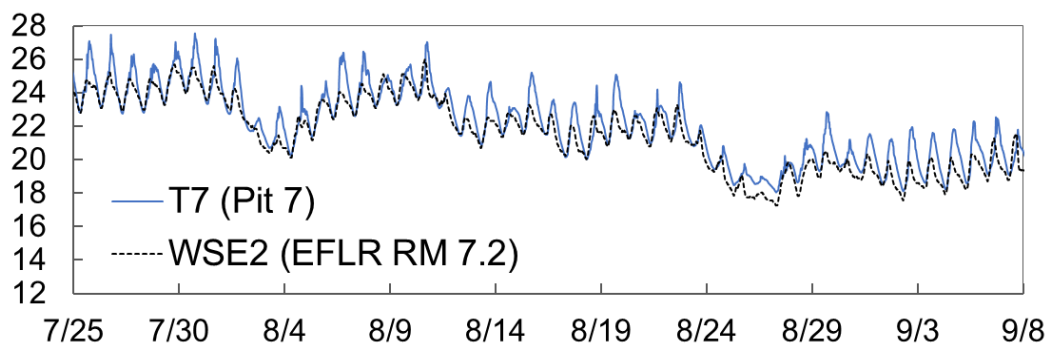


Figure 5b. Comparison of water temperature monitored by LCEP at Pit #7 with that of the EFLR mainstem measured at RM 7.2, just downstream of the Ridgefield Pits reach, during summer 2018.

1.3 WATER TEMPERATURE MODELING

1.3.1 Thermal model overview and inputs

We modeled water temperature using the TufLOW Advection/Dispersion (A/D) add-on module to the TufLOW FV hydraulic model (TufLOW FV 2020, 2013). The module couples water temperature and atmospheric heat information (incident solar radiation, air temperature, humidity, precipitation, and cloud cover) applied at model input boundaries with hydraulic engine outputs to simulate changes in water temperature throughout the model domain using two-dimensional, depth averaged heat transfer equations. The TufLOW hydraulic engine allows flow inputs to be applied at individual grid cell locations, and thus we were also able to simulate groundwater (i.e. cool water) intrusion at locations of interest and predict how it might influence stream temperature dynamics. We ran unsteady (time varying flow) temperature simulations for the Existing Conditions model using input data from the summer 2018 monitoring period to try and replicate temperatures that were observed in the field during that time. Following this model verification process the same simulations were then run for the Alternatives #2/#3 comparison. Table 2 and Figures 6-7 summarize inputs to the A/D module and respective values we applied.

Table 2. Data sources and values applied as Tuflow FV A/D module inputs for water temperature modeling.

Hydraulic and A/D module inputs	Model Location Applied	Data Source
Input Flow	Upstream boundary	USGS Heisson gauge. See Figure 6.
River temperature	Upstream boundary	LCEP August 2018 EFLR hourly data at RM 8.
Longwave solar radiation	Full grid	Zion Klos, Link 2018. See Figure 7.
Shortwave solar radiation	Full grid	Zion Klos, Link 2018. See Figure 7.
Air temperature	Full grid	¹ Kelso, WA hourly observations, August 2018.
Rel. humidity	Full grid	¹ Kelso, WA hourly observations, August 2018.
Cloud Cover	Full grid	¹ Kelso, WA hourly observations, August 2018.
Precipitation	Full grid	¹ Kelso, WA hourly observations, August 2018.
Groundwater temperature	Selected point locs.	² Best guess

Notes: 1) data source = <https://www.wunderground.com/history/daily/us/wa/kelso/KKLS/date>; 2) groundwater magnitude, temperature, and input locations were estimated to the best of our ability based on field observations.

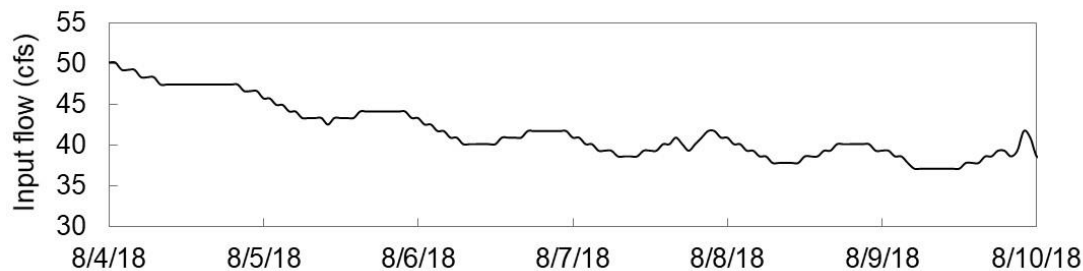


Figure 6. Input flow applied to Tuflow FV water temperature model. Selected flows were chosen to coincide with temperature monitoring observations recorded in 2018, during a period which saw typical low-flow conditions.

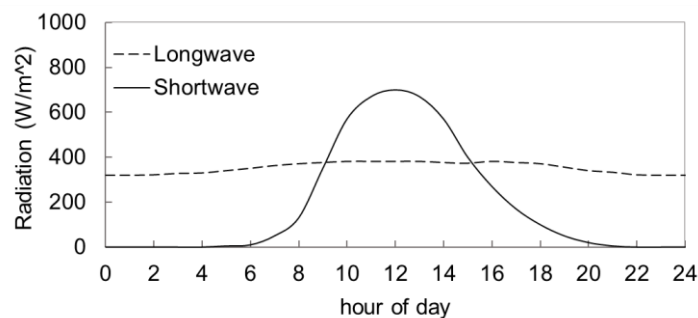
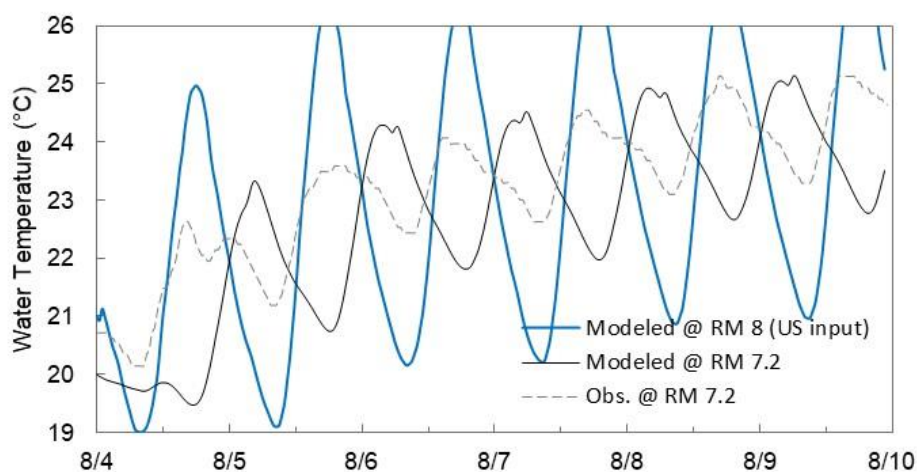
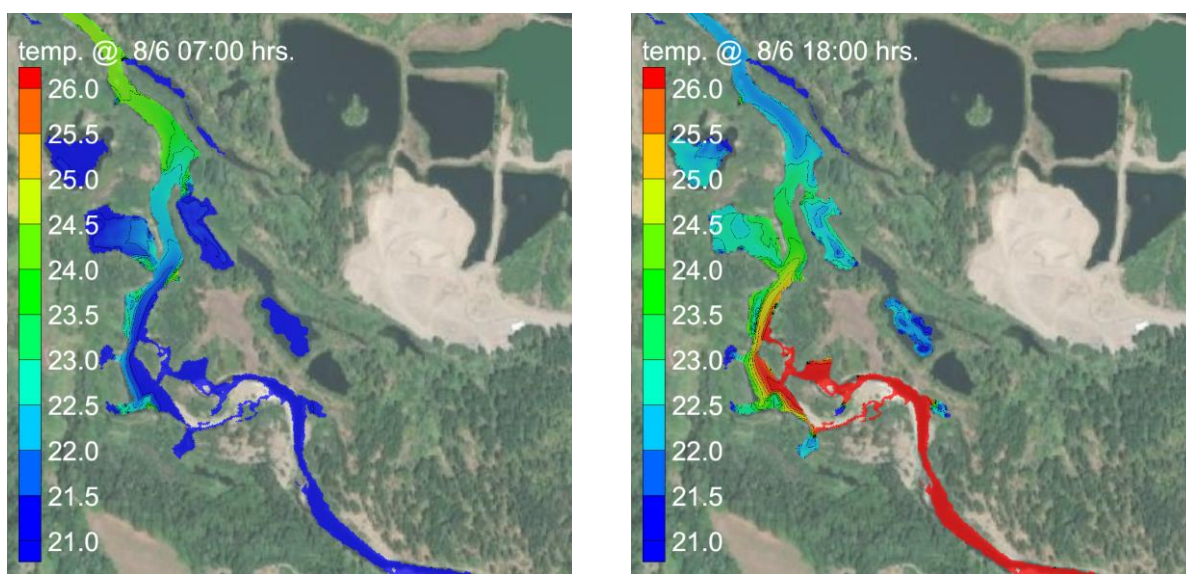


Figure 7. Daily incident solar radiation profiles applied as atmospheric heating inputs in Tuflow FV A/D module. Values are based on studies done by Zion Klos and Link, 2018.

1.3.2 Ridgefield Pits reach, Existing Condition

We ran unsteady low-flow water temperature simulations for the Pits reach to attempt to reproduce existing water temperature patterns that have been observed. Results are shown in Figure 8, including instantaneous map plots at select times (morning versus evening), and time series at select mainstem locations. The model reproduces the reversal of temperature across the Pits reach that occurs between morning and evening, as has been observed, however there is a time shift of several hours relative to the observed condition. This may be due to factors inherent in the startup process

for the model simulations, however we have not fully resolved this pattern to date. The model does predict the attenuation of the diurnal signal as water transits the Pits reach, as was seen in the observed data. Model results for Pit 5 are very close to what was observed and confirm a lack of mixing between this off channel area and the mainstem despite the hydraulic connection that is maintained. Model results for Pit 7 generally follow the observed data, but somewhat underpredict the larger daytime heating events. This may be due to the invert elevations of the model being set too high and isolating the pit from the the mainstem to a higher degree compared to actual conditions. Overall, model results generally predict the water temperature characteristics observed in the Pits reach for the period compared and lend support to our conclusion presented earlier – which is that diurnal variations in atmospheric heating are the primary driver of temperature changes in this reach. Groundwater influence may be an additional, but smaller factor.



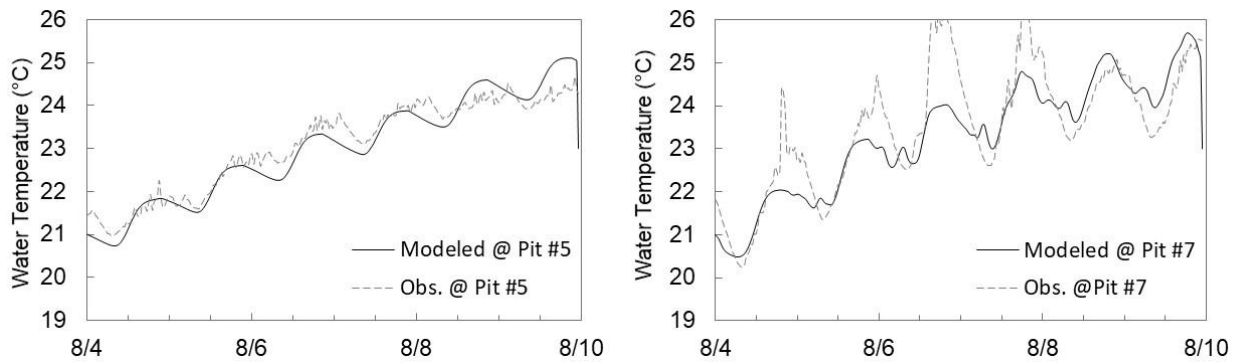


Figure 8. Output results for the Existing Condition water temperature simulation. Top: mapped outputs across the Pits reach shown at 7:00 am (left) and 18:00 pm (right). Middle: time series plots for the model input temperature (upstream) and simulated temperature at the downstream end versus observed temperature at the downstream end. Bottom: Simulated versus observed temperatures in Pits # 5 and #7.

1.3.3 Ridgefield Pits reach, restoration alternatives #2 & #3

LCEP ran low-flow water temperature simulations for proposed restoration alternatives #2 (single thread channel through the Pits reach); and #3 (3-channel network through the Pits reach) to evaluate the anticipated thermal performance relative to each other and to the Existing Condition. Selected temperature and heat inputs were identical to those applied for the Existing Condition, to maintain consistent conditions at the model boundaries (i.e., input flow applied at the upstream boundary, and atmospheric heating applied uniformly over the entire model domain).

The primary concern regarding temperature performance of the restoration alternatives is the potential for accelerated daytime heating within the hybrid 3-channel network of Alternative 3 relative to the single restored Alternative 2 channel, due to the shallower water depths of the Alternative 3 network. At the current design iteration, the Alternative 2 channel averages approximately 0.4 meters at the low-flow (~40 cfs) condition, with depths in the Alternative 3 channels averaging ~0.2 meters. Corresponding channel width/depth ratios, at low-flow, are 45 and 60 respectively for Alternatives 2 and 3. Figure 9 illustrates water depths in the Alternatives 2 and 3 channels under the low-flow conditions simulated.

It should be noted that for both alternatives the overall volume of water in the reach will be considerably less relative to the existing condition, and thus the moderating effect on diurnal heating currently exhibited will be lost. Anticipated shading provided by riparian vegetation placed along restored banks should prevent additional daytime heating, however the reach will likely exhibit temperature characteristics seen in the up and downstream reaches, unless groundwater can successfully be introduced.

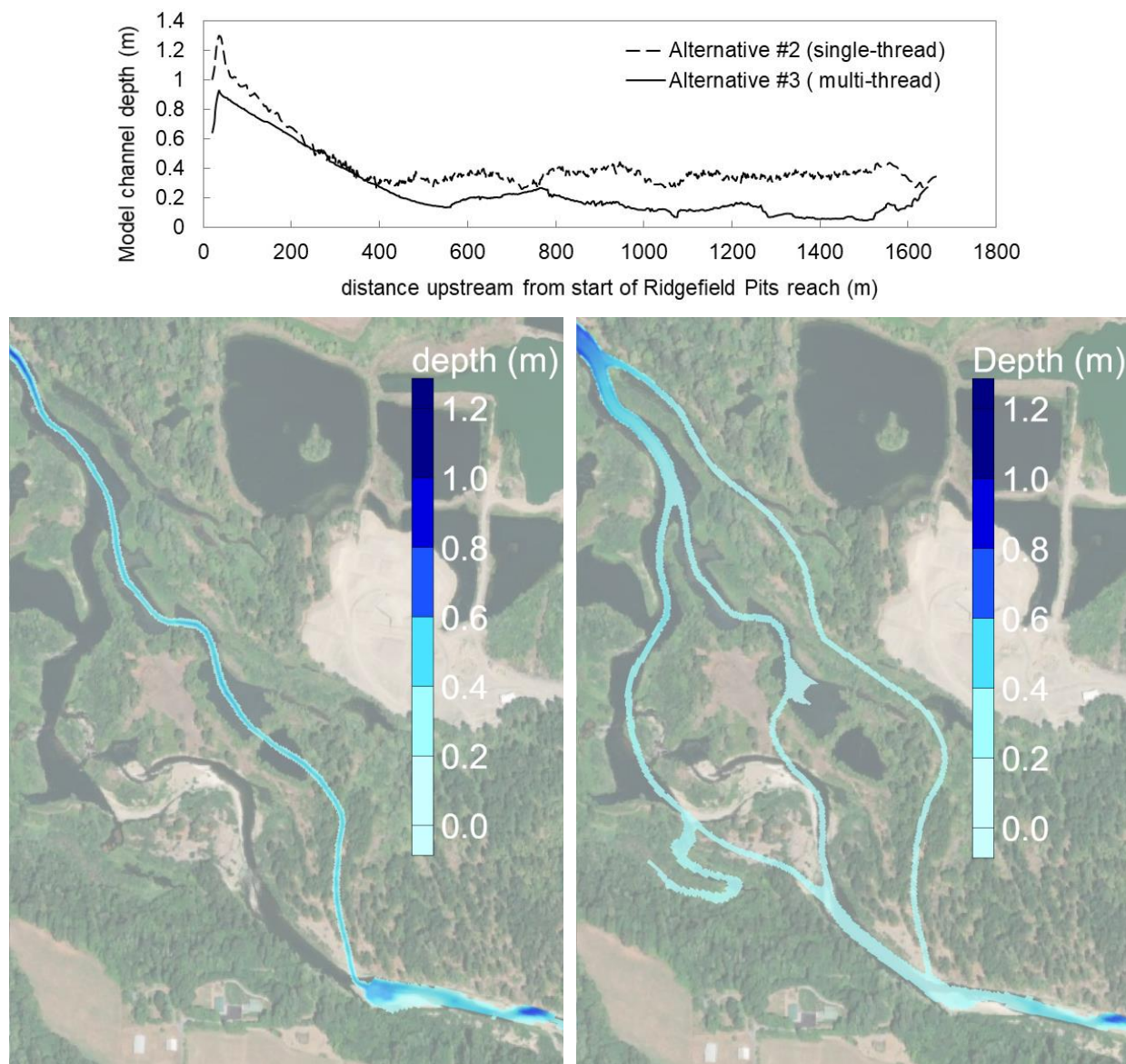


Figure 9. Model channel water depths for restoration Alternatives 2 and 3 under low-flow conditions simulated. Top: longitudinal depth profile extending up channel through Pits reach. Bottom: map profiles.

Temperature results for Alternatives 2 and 3 are compared in Figure 10, for the baseline condition of no groundwater input. The top plots show a uniform temperature profile throughout the reach for both alternatives, with no variation between upstream (US) and downstream (DS) temperatures. This is true throughout day and night. Temperatures that were observed in 2018 are included for comparison, and show the effect that the deeper, existing Pits reach has on moderating diurnal heating and cooling within the reach, resulting in lower daily maximum temperatures, and higher daily minimum temperatures, relative to both restoration alternatives.

The lower plot in Figure 10 compares temperatures at the downstream end of the reach for Alternative 2 versus 3. Model results show slightly cooler overall temperatures for the Alternative 3

hybrid network relative to the single channel Alternative 2. This evidenced by a larger rate of overnight cooling of these channels versus the Alt 2 single-thread, which compensates for increased heating during the day, since the nighttime cooling period is considerably longer relative to the shorter daytime period when air temperatures typically exceed water temperature and solar radiation is of significance. As a result, daily peak temperatures for Alternative 3 are very slightly lower compared to Alternative 2, while daily maximums remain nearly identical.

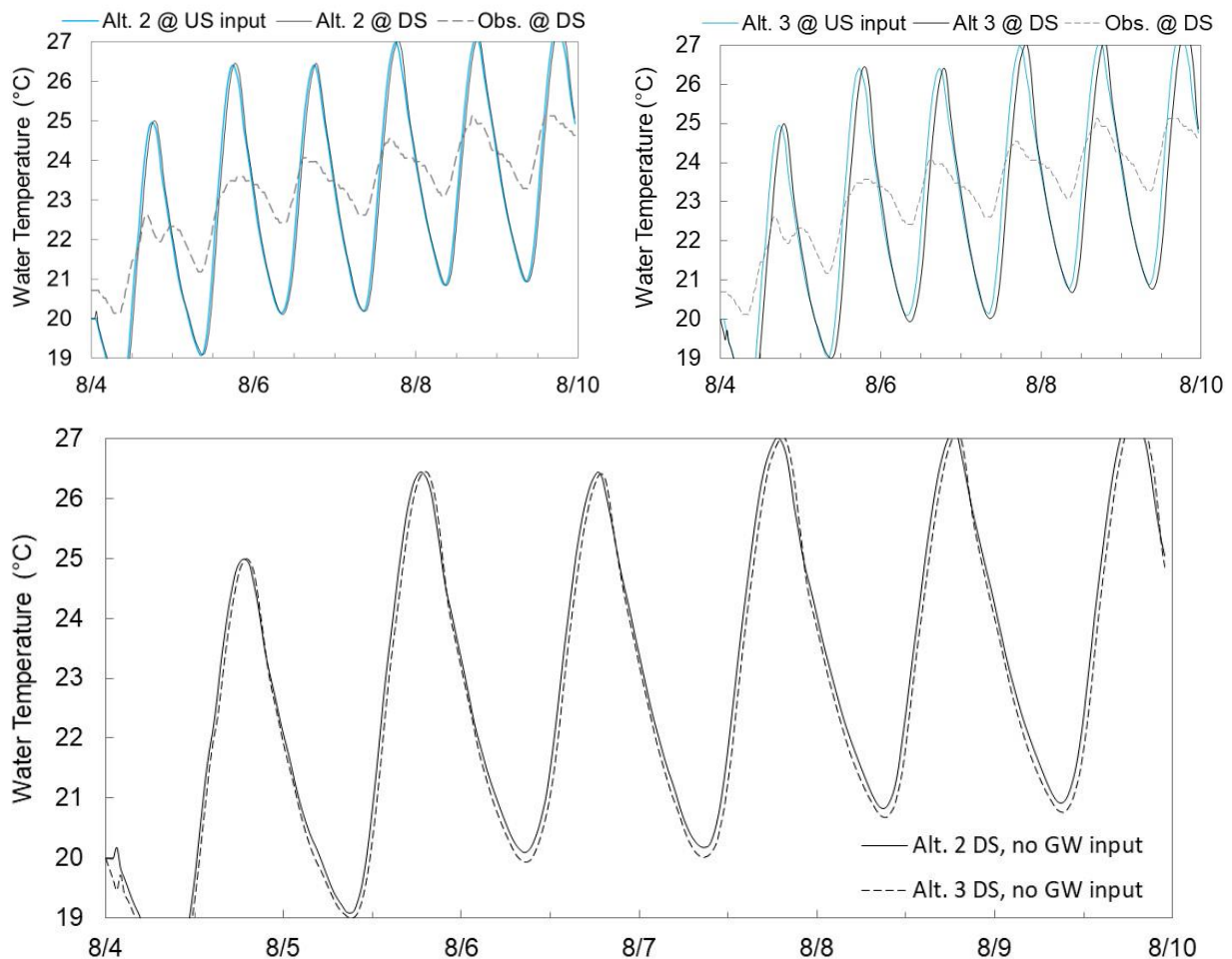


Figure 10. Simulated water temperature for restoration Alternatives 2 and 3, with identical boundary conditions applied as for the Existing Condition model described above, including atmospheric heating effects. Top: Upstream input versus resulting downstream temperatures for Alternative 2 (left) and Alternative 3 (right). Bottom: comparison of resulting downstream temperature for Alternative 2 versus 3.

As a final test identical simulations were run but with groundwater applied at selected locations, to predict the response of both alternatives to this potential cooling influence. Groundwater input locations are shown in Figure 11. Groundwater quantities were kept quite small, at 0.2 cfs for each location. Because of the potential for the multi-thread Alternative 3 channel network to intercept groundwater at a greater number of locations relative to Alternative 2, more inputs were correspondingly added to that model as shown.

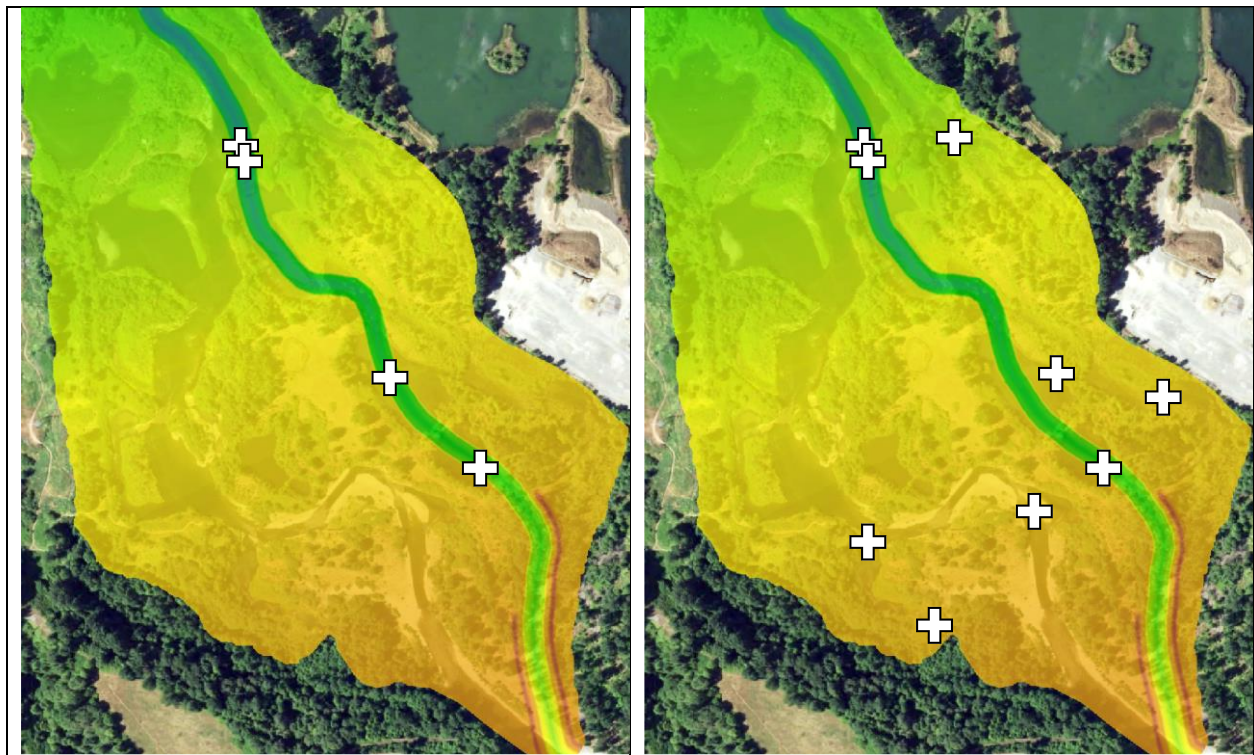
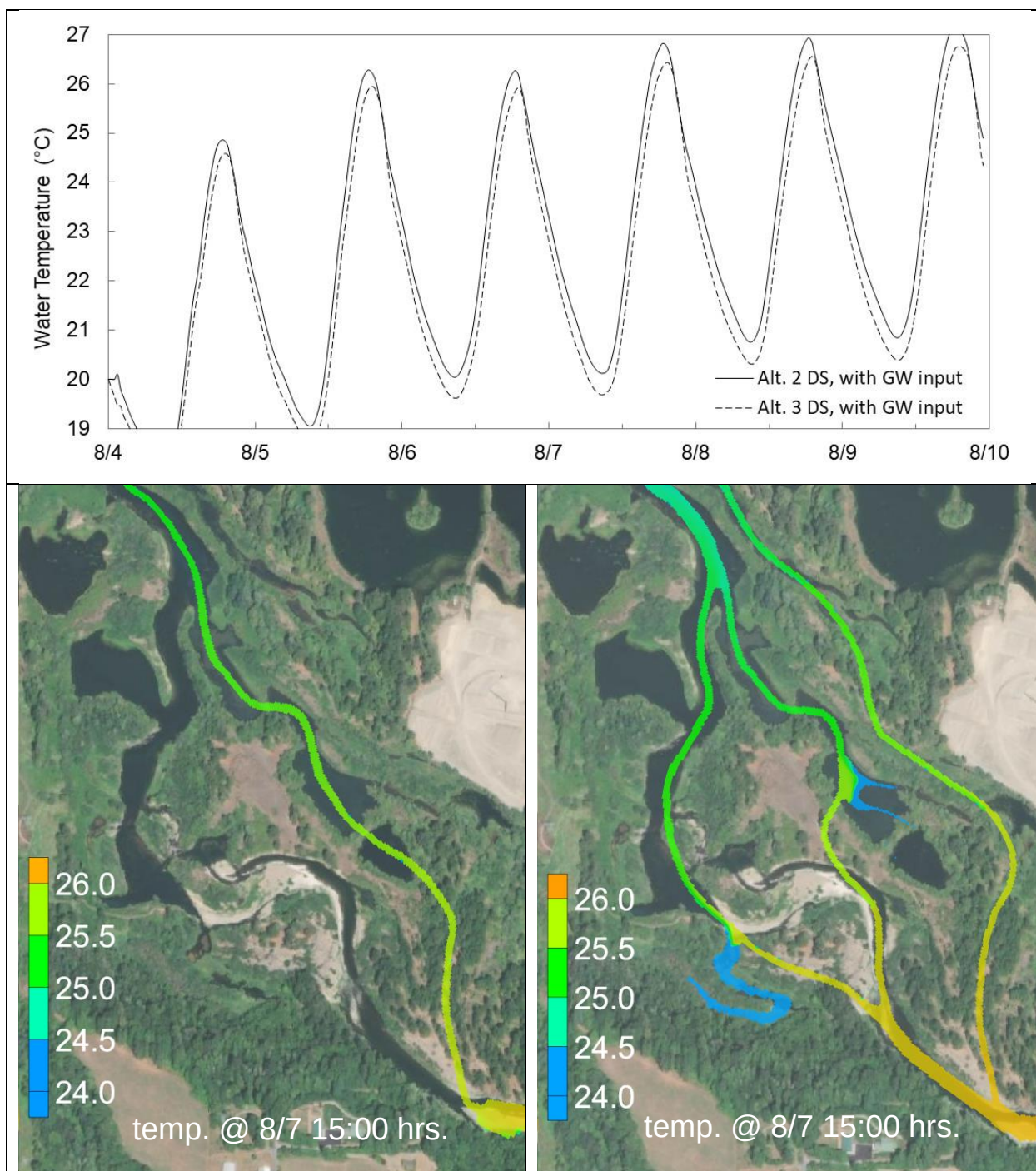


Figure 11. Simulated water temperature for restoration Alternatives 2 and 3, with identical boundary conditions applied as for the Existing Condition model described above, including atmospheric heating effects. Top: Upstream input versus resulting downstream temperatures for Alternative 2 (left) and Alternative 3 (right). Bottom: comparison of resulting downstream temperature for Alternative 2 versus 3.

Model results for the Alternatives simulations with groundwater inputs added are shown in Figure 12. The model again indicates slightly better temperature performance for Alt. 3 compared to Alt. 2, with the groundwater further enhancing this improvement. Overall temperature at the downstream end of the reach is lower for Alt. 3, with minimum peak temperatures reduced by approximately 0.4 degrees. Temperature response across the reach shows some retention of cool water areas in the Alt. 3 channels, whereas larger volume of water in the Alt. 2 single channel largely dilutes the cool groundwater inputs. Alt. 3 has also been designed with alcoves intended to intercept groundwater at locations where they have been observed, and these are shown to remain cool in the model simulations.



1.4 WATER TEMPERATURE ANALYSIS SUMMARY

1.4.1 Observed and simulated trends

The following bullets summarize water temperature characteristics for the Project reach during low flow summer conditions when temperatures are of concern, as described in the preceding sections:

- EFLR mainstem temperatures already exceed most water quality standards at the upstream extent of the Project reach near RM 10 at Daybreak Park (Figure 1).
- Further degradation of EFLR temperature through the Project reach is minimal (Figures 2 and 3, Table 1).
- EFLR mainstem temperature exhibits large diurnal variation in summer due to atmospheric heating and cooling. This variation is reduced through the Ridgefield Pits, where the high volume of slow-moving water attenuates heating and cooling effects, resulting in lower daily high and higher daily low temperatures relative to upstream and downstream reaches (Figure 3).
- Much of the spatial variation in temperature observed in the vicinity of the Pits can be attributed to the moderating effect of the Pits reach on atmospheric heating and cooling. Temperature modeling supports this conclusion (Section 1.3.2).
- Some groundwater may currently influence water temperature through the Pits reach, but this appears to be a relatively small influence, at least during the period of time that was monitored (Section 1.3.2, and additional modeling not presented).
- Groundwater influence is tied to the water table, which fluctuates based on climate and weather patterns. Thus, influence of groundwater on the EFLR mainstem is likely to vary from year to year. This has been evidenced by LCEP's 2021 water temperature monitoring, which showed considerably less cold water in off-channel and side channel areas relative to 2018.
- Little evidence of mixing is observed between the larger Ridgefield Pits #5 and #7 and the EFLR mainstem despite being hydrologically connected throughout the summer (Figures 4,5). Model results support this conclusion (Figure 8)
- Several off-channel and side channel areas have been observed to hold cold surface water during the summer, presumably due to groundwater intrusion (Figure 4). Most of these however do not remain hydrologically connected to the EFLR mainstem during most summer flows, limiting their potential as thermal refuge for juvenile salmonids.
- The confluence of Mill and Manley creeks with the EFLR mainstem presents the largest area of current thermal refuge within the Project reach.
- Overall, the highly dynamic nature of the Project reach results in a complex and dynamic water temperature profile. Restoration actions should retain and potentially enhance positive aspects of this.

1.4.2 Implications for restoration alternatives

The following bullets summarize implications of the observed and simulated EFLR temperature performance for the restoration alternatives that have been considered for the Pits reach, relative to each other and the Existing Condition.

Existing Condition:

- Slow moving, large volume of water with reduced diurnal temperature variation relative to upstream and downstream. Lower daily maximum and higher daily minimum temperatures.
- No current riparian shading, and not likely to improve due to large channel widths.
- From a temperature standpoint, the larger pits (#5 and #7) which remain connected to the mainstem during summer do not appear to degrade its temperature. Other negative factors such as habitat for predators must also be considered.

Alternatives #2 and #3, relative to Existing:

- Based on modeling, water temperatures for both Alternatives will likely exhibit the larger diurnal temperature variations currently seen upstream and downstream of the Pits reach. Thus, daily peak temperatures will be higher, and daily minimum temperatures will be lower, relative to the Existing condition.
- Overall water temperature may be reduced relative to the Existing Condition due to an anticipated rise in the groundwater table from proposed grading.
- Extensive riparian planting along channels that are considerably narrower than the Existing Condition should provide extensive shading and reduce solar heating of the reach during the day, potentially reducing diurnal temperature variation.

Alternative #2 versus #3

- Model results indicate slight improvement in temperature performance for the hybrid three-channel network in Alternative 3 versus the single channel in Alternative 2. Despite the greater water depth and smaller width-to-depth ratio exhibited by Alternative 2, the corresponding reduction in heating is offset by a greater overnight cooling effect seen in the shallower, smaller Alternative 3 channels.
- Temperature performance in Alternative 3 was seen to be further enhanced by simulated groundwater inputs, which persist longer and have more influence in the shallower, lower volume multi-thread channels relative to the single channel.
- Due to time constraints, channels for the Alternative 3 design were not optimized for low flow. Further iterations of low-flow geometry may be possible to further enhance its temperature performance.

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F. Restoration Alternatives Analysis- Memorandum

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MEMORANDUM

To: Technical Oversight Group Members

CC: Jeff Breckel; Amelia Johnston, LCFRB

From: Technical Team: Paul Kolp and Keith Marcoe, Lower Columbia Estuary Partnership & Gardner Johnston, Inter-Fluve

Subject: Ridgefield Pits Restoration Project

Date: July 8, 2020

Overview

This memo summarizes efforts completed to date by the Technical Oversight Group (TOG), including the Technical Team, for the Ridgefield Pits Restoration Design project (project ID #17-1070). The TOG was formed in 2018 to provide guidance for the Ridgefield Pits project. With over 20 stakeholders from state, federal, county, Native American Tribes conservation, private citizen, regional fisheries, and non-profit entities that are interested in restoring and preserving the East Fork Lewis River (EFLR), the TOG constitutes an extensive source of knowledge and expertise that the Technical Team has been able to draw on to inform this project. The Technical Team is comprised of staff from the Lower Columbia Estuary Partnership (LCEP) and Inter-Fluve, Inc. The skills represented by the Technical Team include river engineering, GIS mapping, hydrology and hydraulics, numerical modeling, ecology and geomorphology. The memo documents findings from a series of TOG meetings, analysis by the technical team and development of draft Restoration Goals and Design Alternatives.

Between June 2018 and January 2020, a series of five TOG meetings were held. The initial four meetings focused largely on physical and biological elements of the EFLR and specifically the Ridgefield and Daybreak project reaches, while also capturing important land use and human considerations. The Ridgefield Pits reach (Appendix A) includes the eight pits (Appendix B) as well as the mainstem EFLR, beaver ponds and adjacent alcoves and is located at River Mile 8. The Daybreak reach includes two project sites: Mill Creek confluence with EFLR (located at River Mile 9.5) and two upstream side-channels (located at River Mile 9- Appendix A).

During the fifth meeting, the Technical Team summarized prior meeting results and presented a series of example restoration goals and actions intended to initiate a discussion of restoration options with the TOG. The Technical Team believes that one of the most critical components of the project is developing consensus with the TOG on the restoration goals for the two project

reaches. During and after the meeting, TOG members provided recommendations to the Technical Team on refining the example goals and objectives into a series of draft restoration goals and alternatives.

These draft goals and objectives are presented herein, along with the summary of conditions and the individual TOG recommendations. Example goals and actions initially presented by the Technical Team at the fifth TOG meeting can be found at

[http://s458607291.onlinehome.us/FTP/RidgefieldPits Working Group/meetings/Ridgefield%20Pits%20TOG Example%20Goals %20Actions Targets%20.pdf](http://s458607291.onlinehome.us/FTP/RidgefieldPits%20Working%20Group/meetings/Ridgefield%20Pits%20TOG%20Example%20Goals%20Actions%20Targets%20.pdf)

The following visuals are included as Appendices to aid in reading this memo:

- Project area map including the Ridgefield Pits and Lower Daybreak reaches of the EFLR (Appendix A)
- Aerial photo of the Ridgefield Pits with individual Pit IDs (Appendix B)
- Table of draft restoration Goals and Actions (Appendix C)
- References (Appendix D)

Next Steps

At this time the technical team is requesting feedback from the TOG that will help us refine the draft alternatives presented here into a final set of alternatives that will best address the goals and objectives. Concurrently, the technical team is evaluating the draft alternatives and will incorporate TOG feedback into this analysis, which includes the following components:

- Spreadsheet & hydrodynamic modeling to evaluate hydraulics, sediment transport, channel stability and temperature.
- Comparison of model results to empirical data to further validate model predictions.
- Uncertainty and risk analysis

Upon completion the technical team will review results of the alternatives analysis with the TOG and together select a preferred design alternative for each project sites and project reach. Preliminary design drawings will then be developed for the selected alternatives.

Historical & Current Conditions- Ridgefield and Daybreak Project Reaches

Establishing meaningful restoration goals and objectives requires a critical understanding of how a project site has evolved over time and the forces and events that have shaped it. To develop this understanding of the Ridgefield Pits project area, the technical team reviewed existing literature and data, independently and with the TOG, and convened a series of discussions with the TOG which provided additional insight. Input from TOG members, and numerous existing studies and data sources, provided the basis for describing historical and current conditions. The following sections summarize the primary conditions of the project area in its historical and current state, and how these conditions have evolved and continue to evolve. The ramifications of these changes for how the project site currently supports, and may continue to support, multiple life stages of native salmon and steelhead sets the foundation for

the restoration goals, objectives and alternatives. Findings for the geomorphic conditions that resulted from this effort have been documented in the Geomorphology Report (LCEP 2020), currently available at:

http://s458607291.onlinehome.us/FTP/RidgefieldPits_Working_Group/meetings/EFLR%20Ridgefield%20Geomorph%20Report%20012720.pdf

For our analysis we consider ‘historical’ conditions to be the relatively pristine state of the river that existed prior to extensive development due to European settlement. In fact, the EFLR, including the project site, has been evolving constantly both naturally and due to human activity, and this continuum must be considered when analyzing changes over time. In the following sections we summarize how the river has changed from the time of the earliest data sources that describe it to its current condition, and how it is continuing to change presently.

Historical Conditions

To assess the earliest known condition of the project area and changes that occurred over the next several decades we relied on cadastral survey plots completed by the General Land Office (now part of BLM) in the 1850’s, aerial photos dating back to the 1930’s, Washington Department of Fish & Wildlife (WDFW) spawning survey data, geologic and topographic data, historical records from existing reports, and other anecdotal information. The following list summarizes the condition of the river in the project reach, dating back to the early data sources:

- Extensive spawning and rearing occurred for multiple salmonid species, including Chinook, steelhead and coho, with some records indicating it was also important for chum (personal communication with WDFW and Lower Columbia Fish Recovery Board). The vitality of these focal species to the East Fork Lewis ecosystem, and their precipitous decline over the last century leading to current threatened and endangered status, is well documented, including in the Lower Columbia Fish Recovery Board’s (LCFRB) 2010 Lower Columbia Salmon and Steelhead Recovery Sub Basin Plan. The plan estimates that historical populations of Chinook, coho and steelhead for the East Fork Lewis River subbasin ranged from 1,000 to 40,000 fish depending on species, and historical populations of chum ranged from 100,000 to 320,000 fish, for the combined Lewis and East Fork Lewis subbasins. Washington Department of Fish & Wildlife spawning survey data show use of the entire project reach by all these species from the 1940’s through the 2010’s, highlighting its importance.
- The Ridgefield Pits (and Daybreak Pits) reach was a depositional zone with an anabranching (multi-thread) planform, multiple side-channels and oxbows, and an abundant supply of gravels and wood.
- The channel migration zone (CMZ) encompassed both the current day Ridgefield and Daybreak Pits, over a wide floodplain area of approximately 1,300 acres (sum of acres within EDT Reaches 6A-8A called out in the Recovery Plan, which overlap with the project area), stretching up to 1 mile across the valley floor at its widest.

- The large wood in the channel, and large and robust riparian and floodplain vegetation, likely resulted in relative stability of the channel during regularly recurring floods (i.e. annual to 5-year event).
- Channel adjustments, via scrolling and avulsions, likely occurred during the larger, less common events (> Q5 flood event). These events likely created a complex mosaic of highly productive instream and floodplain aquatic habitats.
- High complexity and a highly connected floodplain and water table likely led to a diversity of habitat types and areas of groundwater intrusion that provided several cold-water inputs.
- Significant changes in land use, including agricultural development and river confinement, were already occurring as early as the 1930's.

Current Conditions

In addition to some of the same sources used to assess historical conditions, numerous existing reports and data sources (Appendix D) provided background for describing present day conditions of the project area. Many of these have been produced in response to environmental degradation, development, and species decline that have occurred within the project reach and throughout the EFLR. The Estuary Partnership and Inter-Fluve also conducted site investigations (from 2017-2019) as part of this project to fill existing data gaps. These included snorkel surveys, water temperature and stage monitoring, sediment sampling, and topographic and bathymetric surveys. Site investigations inform subsequent mapping and analysis, including: juvenile fish distribution, hydraulic, sediment transport and temperature modeling and the geomorphic analysis and report. The following list summarizes the present-day condition of the river, that has resulted from natural and human-derived activity over the past several decades:

- Spawning is occurring for multiple species, but the amount of spawning habitat has been greatly reduced in the Ridgefield Pits area. According to the 2009 Lower East Fork Lewis River Habitat Restoration Plan (LCFRB), “approximately 3,200 feet of lineal riffle habitat was eliminated as a result of the Ridgefield Pits avulsion, and over 50% of off-channel habitat and wetlands in the historical lower river floodplain are no longer accessible to spawning fish as a result of hydromodifications”. WDFW no longer samples in this area for adults due to lack of suitable spawning habitat (a summary of spawning surveys conducted by WDFW can be found here- http://s458607291.onlinehome.us/FTP/Ridgefield%20Pits_Working_Group/Fish/).
- Cold-water inputs from groundwater still exist throughout the project area. Cold water was found in and around: Ridgefield Pits 1,2,8 and 9; the upper side channel at RM 9.0; and within some floodplain beaver ponds. Recorded water temperatures in these areas were 2–7 degrees colder than the mainstem during summer months.
- Our observations suggest that juvenile fish continue to use the Ridgefield Pits area throughout the summer. These findings suggest much greater usage by juvenile salmon

and steelhead than was documented in the aquatic study of the Ridgefield Pits and East Fork Lewis River (CM-10, R2 Consultants 2013). Our surveys also confirm findings from the 2013 report that there are a large number of predatory fish in the area.

- Despite summertime mainstem temperatures that commonly exceed recommended and lethal temperatures for salmon and steelhead (18 and 24 C°, Ecology), snorkel surveys conducted by the Estuary Partnership (2018) in June (see Meeting #2 presentation on juvenile fish use- http://s458607291.onlinehome.us/FTP/Ridgefield%20Pits_Working_Group/meetings/TOG%202-presentation.pdf) and August (when mainstem water temp's exceeded 24 C°) showed juveniles present. In summer months fish were found around cold water seeps, around habitat structure, riffles and cut banks.
- According to the 2009 Lower East Fork Lewis River Habitat Restoration Plan (LCFRB 2009), temperatures in the mainstem commonly exceed the 64°F (18°C) State standard, and occasionally exceed 73.4°F (23°C) in the project reach, which is above the 22°C level considered lethal to rearing salmon and trout. Additional data collected from 2010-2020 suggests that temperatures exceed the water quality standard regularly during summer months (Estuary Partnership, Fish First and WDFW). Estuary Partnership data collected in 2018 showed average daily maximum temperatures ranging from 21–25 °C throughout the mainstem and Ridgefield Pits, with instantaneous values reaching as high as 28°C, from mid-July through mid-September.
- Mill Creek is an important source of cold water, particularly now that summertime temperatures in the mainstem are regularly exceeding TMDL limits. Data collected in 2018 by the Estuary Partnership at the confluence of Mill Creek showed average daily maximum temperatures ranging from 13–15 °C from mid-July through mid-September.
- The historical anabranching channel planform has evolved into a single, confined channel throughout most of the Ridgefield Pits reach, with occasional side channels and very limited floodplain connectivity.
- The channel migration zone below Daybreak Bridge, and through the Ridgefield Pits reach, is confined to a much narrower floodplain area relative to the historical condition. The overall area has declined by approximately 1,300 acres to approximately 660 acres, roughly a 50% decline for EDT reaches 6A–8A (LCFRB, Chapter 4: East Fork Lewis River basin- Habitat Assessment 2005). The reduction in the channel migration zone is largely, but not entirely, due to exclusion from the active Daybreak Pits gravel mining operation.
- Avulsion of the channel into formerly active gravel pits (including the Ridgefield Pits and Mile 9 Pit) created immediate and persistent changes including: relocating the river, interrupting gravel transport, slowing channel velocities, changing channel geometry including depth to width ratios and upstream changes to the longitudinal profile.
- Reduced vegetation presence and reduced hydraulic roughness (i.e. large wood debris) have reduced overall habitat complexity and quantity.

- EFLR flows have potentially become more 'flashy' due to more impervious surfaces, increased development, land use practices and water use which resulted in greater surface water runoff rates and volumes.
- Combined changes in flow patterns and reduced vegetation and hydraulic roughness have likely led to more frequent channel forming events (~annual occurrence) relative to the historic condition (~5-year occurrence or longer). This has potentially contributed to local habitat complexity but may also be causing redd scour and egg burial issues.
- Invasive species introduction, warmer water, and native species habitat degradation has likely increased the abundance of predatory warm water species.
- Sediment has accumulated at the Mill Creek confluence, possibly limiting fish access to cold water refuge in the summer. This may be a result of EFLR flow dynamics and/or upstream land-use practices that have occurred in the headwaters of Mill Creek.
- The future of current mining activity in the Daybreak Pits (adjacent to the Ridgefield Pits), including timelines for termination and transfer of ownership, is unknown.
- It is uncertain whether lands within the Ridgefield Pits that are currently held in private ownership will remain private or be transferred to public holdings. This may potentially impact the scope of possible restoration activity.

The 1996 avulsion of the EFLR into the abandoned Ridgefield Pits, which was mined as early as the 1960's for aggregate, has had substantial negative impacts on aquatic conditions and physical processes. Findings from this project related to biological and physical conditions are summarized below. Some of our findings are consistent with prior studies; however, others are markedly different, in particular the rates of sediment infill for the Ridgefield Pits. Notably, some of these observed differences (that we estimated) are likely due to more recent and improved data resolution.

- Avulsion into the Mile 9 Pit in 1995 resulted in a channel alignment that is causing significant erosion of the bluff along the south bank at this location, threatening private property.
- Upstream migration of the head-cut that developed in response to the 1996 Ridgefield Pits avulsion (described by Norman et al. 1998, and multiple WEST reports) appears to have ceased and the river profile has largely stabilized throughout the project area upstream of the pits, according to our 2019 updated bathymetric profiles.
- Active channel dynamics upstream of Daybreak Bridge (and upstream of the project area) are within the range of historical conditions and do not appear to pose a significant risk to downstream project work (LCEP 2020). It has been noted in TOG discussions however that risk of avulsion in this reach is present, and sediment transport processes have been impaired.
- Trapping of sediment in the Ridgefield Pits has likely reduced sediment transport to downstream reaches, including the transport of spawning gravels. Spawning is known to occur downstream of the pits for several miles.

- Ridgefield Pits 1 and 2 have experienced significant sediment infilling and wood accumulation, much of which occurred within 10 years of the 1996 avulsion. This has resulted in improved habitat diversity, fish use, groundwater intrusion, and channel processes in this area.
- Despite the significant infilling of Ridgefield Pits 1 and 2 that has occurred, our analysis of infilling rates since the 1996 avulsion indicates that overall infilling of the Ridgefield Pits will likely not occur for at least another 50–60 years (2070, minimum). This is considerably slower than prior estimates by WEST and others, which predicted recovery by approximately 2026. Our analysis shows a substantial slowdown in overall filling subsequent to the decade following the avulsion (LCEP 2020). As a result, mainstem habitat below Pits 1 and 2 has remained in a very low-quality state since 1996, characterized by deep, warm pools, slow flow and abundant predatory fish (Estuary Partnership snorkel survey, 2018).
- Ridgefield Pits 8 and 9, which are located off the mainstem EFLR, are subject to groundwater inflows and thus may be providing some thermal refuge for juvenile salmon during summer months. Pit 9 is likely to only be accessible to fish during higher (flood) flows.

Review of Example Restoration Goals and Objectives – TOG Meeting 5, January 2020

Prior to the January 2020 meeting, a document titled *Goals and Actions* was sent by the Technical Team to the TOG. The document was intended to provide a framework for discussion of restoration options for the Ridgefield Pits project area with the TOG. It lists a series of example goals and restoration actions for the project area within 5 categories: Channel Forming and Related Sediment Processes; Floodplain Connectivity; Vegetation; Biology; and Human Elements. The *Goals and Actions* document can be found at [http://s458607291.onlinehome.us/FTP/RidgefieldPits Working Group/meetings/Ridgefield%20Pits%20TOG Example%20Goals %20Actions Targets%20.pdf](http://s458607291.onlinehome.us/FTP/RidgefieldPits%20Working%20Group/meetings/Ridgefield%20Pits%20TOG%20Example%20Goals%20Actions%20Targets%20.pdf).

After review and discussion of the document, the TOG was asked to provide feedback to the Technical Team on the example goals and actions, which the Technical Team could then use as a basis for formulating a draft set of goals and restoration alternatives. The TOG provided feedback at the end of the meeting and during weeks after, as a series of written and verbal comments. These comments are included below, by category, and have been consolidated where duplicates occurred:

Comments on Restoration Goals

Channel Forming and Related Sediment Processes

- Restore a complex, multi-thread channel network that includes greater channel planform complexity.
- Reestablish natural rates of channel adjustment including the appropriate sediment transport processes and allowing the river to rebuild itself.

- Address upstream sources of sediment, prevent entrainment & improve sediment transport processes through the site and downstream of the project.
- Sediment management should be the #1 priority.
- Create more pools in the project area.

Floodplain Connectivity (lateral and vertical)

- Define the floodway, floodplain and CMZ and then let the river be chaotic within that total area.
- Look at returning the river to the historic CMZ including Daybreak Pits and remove human infrastructure.
- Encourage greater interaction with the historic channel migration zone and remove human barriers to channel migration wherever possible, while maintaining or creating protection of property and infrastructure where needed.

Vegetation

- Include robust riparian area w/ beavers.

Biology

- Attempts to ameliorate summer high temps by tapping into the Daybreak pits or engineering this kind of approach in other areas does not sound sustainable or maintainable. The focus of thermal efforts should remain on process driven approaches and action.
- Identifying and reconnecting cold-water areas should be the #1 priority. Addressing the temperature impairment should be in the top two priorities.
- Maximize side-channel cool water areas and address river warming.
- Map thermal refuge areas/subsurface temperatures to help plan actions that encourage thermal regulation.
- Incorporate cooler water into habitat creation.
- Target locations outside that project area, including where water is being impounded and warm water is being discharged to the East Fork. Coordinate with other agencies to determine ways to reduce impoundments and warm water inputs.
- Restore the full range of habitat types historically present in the reach, at historic ratios.
- Develop the proper mix of habitat features (rocks, riffles, runs).
- Increase extent & quality of thermal refuge without compromising existing refuges.
- Create ways to scour out Mill Creek confluence area with the East Fork to preserve the cold water pool and create more and higher quality cool water rearing opportunities.

Human Elements

- Consider river recreation in all project design concepts.
- Investigate the feasibility of expanding future restoration actions into the Daybreak Pits area.
- Can we acquire the necessary property to allow the river to migrate how it used to?
- Enforce and refer to the Shoreline Management Act- Shoreline Plan and Growth Management Act.

Comments on Restoration Actions

TOG member comments related to potential actions were also divided into the same five categories used above.

Channel Forming and Related Sediment Processes

- Encourage greater stability in some areas and create more dynamic channel in other areas by adding habitat and engineering features.
- Move the channel back to its pre-avulsion alignment.
- Move channel back to where it was located before the avulsion.
- Fill in select pits that are thermal barriers and leave others where there is cooler water to serve as alcoves or oxbows.
- Mill Creek upper portions are problematic due to increases sediment delivery and need to be addressed including restoring ditched portions of Mill Cr. between the EFLR and SR 502.

Floodplain Connectivity (lateral and vertical)

- Reset Pits floodplain and channel to increase rate of stabilization without trying to train the river including using Stage 0/Stage 8 approaches.
- Pipe the cooler water from select pits into the restored channel.
- Grade the floodplain on river left, filling select pits while also creating side-channels, oxbows and off-channel areas.
- Use onsite material to begin to fill pits. We don't have enough material to fill all pits- prioritize warm water Pits.
- Remove levees, riprap, and other hydromodifications impeding natural rates of lateral channel adjustment.

Vegetation

- See what recovers naturally before planting.
- Create a fully functioning riparian buffer zone.

Biology

- Reduce/remove levees and other raised features. Build an extensive network of ELJ anchored, alluvium based, vegetated islands throughout the river and floodplain that cause the river to be split into multiple channels.
- Install habitat features including historic wood loading.
- Deliver LWM to channels to meet LWM volume targets based upon natural wood loading levels.
- Introduce structures to provide habitat and natural channel functions.
- Create a complex channel and allow the cooler water to find its own path.
- Create complex channels with multiple side-channel and oxbows.
- Leave Pits 8 & 9, and other places where there is cooler water, and open it to riverine processes and fill Pits where there is warmer water.

Human Elements

- Need sideboards to guide our ability to realize what we can afford and have the actual capability to pull off.

Draft Restoration Goals

Based on comments from TOG members the Technical Team developed six restoration goals for the project area. The first two goals listed below received the most comments compared to the other goals. The intent of the goals is to capture important physical, biological and social dimensions critical to advancing restoration efforts at the project sites. The goals also serve as the foundation for the development of the restoration alternatives.

Goal 1. Restore native vegetation communities: Restore a patchwork mosaic of age classes and native species that dominate riparian and floodplain areas, with vegetation supported by channel migration processes and high seasonal water table. Restoring native vegetation should ultimately contribute to the recruitment and retention of large wood and sediment, reduce erosion and mobilization of fine sediment, and reduce thermal loading to help improve water temperatures.

Objectives

- 1a. Promote conditions where channels are well-connected to the floodplain and CMZ and are able to self-initiate and self-maintain riparian vegetation through channel scrolling processes and overbank deposition of fines. Decrease the depth to the alluvial aquifer.
- 1b. Promote a patchwork mosaic of native vegetation communities with a range of age classes consisting of older coniferous forests, cottonwood galleries, willow-dominated shrub communities, and sedges and rushes.
- 1c. Encourage vegetative growth along stream channels, with persistent vegetation abutting the primary channel and side channels that provides hydraulic roughness, natural stability, shade, and habitat complexity.

Goal 2. Enhance thermal refuge and incorporate cold water areas into restoration efforts:

Protect and enhance existing cold-water areas in order to decrease thermal loading to the mainstem and provide thermal refuge to benefit pre-spawn holding and spawning for coho, Chinook, steelhead and chum and summer juvenile rearing habitat for coho, Chinook and steelhead.

Objectives

- 2a. Protect, enhance, and expand access to existing known cold-water refugia including at tributary confluences (e.g. Mill and Manley), in north-side side-channels, and in Pits 8 and 9 of the Ridgefield Pits.
- 2b. Achieve a low flow channel width-to-depth ratio that is below 15 and ideally below 12.
- 2c. Increase canopy closure from vegetation to greater than 50%.
- 2d. Increase juvenile salmonid over-summer thermal refugia by creating head gradients that result in strong hyporheic exchange flows – i.e. highly sinuous meanders that create strong gradients across gravel bars where hyporheic flow contributes to backbar alcoves; occasional valley wall contacts with alcoves fed by wall-based channels; and offset riffles around islands.

Goal 3. Increase the quality and quantity of Chinook, chum, steelhead and coho spawning and rearing habitat: Create habitat conditions that are consistent with the geomorphic setting. Restore a complex, multi-thread channel network that includes greater channel planform complexity, deep pools with instream cover, riffles for macroinvertebrate production, and pool tail-outs with abundant spawning gravel. Increase floodplain habitat availability and complexity in the form of abandoned oxbows, floodplain wetlands, secondary and side-channel connectivity, and beaver dam complexes that are accessible to fish at a range of flows.

Objectives

- 3a. Achieve a moderate-to-high channel sinuosity (>1.3) to increase planform complexity.
- 3b. Achieve a pool (and riffle) frequency greater than 10 pools per mile in the main channel, co-dominant channels, and active side-channels.
- 3c. Increase large wood quantities to exceed the Fox and Bolton (2007) 75th percentile quantities of wood and key pieces that would be expected under undisturbed conditions. A range of wood size classes should be present, with abundant large pieces exceeding the NOAA 'properly functioning condition' threshold of 80 pieces/mi for wood over 24 inches diameter and 50 feet in length. Wood placements to include individual pieces and jams to provide habitat complexity and to encourage structural formation of bars, pools, and other geomorphic features. Where suitable, jams should recruit mobile wood over time. Wood placements should also occur on floodplains, especially where vegetation is sparse or young, to emulate hydraulic roughness found in natural vegetated floodplains.
- 3d. Increase occurrence of co-dominant and secondary channels (i.e. side-channels) so that 2 to 5 perennial channels (including main channel) occur at any given valley-bottom cross-section.
- 3e. Achieve a low-flow channel margin length that is at least five times the corresponding valley-bottom length.
- 3f. Achieve the presence of zero velocity areas during seasonal high flows in order to provide for flood refuge by juvenile salmonids.
- 3g. Create abundant (>8 acres/mile of stream) connected off-channel wetlands and beaver dam complexes that are accessible to fish throughout the year.

Goal 4. Restore Channel Migration Zone and Floodplain Connectivity: Restore portions of the historical channel migration zone and restore natural rates of floodplain inundation, where possible, by 1) removing hydromodifications; and 2) achieving channel and floodplain geometry and elevation that encourage frequent overbank flows and natural rates of channel adjustment. Investigate the feasibility of expanding future restoration actions into the Daybreak Pits area.

Objectives

- 4a. Expand Channel Migration Zone and floodplain inundation extent by removing (or setting back) levees, riprap, fill, and other hydromodifications impeding channel adjustment or flood inundation to the extent possible given private property and infrastructure constraints.

- 4b. Achieve an active valley width (i.e. extent of intact CMZ and floodplain) that is at least 6 times the active channel width.
- 4c. Achieve overbank flows and significant floodplain inundation that occurs annually for at least 1 month of the year, on average. Five-year flood should create very large inundation.

Goal 5. Create a dynamic channel that allows for natural rates of channel adjustment and sediment transport: Allow for natural rates of channel adjustment in concert with sediment supply and hydrology regime. Maintain depositional conditions, especially within the pits to promote sediment capture and to re-build the grade lost to avulsion, and to restore sediment transport processes into and through the area.

Objectives

- 5a. Achieve slope and channel geometry conditions that are depositional, especially in the Ridgefield Pits segment where net deposition is needed to help build grade lost to gravel mining, but also in other segments that exhibit incision.
- 5b. Achieve bank erosion at meander bends that occurs at a natural rate. Minor erosion may occur every year (<5 feet), with larger adjustments at the 2- to 5-year event (e.g. scrolling) and more dramatic changes (e.g. chute and neck cut-off avulsions) occurring during large floods (>10-year event).
- 5c. Achieve a streambed that is composed of a mix of sediment sizes, with channel bed dominated (>70%) by coarse gravel and cobble and floodplains eventually topped with fine sand and silt. Increase substrate patchiness. Decrease fines to less than 15% in potential spawning areas.

Goal 6. Develop restoration approaches and actions that are consistent with existing land use: Avoid any increase of flood or erosion risk to public or private infrastructure. Take into consideration the potential for a future avulsion of the EFLR into the Daybreak Pits. Consider the implications of designs for recreation users along the river.

Objectives

- 6a. Do not increase flood damage risk to public or private property or infrastructure unless landowner agreement is obtained.
- 6b. Decrease, or at minimum avoid increase of, potential avulsion of the EFLR into the Daybreak Pits.
- 6c. Design actions that adequately address potential risks to river recreational users.

Draft Restoration Alternatives

To address the goals, baseline findings, and comments summarized above, a range of restoration enhancement alternatives were identified. In conjunction with the geomorphic assessment, restoration alternatives were divided into two reaches (Appendix A) including the Lower Daybreak reach [RM 10.2 (most upstream Asterix) to RM 8.0 (middle Asterix)], which includes the side-channels and Mill Creek, and the Ridgefield Pits reach [RM 8.0 (middle Asterix) to RM 7.1 lower Asterix)]. The Draft Restoration alternatives are also summarized in a table (Appendix C).

Ridgefield Pits Reach

1. No Action/Passive Recovery of Pits

Description- This alternative would allow the river to continue to recover without any outside intervention.

Benefits, Limitations & Level of Effort- The benefit of this approach is to allow the river to restore itself without expending capital to try and restore a complex site. Some of the habitat in the areas around Pits 1 and 2, and upstream around RM 8 (where wood and sediment have accumulated) are already showing signs of recovery. Juvenile coho, chinook and steelhead were found to be using these areas during the summer of 2018 (Estuary Partnership). Several adults were also seen in the area. There are several limitations to the 'no action' approach, however. The primary limitation is that current estimates of the pits recovering to pre-avulsion physical conditions are on the order of 50- 60 (or greater) years. Passive recovery will continue to have negative effects on juvenile and adult salmon and steelhead during this recovery period. In the Pits Reach spawning has almost completely disappeared and overall habitat conditions for juveniles and adults have been substantially impacted. The Pits area also presents a bottleneck to salmonids that migrate through the Reach. There are large amounts of predatory fish that key into deeper areas along the mainstem and several of the pits. The depths exceed 10 ft. in these areas, with lower velocities and warmer temperatures that are conducive to predatory fish. Warmer water in several of the pits also increases thermal loading to the EFLR and impacts native aquatic species. The overall level of effort for the passive recovery alternative is anticipated to be low.

Proposed Actions- No action.

2. Relocate Main Channel Back Into/near Pre-1996 Avulsion Channel

Description- This scenario would use channel grading and log jams to relocate the main channel into its former, pool-riffle type, pre-1996 avulsion, channel alignment. LWD supplementation efforts would be focused on increasing LWD density to a level that is typical for an undisturbed stream of this size and climatic region.

Benefits, Limitations & Level of Effort- This effort would likely immediately improve habitat conditions. This alternative would reconnect more than 3,000 ft. of mainstem habitat that was known to be productive in the past. The location of the channel would also potentially benefit from cooler groundwater inputs from the Daybreak Pits. LWD would facilitate gravel trapping, provide hydraulic refuge, cover from predation and a source of detrital material. This would improve spawning and rearing habitat for Chinook, coho, steelhead, and possibly chum, in an area that was known to provide high productivity. Some connected off-channel habitat could be provided in former pit areas.

This alternative proposes to relocate the channel into its pre-avulsion location; however, this is not necessarily its historical location, which we know from the 1854-5 maps had a much wider CMZ and a multi-thread channel network. To return the channel to its pre-avulsion single-thread channel location, significant fortification would have to occur

along the streambanks to the south (river left- looking downstream) to reduce the risk of avulsion back into the pits. This action would further narrow the CMZ and limit floodplain connectivity and would reduce the gradual filling of the pits by stream-mobilized sediments.

The overall level of effort is anticipated to be moderate- high.

Proposed Actions

- Re-locate channel back into its pre-avulsion (e.g. pre-1996) location
- Create berm to reduce potential for river to avulse back into pits
- Remove invasive plants/plant natives to establish a 100 ft. riparian buffer
- Install large wood jams throughout the channel to promote pool formation and sediment retention.
- Increase pool frequency to meet the range of natural variability that would be expected under undisturbed conditions.

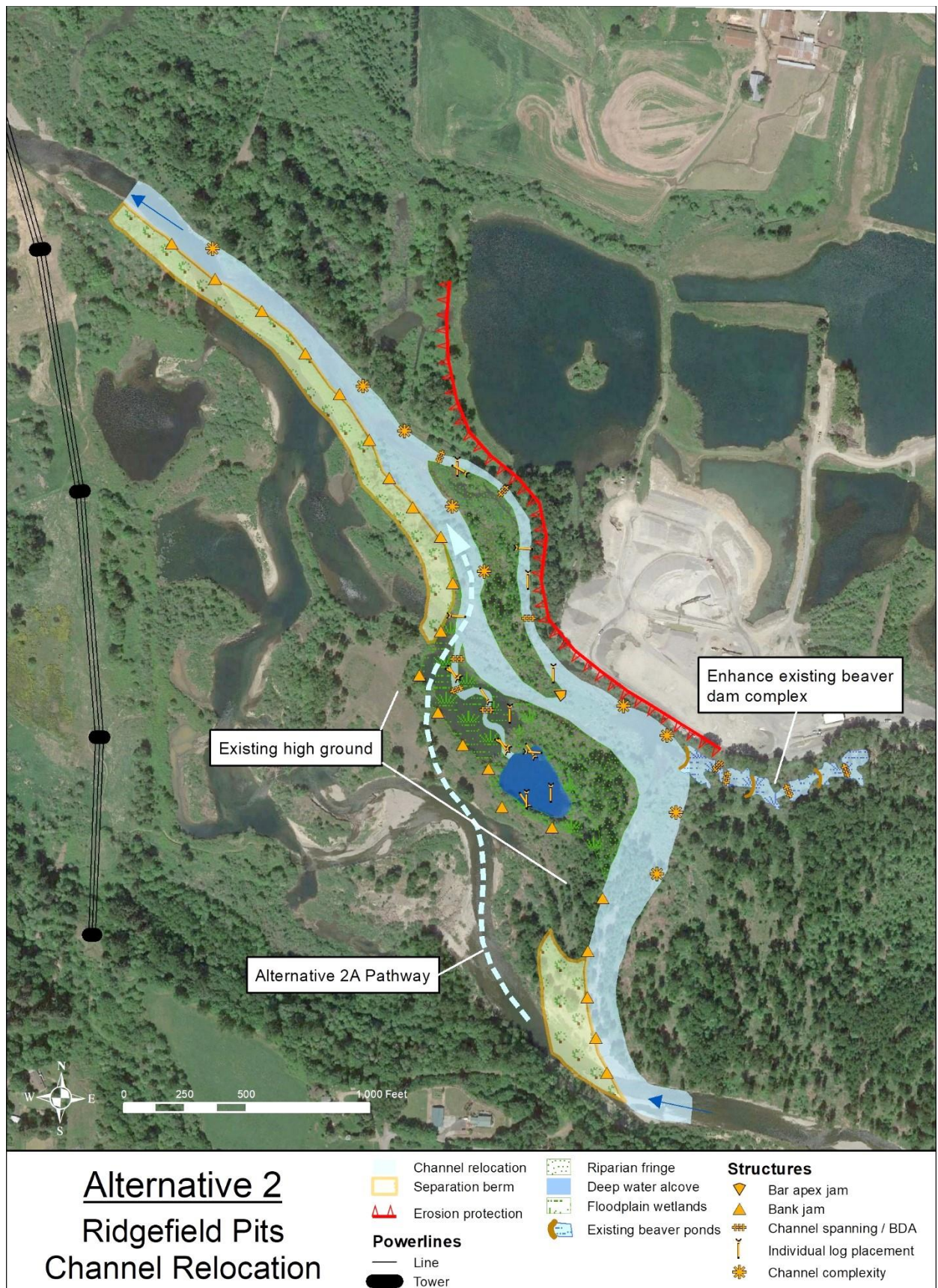


Figure 1. Ridgefield Pits Channel Relocation- Alternative 2 and 2A.

2A. (Sub-Alternative) Create New Flow Path between Pit 8 & EFLR

Description- This scenario would use select grading and log jams to remove land between the river and Pit 8 to relocate the river into a portion of its pre-avulsion flow path, rather than the complete pre-avulsion flow path proposed in Alternative 2. Habitat features, including LWD, would be installed as well as channel grading to create a self-sustaining channel that mimics pre-avulsion conditions including a pool-riffle channel geometry. LWD supplementation efforts would be to increase LWD density to a level similar to an undisturbed stream of this size and climatic region.

Benefits, Limitations & Level of Effort- This effort would likely improve habitat conditions immediately. LWD would facilitate gravel trapping, provide hydraulic refuge and provide habitat cover for juvenile and adult fish. This would also improve spawning and rearing habitat in an area that was known to provide high productivity. Juvenile fish would also have access to a series of beaver ponds that could provide important rearing and hydraulic refuge during higher flows. The area around the beaver ponds and portions of Pit 8 and 9 have cooler groundwater inputs from the Daybreak Pits. These areas would likely be used extensively by juvenile fish and could also offer refuge for fish migrating through the pits area.

This alternative has the same limitations as Alternative 2.

The overall level of effort is anticipated to be moderate.

Proposed Actions

- Remove high ground between the existing channel and Pit 8, re-locating the channel through Pit 8 and into the downstream portion of the pre-1996 avulsion channel location.
- Remove invasive plants/plant natives to establish a 100 ft. riparian buffer
- Install large wood jams throughout the channel to promote pool formation and sediment retention.
- Increase pool frequency to meet the range of natural variability that would be expected under undisturbed conditions.

3. Full Floodplain & Pits Re-Grade

Description- This scenario would include grading and filling to re-contour the pits reach into a multi-thread connected channel and floodplain wetland system. The elevation of the new channel/floodplain system would be lower than the pre-avulsion elevation given the amount of material removed by past mining.

Benefits, Limitations & Level of Effort- This alternative would restore a broad range of habitat mosaics that were likely found at this site historically, including beaver ponds, alcoves, shallow and deeper areas, wetlands and a multi-thread channel alignment. The multi-thread channel alignment would support channel geometry that would yield a wide range of velocity and depth conditions conducive to the species and different life histories that were historically found here. Coho and chum adults would have access to lower velocity areas and be able to key in on co-dominant channels where cold-water inputs or upwelling exists. Chinook and steelhead adults would be expected to utilize the dominant channels in areas with suitable gravels and higher velocities. Juvenile

salmon and steelhead would be able to utilize the site, particularly in areas with cold-water inputs, wood and deeper holes. This alternative would increase the width of the CMZ in this location to approximately 50% of its historical width, a 20% improvement over the approximate 30% of historical width that it currently occupies. Any changes in the channel alignment could result in subsequent changes after flooding events and the channel would not conform to a single thread layout.

Analysis is needed to determine the amount of fill and grading necessary to achieve meaningful habitat improvement, and to determine whether there is enough material available on or near the site. The lateral extent of grading will also need to be determined, including interface with the BPA powerline towers. Sediment transport modeling will be used to help understand the effects of this alternative on sediment transport and aggradation within the pits reach compared to other alternatives listed above including the No Action (existing conditions) alternative.

The overall level of effort is anticipated to be high.

Proposed Actions

- Create anabranching planform with 2-4 co-dominant channels active at low flows, many more channels active at flood flows and abundant oxbows/floodplain wetlands connected during annual high flows.
- Install LWD and habitat features similar to Alternative #2
- Create vegetation buffer similar to Alternative #2
- Support and encourage beaver activity in secondary flow channels and off-channel wetland complexes.
- Evaluate the need for reinforcing existing levee along the Storedahl Haul Road.

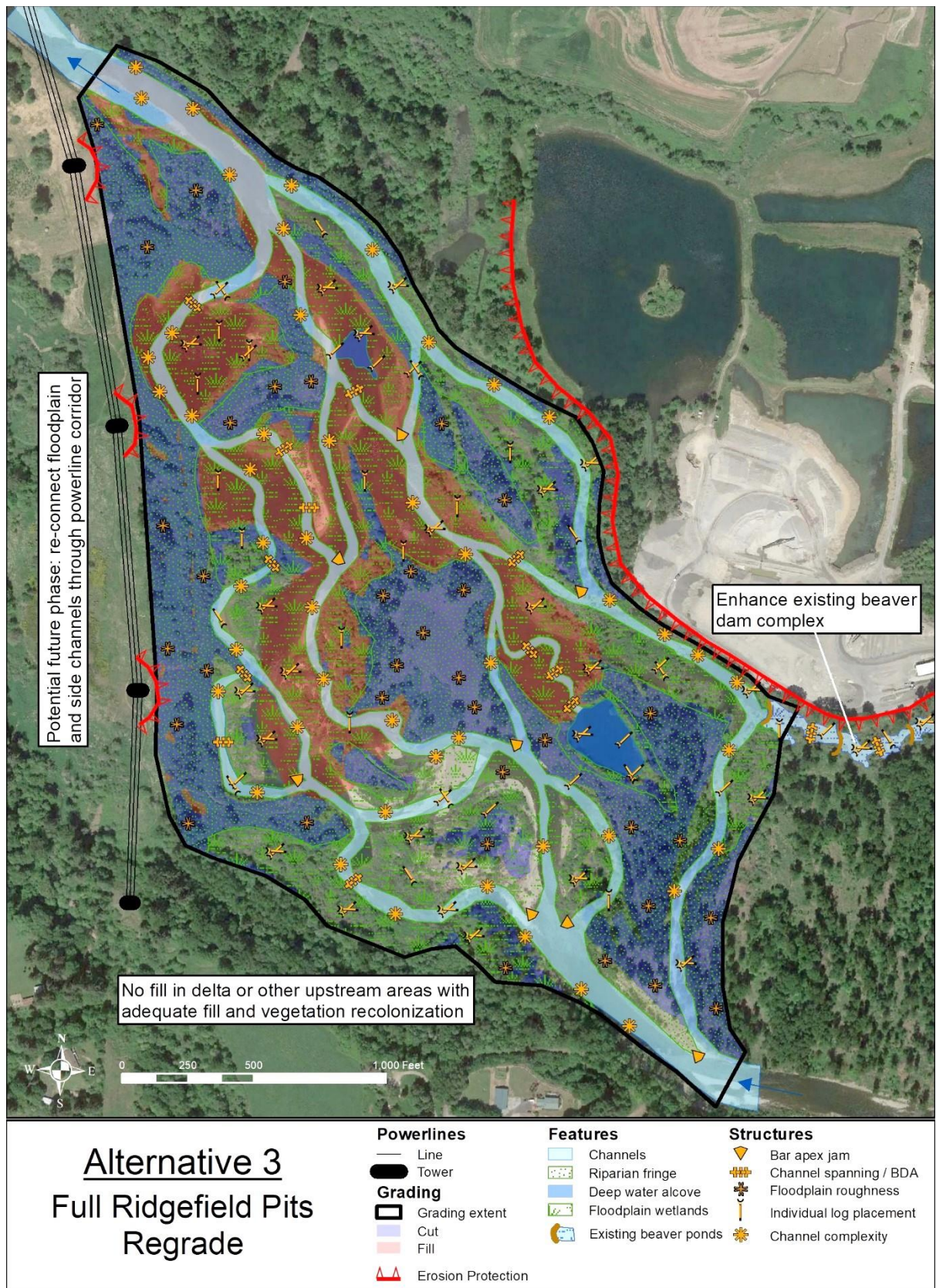


Figure 2. Full Pits Regrade- Alternative 3.

3A. (Sub-Alternative) Select Floodplain & Pits Regrade

Description- This scenario would follow Alternative #3 however pits that have cooler water including Pits 8 & 9 would be largely retained to allow for off-channel thermal refuge, particularly for fish. Grading would focus on river left and areas below Pits 8 & 9. Grading in Pits 8 & 9 could narrow pits substantially to allow for off-channel habitat while also moving towards a more natural river setting.

Benefits, Limitations & Level of Effort- Similar to Alternative #3.

The overall level of effort is anticipated to be high.

Proposed Actions- Similar to Alternative #3.

4. Side-Channel Re-Connections

Description- This scenario would include improving habitat and increasing flow in the two prominent right bank side-channel alignments in the Lower Daybreak reach. Work would include select excavation in the side-channel alignments and placement of new wood structures (or enhancement of existing ones) in the mainstem to help raise/divert water into the side-channels. Wood would also be added throughout both side-channels to improve habitat complexity. Additional analysis is needed to understand the amount of grading and log jam work that would be required to achieve perennial connectivity.

Benefits, Limitations & Level of Effort- This alternative would build on the existing sediment and wood accumulation area that has been occurring over the last 5–10 years along the mainstem and at the entrance to the lower side-channel. Existing wood and pool availability within the lower side-channel is almost non-existent. In the upper side-channel there is some good pool habitat (due to beaver activity) but almost no wood. Wood additions would provide habitat complexity, roughness, and a mechanism for gravel retention. Wood could also serve as valuable grade breaks reducing localized steeper slopes. By adding wood along the mainstem, this would help facilitate additional gravel recruitment, rebuild channel bed elevations, and divert more flow into the side-channels over a greater range of months and flow events. This will increase the available habitat and opportunities for both spawning and rearing fish in the mainstem and side-channels. Actions would be expected to benefit juvenile coho, Chinook, and steelhead; and adult (spawning) coho.

There are a few potential considerations with this alternative. The area around the connection to the mainstem at the entrance of the lower side-channel, and the mainstem bar/depositional area, is dynamic and the elevations have changed over the last 5-10 years. This could lead to some uncertainty in terms of determining elevations of the entrance invert to the lower side-channel and the potential for sediment accumulation.

The overall level of effort is anticipated to be moderate.

Proposed Actions

- Add wood at side channel confluences to enhance connectivity to the mainstem.
- Selectively grade side channel confluence areas to enhance the frequency and duration of hydrologic connectivity.

- Install large wood jams throughout the channels to promote pool formation and gravel retention.
- Increase pool frequency to meet NOAA requirements for properly functioning alluvial river.

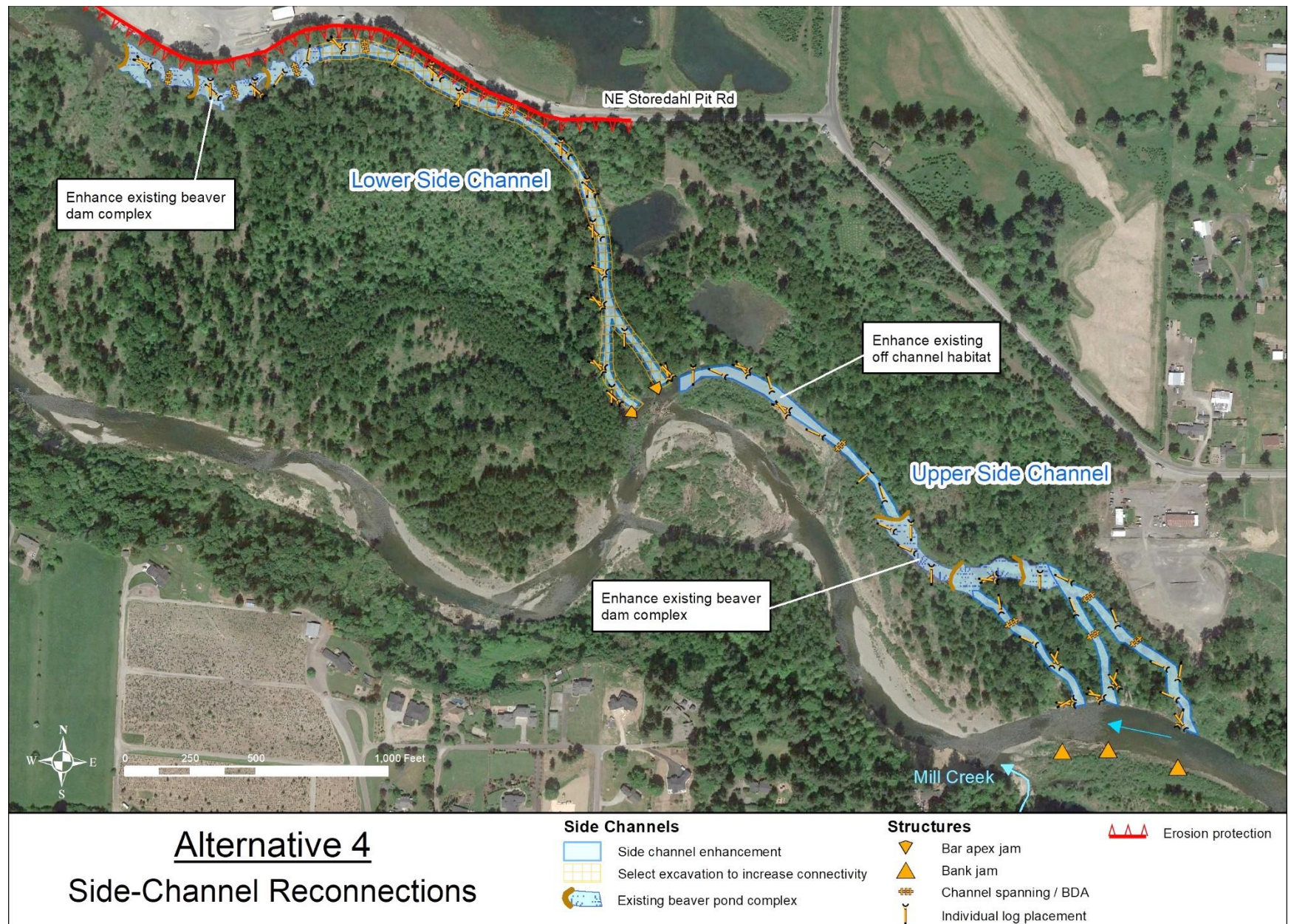


Figure 3. Side-Channel Enhancement- Alternative 4.

5. Mill and Manley Creek Confluence

Description- Efforts at this location would be focused on improving habitat complexity and creating a self-sustaining thermal refuge area, which is located in a backwater alcove and beaver dam complex that receives flow from Mill and Manley Creeks. This scenario would include increasing higher flows across the point bar and into the downstream end of the backwater alcove near the Mill Creek confluence. The intent would be to promote the periodic scour and evacuation of sediments that have accumulated to fill the pool and limit juvenile salmonid rearing habitat capacity. Direct excavation of sediments to provide an immediate boost in the available rearing space could also be performed. LWD structures would be installed in the mainstem to divert flow into the high flow channel at the confluence area. Select excavation may also be required to create greater flow across the bar. Enhancements would also be made to habitat complexity and passage in an existing beaver dam complex.

Benefits, Limitations & Level of Effort- The benefit would primarily be to preserve and enhance a well-documented thermal refuge area that is used heavily by juvenile salmon and steelhead. Over the last several years, sediment has filled in some of the area and has reduced the area available for thermal refuge. Direct excavation of these sediments would increase rearing area. To maintain the pool over time, high seasonal flows across the bar and into this area would be encouraged, and a large wood structure adjacent to the Mill Creek confluence would help maintain a scour pool. The channel would encourage flows to scour out deposited sediment, thereby maintaining sufficient depth and area of the thermal plume. This would be expected to benefit juvenile Chinook, coho and steelhead as well as provide refuge for adult fish moving upstream. Further upstream in the alcove, extending up to and beyond the Manley Creek confluence, there is a beaver dam complex that has been found to have a large number of fish present in the summer (snorkel survey LCEP 2018). Preliminary observations suggest there may be opportunities to would expand the beaver dam complex, add habitat cover, and, improve access to isolated ponds. These actions could benefit juveniles and provide them with an expanded area to hold over during the summer.

There are a few considerations and potential limitations with this alternative. This is a highly dynamic area, with changes every year that affect the position of the mainstem, sediment contributions from the tributaries, and the configuration of the backwater alcove and beaver dam complex. Recent mainstem scrolling patterns suggest that the river is likely to continue to migrate to the north and west away from the area. Over the next several years, this could lead to a natural expansion of the alcove and beaver dam complex that is fed by Mill and Manley Creeks, which could minimize the benefits of scouring out the filled pool at the Mill confluence. Based on input from the TAC, there is also reason to believe that the recent increases in deltaic sediment deposits at the mouth of Mill Creek may be due to changes in flows and associated erosion from activities in the upper Mill Creek watershed – this needs further investigation. There are also potential limitations to installing wood structures and increasing flows into the Mill and Manley confluence areas, including potential effects on the steep bluff between Mill and Manley Creeks and downstream of Mill Creek. Diverting flows from the mainstem could also reduce the rate of down-valley scrolling, which could be counterproductive

since the scrolling is likely to naturally expand the thermal refuge. There are multiple landowners in this area and a high degree of coordination would be needed.

The overall level of effort is anticipated to be moderate-high.

Proposed Actions

- Install large wood jams along the mainstem and upstream of the site to promote flow deflection.
- Perform select excavation in the high flow channel across the bar to encourage scouring flows at the Mill Creek confluence area.
- Install large wood structure adjacent to Mill Creek confluence to help maintain scour pool.
- Excavate Mill Creek deltaic deposits to expand cold water pool.
- Encouraging more mainstem flow into the Mill Creek confluence area would require an investigation of potential effects on bluff erosion and possibly the design of mitigation measures to protect property.
- Enhancement and expansion of rearing in the beaver dam complex.

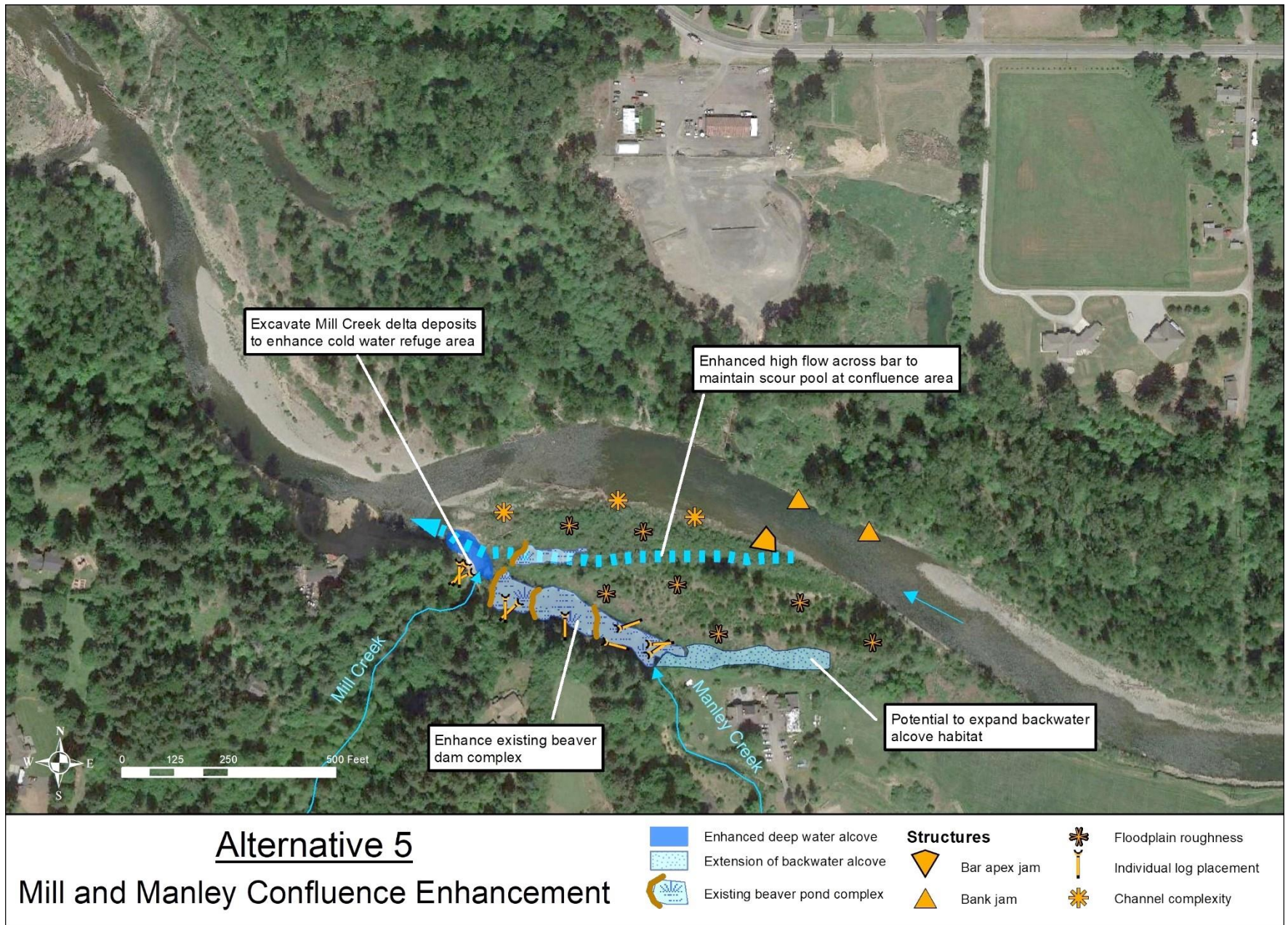


Figure 4. Mill-Manley Confluence - Alternative 5.

6. Mill and Manley Area CMZ Expansion

Description- This effort would work with the County to explore the potential for expanding the width of the CMZ in the north floodplain across from the Mill and Manley confluences. Currently, due to the County maintenance yard and related hydromodifications (i.e. levees and armor), this area has one of the narrowest CMZs in the lower river (see EF Lewis Habitat Assessment, Cramer Fish Sciences and LCFRB 2005). If the southern portion of the maintenance yard could be relocated, then the CMZ could be expanded by approximately 15 acres. Set-back protections in the form of bank armoring, and a levee if needed, could be provided for the maintenance offices, shop buildings, and other structures. This alternative would also include large wood placements on the bar and channel margin on the south side of the river near the Mill-Manley confluence area. Accumulated bedload at the Mill Creek confluence would be excavated to expand the existing alcove habitat area. Enhancements would be made to the existing beaver dam complex.

Benefits, Limitations & Level of Effort- The benefit would be to expand the CMZ in this area and to reduce channel confinement. The confinement would be reduced from an Active Valley Width to Active Channel Width ratio (ACV/ACW) of approximately 3.5 to 5 (~40% reduction in confinement). This would allow for the potential future formation of side-channels in this expanded CMZ as well as creation and fish access to future floodplain habitats including abandoned oxbows, floodplain wetlands, and beaver dam complexes. Wood placements on the river-left (south) bar and channel margin would allow for and encourage the continued down-valley scrolling of the mainstem. Assuming these trends continue, this would be expected to eventually move the mainstem away from the high and actively eroding cliff on the south bank. It would also serve to lengthen the backbar alcove fed by Mill and Manley Creeks, which would provide a natural expansion of an important cold-water refuge area for salmonids. Wood placements in the existing beaver dam complex, and potentially construction of BDAs, would enhance the complexity and expanse of the beaver dam complex that is fed by cool water from Manley Creek.

The overall level of effort is anticipated to be high, particularly given the required coordination with the County and the cost of moving the maintenance yard and providing adequate set-back protections.

Proposed Actions

- Remove the existing levee/berm that extends south and west of the maintenance yard.
- Provide set-back protections for office and shop buildings.
- Excavate deposited sediments at Mill Creek confluence to provide immediate expansion of cold-water refuge habitat.
- Place floodplain roughness on bar at Mill-Manley confluence, and habitat complexity jams along mainstem margin. These placements will encourage vegetation growth on bar and will allow for continued downstream scrolling of mainstem.
- Enhance existing beaver dam complex at Mill-Manley confluence by adding large wood and potentially BDAs.

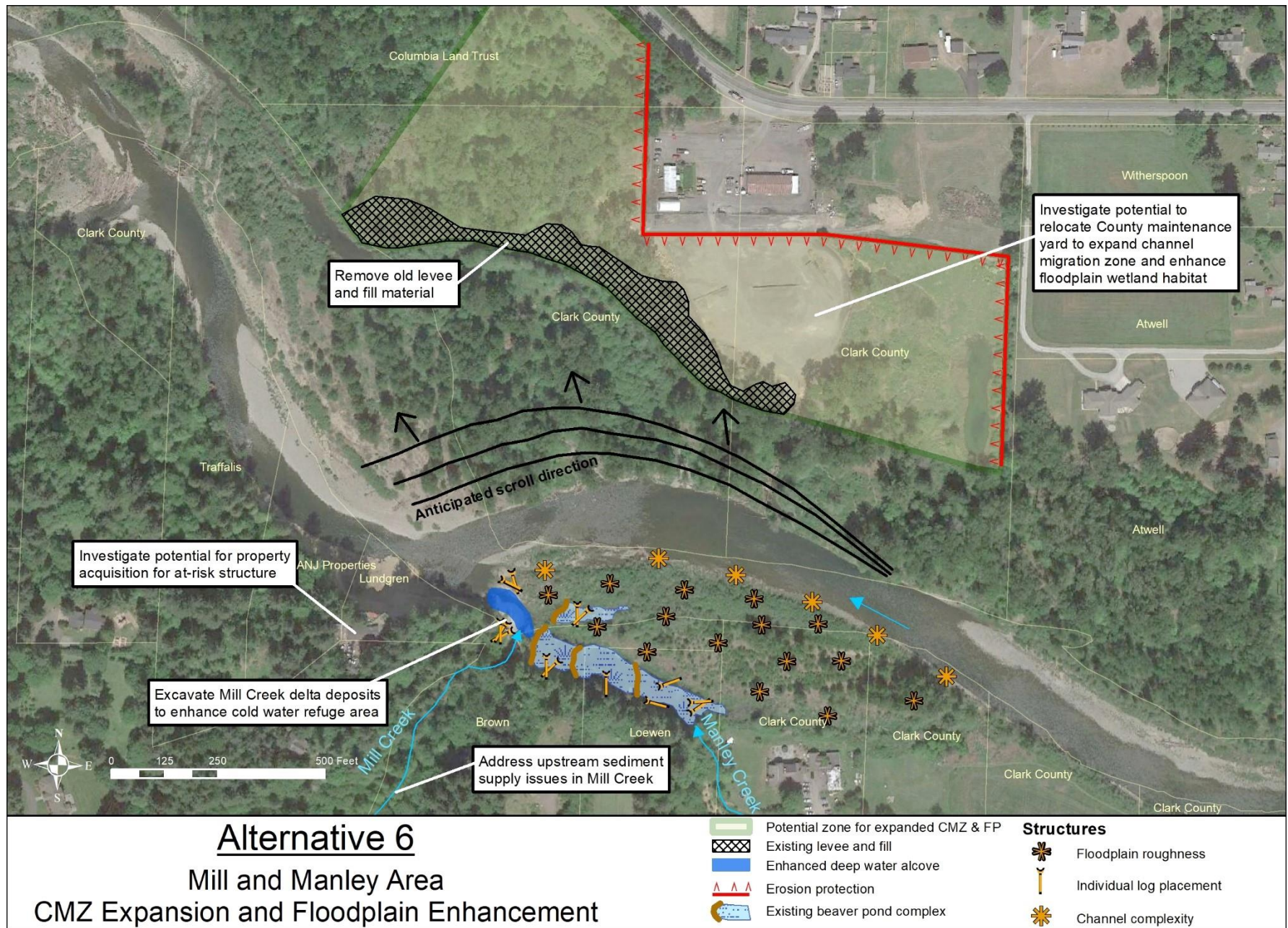


Figure 5. Mill-Manley CMZ Enhancement- Alternative 6.

Appendix A- Project Area Map and Reaches

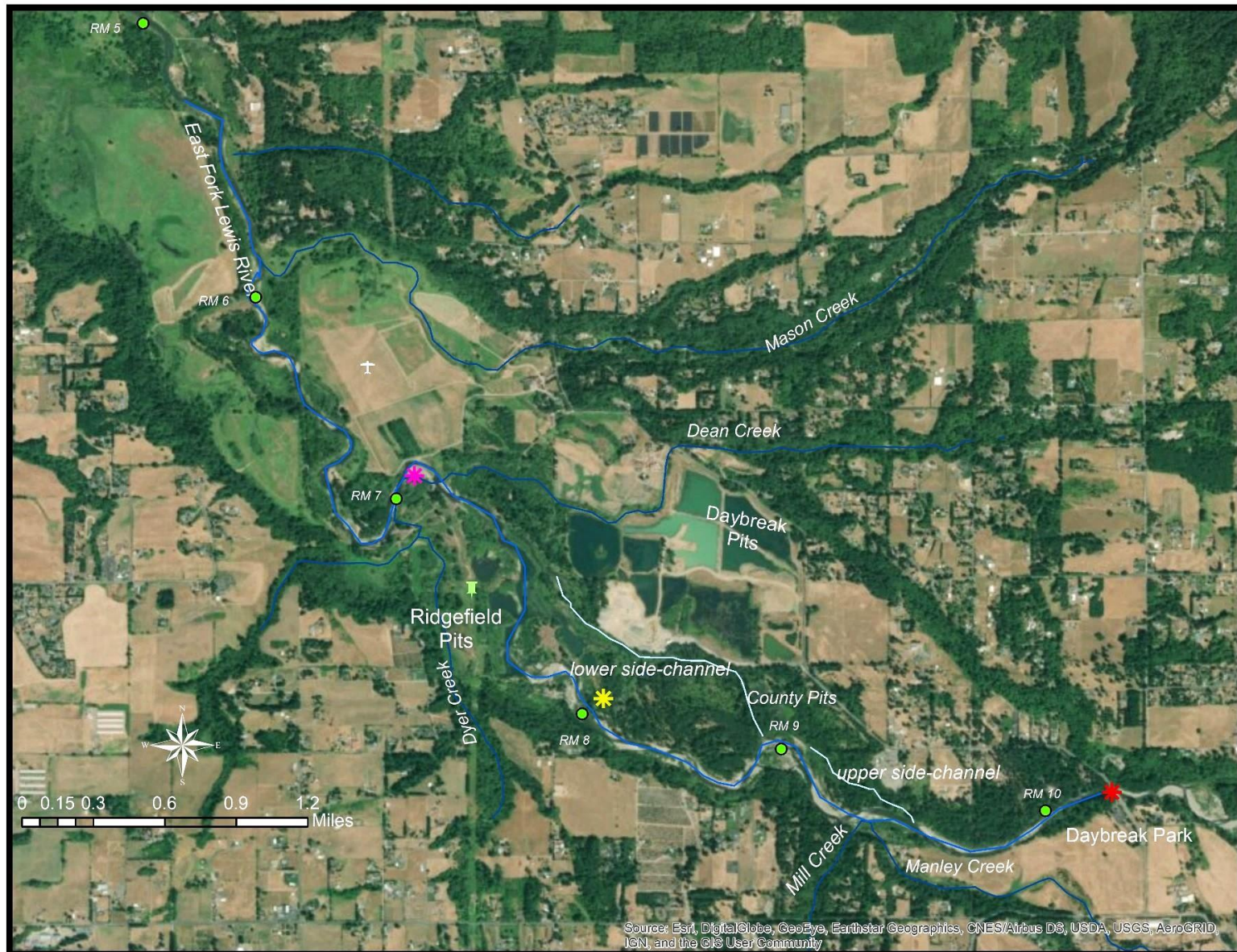


Figure 1. Project area map showing the Daybreak Park reach (RM 10.2- RM 8.0- most upstream Asterix to middle Asterix) and Ridgefield Pits Reach (RM 8.0- RM 7.1- middle Asterix to lower Asterix). Project sites include Ridgefield Pits, upper and lower side-channels and the Mill Creek confluence with EFLR.

Appendix B- Ridgefield Pits



Figure 1. Aerial oblique view looking downstream at the Ridgefield Pits. Pits are numbered 1- 9. Pits 1 and 2 have different coloration to indicate the approximate locations of the former pits. Note the gravel and wood deposition at Pits 1 and 2.

Table 1. Restoration alternatives by reaches. Key for accomplishing restoration objectives is located at the bottom of table.

		Restoration Alternatives					
Goal	Objective	Alt 1: No action	Alt 2/2a: Relocate main channel	Alt 3/3a: Full pits regrade	Alt 4: Side-channel reconnections	Alt 5: Mill-Manley enhancement	Alt 6: Mill-Manley area CMZ expansion
Goal 1: Vegetation	1a. Create channel processes that support veg	No channel processes that support veg in Pits reach. Scour either too frequent/too infrequent to support nat. veg in other rch.	Moderate confinement will limit scrolling. Limited floodplain connectivity.	Multi-thread channels, channel scrolling, shallow water table, frequent floodplain inundation will support native vegetation	Increasing side channel connections will increase dynamic processes within them, supporting native vegetation.	Overbar flow will enhance processes that support veg, but mainstem jams may limit scrolling.	Expanding CMZ will support channel processes that support native veg.
	1b. Create a patchwork mosaic of veg types and ages	Invasive grasses and shrubs dominate Pits reach. Only a couple of stand types and age classes in other reaches.	Supported mainly in new channel corridor, not across full pits area due to continued process limitations.	Restored channel processes and dynamics will achieve patchwork mosaic over time.	Increasing side channel connections will increase veg diversity in those areas.	Only minor influence on overall vegetation conditions.	Restoring more of the CMZ and related processes will increase veg. types and ages in this area.
	1c. Provide streamside veg for key functions	Riparian veg. highly degraded in Pits rch. Streamside veg young and sparse in other rchs.	Can achieve robust riparian buffers along new channel but may need to be actively maintained. Armoring may affect river-right side at gravel processing area.	Robust vegetation along riparian stream margins, with abundant margin habitat created. Wide buffers created in pits reach.	Increased connectivity will support robust streamside veg communities.	Assume riparian work along bar occurs, creating more robust buffer in this location. Otherwise no significant impact.	Only minor impact on streamside veg, at least in the near-term.
Goal 2: Thermal Refugia	2a. Protect and enhance existing refugia	No protections or enhancements of existing refugia	Possible to achieve, assuming existing refugia can be accessed by new channel location.	Multi-thread channel network across wide valley footprint will access known (e.g. Pit 9) and potentially unknown areas of thermal refugia	Increasing side-channel connections increases access to and quality of potential thermal refugia.	The goal is to enhance existing refugia at Mill-Manley confluence area, although there are questions about whether mainstem scrolling may enhance on its own.	Down-valley scrolling of mainstem away from Mill confluence is expected to lengthen tributary/backwater refuge area that receives cool flows from Mill-Manley.
	2b. Width-to-depth <12	width-to-depth >20	Unlikely to achieve with primarily a single-thread channel.	Multi-thread planform will allow channel sizing for individual channels to be at or below 12.	Achievable in side-channels	Slight reduction in w/d in mainstem due to jams but target not reached.	No significant short-term impact on w/d, except for long-term, where new side-channel development would help reduce overall w/d of channels.
	2c. Canopy closure >50%	Canopy closure <20%	Unlikely to achieve with primarily a single-thread channel.	Canopy closure >50% can be achieved due to multi-thread channels and robust riparian veg.	Achievable in side-channels	Not likely to achieve	No significant short-term impact on shade, except for long-term, where new side-channel development would help increase overall shade of channels.
	2d. Create new refugia via hyporheic exchange	Little-to-no refugia created via hyporheic exchange	Only moderate ability to provide hyporheic flow paths given narrower channel corridor, possibly one or two opportunities.	High sinuosity & planform complexity, and transition to coarser substrate will help activate hyporheic flow paths. New alcove and backbar habitats will be created.	Perennial side-channels will help create head gradients that create hyporheic flow paths contributing to thermal refuge areas.	Creating high-flow path is likely to encourage more low flow hyporheic flow contributing to refuge area.	Opening up CMZ will create more possibilities for channels that create hyporheic exchange, and off-channel habitats that receive cool hyporheic flows. But indirect.
Goal 3: Aquatic Habitat	3a. Sinuosity >1.3	Sinuosity ~1.2	Unlikely to achieve given narrow corridor	Sinuosity will be at or above 1.3	Sinuosity is likely to remain similar to existing side-channel alignments, which is ~1.2; However, more connectivity will allow greater future planform adjustment.	No impact on sinuosity	No direct effect, but potential long-term effect by allowing channels to more freely form over a wider CMZ.
	3b. Pools per mile >10	~1-2 pools/mi in Pits. ~7 pools/mi in upstream reach.	Possible to achieve in primary channel	Possible to achieve >10 pools/mi in primary channel as well as co-dominate and secondary channels due to high planform complexity and LW additions.	Possible to achieve in side-channels	No impact on pools/mi.	No direct effect, but potential long-term effect by allowing channels to more freely form over a wider CMZ.
	3c. Large wood targets (Fox & Bolton, NOAA)	Does not achieve any of the targets.	LW can be added to achieve targets	LW can be added to achieve targets	LW can be added to achieve targets in side-channels	LW can be added to achieve targets	LW can be added to achieve targets
	3d. Side-channel frequency 2-5 channels per cross-section	Currently 0-2 perennial channels	0-1 perennial side-channels	Multi-thread network will result in 3-5 channels per valley cross-section.	Will achieve at least low end of scale (2-3 channels).	Somewhat increases side-channels, but only at high flows.	Widening the CMZ will allow for the potential for more side-channels to form.
	3e. Channel margin length >5 times valley length	Channel margin length currently and into the future <5 times valley length	Not possible to achieve with primarily single-thread channel.	Multi-thread network will result in channel margin length > 5x valley length.	Likely to achieve or be very close to target.	No significant change in channel margin length.	Widening the CMZ will allow for the potential for more side-channels to form, thus increasing margin length.
	3f. Existence of zero velocity refuge areas	Few zero velocity areas at high flows	Possible to achieve by taking advantage of existing pits for off-channel high flow refuge.	Complex channel network will result in numerous zero velocity areas during high flows.	Likely to achieve by introducing more flow into off-channel and floodplain areas.	No significant change	Widening CMZ will allow for the potential for more side-channels, backwater channels, alcoves, and floodplain wetlands that retain quiescent water during high flows.
Goal 4: CMZ and Floodplain Connectivity	3g. Floodplain habitats >8 acres/mi	Currently estimated at ~3 acres/mi, but varies among reaches	Unlikely to be able to achieve given limited floodplain extent.	Possible to achieve floodplain habitats > 8 acres/mi. due to extensive floodplain wetlands & off-channel areas	Is likely to significantly improve access to and occurrence of floodplain habitats but may not fully achieve.	Slight increase from enhancement of beaver dam complex & scouring of Mill confluence, but only minor. Target not achieved.	Widening CMZ will allow for the potential for more side-channels, backwater channels, alcoves, and floodplain wetlands with connectivity to the main channel.
	4a. Remove hydromodifications	Existing hydromodifications remain	Levee would need to be constructed to prevent re-avulsion into pits. Armor needed at gravel processing area.	Berms surrounding pits will be removed. Armor protection of gravel processing area will need to stay and possibly be strengthened.	No hydromodifications will be removed and some armoring, such as at the County maintenance yard and along the Storedahl Pit Rd., may need to be strengthened.	Existing hydromodifications remain	This alternative will remove a levee and create set-back protections to the extent needed depending on landowner participation (TBD).
	4b. AVW/ACW >6	AVW/ACW<2 in Pits. AVW/ACW ranges 3.5-8.5 in Daybreak rchs; 3.5 in Mill-Manley area.	AVW/ACW = ~1-2 is significantly below target conditions.	AVW/ACW > 6, even with all channels summed, in widest part of pits. Less width downstream due to powerline towers.	No change in channel confinement. Confinement remains high at Mill-Manley but low at downstream side-channel.	No change in channel confinement, which would remain high in this area.	Current AVW/ACW = 3.5; restored would be ~5
Goal 5: Channel Dynamics and Sediment	4c. Overbank flow > 1 mo/yr	No overbank flow in Pits reach for even large floods. Overbank flow only every 1-2 years for Daybreak reaches	Possible to meet inundation target, but only within the limited new floodplain area.	Designs for channel sizing and floodplain elevation will accomplish overbank flow >1 month per year, on average.	Partially achieves objective by connecting side-channels at lower flows.	Overbank flows across bar likely to increase, but likely not to full extent of target.	Larger floodplain allows for greater inundation, and future side-channels that receive flows more frequently, no significant short-term influence on rates or duration.
	5a. Depositional channels	Pits are depositional. U and L Daybreak are close to equilibrium, with deposition and transport zones.	Single-thread channel with limited floodplain and with a desire to prevent re-avulsion will need to be approximately at equilibrium (bedload in = bedload out)	Pits reach will remain very depositional due to high sinuosity (therefore low gradient) and high floodplain connectivity.	Side-channels will remain depositional, but no significant increase.	No change in depositional features of channels. Likely more scour at Mill confluence area. Deposition on bar expected to continue.	Allowing for and encouraging mainstem scrolling and side-channel development will somewhat increase depositional conditions.
	5b. Natural bank erosion rates	No significant bank erosion in Pits. 7-8 ft/year in U and L Daybreak reaches.	Natural rates of bank erosion will be limited by confining features on each side of new stream corridor.	Banks will be supported by native vegetation, without incised channels and hydromodifications, except for abutting gravel processing area with armor.	Introduction of more flow into side-channels likely to increase erosion and adjustment rates within side-channels.	Short-term reduction in erosion rates at mainstem jams but possible increase or no-change downstream right bank. Effect on erosion at high cliff is uncertain.	Current scrolling along bank with mature native veg. would be allowed to continue and be encouraged.
Goal 6: Human Uses and Risks	5c. Bed substrate >70% grl-cbl; <15% fines for spawn	Dominated by fines in Pits reach. >70% gravel-cobble in Daybreak reaches.	Likely to achieve	Likely to achieve	Unlikely to have significant effect on bed substrate. Possible coarsening due to greater flow introduced but also possible more suspended load introduced as well.	No significant change. Substrate assumed to remain coarse.	No significant change. Substrate assumed to remain coarse.
	6a. Do not increase property or structure risk	Existing risk remains	Likely to achieve. May need to supplement armor to protect gravel processing area and downstream private property.	Likely to achieve. May need to supplement armor to protect gravel processing area and downstream private property.	Likely to achieve. May need to supplement armor along County yard and Storedahl Pit Rd.	Effect on high cliff erosion is uncertain. Angle of attack is more parallel, so could be less, but more flow introduced towards upstream side of bank.	Effect on high cliff erosion is uncertain. Allowing for and encouraging down-valley scrolling is expected to eventually move mainstem away from eroding cliff.
	6b. Avoid Daybreak Pits avulsion	Avulsion is possible in the future; however, in pits reach channel is locked in for the foreseeable future. Overbank flows from up-valley are possible avulsion-source.	This does confine the channel to a location closer to the Daybreak Pits, possibly adding risk of avulsion during very large flood.	Low potential for avulsion- lower overall stream and floodplain elevation & high conveyance of large floods. Overbank up-valley flow still a possible avulsion-source.	No significant impact on Daybreak Pits avulsion risk, unless avulsion were to occur within downstream side-channel.	No increased risk from work in this area. Risk remains the same.	No increased risk from work in this area. Risk may reduce due to greater conveyance at large floods, reducing potential for overbank flows in north floodplain that could enter Pits.
Goal 6: Human Uses and Risks	6c. Consider recreational user risks	Existing risk from large wood	Possible to achieve	Possible to achieve, though multi-thread network and abundant LW could make for challenging boat navigation.	Possible to achieve	Possible to achieve	Possible to achieve

KEY

	Very much accomplishes objective
	Somewhat accomplishes objective
	Does not accomplish objective

Appendix D- References

1. Aerial photos (1939-2002) of project area (digital photo library, USACE).
2. Cadastral Survey Plot from 1854 (General Land Office, BLM).
3. Flood Plains, Salmon Habitat, Sand and Gravel Mining (Norman et al., WA DNR 1998)
4. Geomorphic Analysis of the East Fork Lewis River, Appendix C, prepared as part of a Habitat Conservation Plan & Environmental Impact Statement for the proposed Daybreak Mine expansion (WEST Consultants, Inc. 2001).
5. East Fork Lewis River Basin- Habitat Assessment, Chapter 4. (LCFRB 2005).
6. A Regional and Geomorphic reference for quantities and volumes of instream wood in unmanaged forested basins in Washington State (Fox., M and Bolton, S. 2007).
7. Lower East Fork Lewis River Habitat Restoration Plan (LCFRB 2009).
8. CM-10- Monitoring Report: Ridgefield Pits Bathymetric Survey. Prepared as part of a Habitat Conservation Plan & Environmental Impact Statement for the proposed Daybreak Mine expansion (West Consultants, Inc. 2013).
9. CM-10- Investigate water temperature, DO, fish use and geomorphology. Prepared as part of a Habitat Conservation Plan & Environmental Impact Statement for the proposed Daybreak Mine expansion (R2 Resource Consultants 2013).
10. East Fork Lewis River La Center Wetlands Floodplain Restoration Design Report (Estuary Partnership 2015).
11. East Fork Lewis River Watershed Bacteria and Temperature- Source Assessment Report (Washington Department of Ecology 2018).

G. Technical Oversight Group Written Comments Restoration Alternatives

continues on next page

Attachment G. Technical Oversight Group Written Comments Restoration Alternatives



CLARK-SKAMANIA FLYFISHERS
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Oct. 5, 2020

Paul Kolp and Keith Marcoe
Lower Columbia Estuary Partnership
801 S. Naito Parkway Ste. 401
Portland OR 97204
Paul and Keith:

Thanks for inviting Clark-Skamania Flyfishers to participate in the Ridgefield Pits Technical Oversight Group. Clark-Skamania Flyfishers enthusiastically supports Scenario 3, Full Floodplain and Pit Re-grade. In general, the 250-members of Clark-Skamania urge designers to focus outcomes of the design, not the difficulty of the effort. It will no doubt be costly to move infrastructure, fill mine pits, address flow, install complexity and replant revegetation, but this is the scenario that will offer the highest return for the dollar over the long term. We agree with comments by the Columbia Land Trust: "We should not let initial costs limit our thinking or the preferred option."

What follows is a detailed discussion of the restoration plan and endorsement of Scenario 3 in light of details the working group gathered over the past 2 years.

First, Clark-Skamania members believe that to be effective, the restoration needs to be ambitious and address both the immediate pits area and the reach from Day Break Park to the Powerline Hole. Addressing problems with bank erosion, and channel avulsion in that stretch of river isn't possible until problems at the pits are addressed. But for the pits to become a healthy part of the river again the work plan needs to look ahead to fixing problems such as erosion downstream of Daybreak Park, degradation of cold-water tributaries such as Manley Creek and mass wasting of where Mill Creek flows into the East Fork and the dramatic water removals from Mill Creek, especially late in the summer. In the three decades since the East Fork channel avulsed into the vacant gravel pits, the river has come to pieces. Restoring the pits is the first of many pieces that need to be put back together.

Second: Clark-Skamania believes the design should rely on natural processes to accomplish the objectives. This is particularly true when factoring in climate change. Clark-Skamania does not support use of pipe infrastructure to capture and deliver cold water to support salmonid habitat. Natural flows of springs and tributaries need to be preserved and enhanced. Relocation of the channel to capture natural sources of cold water should be a leading objective as the group enters the design phase. Preserving all sources of cold water, such as the springs at the source of Manley and Mill creeks, should be part of the planning. Cold water is essential for returning the area to viable salmonoid habitat and removing invasive species. Consolidating historic sources of cold water back into the channel needs to be a design priority.

Clark-Skamania supports Scenario 3 – Filling and re-conturing the channel is reasonable and perhaps the only alternative that holds hope of restoring the area for the long term. During a 2019 working group meeting we reviewed photos and maps of the area. In that presentation we learned operators, including Clark County, used drag line dredges to haul gravel into heaps for loading and hauling. The process raised islands while lowering the floodplain. Post WW II that gave way to deep-pit excavation. The methods combined over nearly a century of mining lowered the ELEVATION of the channel and floodplain. To try and restore the East Fork by perching a new channel on the edge of a withering floodplain would be bound to fail. The filling and re-counturing proposed in Scenario 3 is the long-term solution.

Clark-Skamania does not support Scenario 3A. It proposes to retain pits 8 and 9 and their cold water as thermal refuges, which means less cold water for the main channel and the network of braided channels to the southwest. One of the goals of Scenario 3 is to create braided channels that can support a variety of species. Coho and chum in lower velocity channels, chinook and steelhead in faster water. Juveniles would utilize all areas, especially those with woody debris and deep holes. But all four species need cold water, so isolating the cold water inputs to pits 8 and 9 from the broader floodplain restoration works against the diversity of habitat that the plan is aimed at achieving. Also, the work group heard from WDFW, Ecology and others that the number of pools per river mile is one measure of a properly functioning alluvial river. Leaving pits 8 and 9 out of the re-design would remove two of the best performing pools on the floodplain outside the re-contoured river channel. That doesn't make sense. For those reasons, Clark-Skamania opposes Scenario 3A. It might save money, but it doesn't deliver the best long-term outcome.

Clark-Skamania views Scenarios 4, 5 and 6 as compliments to Scenario 3, not alternatives. Reconstructing side channels as proposed in Scenario 4 would create habitat upriver and around the pits. It would offer benefits to juveniles moving downriver, but do nothing for upriver spawning populations.

Installing wood jams and excavating where Manley and Mill creeks flow into the East Fork as proposed in Scenario 5 might create scouring flows that would carry away silt that is diminishing the contribution of those vital tributaries. But it wouldn't stop the wasting away of the high bank downriver. Only moving the channel would accomplish that. Widening the river at the confluence of Manley and Mill creeks as proposed in Scenario 6 might reduce the wasting of the downstream river bank and create scouring flows to improve the contribution of both tributaries. But the scenario doesn't address the pits themselves. It's a small-bore solution for an area with such large problems.

Relocating the channel to the pre-1996 location in Scenario 2 isn't supported by any of the evidence the work group reviewed. Without significant re-conturing it's not a lasting solution. Leaving the river as is and waiting until 2080 for natural processes to fill the pits as proposed in Scenario 1 is basically the path we've been on for two decades. Additional insults to the river like silting at the confluence of Manley and Mill creeks, increase in invasive species and warming flows throughout the area that make it a desert for migrating smolt will diminish the salmon and steelhead recovery that we're all working on. If we choose Scenario 1, we've wasted two years of study and have no way forward.

Specific comments:

- Clark-Skamania believes design should focus on the pits while the plan should extend from the Powerline Crossing upriver to the Daybreak Park area. Anyone who fishes this area knows the reach from the Powerline Hole to Daybreak is prime holding water. It's pre-spawn holding water for coho, Chinook and chum. It is a thermal refuge for upriver steelhead and rearing habitat for all downriver smolt.
- The goal of 50% vegetation cover (Goal 2, objective 2c, page 10) is too low. Clark-Skamania believes the design needs to achieve much higher cover. During the April 2019 work group meeting, the Washington Department of Ecology explained it was working to address high water temperatures and fecal coliform bacteria problems in the East Fork, both above and below the project area. Ecology assessments showed poor riparian conditions and little shade in the lower river including the project reach. Given Ecology's focus on that problem, this work plan needs to reach for more than 50% vegetation cover and could turn to Ecology for funding to achieve that.
- Clark-Skamania disagrees with comments about reducing costs by allowing vegetation to recover naturally before planting. That's risky. Difficult species such as knotweed, blackberry, canary ryegrass, butterfly bush and others may cost more to remove than if all habitat was planted. There is an army of volunteer workers, Clark-Skamania members included, that could help plant 100% of the area.
- The design should make control of the wasting hillside downstream of the confluence of Manley and Mill creeks a primary concern after pit re-conturing. The working group heard often that erosion of that cliff was the major source of sediment that was compromising downstream holding pools and thermal refuges. In 2008, residents led by Bruce Wiseman lobbied for and were granted state funds for in-stream structures to halt the erosion and save their homes at the top of that hill. It failed. If the Estuary Partnership launches a multi-million rehab of the area that doesn't include and explain how the restoration will help address that hillside erosion it risks political backlash and only partial success for restoring the pits.

Steve Jones, Conservation Director

Feedback on Ridgefield Pits Technical Memo
Brice Crayne
Lower Columbia Fish Enhancement Group

Alternative 1: No Action/Passive Recovery of Pits

The no action alternative is obviously the least expensive and this is the only reason to choose this alternative.

I was surprised to see so few predatory fish in the pits while snorkeling. In fact, I was surprised to see so few fish period using the pits that the EFL currently runs through. It appears that the overall lack of forage fish also diminishes the use by predatory fish. There is a huge volume of open water that is providing virtually zero benefits to any fish, native or non-native. I have not snorkeled the isolated pits. The primary reason that the no action alternative is a poor choice is due to the fact that there is so much potential for chum and Chinook spawning and coho and steelhead rearing that is currently not used due to the unnatural state of the river. This includes the area within the immediate vicinity of the pits as well as downstream of the pits where the EFL becomes channelized. Some of the channelized nature must be due to the disconnected sediment transport associated with the pits. Further, the models suggest that the pits will take decades or more to fill the currently active pits. At this time, the EFL will like avulse into one of the other pits at which time it will take decades more to fill those pits and so on and so forth until the entire area is brought back to grade and can start to function more naturally. If we have the know-how, means, and funding to do so, there is no reason to wait for the river to fix itself.

Alternative 2 & 2A: Relocate Main Channel Back Into/near Pre-1996 Avulsion Channel

I agree that some channel re-alignment is necessary but as stated in the memo, attempting to create a single-thread channel in this reach would be fighting natural processes. This is really evident by the current channel network directly upstream of the pits where abundant wood is creating a dynamic, multi-thread channel network more representative of the 1854 river valley. In the case of the EFL where Clark County is purchasing large amounts of the lower floodplain and there is an opportunity to allow the river to spread out and function in a manner that resembles historic conditions, we must take advantage of this opportunity. So many of our rivers have been diked, ditched, and relocated for the convenience of development that to try and restrict flow into a single-thread channel would be a terrible missed opportunity and would not seize the maximum ecological opportunity associated with floodplain-wide restoration.

Alternative 3: Full Floodplain & Pits Re-Grade

This alternative has the greatest certainty of success which outweighs the increased cost associated with the amount of woody material required to accomplish this task. Critics of this alternative will likely say that if you spread the water out too much, there won't be enough water in any one channel for fish to survive. What we have seen in systems like the SF Toutle which has a high sediment load, wide floodplain, and merely lacks the structure shown in the Alternative 3 map, is that the river will choose a dominant path or two each summer depending on where the sediment builds up over the winter and that the amount of hyporheic flow supplements the multi-thread channel network with cool, fresh water, even in isolated pools. The result may be an overall reduction in large pool area (which isn't currently functional) but an overall increase in preferred habitat associated with smaller pools with woody cover and cool water. The floodplain will become saturated over the wet months and then will be slower to release the water during dry months simple because the conveyance through the reach

has been reduced.

There is a strong argument that can be made for strategically recommending that the river occupy areas of cooler water with the expectation that these are the areas where there will be cool upwelling post construction. I'm not opposed to slight filling of the cooler ponds as long as flows are encouraged to occupy these areas. I don't think that these areas should be left as off-channel habitat that will fill in over time because that doesn't maximize their benefits. I would like to see one of the dominant channels flowing through these cooler pits because the upwelling associated with the cool water is preferred spawning habitat for chum and Chinook. These fish won't spawn if there isn't adequate flow, depth, and sediment size. These fish also may not spawn in an area that has adequate flow, depth, and sediment size but is in an area of downwelling instead of upwelling. Last, a fine-sediment bottom, off-channel pond may provide some warmer winter rearing habitat or cooler summer rearing habitat but those are not the limiting factors for Chinook or chum.

Last, this alternative is inherently unpredictable as are natural rivers. While my recommendations are to initially nudge the river into these cooler ponds, restoring natural processes means restoring a river's ability to be dynamic. Thus, I would not consider it a failure if the EFL migrated away from the intended alignment in the first few years. In fact, I would be disappointed if it did not migrate some following the first bank full event.

I would like to see more discussion on the pre-construction of side channels versus allowing the river to create them itself. Are you proposing to remove all of the fish, divert the water, regrade the entire floodplain, spread wood out, and then let the river do what it does? Or are you proposing to strategically pick log jam locations, install piling to assist meeting the stability associated with key pieces, pre-grading side channels, etc.? Or are you even at this stage of design yet?

Side-channel Reconnections

I would like to see both the upper and lower side channels activated during winter base flow elevations. I would not be disappointed if the entire EFL abandoned the left bank downstream of the Mill Creek confluence to occupy the right bank where there is some hyporheic flows, more shade, and there would be less pressure on the high, sandy bank on river left.

I have some concerns about the lower side channel getting stuck against rip-rap used along the NE Storedahl Pit Rd. If the entire river migrates to the right bank, it would have a difficult time leaving a rip-rap wall and may abandon the entire left side of the floodplain.

Mill and Manley Creek Confluence

I understand this is a difficult location to work due to the current bar migration through the center of the floodplain and the risk associated with working near a sandy bank with a private landowners deck hanging over the side. Thus, any concerted effort to maximize cold water refugia that is completed in a strategic manner is supported.

Mill and Manley Area CMZ Expansion

If the county is willing, do it!

Friends of the East Fork Comments to the Lower Columbia Estuary Partnership East Fork Technical Oversight Overview & Alternatives July 8, 2020 Memorandum
Oct. 04, 2020

We appreciate the past and present opportunity to collaborate on these efforts. The Memorandum contains more data & information than reports done in the past and includes much more comprehensive substantive content to address the challenges of today and future. **Our comments are in two parts, an Overview and then a Discussion of the 6 Alternatives.**

OVERVIEW:

That said, the memorandum has not adequately focused on the core problem in the East Fork. **It is the interrelated issue of (1) LOW FLOWS & HIGH SUMMER STREAM TEMPERATURES COUPLED WITH (2) HIGH BEDLOAD SEDIMENTATION that result in the current disastrous stream channel conditions.** These conclusion are supported by earlier work done by river geomorphologists Dr. Barry Sutherland & Dr. Frank Reckendorf and others. **Almost every other issue is fundamentally a sub-set, or primarily a result of these two watershed and stream conditions and is basically a hydrologic and fluvial-geomorphic situation with strongly related biological water quality effects.** And, much of the problem is of anthropogenic (man-made) origin. The impacts show up in in early 1900s historical data and continue with greater intensity on into current data, and information. Stereoscopic review and analysis of aerial photos of all reaches of the East Fork dating back to the 1930s and on to present time document locations and types of activities that have caused these impacts.

The fluvial-geomorphic **COMPETENCE AND ENTRAINMENT** capability to maintain stream channel balance in the river, particularly the lower one-third is very poor. The physical result over time is that many pools have been filled in, and the Channel Width to Channel Depth W/D Ratio **“HYDROLOGIC BANKFUL FLOODED STREAM CHANNEL WIDTH TO THE STREAM CHANNEL FLOOD DEPTH RATIO”** of the stream channel cross-sections have become very high (60 to 120 and more) because the river flow cannot handle the bedload level and consequently makes adjustments that result in the eroding out the stream banks, degradation of spawning riffles, large sediment islands in the middle of the channel that also are involved in the increase of the W/D ratios as well as causing at least four major channel avulsions in the last 20 years.

The history of past gravel mining between Heission Bridge and La Center included mines that in some cases worked both stream banks and the river itself, with little or no restoration afterward. This alone added large amounts of bedload sediment to the river channels downstream. In addition, dikes were added to other areas related to mining and in one case a dike was built out at right angle into the river, which drove the river into the high bank on the opposite side. A more recent avulsion between Daybreak Bridge and Lewisville Park Bridge was associated with a large boulder dike installed several years earlier to protect development on the major floodplain (which the County management allowed to happen years earlier under very questionable circumstances) on the south side of the river. This effectively cut all flood flow relief in that reach of the river and resulted in excessive sediment buildup which forced a large avulsion. This was the second more recent avulsion in the East Fork above Daybreak Bridge.

The results of these conditions show up in an extreme way when flows began to diminish later in the

year, the water depth is both very shallow and subject to faster and higher heating levels as well as less capability of the river to effectively handle various kinds of sources of water pollution (chemical, biological, and temperature). In simpler terms, it is somewhat similar to putting a given amount of water in a tall glass which ends up being relatively deep, versus putting the same amount into a large dishpan with the result that the water level in the pan is very low. In addition, in various areas of the watershed, infiltration rates have been reduced which also lower groundwater and surface water yields as well as affecting storm and snowmelt runoff characteristics. **The lower one third of the East Fork, in most of the channel reaches, is now in that dishpan condition, making it subject to a wide range of undesirable conditions and cumulative effects ---both biological and physical/geomorphic.**

With these existing conditions, **PLANTING TREES ALONE WILL NOT ADEQUATELY ADDRESS THE TEMPERATURE PROBLEM** and could result in future restoration and improvement programs and project funding being out of balance with this aspect of the critical problems in the East Fork ---this has not been adequately addressed in the Draft Ecology 2020 East Fork Cleanup Plan or in the Ridgefield Pits Restoration Design Project Draft Alternatives.

Currently there are at least five (5) major sediment source located in reaches within the lower East Fork, starting above Lewisville Park just below the outlet of Rock Creek North. These large bank erosion/sediment sources should be given treatment priority. Their very high on-site and downstream bank and channel negative impacts on the river are biological as well as fluvial-geomorphic. It is well known that low flow volumes in the East Fork have direct effects on water quality, particularly in summer time. Groundwater inflow is also affected by poor channel and watershed conditions as well as the floodplain and tributary stream disturbances from anthropogenic activities that are on the increase in some areas of Clark County. Illegal water diversions, building along streambanks and in designated wetlands-recharge areas, heavier and new well drawdown, as well as building of rural ponds (past & present) all during a period of decline of infiltration into the Troutdale Aquifer are adding to the water related problems. Weak and limited compliance by Clark County with the WA State Growth Management Act, and Shorelines Act is also having an impact on water runoff, groundwater and streams.

TO DATE, HISTORY SHOWS THAT EXISTING AND NEW RULES AND REGULATIONS WILL DO LITTLE GOOD AS LONG AS COMPLIANCE IS VOLUNTARY AND NOT MANDATORY IN CLARK COUNTY. CURRENT MONITORING IS INADEQUATE AND ENFORCEMENT/COMPLIANCE IS "COMPLAINT BASED" WHICH ALSO IS INADEQUATE AND NEEDS A MAJOR IMPROVEMENT IN MONITORING TO DISCOVER IMPENDING PROBLEMS AND ADDRESS THEM WITH SUBSTANTIVE SOLUTIONS.

Side-channel improvement and expansion has been mentioned in the draft documents as a source of both cooler and more groundwater inflow to the river. It appears that although both have value, flood overflow channels are being mixed in with and attributed with the same characteristics and effects of true side-channels. They are not the same both physically and in attributes. Side-channels are not connected to the main river at their upper end, and often they have springs and upwelling areas that provide both rearing for salmonid fry as well as cooler water inflow to the river. Overflow channels are subject to high sedimentation from flood flows and do not function as well biologically or have the higher water quality and quantity attributes. However, both may suffer from the effects of beavers building large dams along their channels and creating temperature and fish use issues. Beaver effects in broad valleys and meadows with limited forest vegetation are often quite different from that in a forested stream channel that is confined or part of a narrow valley. Such is the case on the East Fork and a number of tributary salmonid streams in the East Fork have beaver problems that result in significant drying up of critical pools and loss of salmon and steelhead fry.

GOALS & OBJECTIVES:

The Goals & Objectives appear to cover the most critical and basic needs related to lower river restoration. A few need some additional work to provide more substantive information.

DISCUSSION OF THE SIX (6) DRAFT ALTERNATIVE TREATMENTS FOR REACHES IN THE LOWER EAST FORK:

Alt.-1 This alternative is the standard “continue the path of the present programs into the future strategy” and is used to measure net changes with other proposed alternatives.

ALT-2 This alternative would recover a significant reach of upwelling cooler water, restore some highly valuable salmon (including Chum) spawning habitat. There is also a flood overflow channel connected to it along the Storedahl West Daybreak Pit access road. Sediment from that channel has not been a major problem in the past largely because of the old mining ponds in flows thru. The original channel was relatively stable before the 1996 flood. Note that the ponds were not breached during the flood but were allowed to breach based on discussions with WA Dept. F&W and the new owner of the Ridgefield Pits. The results covered in the information in the LCEP-Technical Oversight discussions identifies the severe down cutting that occurred at the entrance to the pit and also upstream. Restoring the flow level to allow reactivation of the lost channel reach and adjusting or creating a controlled flow level into the Ridgefield Pits is not an unusual application of technology and has been done elsewhere. The pits would receive minimum treatment. The option of proposing creating multi-thread channels in the area is a challenging technique and poses major long-term problems in stream with high bedload such as the lower East Fork.

Alt.-3 This alternative is very ambitious but with the high bedload sedimentation of the river, it is doubtful if it would be geomorphically balanced and would likely end up being an unstable “hot zone” rather than a cool water recharge reach.

Alt.-4 There is total of about 6 true Side-Channels and Flood Overflow Channels combined. As stated earlier in this comment document ---they are not the same and have different attributes, but can be used to improve the river in terms of temperature, water inflow, and fisheries (particularly fry & juveniles). In some cases, their performance is reduced due to the construction on beaver dams.

Alt.-5 Restoration and enhancement of the pool at the outlet of Mill Creek North into the East Fork has some challenging fluvial-geomorphic river reach conditions as well as some related ongoing fish pool salmon and steelhead fish rearing operations in two pools located nearby in the lower part of Manly Road Creek. The outlet of Mill Creek is located in the transition zone of an inside bend and an outside bend as illustrated in the Alternate 5 illustration labeled Figure 4. Gaining adequate velocity to sweep out the filled in pool is unlikely. Installing some kind of drop structure system that would keep the pool clean once it was physically emptied, might be possible. Also, diverting the river into a new channel, using the current flood overflow channel on the north bank could be considered but would require a separate channel for Mill Creek.

The site is further complicated by the extreme bedload coming from the severely eroding high cliff just below the pool. There are proven new methods to effectively deal with this kind of cliff erosion situation and should be considered. Diverting water into the lower fish rearing pool would be met with opposition from Friends of the East Fork, Fish First, Clark-Skamania Flyfishers, and Healing Waters Veterans – Vancouver Group because of potential impact on the two rearing pools in lower Manly Road Creek and potential loss or degradation of substantial investments since 2006.

Alt.-6 Moving the channel location northward from the confluence of Mill Creek North and Manly

Road Creek would require a complete re-location and building of a whole new section of channel thru the existing flood overflow channel, as just changing the curvature of the outside bend would lead to a greater impact on the high cliff to the south. A wide variety of treatments would be needed, including log cribbing, to achieve and maintain the desired results.

SUMMARY:

There is much more that needs to be discussed in our mutual/collaborative search for solutions on the lower East Fork, but we need to put more focus on the main problems that almost everything else derives from---**low water flows and high stream temperatures and their historical & current causes**. Also, in the modeling that is being done, I would like to see the results of “sensitivity tests on key input parameters to see how critical each is to the results of a given solution and how much variance and validity is associated with them in a given model.

In addition there is a people problem that hinders effective support of river restoration. Many people of the younger generation or new to the Portland/Vancouver area are under the impression that the river has always been in the current condition or slightly better. We need to give them an accurate valid “yard-stick along with the benefits” if we expect to get their long-term support for these and related kinds of Conservation & Good Land & Water Stewardship programs and projects. And lastly, a variety of instream treatments need to be used because the nature of a particular problem(s) in a given river reach varies and a mix of treatments, not just wood ELJs is needed to be successful. There are plenty of proven new as well as old treatments being used effectively thru out the USA that must be considered if we are really serious about succeeding in this effort.

Respectfully,

Richard Dyrland, retired Federal Regional Hydrologist
Lewis River, 27511 NE 29th Ave, Ridgefield WA 98642
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Friends of the East Fork

Jim Byrne
WDFW Fish Biologist (retired)

Draft Restoration Alternatives

- | | |
|---|---|
| 1. No Action/Passive Recovery of Pits. | No, something must be done. |
| 2. Relocate Main Channel Back Into/near Pre-1996 Avulsion Channel | No, too expensive. |
| 3. Full Floodplain & Pits Re-Grade | Some, Need to concentrate as much hyporheic flow into mainstem as much as possible. Cut costs by only focusing on re-establishing groundwater inputs. |
| 4. Side-Channel Re-Connections
into side channels. | No, Water needs to remain in main stem, not diverted |
| 5. Mill and Manley Creek Confluence | No, Mill Creek gravel issues must be addressed first. |
| 6. Mill and Manley Area CMZ Expansion | No, Mill Creek gravel issues must be addressed first. |

NMFS Comments

Ridgefield Pits Restoration Project Memo to Technical Oversight Group

Draft Restoration Goals:

Goal 1: Restore Native Vegetation Communities

- NMFS agrees this is a valuable component to the Ridgefield pits restoration efforts. In addition to providing sources of wood to be recruited, this goal and its subsequent objectives are in alignment with several key priorities identified by the LCFRB within the EFLR sub-basin recovery plan

Goal 2: Enhance Thermal Refuge

- NMFS believes this is a vital component to the restoration efforts. Cold-water refugia is a habitat feature necessary for ESA listed salmonids throughout their life histories, and in the face of climate change protection/enhancement of these areas will be pivotal in recovery efforts. The objectives of this goal will all support the protection/enhancement of cold-water refugia sites. However without grading of avulsed pits, their lentic nature will support warm water and negate any benefits to restoration of cold water refugia sites.

Goal 3: Increase Quality and Quantity of Spawning and Rearing Habitat

- All of these ESA listed species are “Primary” populations with respect to recovery within the Lower Columbia River. NMFS is highly supportive of any habitat restoration/enhancement projects that have the potential to increase the production potential within the EFLR. All of the objectives for this goal meet or exceed minimum design criteria for habitat restoration projects. If implemented there is no doubt the quantity and quality of spawning and rearing habitat would be increased.

Goal 4: Restore Channel Migration Zone and Floodplain Connectivity

- This goal and objectives, while important, and consistent with a key priority within the LCFRB EFLR sub-basin recovery plan, seems to clash with Goal 6. It may be advantageous to combine goals 4 and 6 as they rely so heavily on one another to be successful.

Goal 5: Create A Dynamic Channel Which Supports Adjustments and Sediment Transport

- NMFS agrees with this goal and objectives, and agrees is pivotal in the restoration of the Ridgefield pits.

Goal 6: Develop Restoration Approaches and Actions Consistent With Existing Land Use

- See goal 4 above

Draft Restoration Alternatives:

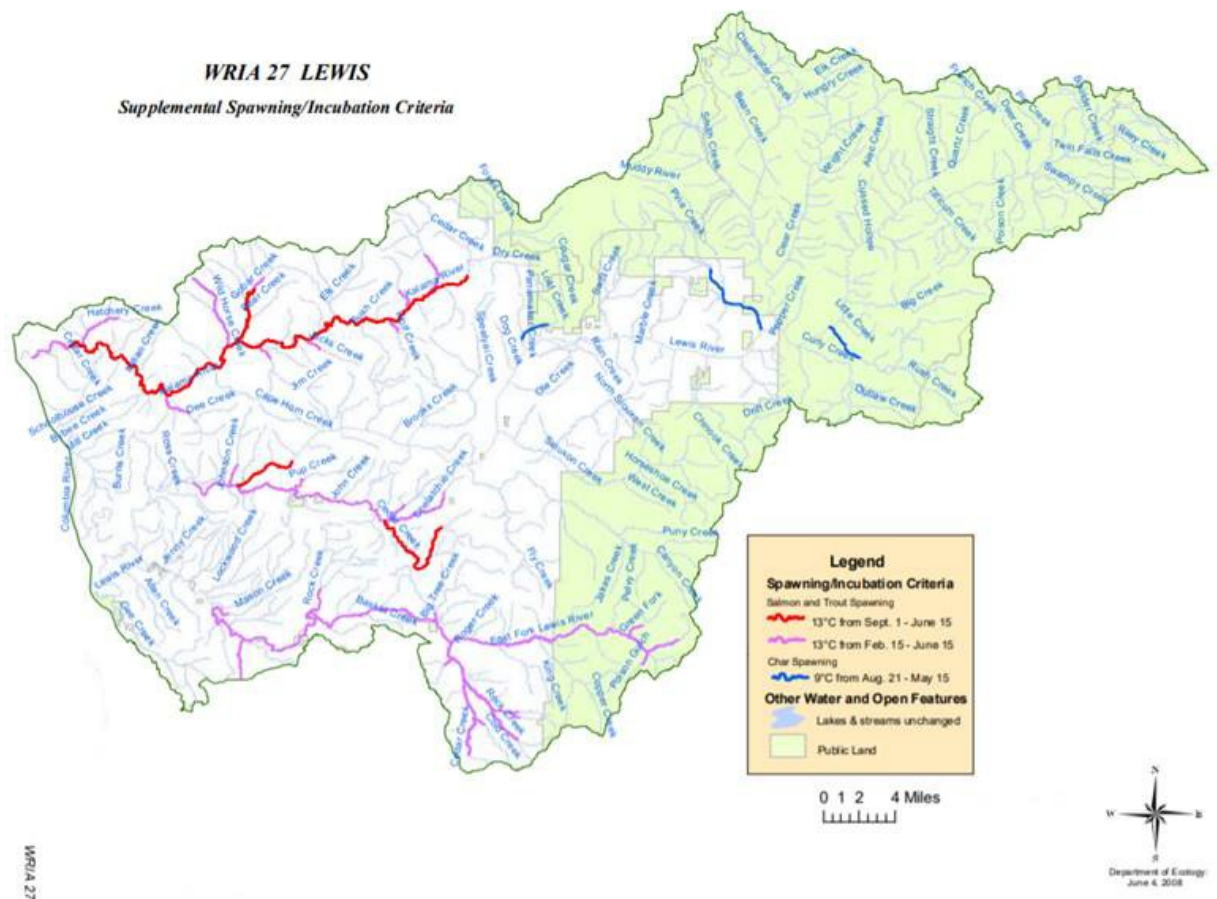
NMFS is most supportive of the Full Floodplain and Pits regrade, and believes this is the best option with respect to contributing to the recovery of the “Primary” ESA populations within the EFLR. It should be noted that NMFS is supportive of any habitat restoration actions, which support the recovery of ESA listed species and their critical habitats. However, we also understand that cost and other outside factors could influence the final restoration designs and future implementation of the Ridgefield Pits Restoration Project. Additionally, NMFS would be least supportive of the No Action/ Passive Recovery alternative, and would need significant evidence that the relocation of the main-channel alternative

would have a very low chance of failure (avulsing back into the pits), before supporting this alternative. Finally, NMFS thanks you for the opportunity to comment on the Ridgefield Pits Restoration Alternatives Memo, and looks forward to future collaboration with the Technical Oversight Group. We are standing by to assist with any pre-consultation requests with respect to ESA take coverage on proposed restoration activities. Please feel free to contact me (Joshua.ashline@noaa.gov) if you have any questions or concerns.

Department of Ecology
Devan Rosterfer

Greetings Technical Team for the Ridgefield Pits Restoration Design Project (Paul, Keith, and Gardner)
Thank you for providing the Technical Oversight Group with the opportunity to review the Ridgefield Pits Restoration Project Memo from July 8, 2020. I apologize for my delayed review. I have been busy publishing the [Draft East Fork Lewis River Water Cleanup Plan](#) but I hope my comments are helpful. Please let me know if you have any questions or want to discuss.

- The temperature water quality standard for the East Fork Lewis River is 16 degrees Celsius (68 degrees Fahrenheit) to support core summer salmonid habitat. This memo says the standard is 18 degrees. Reference [WAC 173-201A-020](#).
- The watershed also has supplemental spawning and incubation criteria of 13 degrees Celsius applicable from February 15 to June 15 for protection of salmonid species. In the East Fork Watershed, this supplemental spawning criteria overlaps with your project area. Please note there is no "TMDL Limit," as referenced on page 5. The goal or target is to meet the water quality standards in the watershed (16 degrees year round, 13 degrees February to June).



The [East Fork Lewis River Source Assessment](#) determined that from river mile 0 to 7, the average tree height potential is around 75 feet, with an estimated overhang potential of approximately 7.5 feet. Above river mile 7 the average 100-year tree height potential is around 150 feet, with an estimated overhang potential of approximately 15 feet. Ecology recommend maximizing site-potential tree height and overhang potential.

On page 10, goal 2C suggests a shade target of 50% for riparian vegetation. The system potential vegetation target in the watershed is 85%. However, the 50% target seems reasonable for this area. Here is a breakdown of potential shade, current effective shade, and shade deficits by river mile. You may consider matching your targets for reforestation with the potential shade that can be achieved at each river mile.

Table 48. Shade deficit results in the middle watershed.

River Mile	Average Potential Shade (%)	Average Effective Shade (%)	Average Shade Deficit (%)
6-7	47	15	31
7-8	42	5	36
8-9	42	12	30
9-10	54	15	40
10-11	65	21	40
11-12	55	13	45
12-13	67	16	49
13-14	72	39	37
14-15	70	43	29
15-16	69	40	25
16-17	71	36	38
17-18	71	41	28
18-19	74	46	27
19-20	80	47	34
TOTAL	63%	28%	35%

- Please describe how this Ridgefield Pits Restoration Design Project and proposed alternatives are related to the East Fork Lewis River Thermal Assessment and the recent award for the East Fork Lewis River Habitat Improvements project. How will the Thermal Assessment inform restoration at Ridgefield Pits? How will the Thermal Assessment and Ridgefield Pits project influence the new East Fork Lewis River Habitat Improvements project? Are there plans in place for work upstream at Daybreak Park or north of Daybreak Bridge?
- Have you considered quantifying the streamflow restoration / baseflow augmentation benefits from this restoration effort? Having an understanding of how much CFS would be restored to the river with each restoration alternative could help support decision making and make this project eligible for [streamflow restoration funding](#).
- I appreciate that you include an estimated “level of effort” for each of the restoration efforts. A cost-benefit analysis for each restoration alternative might also help support future decision-making.

- Outlining which restoration alternatives are most feasible from a permitting standpoint could also support decision making. Similarly, understanding the feasibility of each project within the boundaries of the shoreline management act and critical areas ordinances could be helpful. If critical areas will be impacted, or impacts to fish and wildlife are expected, how will these impacts be avoided, minimized or mitigated for each alternative?
- Attached are two maps showing WSDOT priorities for stormwater retrofits / fish passage barriers in the watershed. Do any of these priorities overlap with Mill Creek?

If you need additional information on Ecology's work in the watershed and the priorities that have been established, the [Draft East Fork Lewis River Water Cleanup Plan](#) was recently published for [public comment](#). Priorities for riparian restoration are the middle watershed which has average shade deficits of 35%. River miles 9 to 13 have shade deficits over 40% and river miles 6 to 8 have shade deficits over 30%. Priorities for streamflow restoration, based off the *Surface/Groundwater Exchange Along the East Fork Lewis River* include river miles 4.6 to 7.3 and 7.3 to 8. These priorities directly overlap with your project area. If you plan to seek implementation funding from Ecology through the [Water Quality Combined Funding Program](#), it will be important for you to communicate in grant applications how this project will make progress towards lowering water temperature, restoring streamflow, and increasing shade in priority areas.

Table 52. Priority river miles for groundwater inflow.

River miles	Location	CFS of groundwater inflow per mile (cfs/mile)
4.6 to 7.3 Lower and middle watershed	Lower and middle watershed	13.3
7.3 to 8 Middle watershed	Middle watershed	6.3
26.9 to 29 Upper watershed	Upper watershed	6.1
10.1 to 13.2 Middle watershed	Middle watershed	2.0

In addition to augmenting streamflow at priority river miles, the following recommendations were provided in the *Surface Water/Groundwater Exchange Along the East Fork Lewis River* report.

- Track and analyze water levels over time in the Sand and Gravel Aquifer, which is the main water source for the East Fork Lewis River
- Determine where the river is directly connected with the Sand and Gravel Aquifer to help clarify where the river is gaining groundwater.

Will any of the information from the *Surface Water/Groundwater Exchange Along the East Fork Lewis River* report be considered in your restoration alternatives or future work?

I hope my thoughts and feedback are helpful. I am excited to see this project to move forward and get closer to implementation!

Please let me know if you have additional questions,

Devan Rostorfer - Water Quality Implementation Specialist - TMDL Lead Washington State
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[East Fork Lewis River Partnership](#) | [East Fork Lewis River Partnership Meeting Materials](#)



Howe, David L

WDFW Habitat Program Manager

- Alternative 2 has the additional risk of not being accepted by Storedahl because of a perception of increased flood risk. There may be some political risk with this alternative. Alternative 3 could benefit from the perception of reduced flood risk to the northern berm protecting the Storedahl operation. There would need to be more work here to ensure this doesn't happen.
- If cost is a potential constraint for Alternative 3, what about a *partial* re-grade using available materials. For example, what if we can decrease the fill timeframe for the ponds from 60 years to 20?
- Alternative 3A involves leaving ponds 8 and 9 to maintain cold water refugia. How does this affect long-term gravel recruitment downstream? While I can see the benefit of maintaining cold water inputs, if it comes at a cost of extending the duration of time for downstream reaches to regain their historic spawning potential due to lack of gravel recruitment, I'm not sure that's an acceptable trade off. Seems like we need more information here.

Uber, Alex

Environmental Engineer WDFW

Mr. Uber made numerous comments and suggestions in the main body of the document using "track changes". These comments can be obtained by contacting WDFW or the Estuary Partnership.

Dave Brown
Northwest Wild Fish Rescue

Paul: To me u have not addressed the water or even attempted to. Know there there are a lot of water permits on the river and guess even more illegal withdrawals. To me we need minimum of at least 200 cfs to make anything u do work. Has anybody ckd permits to see how many there are? Seen what has happened on Rock creek where water right of 1.5 cfs was put into the creek? Water runs most of the year now but most important some pools maintain water all year and fish populations are up. If weren't for illegal withdrawals I believe it would run all summer. Seeing more steelhead and they are in 2 years. Still don't believe u are working on a water solution? Are u? If so what? Been 2 years and not a preliminary plan. Fish are on a uptick since made a gene bank stream according to my informal surveys. We need action now!!! Call me anytime if u wish to talk. Dave. 360 907 7333
Sent from my iPhone

Don Swanson
Landowner

Hello Paul,

I like the idea of a combination of 2&2A. Version 3 is quite extensive and looks like it does not consider the BPA row. It is 287ft wide and has room for a second line on the East side. I do think a 1/3 of the flood should go along the west hill base and reenter the river about where your first project is at the carbody hole. I think the mouth of Mill creek should be excavated and made readily accessible for fish. The river is dynamic enough without enhancing it into chaos. The steepness of the river gages rainfall and rain on snow reaction should be A point of measurement to judge the health of the watershed. Slow up and slow down. Not a flush. This will give the aquifer a chance to fill and give cool water to the streams in the holes. Projects designed to slow storm water runoff should be designed upstream. Also less energy will allow the river to build pools and not get blown out. I believe wood is good in the river system, but it should be near the River for shade and recruitment. We have many species of water fowl that need open grass fields to be safe and to feed.

Thanks for your patience and the chance to comment,

Don Swanson

Ian Sinks

Columbia Land Trust

Overall, I appreciate the quality and quantity of information in the memo - well done! My first reaction to the overview of the issues and strategies that were identified during the process was that I don't agree with some of the options. But that, of course, was not the point. I appreciate that you captured the options and opportunities discussed to set the framework for the alternatives review. Again, well done.

My primary high-level comment is that if the recovery of the East Fork Lewis River is going to be a serious effort, which I think it should be, then it needs to be process based, ambitious and needs to address both the reach level issues identified in the memo but also some of the wider watershed issues outside the scope of your analysis.

There are ways to accomplish restoration objectives that are not process based, but I believe, and the scientific literature strongly supports, that to achieve sustainable results then natural processes must be engaged to accomplish the objectives. This is particularly true when factoring in climate change. To this end I am not supportive of strategies that, for example, use pipe infrastructure to capture and deliver cold water to support salmonid habitat. In my experience, these approaches often fail and almost certainly require regular and costly maintenance while providing a more limited level of functionality.

If we are going to recover the EFLR to a functional condition then I think it is worth the investment to do it comprehensively. We should be ambitious. It might be the costliest option up front to move infrastructure, fill mine pits, address flow, install complexity, and complete revegetation on the whole reach, but this is the option that will return the best, most certain results, and highest return for the dollar over the long term. We should not let initial costs limit our thinking or the preferred option. If the EFLR is worth restoring, and I think it is, then the funding will be there. Partial measures are what has gotten the river to where it is today, and won't help get the river back to where I think the whole group hopes it can be again. At least in this, you should have group unanimity.

I also feel that the Achilles heel of this effort is the surrounding watershed (Mill Creek, perhaps as a particular example) and water withdrawal that has significant and fundamental impacts on late season flow. On this second point, I am not sure that project objectives can be fully realized unless this is addressed in some manner.

I am strongly supportive of Alternative 3 - full floodplain and pits re-grade. I think this is the approach that will be most successful in achieving the vision for the EFLR. It also works with Alternative 4, 5 and 6 project elements, which can be phased in as complementary projects as funding is available (not sure what the right order is, but I think moving from upstream to downstream makes sense). Relocating the channel to the pre-1996 location (Alternative 2) is a bad idea unless it is supported geomorphically. There is a reason the channel avulsed, and simply moving the channel back likely won't work. Alternative 1 is always an option - the river will recover over time (barring additional insults to its function) but I believe there is need for proactive action if the fish populations are to sustain in the watershed.

Some additional, more specific, comments include:

- Defining the CMZ is a critical step. I think it should include the Daybreak pits (currently being protected in the HCP restoration plan), but only if the hydrology and geomorphic processes can support this approach. I don't think it is a good idea to have a portion of the floodplain isolated, but the significant alterations to the historic CMZ and hydrology may preclude including this area into a long-term design given the HCP and likely landowner willingness to open that process up.
- Is your reference to 50% vegetation cover an objective for the stream channel or the floodplain as a whole? Seems low if for the floodplain.
- The comment about reducing costs by allowing vegetation to recover naturally before planting is a risky one in that area - the weed presence of particularly difficult species is high (knotweed, thistle, knapweed, blackberry, canarygrass, butterfly bush, others). It may cost more in the long run if you let the invasion happen, then implement control, then plant and then continue maintenance control for a number of years.
- I really like the alternatives analysis summary table. It might be worth adding a column to evaluate the self-sustaining nature of the approach and/or its resilience to changing conditions (climate change, flow, etc).

Thanks Paul. Great tech memo and process. Feel free to call with any questions. Ian

Ian Sinks | Stewardship Director

he | him | his

Columbia Land Trust

850 Officers' Row | Vancouver, WA 98661 Direct: (360) 213-1206 | Cell: (503) 799-9505

isinks@columbialandtrust.org

Bruce Wiseman
Landowner

Good morning, Paul,

Thanks for your note/reminder. I had looked through the July info when I received it and then promptly filed it away and had forgotten you were looking for feedback!

Most, if not all, of my remarks will be directed to the areas immediately upstream of the Ridgefield Pits, as that's where our property is located and naturally what I'm most familiar with.

This property has been in our family since 1963 when my folks purchased 130 acres along the E. Fork. After my father died in 1979, I was fortunate to have the opportunity to move back into the county in 1982, and I managed the Ridgefield National Wildlife Refuge complex until I retired in 12/1997. When my family and I moved into my folk's home we also began farming Christmas trees which we continue to do today.

My father had a long 34-year career with the same US Fish and Wildlife Service as I worked for and this farm was also his dream. He worked closely with different agencies in 'managing' the river during 1963-1979, including mining rock, under permit, in the flood plain along our property. I have a very large file of his that documents meetings, phone calls, etc, during those years, documenting the evolution of differing philosophies on how best to 'manage' the river. The last actual mining that was completed under his permit appears to be in 1971 or 72.

From 1972-1996, as old photos document, a six or seven-acre pond remained from remnants of the gravel operation on our property. In February of 1996 (not 1995 as I believe your document states), the dike protecting the pond was over-topped, swiftly destroying and filling it with gravels/sediments. I was standing on the dike, filming its demise that evening with an old 8-track camera. (I might add also, that the Ridgefield Refuges also sustained millions of dollars of damage during that flood.) During this 150-year flood event (on the E. Fork) the old river channel had aggraded to the extent that the new channel nearly dried it up. Keep this in mind when I visit about reconnecting with historical channels.

For lack of time, I'm only going to hit the high points of what I consider as pertinent to the properties from our property upstream to the Daybreak County maintenance yard.

Lack of redds/egg burial is a huge problem below our property. This is directly in response to the huge erosion problems along the south bank of the river along not only our property but

also along the high back opposite the county maintenance yard, immediately upstream. You may or may not be aware that in approximately 1966 Clark County constructed a dike that completely destroyed what was then the main channel of the river, moving the entire river into a less-used side channel (that became the main channel). The dike provided protection to their maintenance yard. In so doing, however, it diverted the full force of the river against the 100-foot cliff on the opposite (south) side of the river. For nearly 60 years that bluff has been depositing huge sediment loads into the river, with resultant consequences. Working with the county while trying to put a plan together for protecting our property, post 1996, the County did remove their dike, but that original channel was never restored. I believe part of doing so is noted in one of your Alternatives.

Subsequent to the '96 flood, high flows (and floods) continued to erode further south along out property, and finally reached (1999) the toe of our high bluff where it has, and continues to, also dump huge loads of sediments into the river. During one such flood event in 1999, there was a 'slump', and uphill movement, setting off what has been determined to be an old historical landslide area. This slide actually made its way to the top of our cliff at one of my neighbor's yards! Numerous slumps continue as the toe of the cliff erodes.

It was subsequent to that slide that I personally began to solicit help to address this serious erosion problem, but also the threat to our properties/homes. There was not one County, State or Federal agency that would lend a hand to even begin looking at the problem/solution. Fish First stepped up and during the next 7-8 years, 'we' worked trying to find a solution and funding to address 'our' problem. I personally was able to cobble together nearly \$600,000 and it was only through some political persuasion that permits were finally received to allow the construction - but of only 50% of our designed project. The critical upper 50% of the project that would have been completed, out of the river, was not approved by the permitting agencies. It was actually like they wanted to project to fail. Unfortunately, the river did exactly as we predicted pre-construction; a flood event avulsed across the upper proposed project area, eroding tons of gravels downstream onto our lower project, partially destroying a lower constructed structure. The upper portion of the project actually caught stream gravels and in so doing moved the river further away from our high bluff - but it buried the structures, destroying the fish/wildlife enhancements that had been designed into the project. Even though our permit allowed for 'maintenance' of the project, post construction, once again the permitting agencies denied our requests.

So much for background/history.

Point being, short of drying up/diverting the river, working on these two huge eroding cliffs and reducing the severe erosion from them is nearly impossible, but critical to accomplish. The only way to address this then is to open up old historical channels on the north side of the river to reduce flows against the bluffs. Your alternatives address doing this but there are additional channels that are not identified, both adjacent our property but also below the county's maintenance yard. Opening historic channels will meet/address many of your goals. Many of these channels already have adequate buffer zones, with trees and understory vegetation that would eliminate plantings; there would be

immediate (shade) decreased critical water temperatures when the river is partially diverted/high flows. These projects can be accomplished out of the river under dry conditions, will therefore be much less expensive than working in the river, and permitting 'should' also be easier?

There's been a wealth of documentation on the East Fork. I don't know if you've seen an evaluation prepared by Dr. Frank Reckendorf in 2010, but you might want to read it for a little more recent history. It's titled; East Fork Lewis River (RM13 to RM6) Including West Daybreak Park Project Reach.

Don't hesitate to call if you've got questions. Like I said, my comments are very local, along our stretch of the river. At this time, in the scheme of things and knowing what we had to go through trying to get permits 10-12 years ago, I don't see anything being allowed in the river that would address the severe sediment loading occurring from these two high cliff areas.

There is just no access from the south. Therefore, opening up the historical channels across (north) are solutions that should seriously be considered. Getting at least the high flows/flood events away from both cliffs would accomplish many of your stated goals for this once identified 'Blue Ribbon' river. (I've got a picture of my father holding up a 25 # steelhead that he caught right below our house!)

Regards,

Bruce Wiseman
The Tree Wisemans
360-600-5062

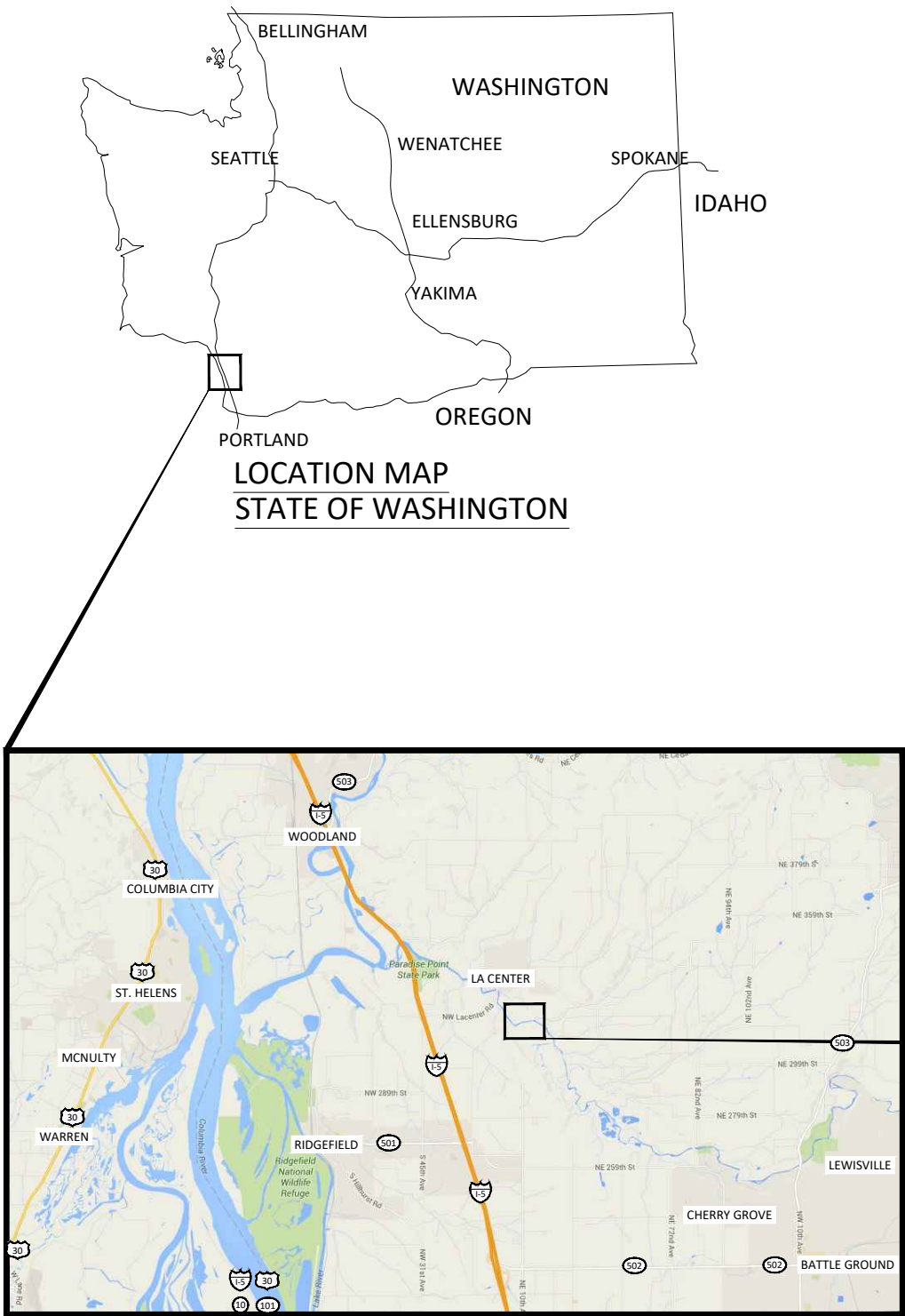
H. Preliminary Design Drawings

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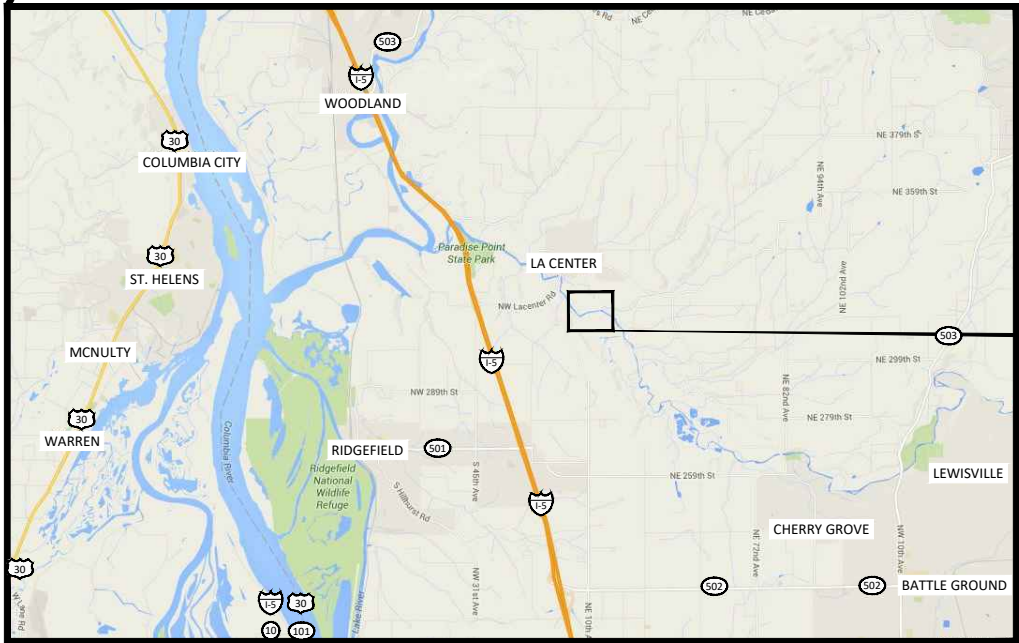
Lower East Fork Lewis River

Ridgefield Pits Restoration Preliminary Design

June 2021



LOCATION MAP
STATE OF WASHINGTON



VICINITY MAP
NOT TO SCALE



SITE MAP
NOT TO SCALE

SHEET LIST

- 1 - COVER, LOCATION, AND SHEET LIST
- 2 - GENERAL NOTES
- 3 - EROSION CONTROL NOTES
- 4 - EROSION CONTROL
- 5 - EXISTING CONDITIONS
- 6 - PROPOSED CONDITIONS OVERVIEW, ACCESS & STAGING
- 7 - PRELIMINARY GRADING PLAN - RIDGEFIELD PITS
- 8 - PRELIMINARY GRADING PROFILES - RIDGEFIELD PITS
- 9 - PROPOSED CONDITIONS - RIDGEFIELD PITS
- 10 - PROPOSED CONDITIONS - LOWER SIDE CHANNEL
- 11 - PROPOSED CONDITIONS - MILL AND MANLEY CONFLUENCE AREA
- 12 - TYPICAL CROSS SECTION
- 13 - TYPICAL DETAILS
- 14 - TYPICAL DETAILS
- 15 - TYPICAL DETAILS
- 16 - PLANTING PLAN

COORDINATES:
LATITUDE 45.82389
LONGITUDE -122.62766

SECTION 28, TOWNSHIP 4N, RANGE 2E

WATERBODY: EF LEWIS RIVER
TRIBUTARY OF: LEWIS RIVER

THE CONTRACTOR SHALL ATTEND A PRE-CONSTRUCTION MEETING WITH OWNER AND OWNER'S REPRESENTATIVE PRIOR TO MOBILIZING TO SITE AND BEGINNING CONSTRUCTION.

ALL WORK SHALL CONFORM TO THE CURRENT EDITIONS OF STANDARD PLANS AND SPECIFICATIONS OF THE WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (WSDOT), AND LOCAL STANDARDS UNLESS INDICATED OTHERWISE BY THE CONTRACT DOCUMENTS. IN CASE OF A CONFLICT BETWEEN THE REGULATORY STANDARDS OR SPECIFICATIONS, THE MORE STRINGENT WILL PREVAIL.

ALL WORK SHALL BE IN COMPLIANCE WITH REQUIREMENTS STATED IN PERMITS ISSUED FOR THIS PROJECT.

WDFW IN-WATER WORK PERIODS

WORK SHALL OCCUR DURING THE PERMITTED IN-WATER WORK PERIOD STATED IN THE HYDRAULIC PROJECT APPROVAL.

EXISTING DATA

TOPOGRAPHIC DATA WAS COLLECTED BY INTER-FLUVE USING RTK AND TOTAL STATION IN OCTOBER - DECEMBER 2016 AND OCTOBER 2019.

HORIZONTAL DATUM: STATE PLANE NAD83 WASHINGTON SOUTH
VERTICAL DATUM: NAVD88

HYDROLOGY INFORMATION FROM USGS + DOE STREAM GAGES.

HYDRAULIC MODELING BY LOWER COLUMBIA ESTUARY PARTNERSHIP USING TUFLOW.

GIS DATA INCLUDING: AERIAL PHOTOGRAPHY, LIDAR, FISH USE, SURFACE SOILS INFORMATION, LAND OWNERSHIP, AND TRANSPORTATION ROUTES PROVIDED BY VARIOUS AGENCIES.

SOILS

SUBSURFACE SOILS ARE EXPECTED TO BE FINES, SANDS, GRAVELS AND COBBLES. CONTRACTOR SHALL CONDUCT OWN INVESTIGATIONS IF ADDITIONAL DATA IS REQUIRED AT NO ADDITIONAL COST.

MAPPED SOILS IN THE PROJECT AREA ARE INCLUDED IN THE FOLLOWING TABLE. SOILS DATA IS FROM THE USDA - NATURAL RESOURCES CONSERVATION SERVICE, WEB SOIL SURVEY MAPPER, ACCESSED JUNE 2021.

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Rc	Riverwash, cobbly	90.5	25%
W	Water	88.3	24%
WgB	Washougal gravelly loam, 0 to 8 percent slopes	69.4	19%
PuA	Puyallup fine sandy loam, 0 to 3 percent slopes	59.3	16%
HoG	Hillsboro silt loam, 30 to 65 percent slopes	21.5	6%
WaA	Washougal loam, 0 to 3 percent slopes	13.8	4%
WhF	Washougal stony loam, 30 to 60 percent slopes	10.4	3%
PhB	Pilchuck fine sand, 0 to 8 percent slopes	6.9	2%

UTILITIES

THE CONTRACTOR SHALL BE SOLELY RESPONSIBLE FOR HAVING UTILITIES LOCATED PRIOR TO CONSTRUCTION ACTIVITIES.

THE CONTRACTOR SHALL CALL (800-424-5555) FOR UTILITY LOCATE PRIOR TO CONSTRUCTION

THE CONTRACTOR SHALL IMMEDIATELY CONTACT THE EFFECTED UTILITY SERVICE TO REPORT ANY DAMAGED OR DESTROYED UTILITIES.

THE CONTRACTOR SHALL PROVIDE EQUIPMENT AND LABOR TO AID THE EFFECTED UTILITY SERVICE IN REPAIRING DAMAGED OR DESTROYED UTILITIES AT NO ADDITIONAL COST.

				GS DRAWN	GJ, MR DESIGNED	-- CHECKED	RIDGEFIELD PITS RESTORATION PRELIMINARY DESIGN LOWER EAST FORK LEWIS RIVER	 501 Portway Avenue, Suite 101 Hood River, OR 97031 541.386.9003 www.interfluve.com	GENERAL NOTES	SHEET
				----	5/7/21					2 of 16
				APPROVED	DATE	PROJECT				
NO.	BY	DATE	REVISION DESCRIPTION							

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CONSTRUCTION STAKING

CONTRACTOR WILL PROVIDE STAKING OF PROJECT LIMITS, GRADE STAKES, AND ELEVATION CONTROL POINTS. SOME FIELD ADJUSTMENTS TO THE LINES AND GRADES ARE TO BE EXPECTED.

CONTRACTOR SHALL MEET WITH THE OWNER AND OWNER'S REPRESENTATIVE TO DEFINE AND MARK LIMITS OF DISTURBANCE PRIOR TO MOBILIZATION OF EQUIPMENT OR MATERIALS ONTO THE SITE.

THE CONTRACTOR SHALL REPLACE DAMAGED OR DESTROYED CONSTRUCTION STAKES AT NO ADDITIONAL COST.

CONSTRUCTION MATERIALS

ALL MATERIALS QUANTITIES ARE BASED ON IN-PLACE CONDITION DETERMINED BY A PRE-PROJECT CONDITION SURVEY COMPARED AGAINST A PROJECT CONDITION SURVEY

CONTRACTOR SHALL ALLOW FOR EXPANSION OF EXCAVATED MATERIAL AND COMPACTION OF PLACED MATERIAL AT NO ADDITIONAL MEASURE OR COST. MEASUREMENT AND PAYMENT SHALL NOT BE BASED ON WEIGHT TICKETS OR TRUCK MEASURE WITHOUT PRIOR WRITTEN APPROVAL.

LOCATION, ALIGNMENT, AND ELEVATION OF LOGS AND LOGS WITH ROOT WADS ARE SUBJECT TO ADJUSTMENT BASED ON FIELD CONDITIONS, AND MATERIAL SIZE.

ANY EXCESS MATERIAL SHALL BE STOCKPILED NEATLY IN AN APPROVED LOCATION OF THE STOCKPILE AND STAGING AREA. AT COMPLETION OF WORK, THE MATERIAL SHALL BECOME THE PROPERTY OF THE CONTRACTOR AND SHALL BE REMOVED FROM THE SITE FOR LEGAL DISPOSAL.

CONSTRUCTION ACCESS/TRAFFIC CONTROL

CONTRACTOR SHALL SUBMIT AN ACCESS, STAGING, AND STOCKPILE PLAN TO THE OWNER'S REPRESENTATIVE FOR APPROVAL PRIOR TO MOBILIZATION.

PUBLIC ACCESS TO/ALONG ROADWAYS SHALL BE MAINTAINED AT ALL TIMES.

THE CONTRACTOR IS SOLELY RESPONSIBLE FOR OBTAINING ANY REQUIRED TRAFFIC CONTROL OR ACCESS PERMITS.

THE CONTRACTOR IS SOLELY RESPONSIBLE FOR PROVIDING ANY REQUIRED TRAFFIC CONTROL INCLUDING, BUT NOT LIMITED TO, SIGNAGE AND FLAGGERS.

ALL SAPLINGS AND TREES TO BE TRANSPLANTED OR REMOVED SHALL BE CLEARLY MARKED AND APPROVED BY THE OWNER AND OWNER'S REPRESENTATIVE.

ALL EQUIPMENT, MATERIALS AND PERSONNEL SHALL REMAIN WITHIN THE LIMITS OF DISTURBANCE.

THE CONTRACTOR SHALL KEEP THE WORK AREAS IN NEAT CONDITION, FREE OF DEBRIS AND LITTER FOR THE DURATION OF THE PROJECT.

CONTRACTOR SHALL IMPLEMENT MEASURES TO CONTROL AND MINIMIZE WIND BLOWN DUST FROM THE SITE.

ALL DISTURBED AREAS INCLUDING ROADS, DRIVEWAYS AND ACCESS ROUTES SHALL BE RESTORED TO ORIGINAL CONDITION OR BETTER AND RE-VEGETATED PER PLANS.

ALL DISTURBED AREAS OUTSIDE THE LIMITS OF DISTURBANCE SHALL BE RESTORED TO ORIGINAL CONDITION OR BETTER AT NO ADDITIONAL COST.

ANY FENCES REMOVED FOR ACCESS OR CONSTRUCTION SHALL BE REPLACED BY THE CONTRACTOR AT NO EXPENSE TO THE OWNER.

STAGING AND STOCKPILE AREAS

STAGING AND STOCKPILE AREAS WILL BE FLAGGED BY THE OWNER.STAGING AREAS USED FOR CONSTRUCTION EQUIPMENT STORAGE, VEHICLE STORAGE, FUELING, SERVICING, AND HAZARDOUS MATERIAL STORAGE SHALL BE 150 FEET OR MORE FROM ANY NATURAL WATER BODY OR WETLAND. NATURAL MATERIALS MAY BE STOCKPILED NEAR INSTALLATION AREAS.

EROSION/SEDIMENTATION CONTROL (ESC) PLAN

THE EROSION AND SEDIMENT CONTROL (ESC) PLAN PROVIDED IS FOR INFORMATIONAL PURPOSES ONLY, THE CONTRACTOR SHALL BE SOLELY RESPONSIBLE FOR PROVIDING EROSION CONTROL MEASURES TO COMPLY WITH APPLICABLE REGULATIONS.

THE RECOMMENDATIONS FOR AN ESC PLAN INCLUDED HEREIN WILL PROVIDE A GUIDELINE FOR THE CONTRACTOR TO DEVELOP AND IMPLEMENT AN ESC PLAN.

- A. THE IMPLEMENTATION OF AN ESC PLAN AND THE CONSTRUCTION, MAINTENANCE, REPLACEMENT, AND UPGRADING OF THESE ESC FACILITIES IS THE RESPONSIBILITY OF THE CONTRACTOR UNTIL ALL CONSTRUCTION IS COMPLETED AND APPROVED AND VEGETATION/LANDSCAPING IS ESTABLISHED.
- B. THE BOUNDARIES OF THE CLEARING LIMITS SHOWN ON THIS PLAN SHALL BE CLEARLY FLAGGED IN THE FIELD PRIOR TO CONSTRUCTION. DURING THE CONSTRUCTION PERIOD, NO DISTURBANCE BEYOND THE FLAGGED CLEARING LIMITS SHALL BE PERMITTED. THE FLAGGING SHALL BE MAINTAINED BY THE CONTRACTOR FOR THE DURATION OF CONSTRUCTION.
- C. ESC FACILITIES AS APPROXIMATELY SHOWN ON THIS PLAN ARE TO BE CONSTRUCTED PRIOR TO CLEARING AND GRADING ACTIVITIES, AND IN SUCH A MANNER AS TO ENSURE THAT SEDIMENT AND SEDIMENT-LADEN WATER DO NOT ENTER SURFACE WATERS, THE DRAINAGE SYSTEM, OR VIOLATE APPLICABLE WATER STANDARDS.
- D. THE ESC FACILITIES SHOWN ON THIS PLAN ARE THE MINIMUM REQUIREMENTS FOR ANTICIPATED SITE CONDITIONS. DURING THE CONSTRUCTION PERIOD, THESE ESC FACILITIES SHALL BE UPGRADED AS NEEDED AT NO ADDITIONAL COST FOR UNEXPECTED STORM EVENTS AND TO ENSURE THAT SEDIMENT AND SEDIMENT-LADEN WATER DO NOT LEAVE THE SITE.
- E. THE ESC FACILITIES SHALL BE INSPECTED DAILY BY THE CONTRACTOR AND MAINTAINED AS NECESSARY TO ENSURE THEIR CONTINUED FUNCTIONING.
- F. THE ESC FACILITIES ON INACTIVE SITES SHALL BE INSPECTED AND MAINTAINED A MINIMUM OF ONCE A WEEK OR WITHIN THE 24 HOURS FOLLOWING A STORM EVENT.
- G. STABILIZED CONSTRUCTION ENTRANCES AND ADDITIONAL MEASURES MAY BE REQUIRED AND SHALL BE MAINTAINED FOR THE DURATION OF THE PROJECT TO ENSURE ALL ACCESS ROADS ARE KEPT CLEAN AT NO ADDITIONAL COST.

INSPECTION AND MAINTENANCE

ALL ESC FACILITIES SHALL BE INSPECTED, MAINTAINED, AND REPAIRED AS NEEDED TO ASSURE CONTINUED PERFORMANCE OF THEIR INTENDED FUNCTION. ALL ESC FACILITIES SHALL BE INSPECTED DAILY AND WITHIN 24 HOURS AFTER ANY STORM EVENT GREATER THAN 0.5 INCHES OF RAIN PER 24 HOUR PERIOD AND AFTER EVENTS EXCEEDING 2 HOURS DURATION.

CONTRACTOR'S ESC RECORD

WEEKLY REPORTS SUMMARIZING THE SCOPE OF INSPECTIONS, THE PERSONNEL CONDUCTING THE INSPECTION, THE DATE(S) OF THE INSPECTION, MAJOR OBSERVATIONS RELATING TO THE IMPLEMENTATION OF THE CONTRACTOR'S EROSION AND SEDIMENT CONTROL PLAN, AND ACTIONS TAKEN AS A RESULT OF THESE INSPECTIONS SHALL BE PREPARED AND RETAINED ON SITE BY THE CONTRACTOR. IN ADDITION, A RECORD OF THE FOLLOWING DATES SHALL BE INCLUDED IN THE REPORTS:

- 1. WHEN MAJOR GRADING ACTIVITIES OCCUR.
- 2. DATES OF RAINFALL EVENTS EITHER EXCEEDING 2 HOURS DURATION OR MORE THAN 0.5 INCHES/24 HOURS.
- 3. WHEN CONSTRUCTION ACTIVITIES TEMPORARILY OR PERMANENTLY CEASE ON SITE, OR ON A PORTION OF THE SITE.
- 4. WHEN STABILIZATION MEASURES ARE INITIATED FOR PORTIONS OF THE SITE.
- 5. ESC RECORDS SHALL BE MADE AVAILABLE TO THE OWNER AND OWNER'S REPRESENTATIVE ON REQUEST AND SHALL BE PROVIDED FOR REVIEW AND APPROVAL PRIOR TO APPLICATION FOR PAYMENT.

STABILIZE SOILS AND PROTECT SLOPES

FROM MAY 1 THROUGH SEPTEMBER 30, ALL EXPOSED SOILS SHALL BE PROTECTED FROM EROSION BY MULCHING, HYDROSEED COVERING, OR OTHER APPROVED MEASURES WITHIN THREE DAYS OF GRADING. FROM OCTOBER 1 THROUGH APRIL 30, ALL EXPOSED SOILS MUST BE PROTECTED WITHIN 2 DAYS OF GRADING. SOILS SHALL BE STABILIZED BEFORE A WORK SHUTDOWN, HOLIDAY OR WEEKEND IF NEEDED BASED ON THE WEATHER FORECAST. SOIL STOCKPILINGS MUST BE STABILIZED AND PROTECTED WITH SEDIMENT TRAPPING MEASURES. HYDROSEED ALL DISTURBED AREAS AS SOON AS PRACTICAL NOT INDICATED IN THE CONTRACT DOCUMENTS FOR OTHER PERMANENT STABILIZATION MEASURES.

DESIGN, CONSTRUCT, AND PHASE CUT AND FILL SLOPES IN A MANNER THAT WILL MINIMIZE EROSION. REDUCE SLOPE VELOCITIES ON DISTURBED SLOPES BY PROVIDING TEMPORARY BARRIERS. STORMWATER FROM OFF SITE SHOULD BE HANDLED SEPARATELY FROM STORMWATER GENERATED ON SITE.

AFTER FINAL SITE STABILIZATION

ALL TEMPORARY EROSION AND SEDIMENTATION CONTROL MEASURES SHALL BE REMOVED WITHIN 30 DAYS AFTER FINAL SITE STABILIZATION IS ACHIEVED OR AFTER THE TEMPORARY BEST MANAGEMENT PRACTICES (BMPs) ARE NO LONGER NEEDED. TRAPPED SEDIMENT SHALL BE REMOVED FROM THE SITE OR INCORPORATED INTO FINISHED GRADING. DISTURBED SOIL AREAS RESULTING FROM REMOVAL SHALL BE PERMANENTLY STABILIZED

CONSTRUCTION DEWATERING

TEMPORARY COFFERDAMS SHALL BE USED TO ISOLATE IN-CHANNEL EXCAVATION AREAS FROM THE RIVER.

DEWATERING OF IN-CHANNEL WORK AREAS SHALL OCCUR CONCURRENT WITH FISH RESCUE. CONTRACTOR SHALL PROVIDE AMPLE TIME TO SCHEDULE FISH RESCUE. IF DIVERSION FAILS DUE TO CONTRACTOR NEGLIGENCE, FISH RESCUE SHALL BE REPEATED AT CONTRACTOR'S EXPENSE.

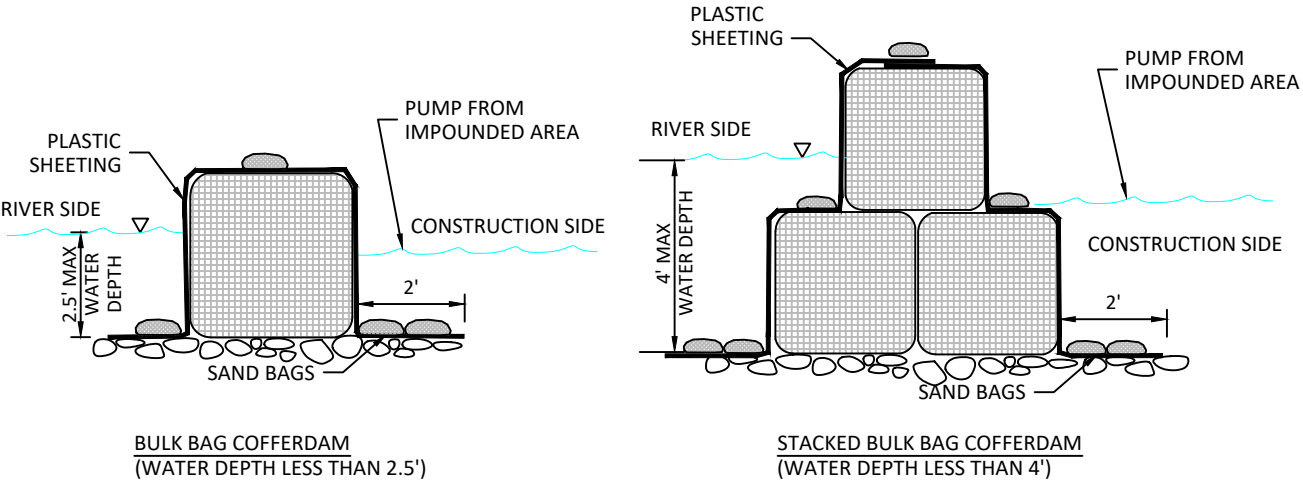
CONTRACTOR SHALL PERFORM CONSTRUCTION DEWATERING IN SUCH A MANNER AS TO AVOID THE RELEASE OF SEDIMENT-LADEN WATER TO SURFACE WATERS. SEDIMENT LADEN WATER MAY BE PUMPED TO AN UPLAND DISCHARGE LOCATION AND ALLOWED TO SHEET FLOW THROUGH EXISTING VEGETATION BEFORE INFILTRATING INTO THE GROUND. IF THIS METHOD IS NOT SUFFICIENT TO PREVENT RETURN OF TURBID WATER TO THE RIVER, A 'DIRT-BAG' OR SEDIMENT RETENTION STRUCTURE MAY BE REQUIRED AS NECESSARY TO COMPLY WITH LAWS AND PERMIT REQUIREMENTS AT NO ADDITIONAL COST TO THE OWNER.

DEWATERING, WHEN NECESSARY, WILL BE CONDUCTED OVER A SUFFICIENT PERIOD OF TIME TO ALLOW SPECIES TO NATURALLY MIGRATE OUT OF THE WORK AREA AND WILL BE LIMITED TO THE SHORTEST LINEAR EXTENT PRACTICABLE.

- A) DIVERSION AROUND THE CONSTRUCTION SITE MAY BE ACCOMPLISHED WITH A COFFERDAM AND A BY-PASS CULVERT OR PIPE, OR A LINED, NON-ERODIBLE DIVERSION DITCH. WHERE GRAVITY FEED IS NOT POSSIBLE, A PUMP MAY BE USED, BUT MUST BE OPERABLE IN SUCH A WAY AS TO AVOID REPETITIVE DEWATERING AND REWATERING OF THE SITE. IMPOUNDMENT BEHIND THE COFFERDAM MUST OCCUR SLOWLY THROUGH THE TRANSITION, WHILE CONSTANT FLOW IS DELIVERED TO THE DOWNSTREAM REACHES.
- B) ALL PUMPS WILL HAVE FISH SCREENS TO AVOID JUVENILE FISH IMPINGEMENT OR ENTRAINMENT, AND WILL BE OPERATED IN ACCORDANCE WITH NMFS'S CURRENT FISH SCREEN CRITERIA (NMFS 2014, OR MOST RECENT VERSION). IF THE PUMPING RATE EXCEEDS 3 CUBIC FEET PER SECOND (CFS), A NMFS HYDRO FISH PASSAGE REVIEW WILL BE NECESSARY.

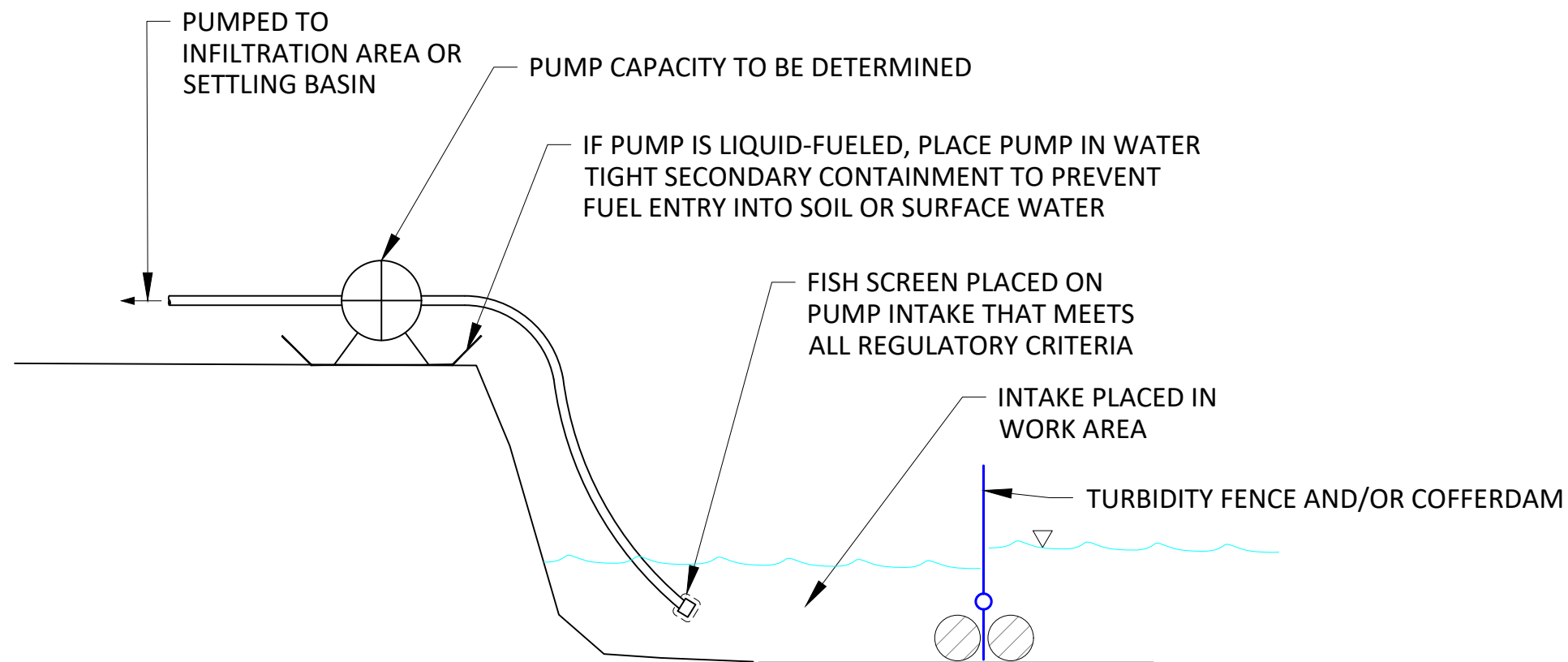
CONTRACTOR SHALL PROVIDE VISQUINE OR GEOTEXTILE LINER OR PLYWOOD OR METAL PLATING AS NECESSARY TO DISSIPATE PUMP DISCHARGE JET TO PREVENT EROSION.

OWNER'S REPRESENTATIVE SHALL APPROVE DEWATERING DISCHARGE LOCATION PRIOR TO IMPLEMENTATION.



BULK BAG NOTES:

- 1. BULK BAG COFFERDAM SHALL BE CONSTRUCTED OF SEVERAL UNITS OF BULK BAGS FILLED WITH WASHED SPAWNING GRAVEL, AND ABUTTED SIDE BY SIDE TO CREATE A ROW THAT SEPARATES THE CONSTRUCTION SITE FROM THE RIVER.
- 2. IF WATER DEPTH EXCEEDS 85% OF THE BULK BAG HEIGHT, AN ADDITIONAL TOP ROW OF BULK BAGS SHALL BE INSTALLED, SUPPORTED BY TWO BOTTOM ROWS OF BULK BAGS.
- 3. BULK BAG COFFERDAM SHALL BE SEALED BY COVERING THE COFFERDAM WITH PLASTIC SHEETING HELD IN PLACE BY SANDBAGS FILLED WITH PEA GRAVEL. PLACED IN ROWS ON TOP OF COFFERDAM, AND AT TOE OF COFFERDAM. THE PLASTIC SHEETING SHALL BE DRAPED ALONG THE CHANNEL BOTTOM ON BOTH SIDES OF THE COFFERDAM WITH OUTWARD EDGE OF SHEETING MINIMUM 2-FEET FROM TOE OF COFFERDAM. THE DRAPED PORTION OF PLASTIC SHEETING SHALL BE PINNED TO THE CHANNEL BED BY MINIMUM TWO ROWS OF STANDARD SANDBAGS.
- 4. IF POSSIBLE, THE ENDS OF THE COFFERDAM SHALL BE EXTENDED ONTO A DRY GRAVEL BAR. IF THE END MUST BE TERMINATED AT A WET RIVERBANK, THE COFFERDAM SHALL BE TIGHTLY SEALED TO THE GROUND BY PLASTIC SHEETING AND STANDARD SANDBAGS. MULTIPLE LAYERS OF SHEETING AND SANDBAGS MAY BE REQUIRED TO FORM A WATERTIGHT SEAL.
- 5. BULK BAGS SHALL BE WATERPROOF CUBE-SHAPED POLYPROPYLENE WOVEN FABRIC BAGS WITH FULLY OPEN TOP, FLAT BOTTOM, FOUR LOOPS, MINIMUM 2-TON WEIGHT CAPACITY, MINIMUM 5:1 SAFETY FACTOR.
- 6. PLASTIC SHEETING SHALL BE MINIMUM 6-MIL THICKNESS. ROLL LENGTH SHALL BE LONG ENOUGH TO ENSURE THAT ENTIRE LENGTH OF COFFERDAM WILL BE COVERED WITHOUT A SEAM. MINIMUM 12-FT WIDE ROLL SHALL BE USED FOR SINGLE LAYER BULK BAG COFFERDAM. TWO LENGTHS OF 12-FT WIDE ROLL SHALL BE USED FOR 2-LAYER STACKED BULK BAG COFFERDAM.
- 7. CONTRACTOR SHALL PROVIDE PUMPING SUFFICIENT TO LOWER WATER SURFACE IN THE IMPOUNDED AREA IN ORDER TO CAUSE ANY LEAKS UNDER THE COFFERDAM TO PASS WATER TOWARD THE WORK AREA INSTEAD OF FROM THE WORK AREA TO THE RIVER. DISCHARGE TURBID WATER TO UPLAND FLOODPLAIN.
- 8. BULK BAG COFFERDAM SHALL BE COMPLETELY REMOVED AFTER CONSTRUCTION IS COMPLETED AND TURBIDITY HAS BEEN REMOVED.
- 9. ALTERNATE COFFERDAM MATERIALS AND CONFIGURATIONS MAY BE ALLOWED BUT SHALL NOT BE IMPLEMENTED WITHOUT REVIEW AND APPROVAL BY THE OWNER. CONTRACTOR SHALL PROVIDE SHOP DRAWINGS AND/OR VENDOR CUT SHEETS FOR SUBSTITUTIONS.
- 10. IF NECESSARY, GAPS BETWEEN BULK BAGS SHALL BE FILLED WITH WASHED GRAVEL TO SEAL AND IMPROVE COFFER DAM. DISPOSAL OF ROCK WASH SHALL BE DETERMINED BY OWNER.

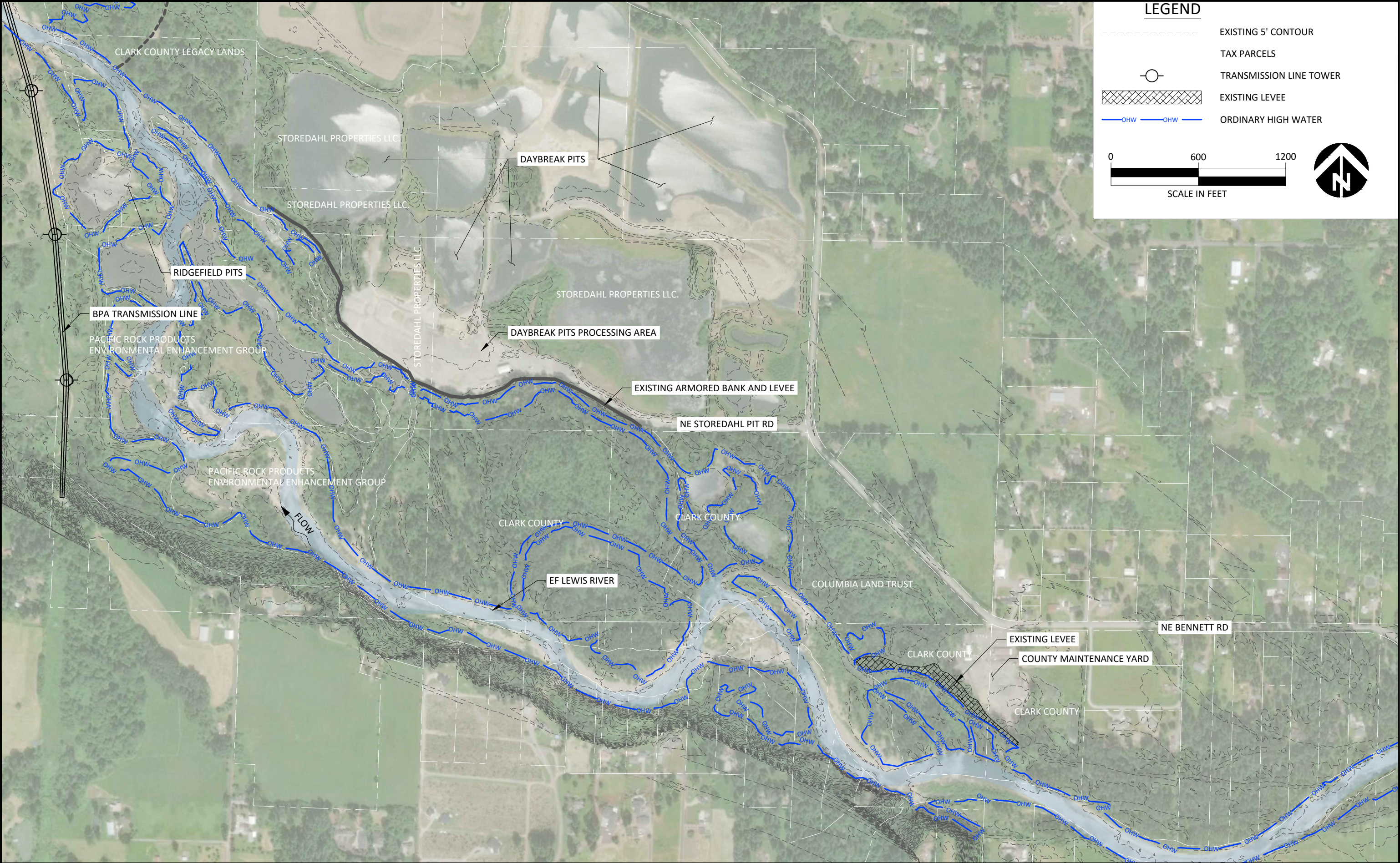


NOTES:

1. PREFERENCE IS TO LAND APPLY WITHOUT DIGGING A SETTLING BASIN. IF LAND APPLICATION SITE IS INADEQUATE TO PREVENT ENTRY OF TURBID WATER INTO STREAM, SETTLING BASIN SHALL BE CONSTRUCTED IN A PREVIOUSLY DISTURBED AREA.
2. SETTLING BASIN SHALL BE MONITORED FOR SILTATION AND REDUCTION IN INFILTRATION RATES WHILE IN USE.

TYPICAL PUMP DETAIL
NOT TO SCALE

				GS DRAWN	GJ, MR DESIGNED	-- CHECKED	RIDGEFIELD PITS RESTORATION PRELIMINARY DESIGN LOWER EAST FORK LEWIS RIVER	 501 Portway Avenue, Suite 101 Hood River, OR 97031 541.386.9003 www.interfluve.com	EROSION CONTROL	SHEET
						4 OF 16				
NO.	BY	DATE	REVISION DESCRIPTION	APPROVED	DATE	PROJECT				



NO.	BY	DATE	REVISION DESCRIPTION

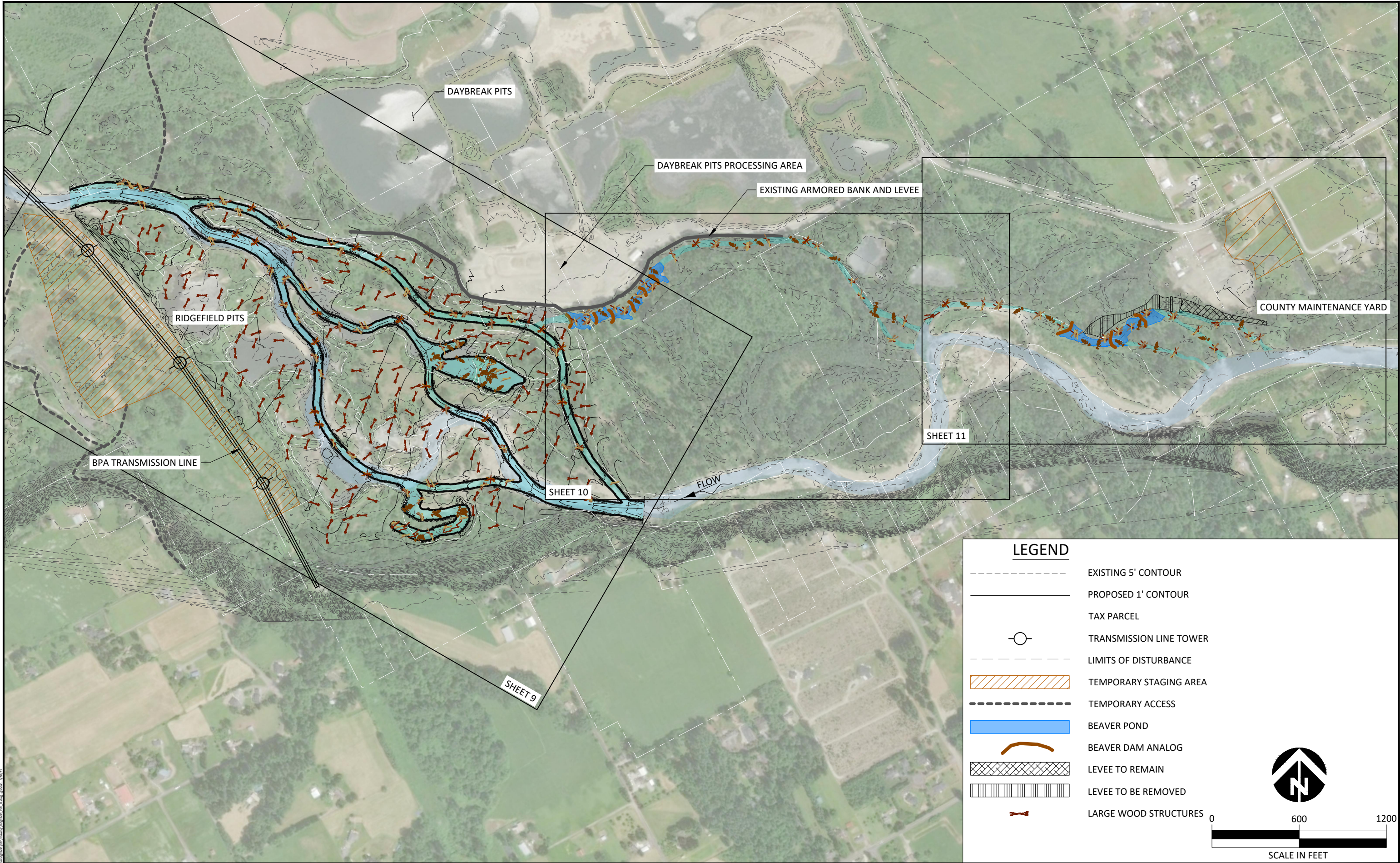
GS	GJ, MR	--
DRAWN	DESIGNED	CHECKED
----	5/7/21	
APPROVED	DATE	PROJECT

RIDGEFIELD PITS RESTORATION
PRELIMINARY DESIGN
LOWER EAST FORK LEWIS RIVER



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EXISTING CONDITIONS



NO.	BY	DATE	REVISION DESCRIPTION

GS	GJ, MR	--
DRAWN	DESIGNED	CHECKED
----	5/7/21	
APPROVED	DATE	PROJECT

RIDGEFIELD PITS RESTORATION
PRELIMINARY DESIGN
LOWER EAST FORK LEWIS RIVER

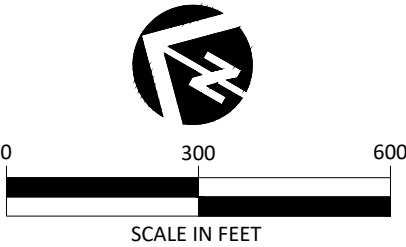


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PROPOSED CONDITIONS OVERVIEW,
ACCESS & STAGING

LEGEND

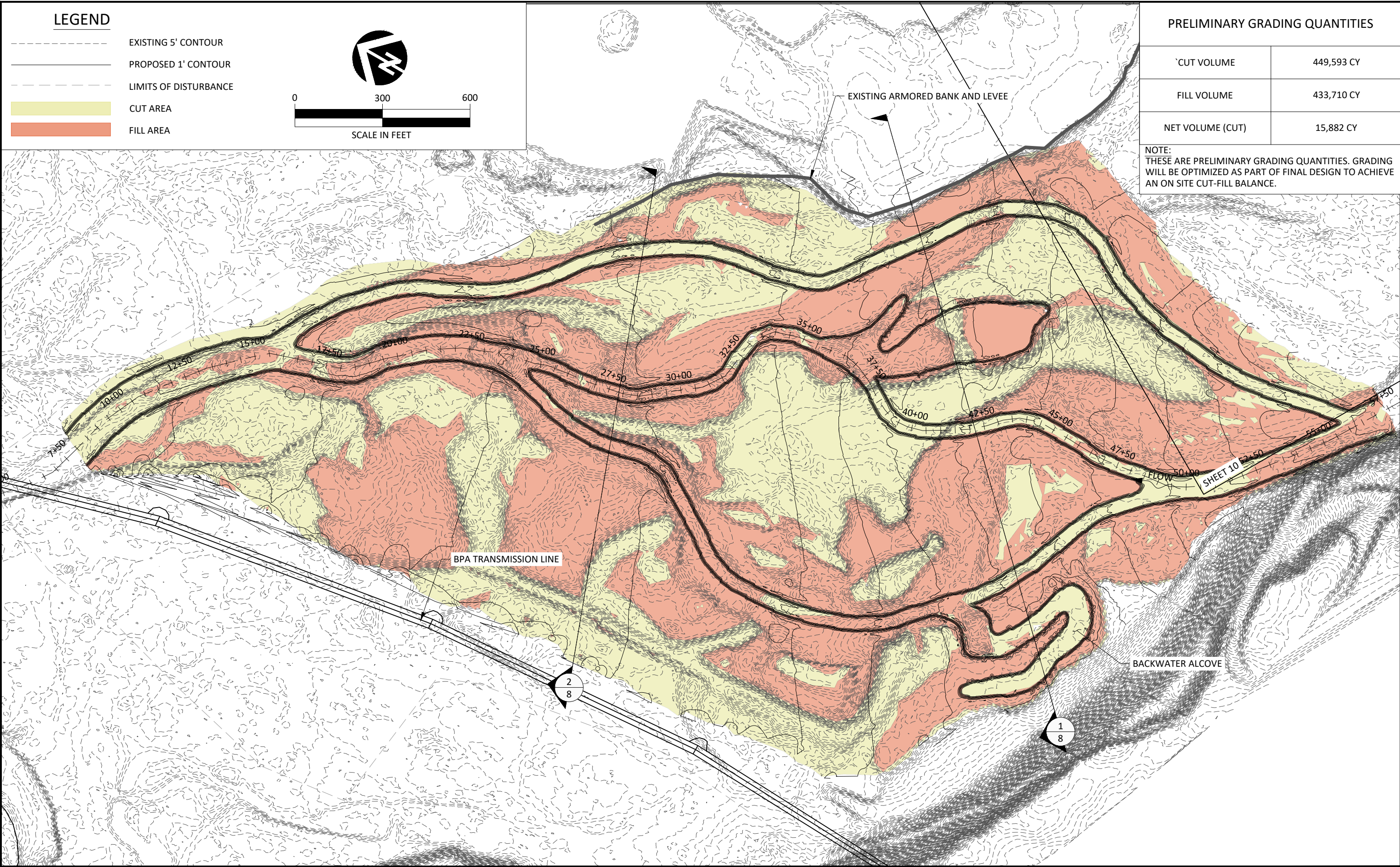
- EXISTING 5' CONTOUR
- PROPOSED 1' CONTOUR
- LIMITS OF DISTURBANCE
- CUT AREA
- FILL AREA



PRELIMINARY GRADING QUANTITIES

'CUT VOLUME	449,593 CY
FILL VOLUME	433,710 CY
NET VOLUME (CUT)	15,882 CY

NOTE:
THESE ARE PRELIMINARY GRADING QUANTITIES. GRADING
WILL BE OPTIMIZED AS PART OF FINAL DESIGN TO ACHIEVE
AN ON SITE CUT-FILL BALANCE.



NO.	BY	DATE	REVISION DESCRIPTION

GS DRAWN	GJ, MR DESIGNED	-- CHECKED
----	5/7/21	PROJECT
APPROVED	DATE	

RIDGEFIELD PITS RESTORATION
PRELIMINARY DESIGN
LOWER EAST FORK LEWIS RIVER

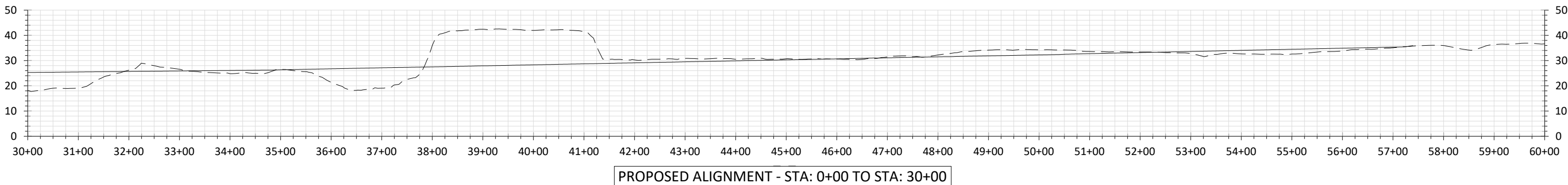
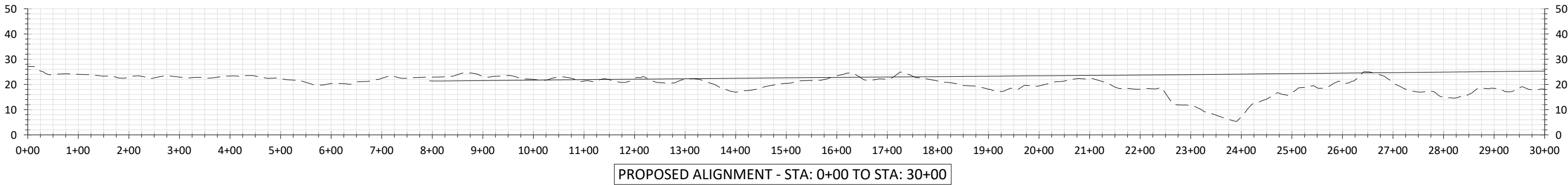


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PRELIMINARY GRADING PLAN -
RIDGEFIELD PITS

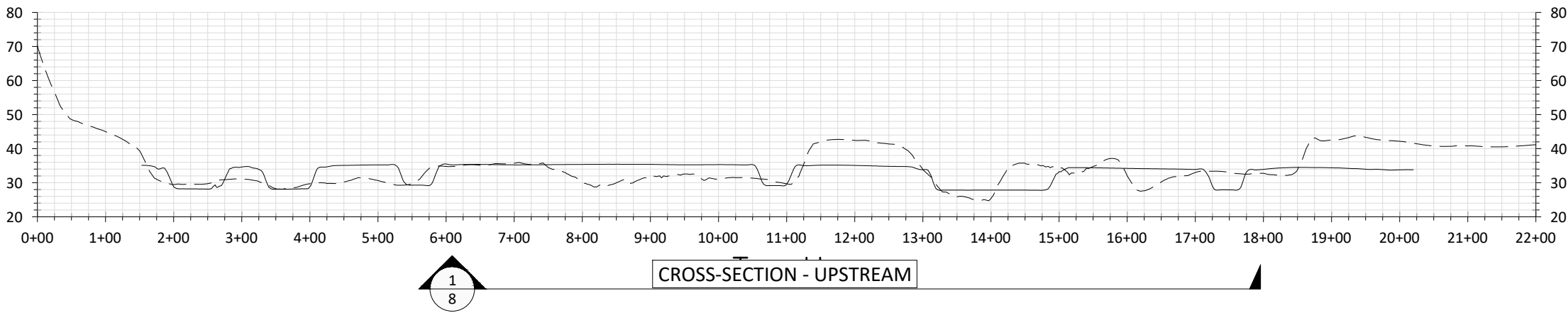
GRADING PROFILES

NOTE: ADDITIONAL LONGITUDINAL PROFILE DETAILS, INCLUDING POOLS, RIFFLES, AND CHANNEL BED COMPLEXITY WILL BE DEVELOPED IN FINAL DESIGN STAGE.



GRADING SECTIONS

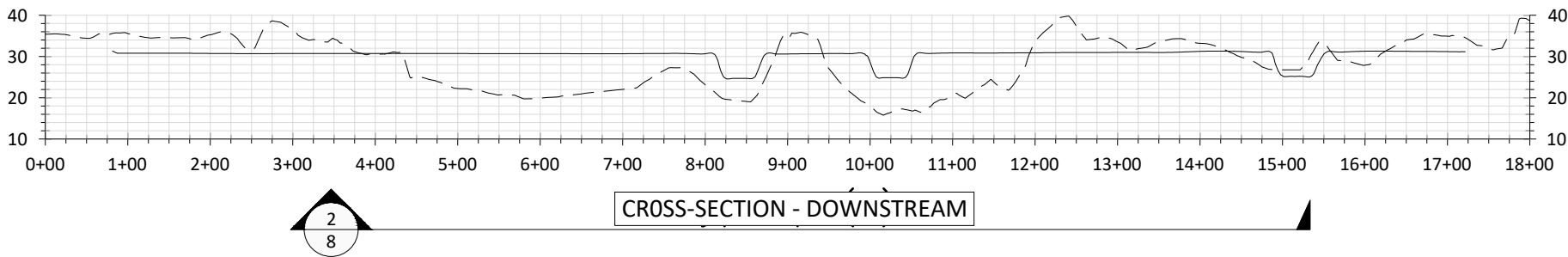
NOTE: ADDITIONAL LONGITUDINAL PROFILE DETAILS, INCLUDING POOLS, RIFFLES, AND CHANNEL BED COMPLEXITY WILL BE DEVELOPED IN FINAL DESIGN STAGE.



LEGEND

--- EXISTING GRADE

— PROPOSED GRADE



NO.	BY	DATE	REVISION DESCRIPTION

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DRAWN	DESIGNED	CHECKED
----	5/7/21	
APPROVED	DATE	PROJECT

RIDGEFIELD PITS RESTORATION
PRELIMINARY DESIGN
LOWER EAST FORK LEWIS RIVER

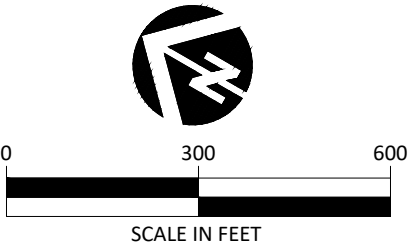


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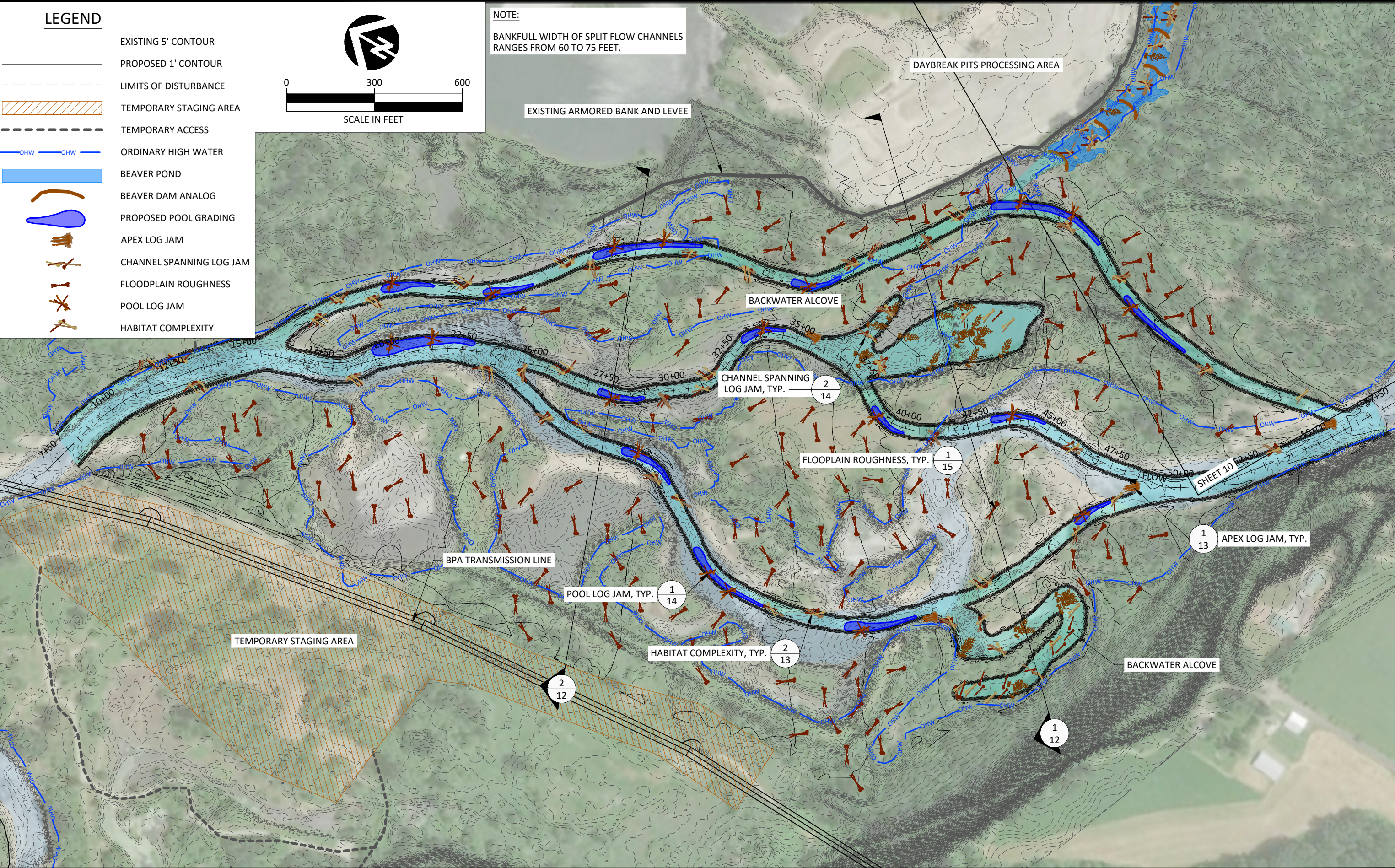
PRELIMINARY GRADING PROFILES -
RIDGEFIELD PITS

LEGEND

- EXISTING 5' CONTOUR
- PROPOSED 1' CONTOUR
- LIMITS OF DISTURBANCE
- TEMPORARY STAGING AREA
- TEMPORARY ACCESS
- ORDINARY HIGH WATER
- BEAVER POND
- BEAVER DAM ANALOG
- PROPOSED POOL GRADING
- APEX LOG JAM
- CHANNEL SPANNING LOG JAM
- FLOODPLAIN ROUGHNESS
- POOL LOG JAM
- HABITAT COMPLEXITY



NOTE:
BANKFULL WIDTH OF SPLIT FLOW CHANNELS
RANGES FROM 60 TO 75 FEET.



NO.	BY	DATE	REVISION DESCRIPTION

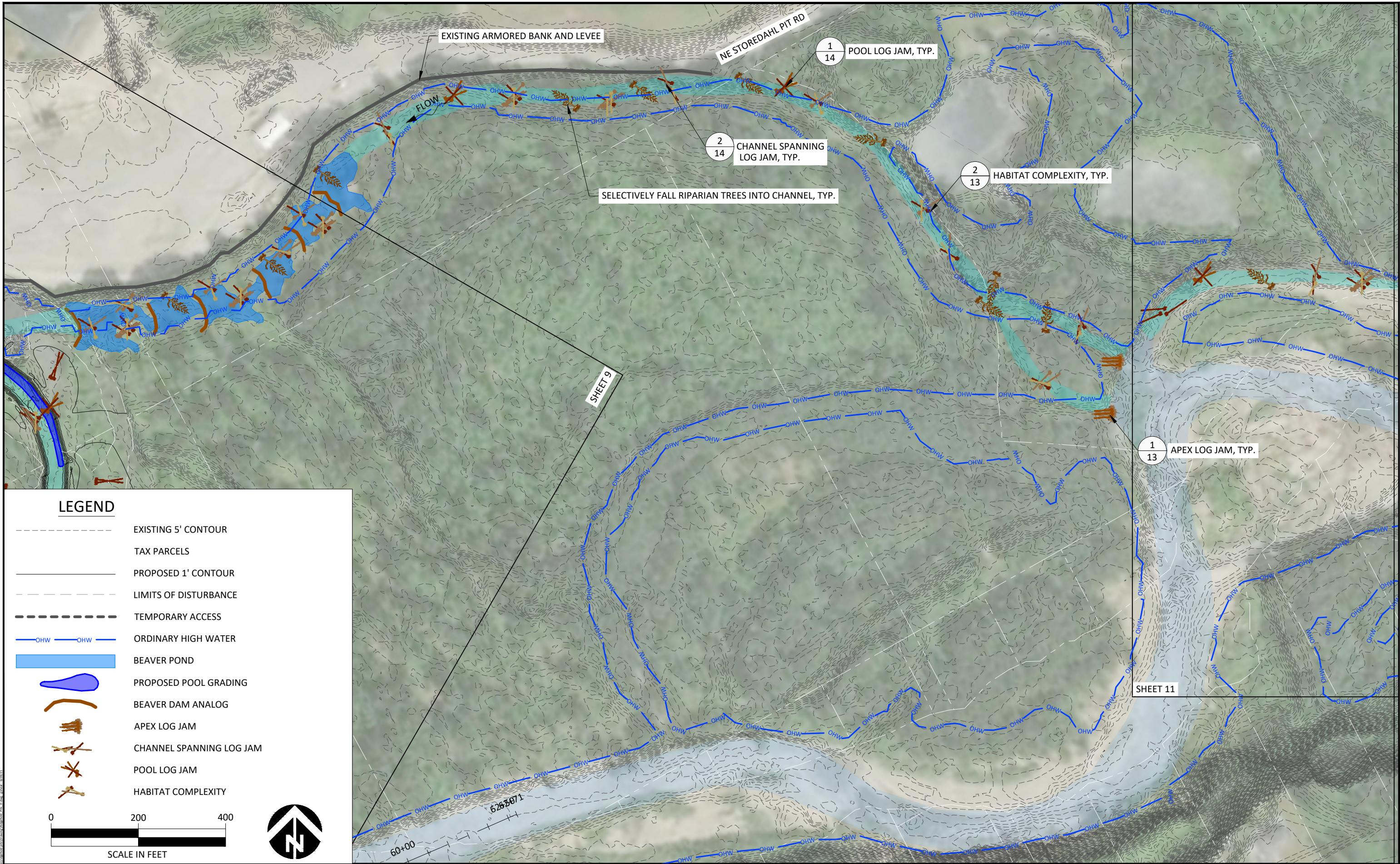
GS DRAWN	GJ, MR DESIGNED	-- CHECKED
----	5/7/21	PROJECT
APPROVED	DATE	

RIDGEFIELD PITS RESTORATION
PRELIMINARY DESIGN
LOWER EAST FORK LEWIS RIVER



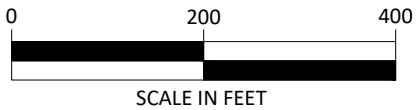
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PROPOSED CONDITIONS -
RIDGEFIELD PITS



LEGEND

- EXISTING 5' CONTOUR
- TAX PARCELS
- PROPOSED 1' CONTOUR
- LIMITS OF DISTURBANCE
- TEMPORARY ACCESS
- OHW OHW ORDINARY HIGH WATER
- BEAVER POND
- PROPOSED POOL GRADING
- BEAVER DAM ANALOG
- APEX LOG JAM
- CHANNEL SPANNING LOG JAM
- POOL LOG JAM
- HABITAT COMPLEXITY



NO.	BY	DATE	REVISION DESCRIPTION

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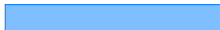
RIDGEFIELD PITS RESTORATION
PRELIMINARY DESIGN
LOWER EAST FORK LEWIS RIVER

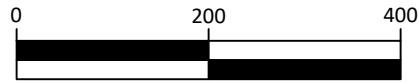


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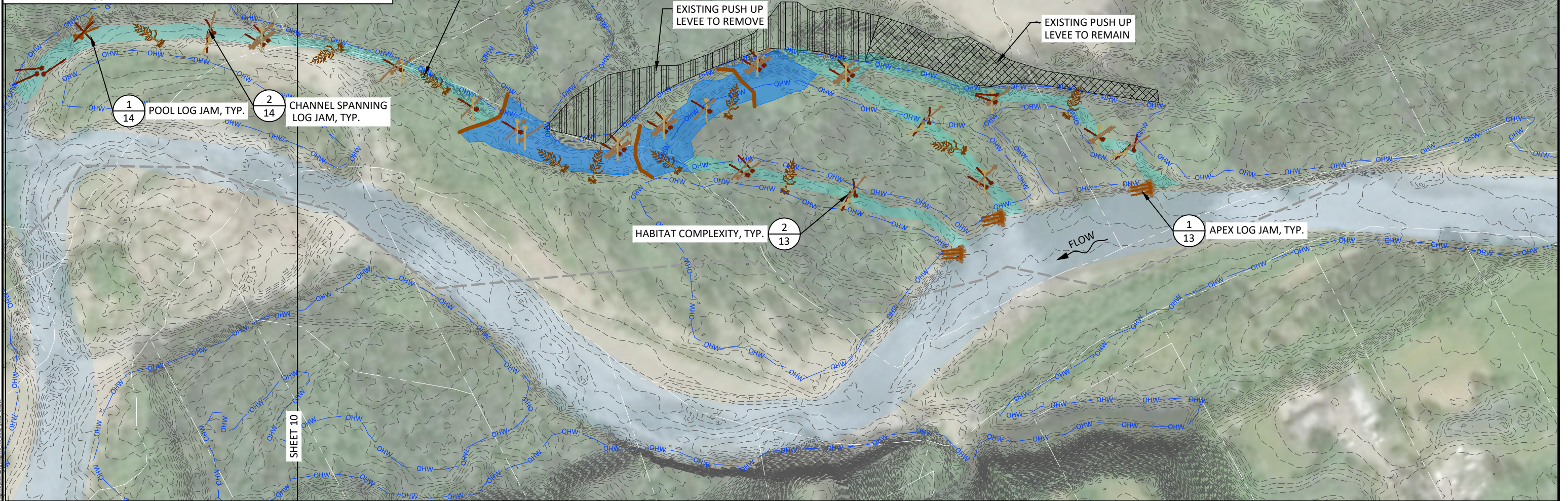
PROPOSED CONDITIONS - LOWER
SIDE CHANNEL

LEGEND

- | | |
|---|--------------------------|
|  | EXISTING 5' CONTOUR |
|  | TAX PARCELS |
|  | PROPOSED 1' CONTOUR |
|  | LIMITS OF DISTURBANCE |
|  | TEMPORARY STAGING AREA |
|  | TEMPORARY ACCESS |
|  | ORDINARY HIGH WATER |
|  | BEAVER POND |
|  | BEAVER DAM ANALOG |
|  | LEVEE TO REMAIN |
|  | LEVEE TO BE REMOVED |
|  | APEX LOG JAM |
|  | CHANNEL SPANNING LOG JAM |
|  | POOL LOG JAM |
| | HABITAT COMPLEXITY |



SCALE IN FEET



<u>GS</u>	<u>GJ, MR</u>	<u>--</u>
DRAWN	DESIGNED	CHECKED
<u>----</u>	<u>5/7/21</u>	
APPROVED	DATE	PROJECT

RIDGEFIELD PITS RESTORATION
PRELIMINARY DESIGN
LOWER EAST FORK LEWIS RIVER

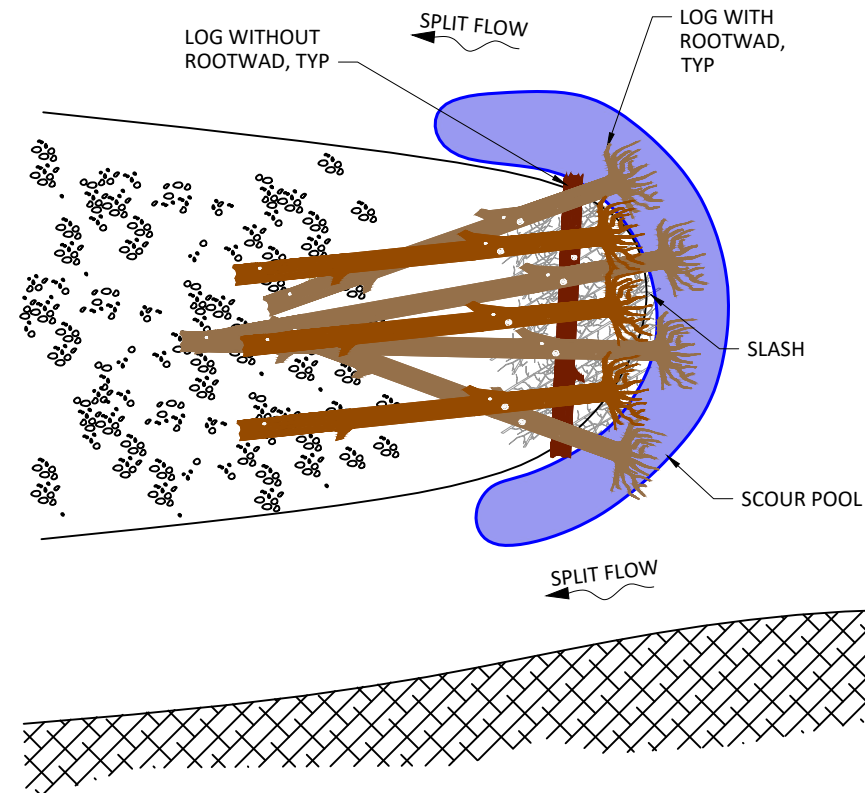


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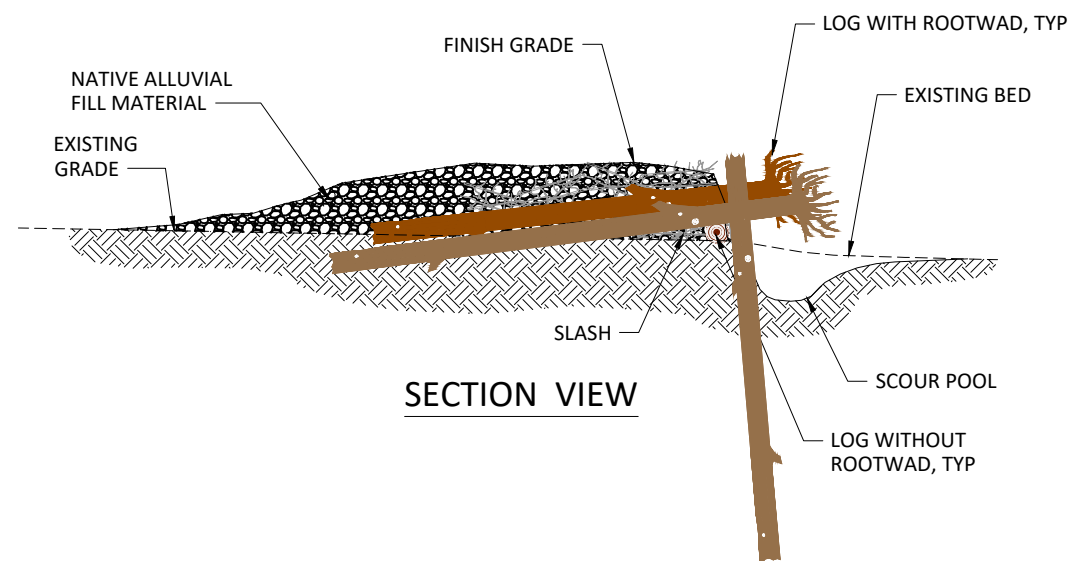
PROPOSED CONDITIONS - MILL AND MANLEY CONFLUENCE AREA

SHEET

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PLAN VIEW

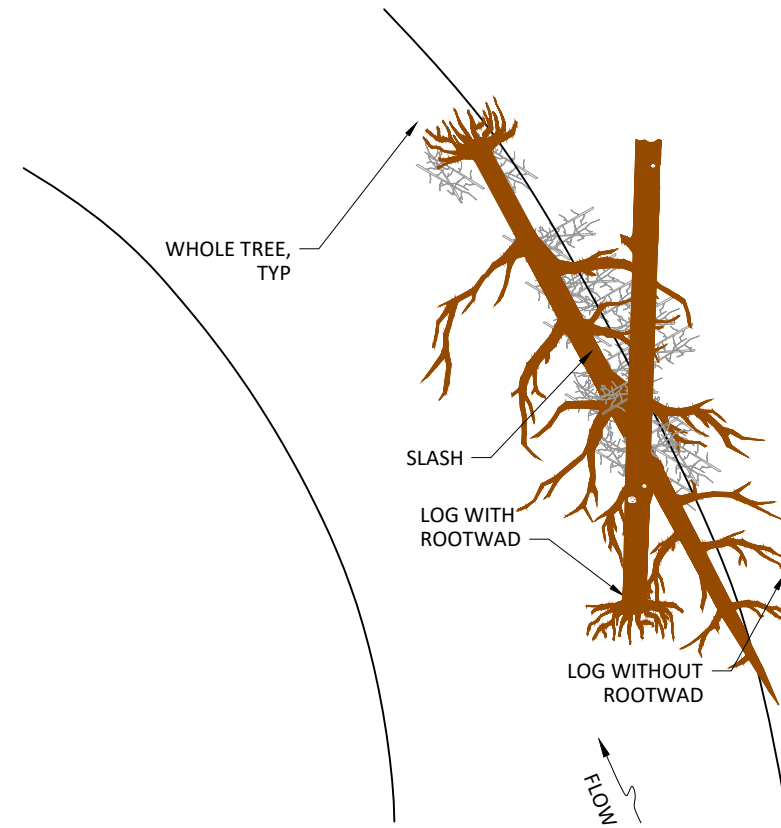


SECTION VIEW

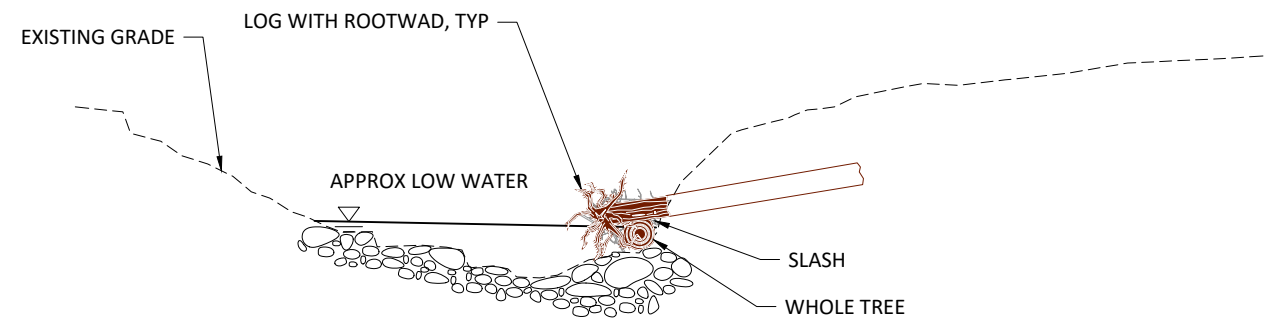
1
13 TYPICAL BAR APEX LOG JAM
NOT TO SCALE

NOTES

SPECIFIC ORIENTATION OF LOGS AND BALLAST MATERIALS MAY VARY FROM TYPICAL DRAWINGS DEPENDING ON SIZE AND SHAPE OF MATERIAL DELIVERED OR SALVAGED.



PLAN VIEW



SECTION VIEW

2
13 TYPICAL HABITAT COMPLEXITY LARGE WOOD
NOT TO SCALE

NO.	BY	DATE	REVISION DESCRIPTION

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----	5/7/21	
APPROVED	DATE	PROJECT

RIDGEFIELD PITS RESTORATION
PRELIMINARY DESIGN
LOWER EAST FORK LEWIS RIVER

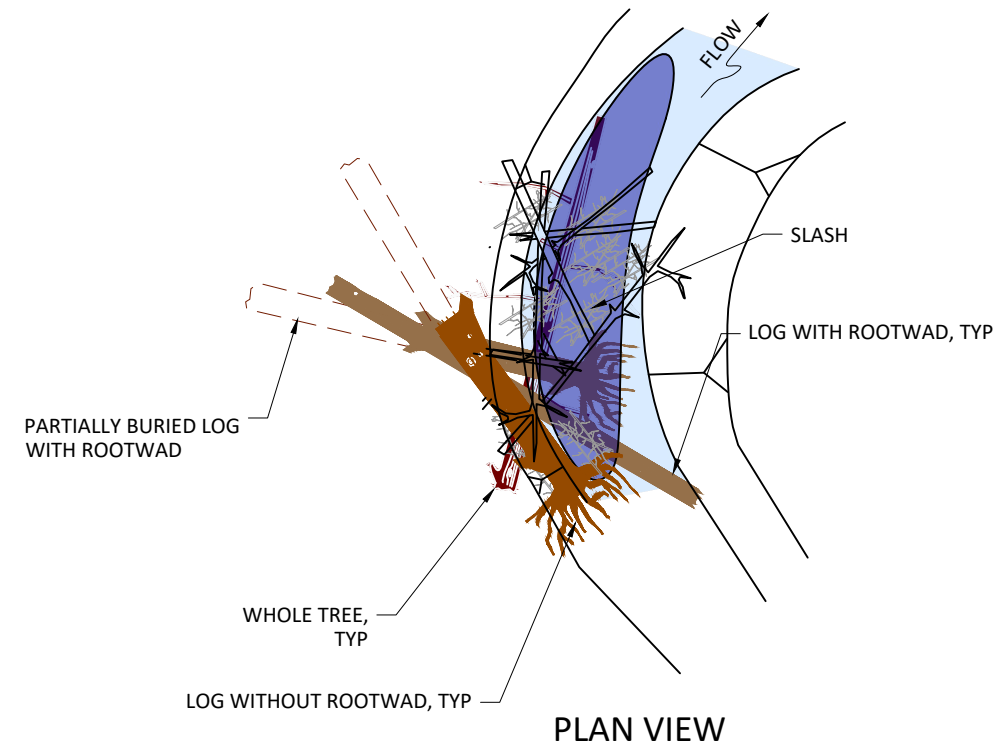


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TYPICAL DETAILS

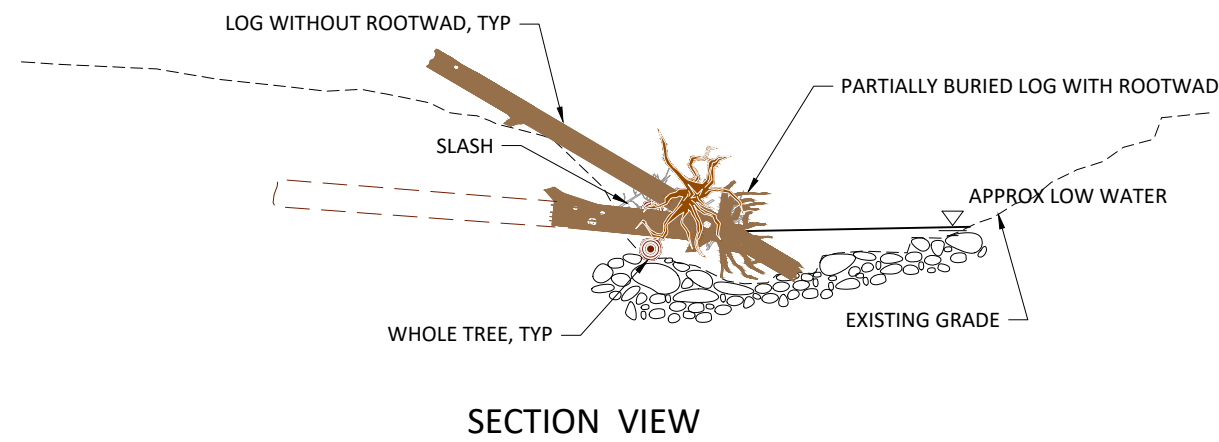
SHEET

13 OF 16

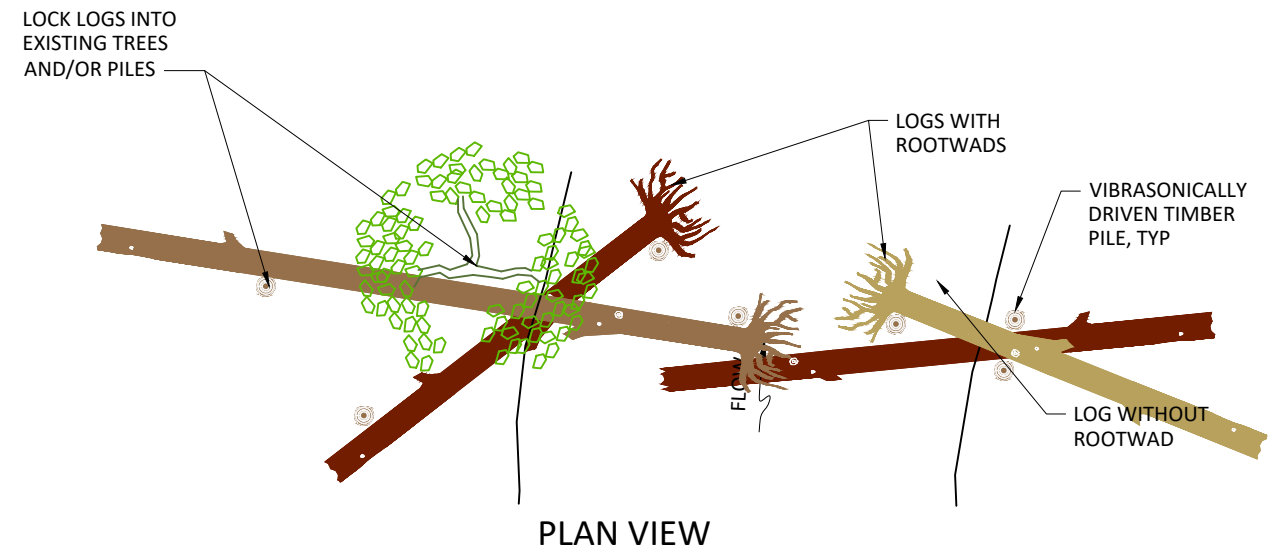


NOTES

SPECIFIC ORIENTATION OF LOGS AND BALLAST MATERIALS MAY VARY FROM TYPICAL DRAWINGS DEPENDING ON SIZE AND SHAPE OF MATERIAL DELIVERED OR SALVAGED.



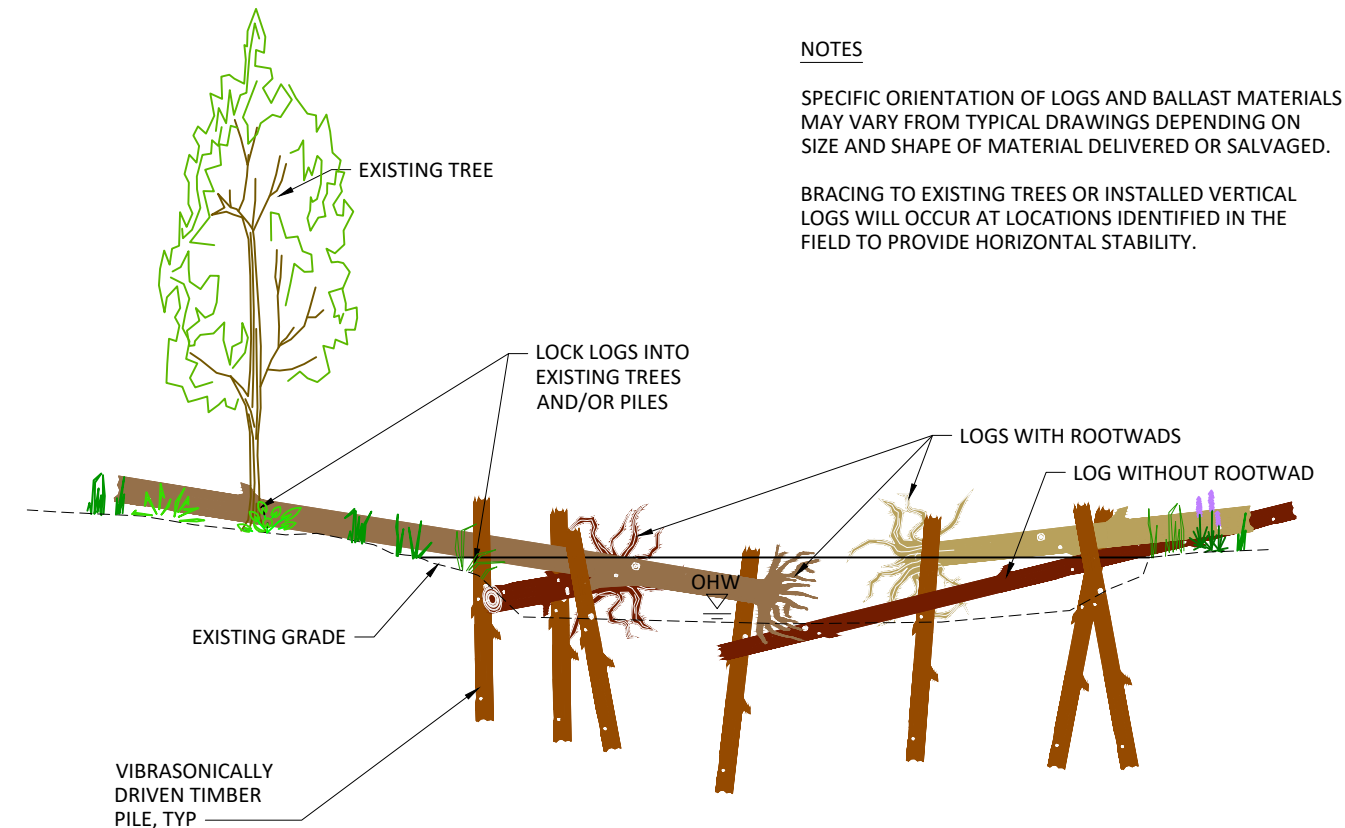
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14 TYPICAL POOL LOG JAM
NOT TO SCALE



NOTES

SPECIFIC ORIENTATION OF LOGS AND BALLAST MATERIALS MAY VARY FROM TYPICAL DRAWINGS DEPENDING ON SIZE AND SHAPE OF MATERIAL DELIVERED OR SALVAGED.

BRACING TO EXISTING TREES OR INSTALLED VERTICAL LOGS WILL OCCUR AT LOCATIONS IDENTIFIED IN THE FIELD TO PROVIDE HORIZONTAL STABILITY.



2
14 TYPICAL CHANNEL SPANNING LARGE WOOD
NOT TO SCALE

NO.	BY	DATE	REVISION DESCRIPTION

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APPROVED	DATE	PROJECT

RIDGEFIELD PITS RESTORATION
PRELIMINARY DESIGN
LOWER EAST FORK LEWIS RIVER

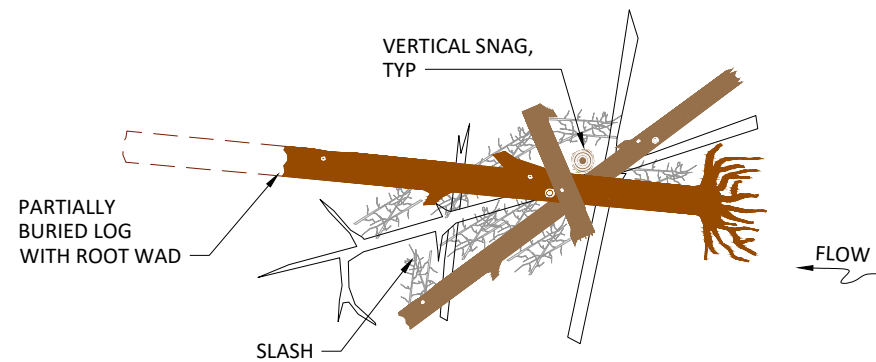


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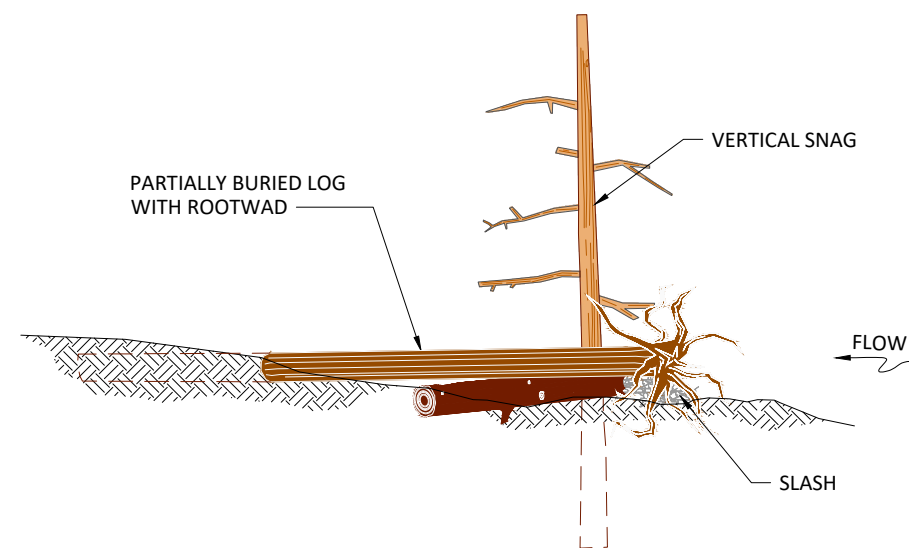
TYPICAL DETAILS

SHEET

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PLAN VIEW



SECTION VIEW

NOTES

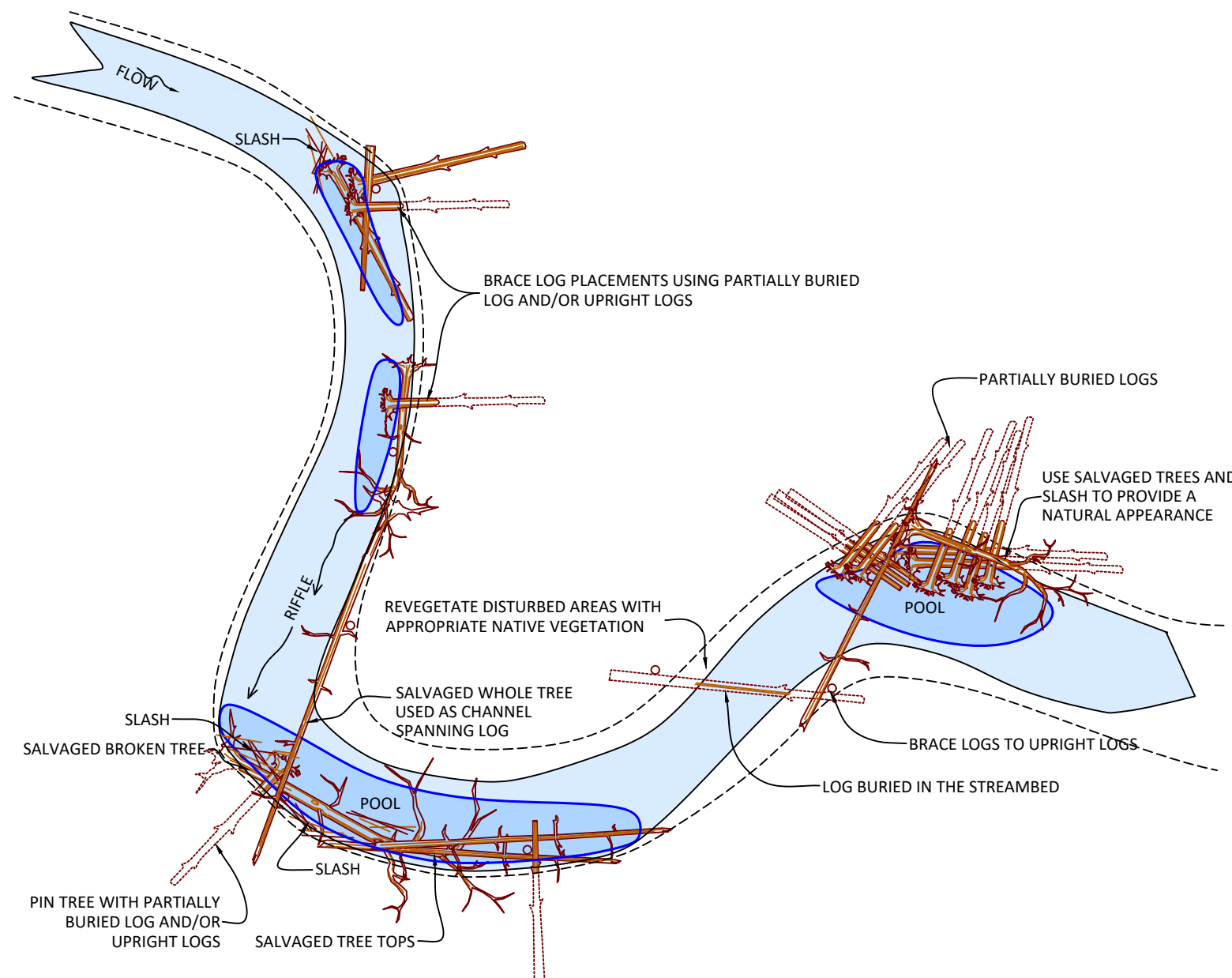
SPECIFIC ORIENTATION OF LOGS AND BALLAST MATERIALS MAY VARY FROM TYPICAL DRAWINGS DEPENDING ON SIZE AND SHAPE OF MATERIAL DELIVERED OR SALVAGED.

BRACING TO EXISTING TREES OR INSTALLED VERTICAL LOGS WILL OCCUR AT LOCATIONS IDENTIFIED IN THE FIELD TO PROVIDE HORIZONTAL STABILITY.

FLOODPLAIN WOOD PHOTO

NOTES:

1. TREES AND SHRUBS WITHIN CLEARING LIMITS SHALL BE SALVAGED AND REUSED AS LOGS AND SLASH IN HABITAT STRUCTURES. TO THE EXTENT PRACTICABLE, PRESERVE BRANCHES AND ROOTS ON TREES REMOVED DURING CLEARING AND GRUBBING.
2. WOOD STRUCTURES SHALL BE STABILIZED. STABILIZATION METHODS INCLUDE PARTIAL BURIAL, BRACING AGAINST STANDING TREES, OR TIMBER PILES.



1
15 TYPICAL FLOODPLAIN ROUGHNESS WOOD
NOT TO SCALE

2
15 TYPICAL SIDE-CHANNEL WOOD PLACEMENT
NOT TO SCALE

NO.	BY	DATE	REVISION DESCRIPTION

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TYPICAL DETAILS

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