Appendix B
Spawning Habitat Assessment Technical Memoranda

B1 Chinook Salmon Spawning Habitat Mapping Technical Memorandum

TECHNICAL MEMORANDUM

Date: May 31, 2024
To: Matt Dillin, Chehalis River Basin Flood Control Zone District
From: Paul DeVries PhD PE CFP and Kai Steimle, Kleinschmidt Associates
Cc: MaryLouise Keefe, Kleinschmidt Associates
Re: Mapping of Chinook Salmon Spawning Habitat in the Mainstem Upper Chehalis River in 2023

Preface

Following the release of Draft Environmental Impact Statements (DEISs) by the Washington Department of Ecology (Ecology) and the United States Army Corp of Engineers (Corps) for the proposed Flood Retention Expandable (FRE) Facility, the project's proponent, the Chehalis Flood Control Zone District (District) has undertaken more detailed technical studies to increase understanding of the nature of potential project impacts to environmental resources. These studies have been undertaken to provide the basis for development of avoidance, minimization, and mitigation measures for the project. Chinook salmon (*Oncorhynchus tshawytscha*) spawning habitat within the mainstem Chehalis River was identified among potentially affected resources in the DEISs. This technical memorandum presents the results of detailed field mapping performed for the District of potentially available spawning habitat for Chinook salmon in the upper Chehalis River mainstem, information that was not presented in the DEISs which instead presented information from redd surveys. It is a companion to separate technical memoranda that address coarse and fine sediment transport processes and salmonid spawning habitat scour risk. These technical memoranda are necessary for developing an understanding of the mechanisms affecting sediment transport and aquatic habitat sufficient for the District to formulate appropriate avoidance, minimization, and mitigation measures for the proposed project. These measures will be fully described in the District's forthcoming mitigation plan, which will incorporate the memoranda as technical appendices.

Executive Summary

This memorandum presents the results of field mapping of suitable Chinook salmon spawning habitat in the Chehalis River mainstem between Fisk Falls and Rainbow Falls, which are located at approximately River Mile (RM) 113.5 and RM 97, respectively. This information is necessary to develop appropriate mitigation actions that would offset impacts associated with effects of the proposed FRE facility on Chinook salmon spawning success. Chinook salmon using the upper Chehalis River spawn predominantly in the mainstem channel between the two falls; however, spawning-sized substrates are generally limited in this reach. Bedrock is a prevailing surface and substratum feature throughout most of the spawning reach over which gravel deposits form a mantle cover. The amount of gravel present and available for use by spawning fish reflects a balance between supply and a high transport capacity. The

supply increases with frequency and extent of mass wasting delivering material to the channel, and the availability of substrates suitable for spawning decreases over time as the material is transported and dispersed downstream .

When addressing salmon spawning habitat, the NEPA and SEPA DEISs' analyses relied primarily on redd survey data collected within ten years after the extreme 2007 flood event during which more than 15 times the estimated average annual quantity of sediments were delivered to the upper Chehalis River channel network (Nelson and Dubé 2016). Kleinschmidt Associates (Kleinschmidt) staff noticed during field visits in 2022 and 2023 that areas with redds recorded in the past did not contain suitable spawning habitat subsequently, indicating transport of spawning gravels downstream without replenishment. Interpretations of potential impacts on Chinook Salmon spawning habitat as described in the DEISs were thus likely influenced by its increased availability for several years after the extreme 2007 event compared with what may be more typical conditions.

To improve our knowledge of substrate dynamics, spawning impacts, and potential for mitigation under what may be more typical conditions, the District undertook extensive analyses and studies beginning in 2023 that were focused on sediment transport and deposition characteristics that control availability of spawning habitat and spawning success. The studies included updated mapping of locations where substrate size and hydraulics were suitable to support Chinook salmon redds. The gravel mapping survey characterized the following attributes of spawning habitat:

1. Approximate spatial extent within mesohabitats generally suitable for Chinook salmon spawning based on meeting physical habitat requirements for:
   A. Substrate size, mapped according to dominant/subdominant mix of gravel and cobble, and
   B. Water depths predicted by a HEC-RAS hydraulic model for the typical lower-range of flows used by spring-run and fall-run Chinook salmon during the spawning season ;
2. Judged risk of deep scour based on distance to upstream supply of suitably sized gravels and cobbles that could replace material transported downstream during high flows; and
3. Availability of depth or structural cover for adult Chinook salmon nearby within the same or adjacent mesohabitat.

Pebble counts were performed at selected locations to verify that the dominant-subdominant classification used to identify suitable substrates visually was consistent with published grain size distribution characteristics for Chinook salmon spawning habitat.

The resulting maps and data are presented in this report. The results lead to the following key observations:

1. The availability of suitable Chinook Salmon spawning habitat in summer/fall of 2023 was substantially less overall than suggested by post-2007 event redd count data relied on by the DEISs. Many locations where salmon and steelhead redds have been mapped in the past were

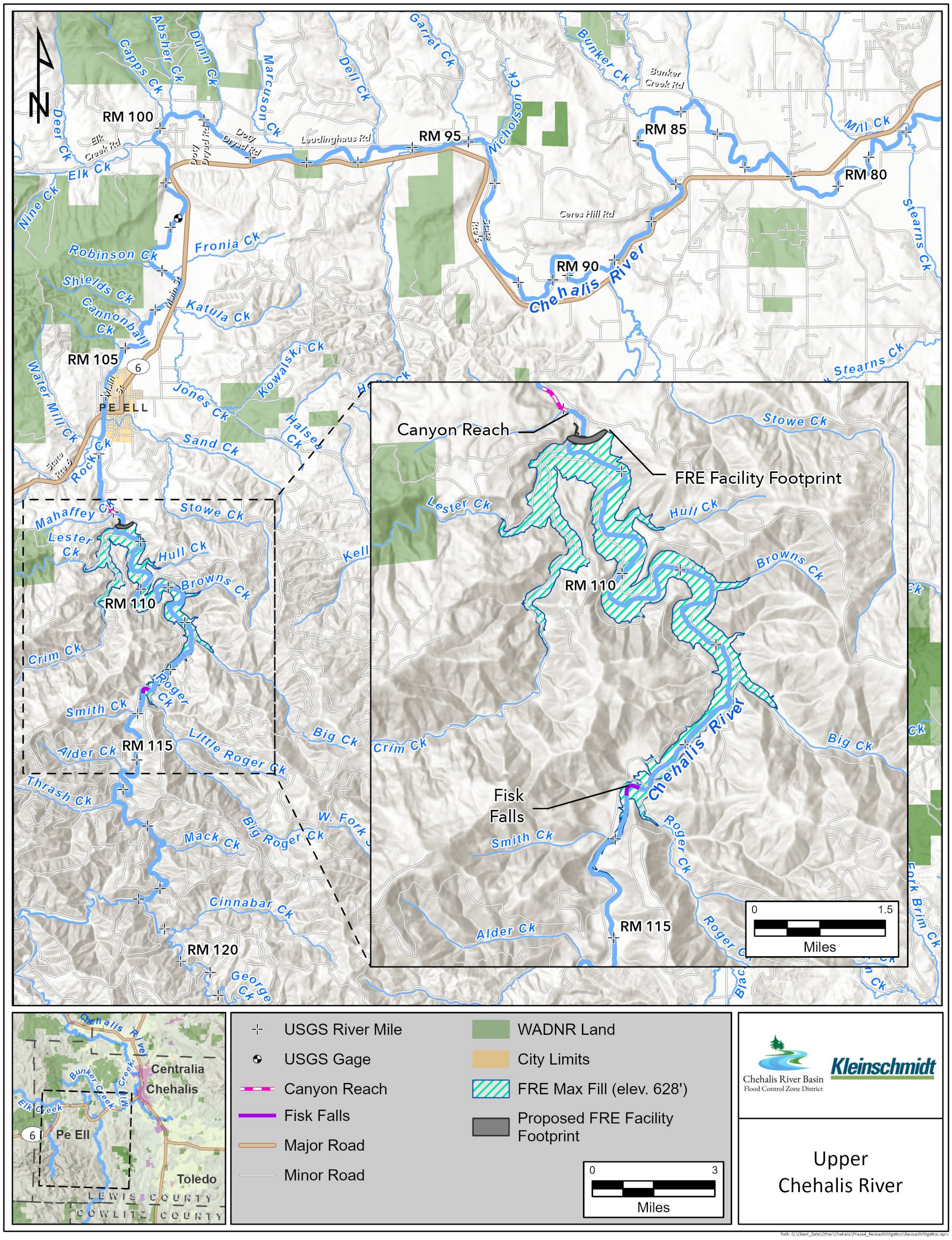
observed to be lacking in suitable gravels in 2023. This finding is consistent with the general geomorphic framework in which gravel supply in moderate-gradient, confined streams used by spawning salmonids in the Washington and Oregon coast range is generally controlled over the long term by mass wasting in the form of landslides and debris flows in the headwaters, where the abundance of suitably sized gravel and cobble increases episodically and then decreases over time until the next major mass wasting event.

2. Chinook salmon spawning habitat distributions are patchy within the upper Chehalis River mainstem. More areas with suitable substrates are located in pool tails and side bars, which are more susceptible to deep scour than riffle crests and riffles that are more limited in number and area. Pool tail/riffle crest spawning habitat is distributed more uniformly along the length of the river, whereas there is proportionally more side-bar spawning habitat and less riffle spawning habitat upstream of the proposed FRE location (RM 108.5) than downstream.
3. Within the 16.5 miles surveyed, most spawning habitat upstream of the FRE location was mapped within the first 2 miles below Fisk Falls; downstream of the FRE location, most habitat was mapped in a 4 mile reach in the Pe Ell Valley. Both reaches have historically supported more Chinook salmon spawning than elsewhere in the upper Chehalis River. This distribution of gravels is consistent with the reach locations being below large-scale breaks in channel slope, and with coarse sediment transport modeling performed by Kleinschmidt (Kleinschmidt 2024).
4. Spawning habitat in the Pe Ell valley and downstream generally had a lower overall judged risk of deep scour than between the proposed FRE location and Fisk Falls, and a smaller proportion of habitats with large wood or pool cover nearby.

Background

The District is proposing to construct an FRE facility to reduce the risk of flood damage along the mainstem Chehalis River. The proposed FRE facility is located approximately 1.7 miles upstream from the city of Pe Ell, Washington in the upper Chehalis River watershed (Figure 1). The primary purpose of the FRE facility is to reduce flooding coming from the Willapa Hills by storing floodwaters in a temporary reservoir during major floods. In 2020, the two draft DEISs released for this project (by Ecology under Washington State's Environmental Policy Act and the Corps under the National Environmental Policy Act) projected that by temporarily storing peak flows during major or catastrophic flood events, the FRE facility operations would alter sediment transport and deposition processes and thereby impact channel forming processes and spawning habitat quantity and quality. This in turn was hypothesized to impact reproductive success of fish species relying on spawning habitat within the potential reservoir footprint and downstream (Ecology 2020, Corps 2020). Impacts were generally represented as occurring upstream of Elk Creek (around RM 100).

Figure 1
Map of Chehalis River Study Reach, Including Location of Important Landmarks Indicated in This Technical Memorandum.



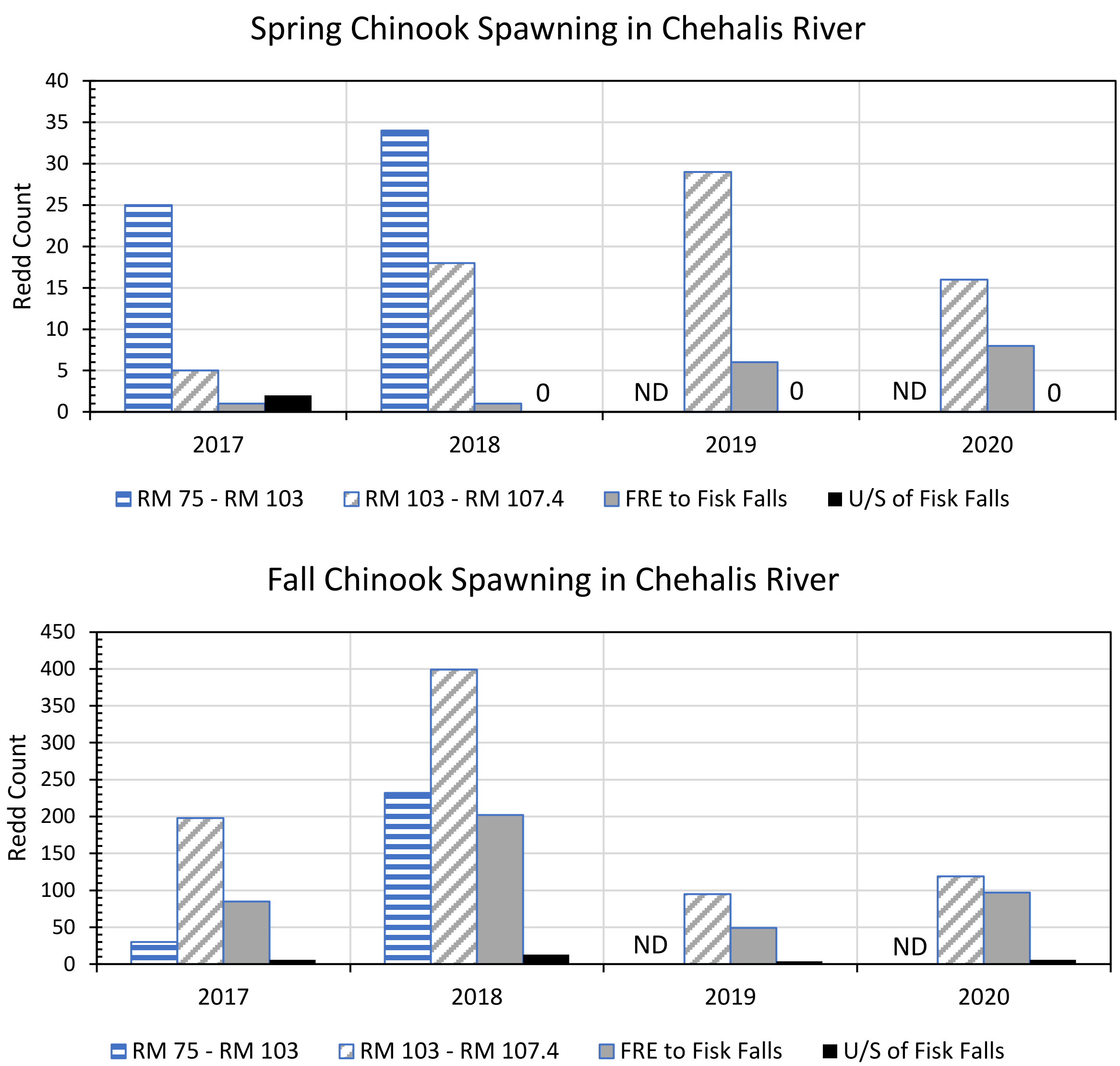
While fall-run Chinook salmon, coho salmon (*O. kisutch*) and steelhead (*O. mykiss*) are all found in the basin and have segments of their populations that are mainstem spawners, the DEISs indicated that spring-run Chinook salmon populations were likely to suffer the greatest potential impact of FRE operations on spawning habitat. This is largely due to their restricted distribution as compared to other salmonid species in the basin. In the Upper Chehalis basin, both spring-run and fall-run Chinook salmon spawn predominantly in the mainstem, with greatest concentrations of redds recorded previously in the first two and a half miles below Fisk Falls and within the upper four to five miles of the Pe Ell valley reach below where the river exits the Willapa Hills (Washington Department of Fish and Wildlife [WDFW] electronic data for 2015-2021 received from Ecology; Phinney et al. 1975; WG and Anchor 2017; Ferguson et al. 2017; Ronne et al. 2020; Figure 2). There are few tributaries in the upper basin that are large enough and have sufficient gravel deposits to provide spawning habitat for Chinook salmon; these tributaries are primarily located downstream of the proposed location of the FRE (Phinney et al. 1975). Smith and Wenger noted that spawning gravels were limited in quantity in the upper tributaries including Crim Creek, Lester Creek, Big Creek, Roger Creek, and Thrash Creek (Smith and Wenger 2001). Steelhead and coho salmon spawn more extensively than Chinook salmon in tributary habitats, most of which would not be influenced by FRE operations (Ronne et al. 2020). In addition, there would likely be more locations and opportunities to mitigate for impacts to those two species by providing access to disconnected spawning habitat than there would be for Chinook salmon. Thus, the focus for mitigation of impacts to spawning habitat will primarily be most important with respect to Chinook salmon using the mainstem.

The DEISs concluded FRE operations may have a direct impact on Chinook salmon spawning over a broad area, but did not identify specific spawning habitat locations or evaluate how spawning habitat availability may vary over time. Such knowledge is needed to identify reach-level impacts and corresponding specific mitigation actions that are appropriate and sufficient. Accordingly, the District desired to have information on actual distributions of spawning habitat, and how those distributions might change over time. This technical memorandum presents the results of spawning habitat mapping performed in 2023 between Fisk Falls and Rainbow Falls, and evaluates implications and potential effects of FRE operations in the context of spawning habitat availability.

Methods

Spawning habitat was mapped in the field using a Geographic Information System tablet with a Global Positioning System (GPS) using Global Navigation Satellite System location capability. The survey extended from the base of Fisk Falls starting at approximately RM 113.5 downstream to Rainbow Falls at approximately RM 97. Biologists walked the river in the downstream direction and looked for locations where Chinook salmon would be expected to spawn based on mesohabitat type and presence of suitably sized substrates. Surveys were conducted at various times between June and October 2023 when flows ranged between 18 and 126 cubic feet per second (cfs) at the United States Geological Survey (USGS) stream gage at Doty (USGS Gaging Station No. 12020000).

Figure 2
Redd Numbers Counted in Four Reaches of the Mainstem Chehalis River Between the Newaukum River and the West Fork-East Fork Confluence Each Year from 2017-2020. Data Were Not Collected Downstream of RM 103 in 2019 and 2020 ("ND").



A patch of riverbed was mapped as having suitable spawning gravels where (i) the overall substrate size mix fell within the general range used by spawning Chinook salmon, (ii) the channel morphology was consistent with typical spawning mesohabitats, and (iii) the substrate would be wetted with water depths exceeding a minimum criterion during base flow levels (i.e., between higher pulse flow events) in the key months when spring-run and fall-run Chinook salmon spawn (generally September through

November; cf. Figure E-4 in Ecology 2020). Specifically, the following criteria were relied on to define suitable spawning habitat:

- Substrate patches meeting general WDFW instream flow study habitat suitability criteria for Chinook Salmon (WDFW 2022), where the majority of visible stones in the patch accounting for more than approximately 80% of the surface area have intermediate axis diameters between 0.5” and 6”, values that are associated with a habitat suitability index > 0.5. Patches were classified according to dominant and subdominant size ranges present, where small gravel (SG) = 0.5”-1.5”; large gravel (LG) = 1.5”-3”, and small cobble (SC) = 3”-6”.
- Substrate patches falling within one of the following mesohabitat types/locations where hyporheic flows might exist:
  - Pool tail
  - Riffle Crest
  - Riffle
  - Low sloping (cross-stream) apex bar
  - Side channel
- A minimum depth over the suitable substrate of 0.5’ for any flow less than the upper base flow that may occur during the spawning season, taken to correspond to approximately 500 cfs at the USGS Gaging Station No. 12020000, Chehalis River near Doty, Washington. Flows upstream of the proposed FRE facility were taken to be approximately half the flow at the gage based on the ratio of drainage area above Crim Creek to drainage area at the gage. Stage-discharge curves were estimated for HEC-RAS cross sections upstream of the proposed FRE facility location and used in the field to estimate the upper limit of water surface elevation relative to the water level on the date of the survey (graphs are presented in Attachment 1).

Each patch was mapped as a polygon delineating approximate area meeting these criteria over a background aerial photograph on the GPS-enabled computer tablet. In addition to substrate class and mesohabitat type, each polygon was also characterized in terms of the following attributes:

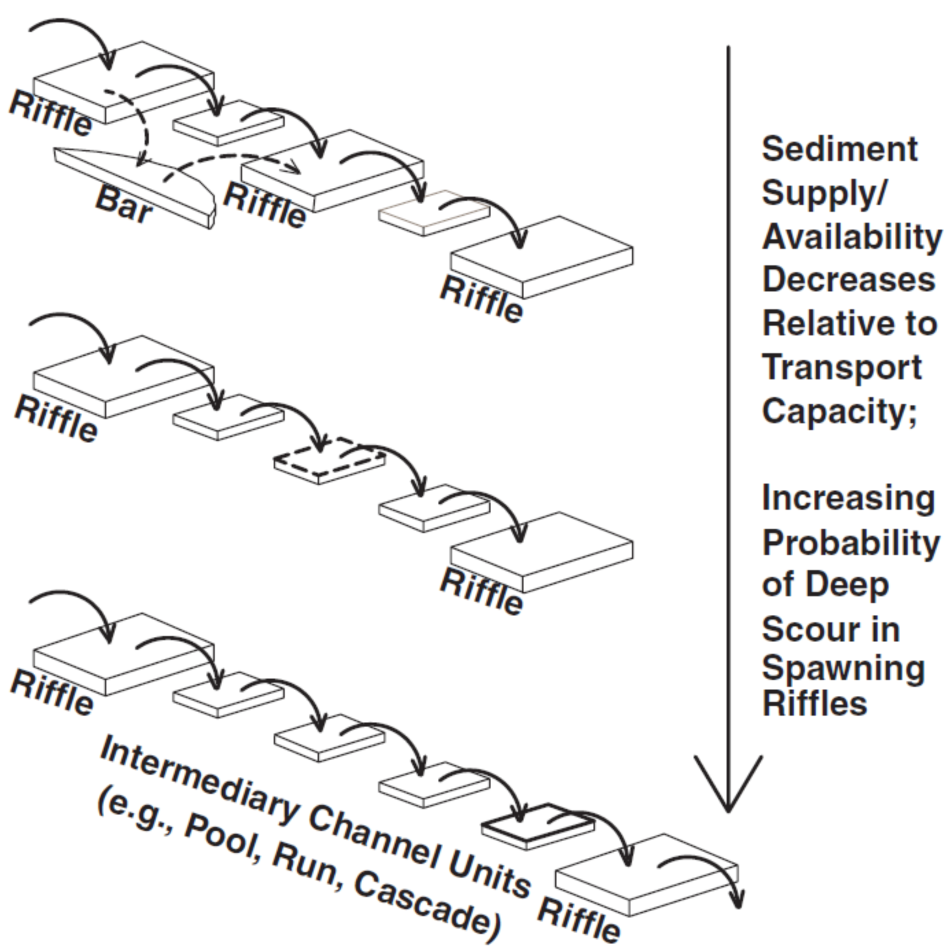
- Judged risk of deep scour following the conceptual framework depicted in Figure 3, where:
  - Low Risk = There is visually an abundant area of similarly sized substrate material within approximately five bankfull widths upstream that can replace local substrates that are mobilized downstream during high flows (i.e., low risk of sediment transport rate imbalance);
  - High Risk = The mapped patch is isolated without much material evident in proximity upstream, susceptible to scour without sufficient replacement of material from upstream during sediment transporting flows; and
  - Medium Risk = Where neither low nor high risk is clearly indicated.
- Estimated wetted depth range across patch at the time of survey (deepest – shallowest); upstream of the proposed FRE location this could include a negative value for exposed portions

based on the stage-discharge graphs predicted by the HEC-RAS model to project suitability at other flows (see Attachment 1).

- Presence of Chinook salmon or steelhead redds if observed. When a 'clean' depression was found in the streambed that was not clearly indicative of a redd, it was counted as a possible false redd.
- Availability of large wood and/or pool cover nearby for spawners to escape to when disturbed or for resting while spawning.

Pebble counts were performed at selected locations to characterize general grain size distribution of different representative dominant/subdominant textures that may be used by spawning Chinook salmon including LG/SG, LG/SC, SC/SG, SC/LG, SG/LG (order of mixtures roughly represents from highest to lowest suitability). The intermediate axis of 100 stones was measured for each pebble count.

Figure 3
Conceptual Representation of the Relation Between Local Sediment Supply and Scour Depth; from DeVries (2008).



Results

Summary data are tabularized in Attachment 2, and corresponding mapping figures are presented in Attachment 3. All references to river mile are based on USGS' river mile assignments. The following key observations were made based on the results with implications discussed in the next section:

- One hundred and seven suitable gravel patches were mapped across approximately 16.5 miles of river. Thirty-six (36) percent of the patches were located upstream of the FRE site. Of these, 71 percent were between RM 111.5 and Fisk Falls (Table 1).
- Gravel patch area estimates were relatively small overall, ranging between 15-3,052 square feet, with 98 patches less than 1000 square feet in area. Gravel and cobble stored on elevated bars were assessed as likely unsuitable or unusable for spawning at typical spawning flows.
- Based on cumulative area, 11 percent and 56 percent of mapped spawning habitat above Elk Creek occurred within the first 1.5 miles below Fisk Falls and 4.0 miles in the vicinity of Pe Ell, respectively, downstream of large-scale breaks in river gradient located respectively at around RM 113.9 and RM 107.6 (Figure 4). Many other locations where salmon and steelhead redds have been mapped in the past were not observed to have suitable spawning habitat in 2023.
- Pool tail and side-bar mesohabitats provided the most spawning habitat in 2023, accounting for approximately 36 percent and 26 percent of total mapped area above Elk Creek, respectively (Figure 4). These mesohabitats have been associated with a higher risk of deep scour than in the other spawning meso-habitats (e.g., Schuett-Hames et al. 2000; DeVries 2008). In the 2023 survey, riffles, riffle crests, and runs accounted for 24 percent, 9 percent, and 6 percent of total mapped spawning habitat area, respectively.
- Pool tail/riffle crest spawning habitat was distributed more uniformly along the length of the river, whereas there was proportionally more side-bar spawning habitat and less riffle spawning habitat upstream of the proposed FRE location (RM 108.5) than downstream (Figure 4).
- Grain size distributions of mapped spawning habitats were well within the general suitability range reported for Chinook salmon and steelhead by Kondolf and Wolman (1993) (Figure 5).
- Spawning habitat in the Pe Ell valley had a lower overall judged risk of deep scour than between the proposed FRE location and Fisk Falls (Figure 6), and a smaller proportion of habitats with large wood or pool cover nearby (Figure 7).

Table 1

Count and Density of Suitable Chinook Salmon Spawning Gravel Patches Mapped in 2023 Survey.

REACH (RM)	NUMBER OF PATCHES	NUMBER/MILE
113.5 – 111.5	27	13.5
111.5 – 108.5	11	3.7
108.5 – 106.8	3	1.8
106.8 – 101.8	56	11.2
101.8 – 97.0	10	2.1

Figure 4
Cumulative Area of Chinook Salmon Spawning Habitat Mapped in the Chehalis River Mainstem in Fall 2023 Moving Downstream Between Fisk Falls and Rainbow Falls, Summed Over for All Mesohabitat Types (top) and the Four Most Common Mesohabitat Types (bottom; curves end at lowermost spawning patch encountered). Red Dashed Ovals Delineate Majority of Spawning Habitat Available.

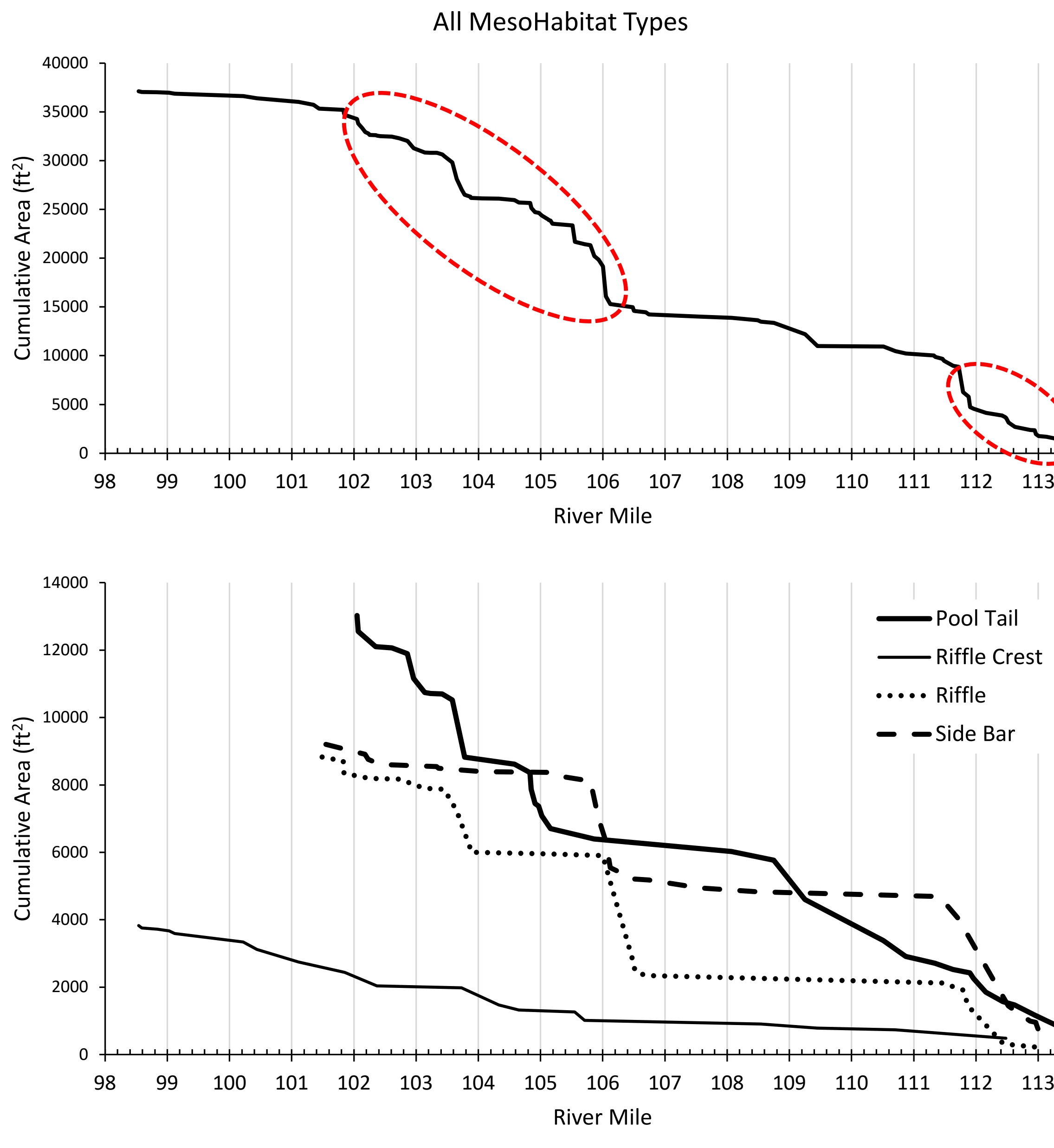


Figure 5
Pebble Count Grain size Distributions Sampled at Various Mapped Chinook Salmon Spawning Habitat Locations in the Upper Chehalis River. The Horizontal Bars Represent the Range of Reported D_{50} Values Compiled by Kondolf and Wolman (1993) for Spawning Steelhead (filled bar) and Chinook Salmon (open bar). RM = Approximate River Mile Location of Sample.

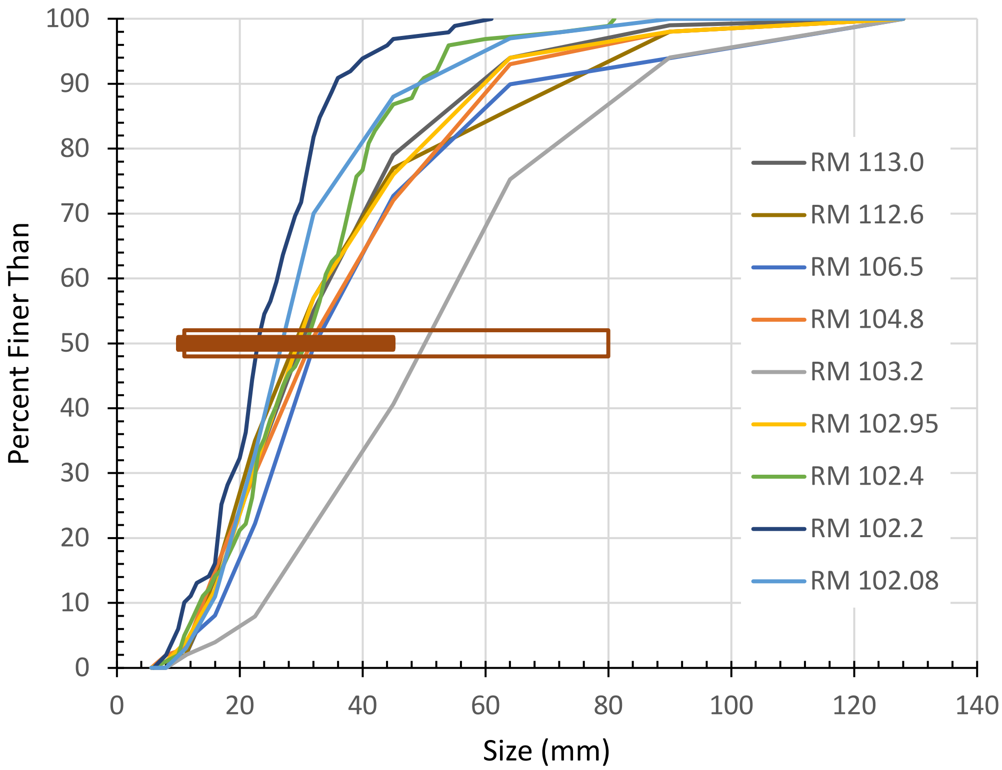


Figure 6
Relative Differences in Levels of Risk for Deep Scour to Occur in Mapped Chehalis River Chinook Salmon Spawning Habitats Located Upstream (top) and Downstream (bottom) of the Proposed FRE Facility, Based on Proportion of Total Areas Mapped in Each Reach.

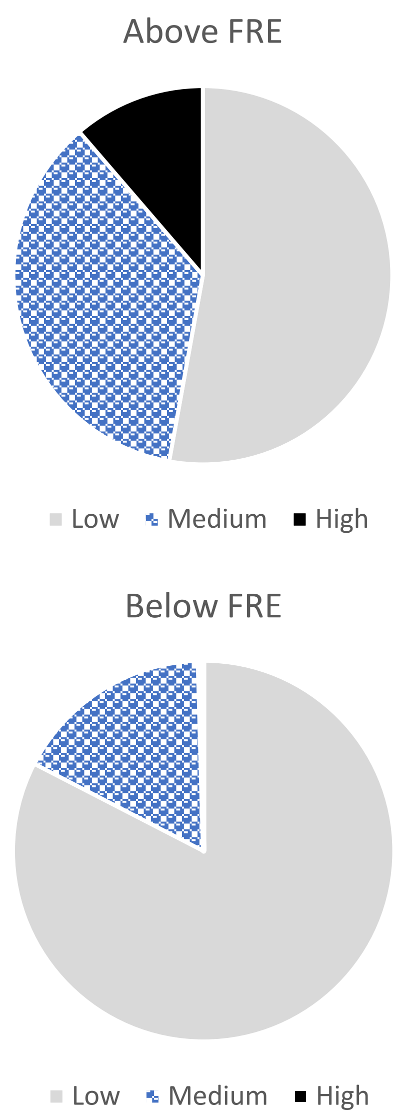
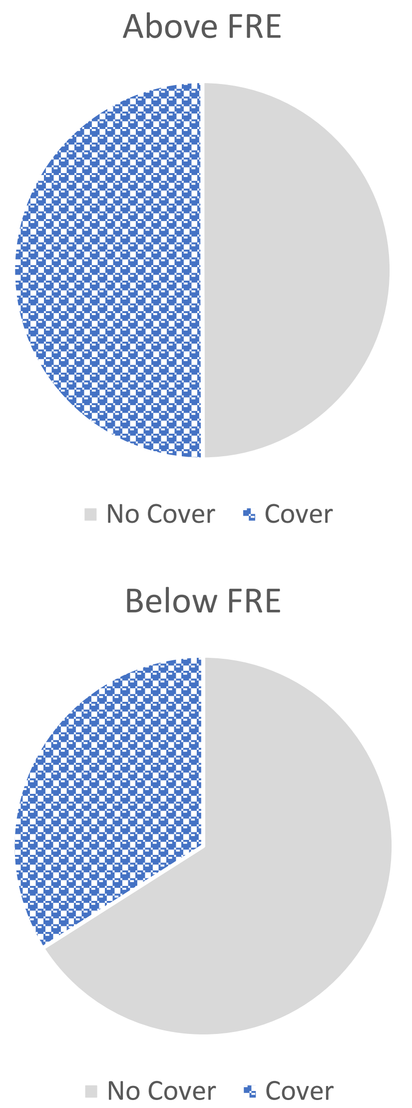


Figure 7
Relative Differences in Spawning Habitat Area Proximal to Large Wood or Pool Cover vs. No Cover in Mapped Chehalis River Chinook Salmon Spawning Habitats Located Upstream (top) and Downstream (bottom) of the Proposed FRE Facility, Based on Proportion of Total Areas Mapped in Each Reach.



Discussion

As noted in Kleinschmidt's (2024) coarse sediment transport assessment, the longitudinal elevation profile of the Chehalis River (Figure 8) indicates there are two reaches where most long-term gravel and cobble deposition would be expected, both with and without FRE operation:

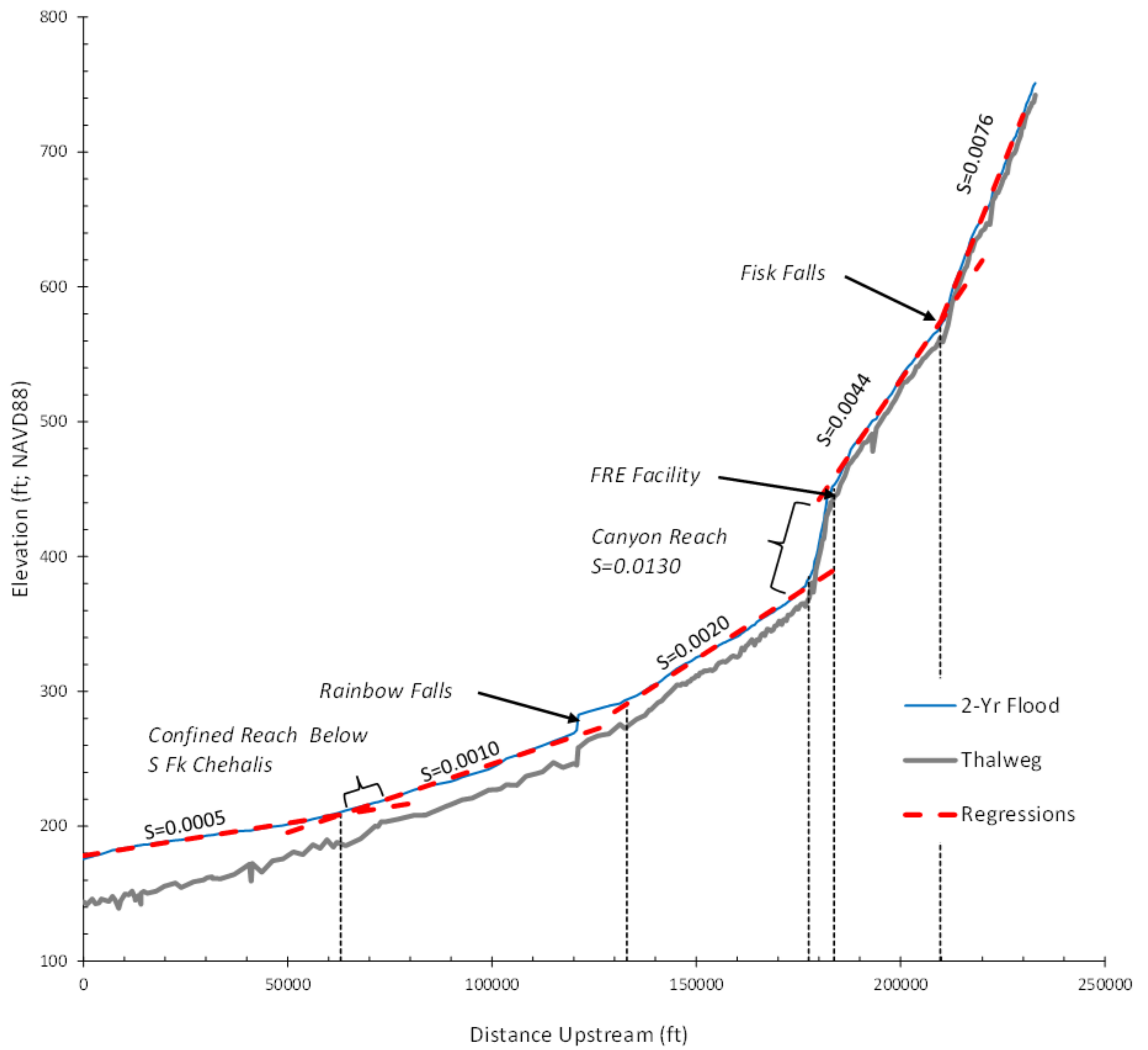
- Below the slope break at Fisk Falls, and
- Below the slope break where the river enters the Pe Ell valley.

As also noted, these areas correspond with major historic Chinook Salmon spawning areas both before (Phinney et al. 1975) and after Fisk Falls was modified in 1970 and 1980 to improve upstream passage conditions (Light and Herger 1994; WG/Anchor 2017; WDFW redd count data). The relatively limited availability of mainstem spawning habitat mapped in 2023 is more consistent with these longer-term historic depositional reaches and spawning area distributions than with the broader distribution of redds indicated previously (WG/Anchor 2017; Ronne et al. 2020), and with long-term spawning escapement data that indicate the fraction of the basin's Chinook Salmon stock using the upper Chehalis River mainstem to spawn is much smaller on average than in the other major tributaries combined (Litz et al. 2023).

The 2023 data are also consistent with the observations of Isaak and Thurow (2006) that Chinook Salmon spawning distributions tend to be clustered rather than random, with preferred spawning areas in low gradient pool-riffle channels flowing through wide alluvial valleys. The mapping results similarly indicated approximately five times the area of spawning habitat was found in the lower gradient, somewhat less confined Pe Ell valley reach than in the steeper channel reach between the proposed FRE location and Fisk Falls.

Moreover, the general scarcity of spawning habitat in 2023 is consistent with a hypothesis that mainstem spawning habitat quantities within the inundation zone and downstream fluctuate over time in response to episodic mass wasting inputs over large areas. Smith and Wenger reported landslides to be the primary source of sediments to the upper Chehalis River (Smith and Wenger 2001). Montgomery et al. found the upper Chehalis watershed to be one of the basins with the greatest number of landslides per unit drainage area in western Washington and Oregon (Montgomery et al. 1998). Correspondingly, volumes of coarse sediments delivered to the channel likely increased substantially after episodic, major events like 1972, 1990, and especially 2007 (Nelson and Dube 2016). Given the high transport capacity and low threshold for motion indicated in Kleinschmidt's coarse sediment transport assessment (Kleinschmidt 2024), spawning gravel quantities would be expected to decrease over time as the episodically delivered material is transported and dispersed downstream until the next major event (cf. WG and Anchor 2017). This would be consistent with coarse gravel supply and transport processes observed in other coastal mountain streams in western Washington and Oregon (e.g., Everest and Meehan 1981; Benda 1990; Benda and Dunne 1997; May and Gresswell 2004; Miller et al. 2008; Pfeiffer et al. 2019).

Figure 8
Longitudinal Elevation Profile of the Chehalis River Thalweg and Simulated 2-year Flood Level Upstream of the Newaukum River Confluence. Five Distinct Large Scale Slope Breaks Are Evident in Addition to the Highly Localized Geologic Control at Rainbow Falls, at the Locations Indicated by the Vertical Dashed Lines, with Corresponding Regressed Reach Slopes Derived from the Water Surface Profile.



The 2007 event was notably associated with substantially more landslide inputs than the other two years (cf. Sullivan and Carlson 1994; Smith and Wenger 2001; Sarikhan et al. 2008; Nelson and Dube 2016). Consequently, the sediment sampling and corresponding gravel characterizations presented in the DEISs may not have been representative of conditions present in most years, and instead may represent transitional conditions associated with the unusually large mass wasting volume delivered to the channel network in 2007. This in turn may have resulted in a broader distribution of redds as depicted in Ecology (Ecology 2020) than indicated by the 2023 mapping results. The time for the channel to return to pre-event conditions varies with channel network and event history, but can range from 5 years to several decades (e.g., Lisle 1981; Madej 1995; Benda and Dunne 1997). Light and Herger's description of spawning habitat availability in the Chehalis River suggest that the channel was returning to pre-1990 event conditions after a roughly a 5-year time frame (Light and Herger 1994). The spawning habitat mapping data suggest that the time to return to pre-2007 event conditions was longer, but likely was within a roughly fifteen-year time frame, which is relatively short considering the extreme number of landslides and volume of material delivered to the Upper Chehalis River channel network during that event (Sarikhan et al. 2008; Nelson and Dube 2016).

The spawning mapping results also have bearing on expected survival to emergence of Chinook Salmon offspring. Light and Herger noted that substrates in the spring Chinook Salmon dominant-use-zone between Fisk Falls and the Pe Ell valley was mostly boulder and bedrock with patches of gravel occurring most commonly at bends (Light and Herger 1994). Chinook Salmon redds were considered especially vulnerable to scour in the mainstem. The 2023 spawning habitat mapping results are consistent with these observations in this context where the judged scour risk is higher overall above the FRE than below in the Pe Ell valley (Figure 6). In years between significant landslide events, redd scour may become increasingly prevalent in other reaches irrespective of FRE operations until the next event because of local sediment transport rate imbalances developing as more material is transported downstream than is supplied from upstream, and the distance between useable spawning habitat patches increases (Figure 3). The episodic nature of gravel inputs combined with high scour susceptibility suggest that the distribution and abundance of stable spawning habitat in the upper Chehalis River basin vary over time which in turn may be a key factor influencing reproductive success of mainstem spawners.

The 2023 mapping results indicate there is more spawning habitat presently in the spawning reach within the Pe Ell valley than in the reach below Fisk Falls, and that the habitat in the downstream reach may have a lower risk of deep scour. These observations are consistent with the results of coarse sediment transport analyses performed by Kleinschmidt, which calculated larger stable stone sizes, higher bedload transport rates, and greater spatial variability in aggradation-degradation tendencies in the reach below Fisk Falls than downstream (Kleinschmidt 2024). These attributes indicate a greater risk of substrate instability in the reach below Fisk Falls. Accordingly, the data and analyses suggest the potential for Chinook Salmon reproductive success is higher in the Pe Ell valley than upstream, and that habitats in the Pe Ell valley could benefit from adding large wood in mesohabitat units proximal to spawning areas to increase availability of cover for spawning adults.

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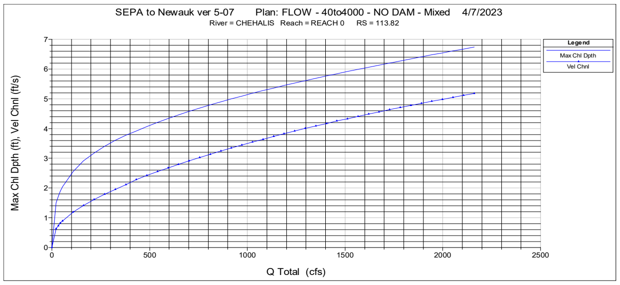
ATTACHMENT 1

STAGE-DISCHARGE CURVES PREDICTED AT HEC-RAS MODEL CROSS-SECTIONS BETWEEN THE PROPOSED FRE FACILITY LOCATION AND FISK FALLS

Note: River Mile (RM) Designations in the Graphs are from DEIS Model Cross-section Station Assignments and Differ from USGS RM Depicted in Attachment 2


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 113.82
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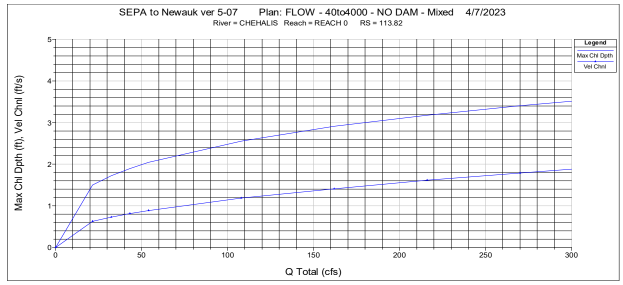
Q Total (cfs)
Legend
Max Chl Dpth
Vel Chnl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Q Total (cfs)
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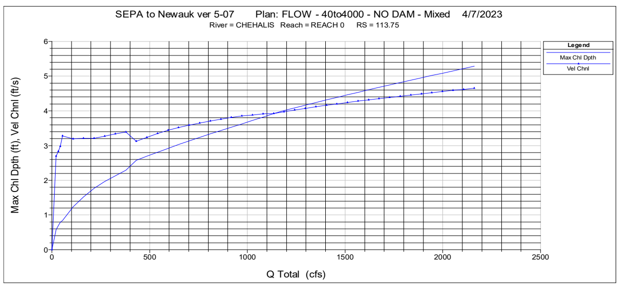
Vel Chnl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Q Total (cfs)
Legend
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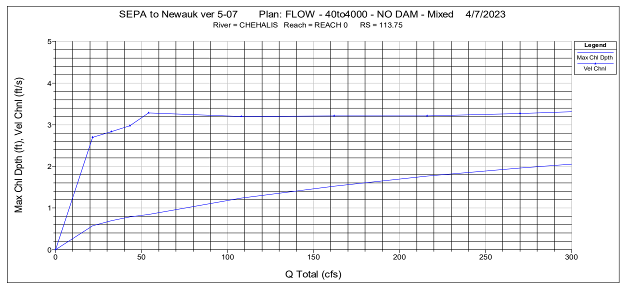
Vel Chnl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Legend
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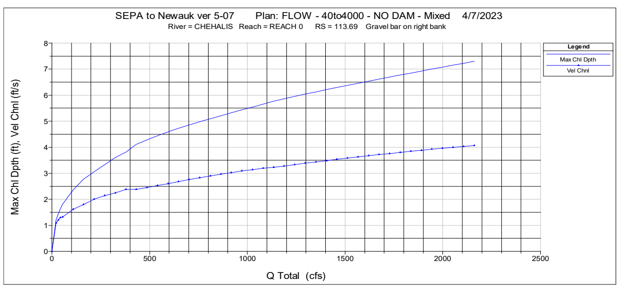
Vel Chnl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Legend
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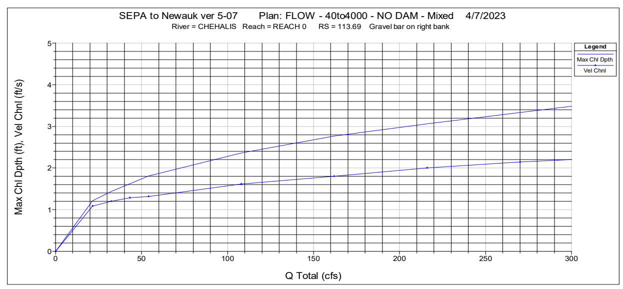
Vel Chnl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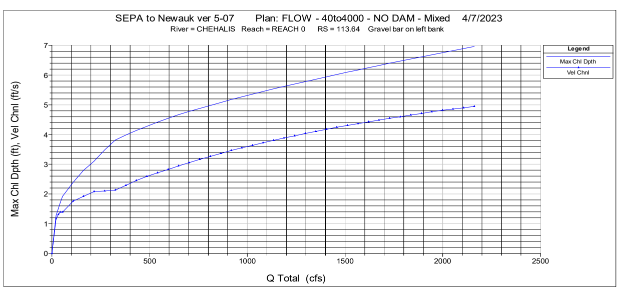
Vel Chnl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Legend
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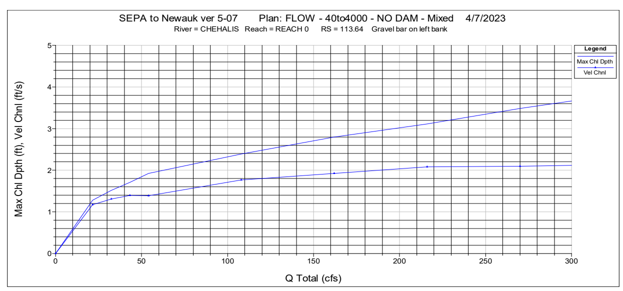
Vel Chnl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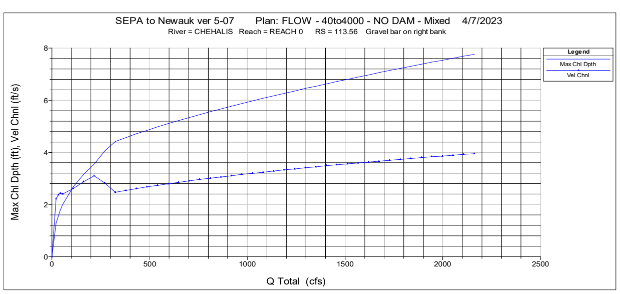
Vel Chnl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Legend
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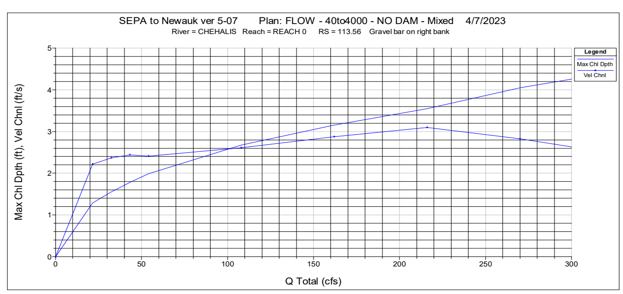
Vel Chnl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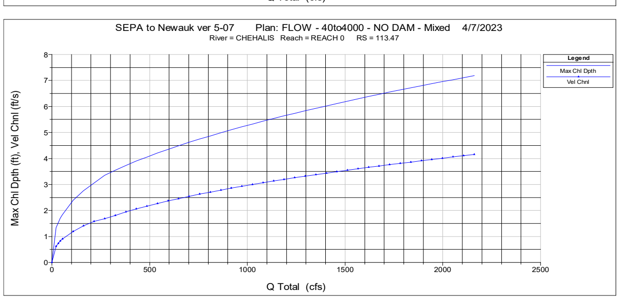
Q Total (cfs)
Legend
Max Chl Dpth
Vel Chnl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Legend
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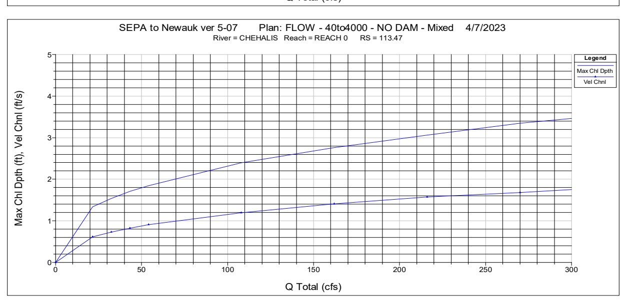
Vel Chnl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Q Total (cfs)
Legend
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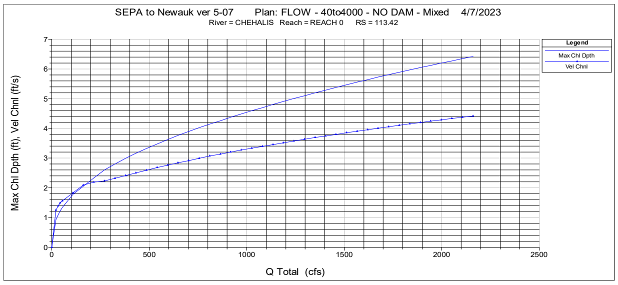
Vel Chnl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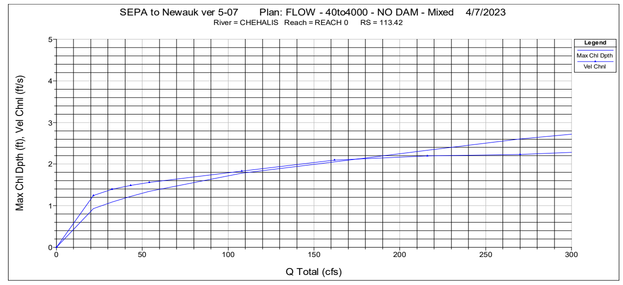
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)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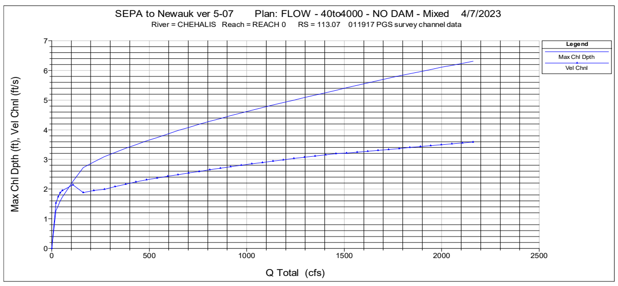
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)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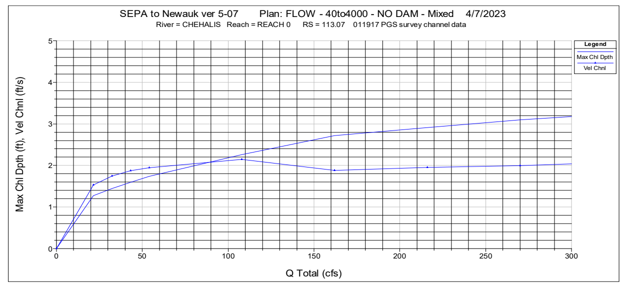
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)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Vel Chnl
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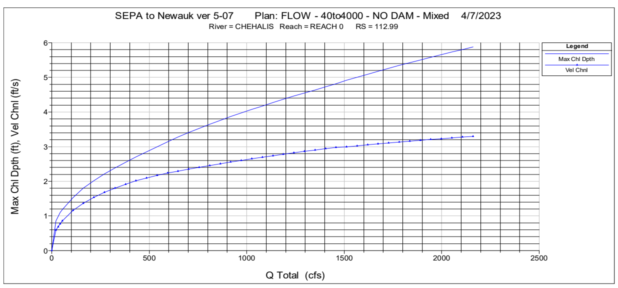
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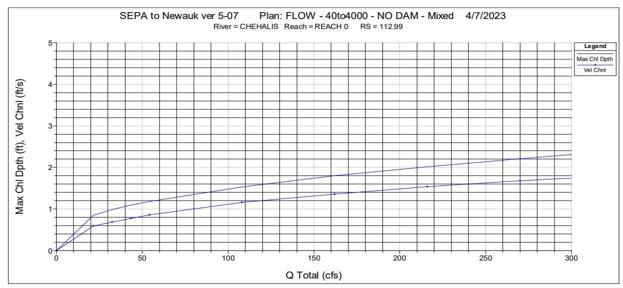
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Vel Chnl
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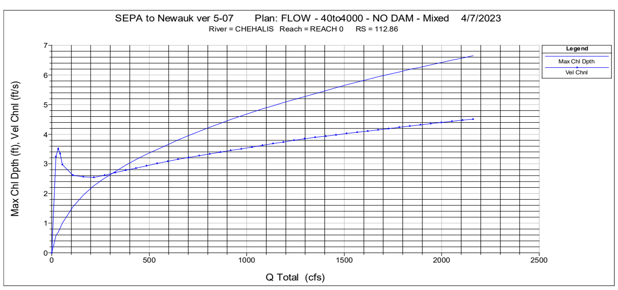
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Vel Chnl
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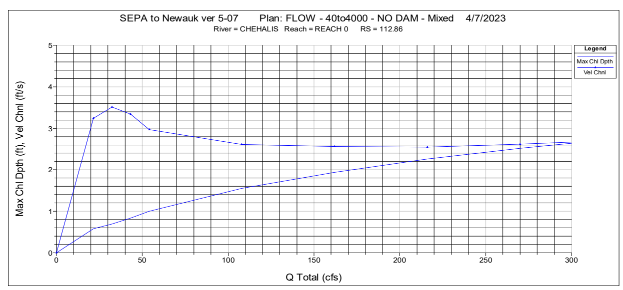
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Vel Chnl
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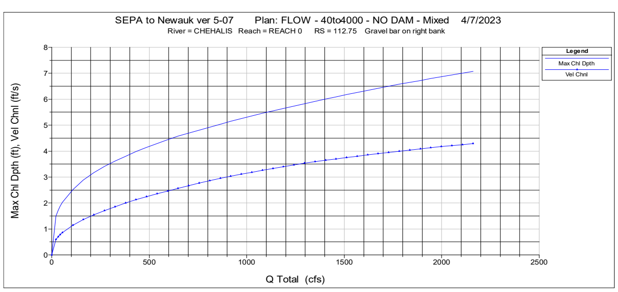
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Vel Chnl
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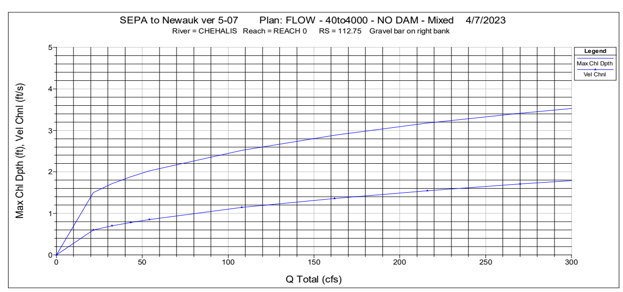
Q Total (cfs)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Max Chl Dpth
Vel Chnl
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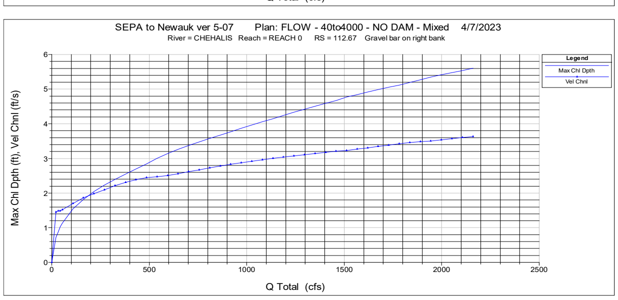
Q Total (cfs)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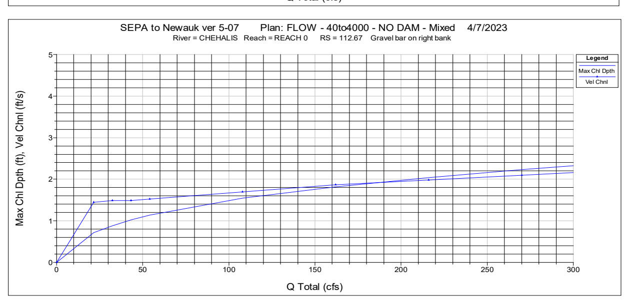
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)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Vel Chnl
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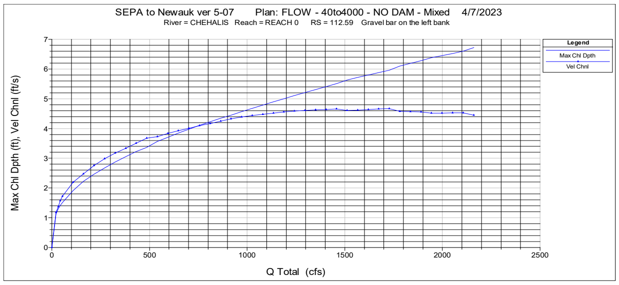
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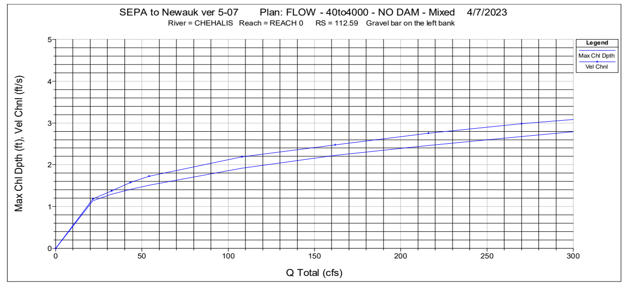
Legend
Max Chl Dpth
Vel Chnl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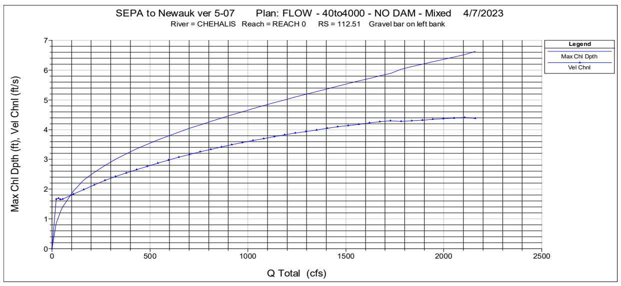
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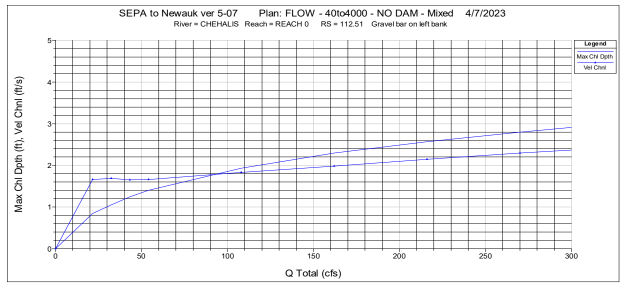
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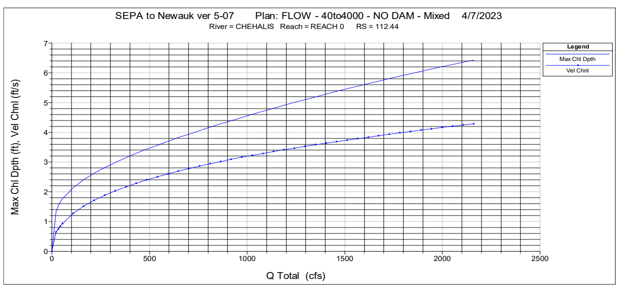
Vel Chnl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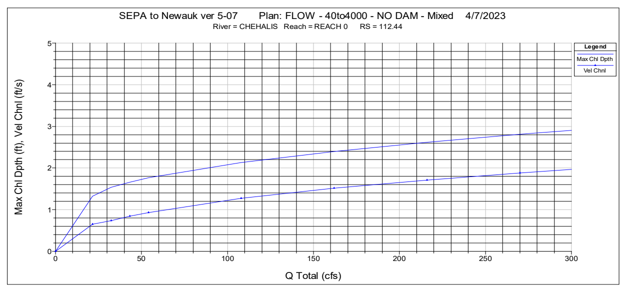
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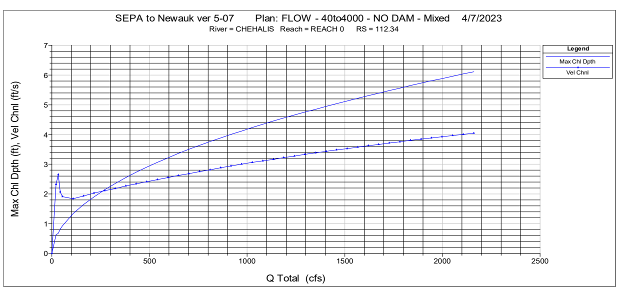
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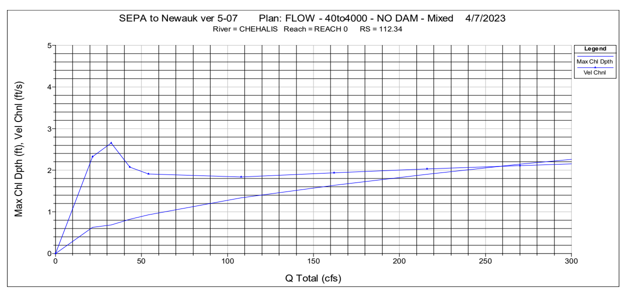
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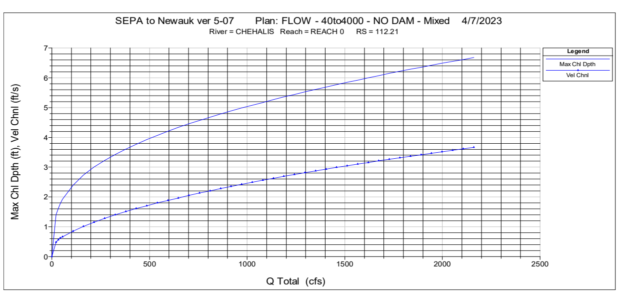
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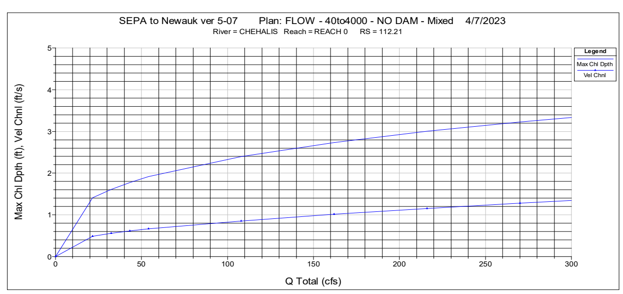
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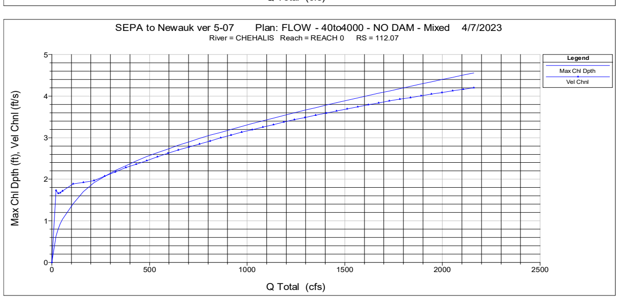
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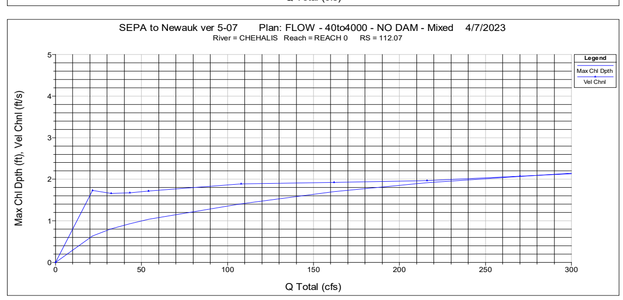
Vel Chnl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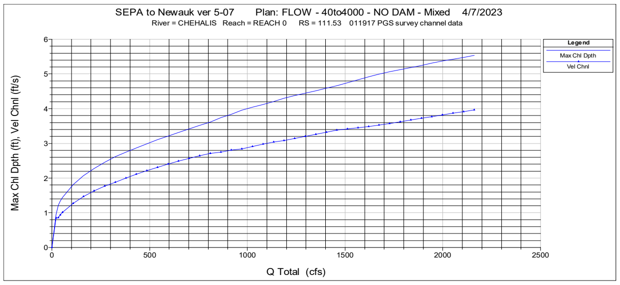
Vel Chnl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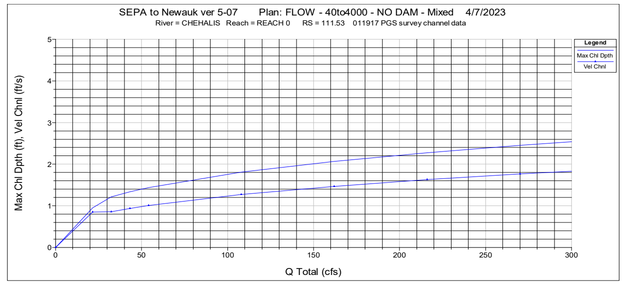
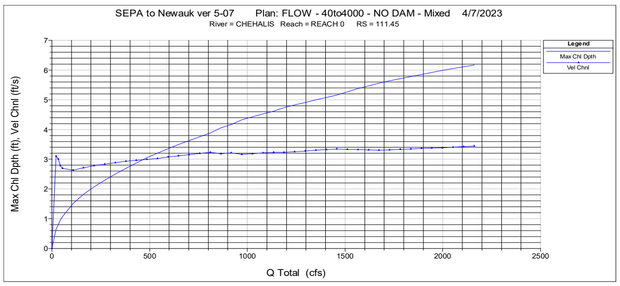
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 111.53 011917 PGS survey channel data
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 111.45
Legend
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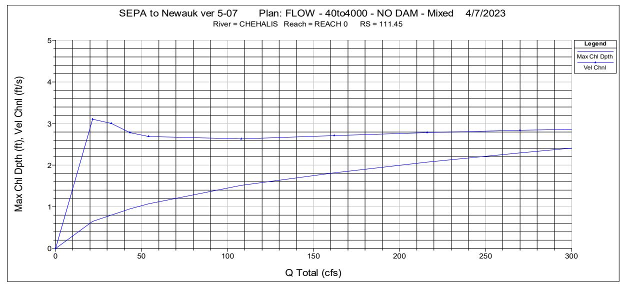
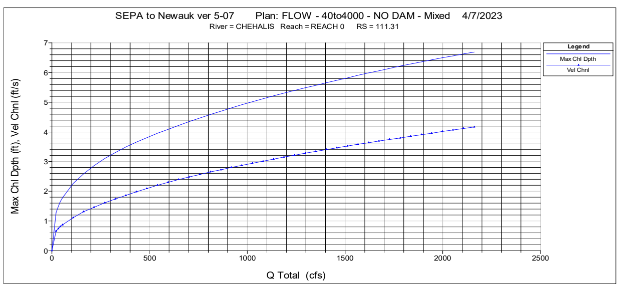
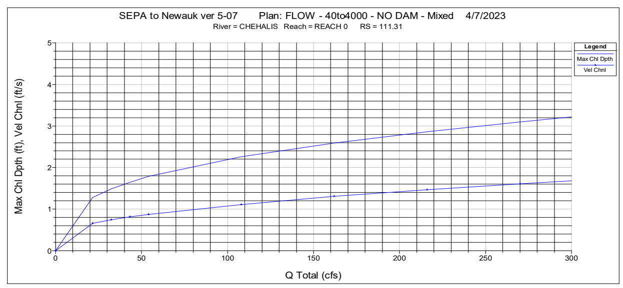
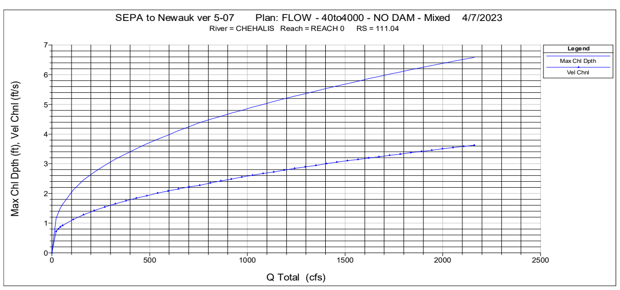
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 111.45
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 111.31
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 111.31
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 111.04
Legend
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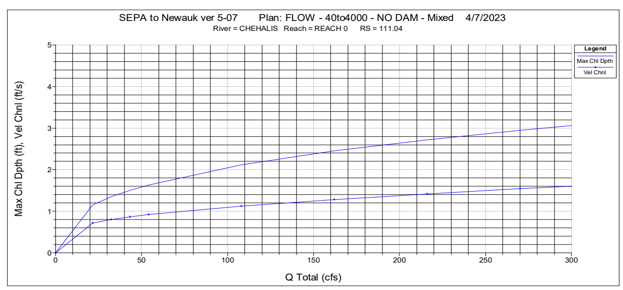
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 111.04
Legend
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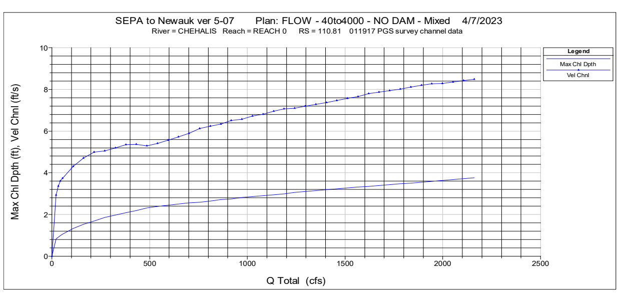
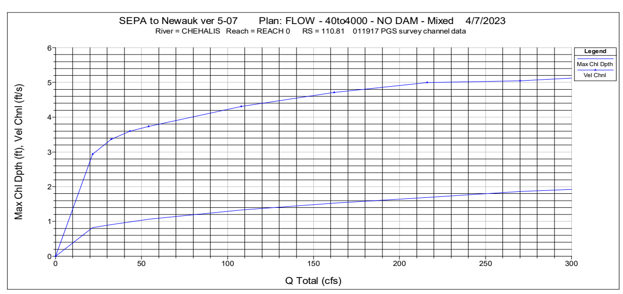
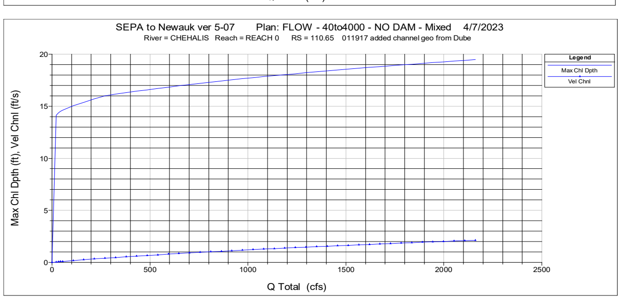
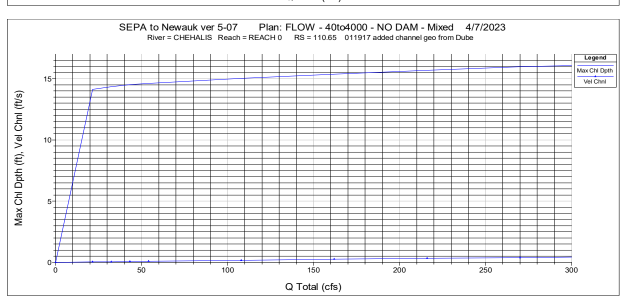
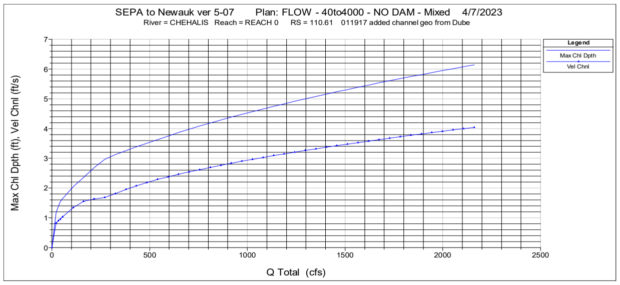
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

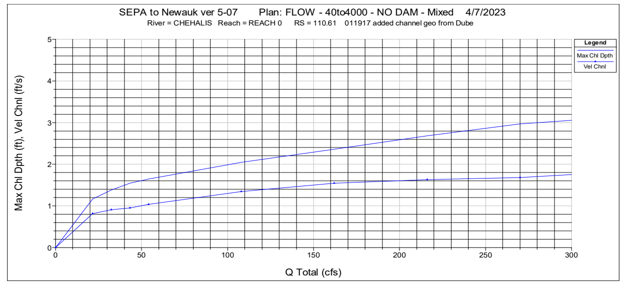

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.81 011917 PGS survey channel data
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

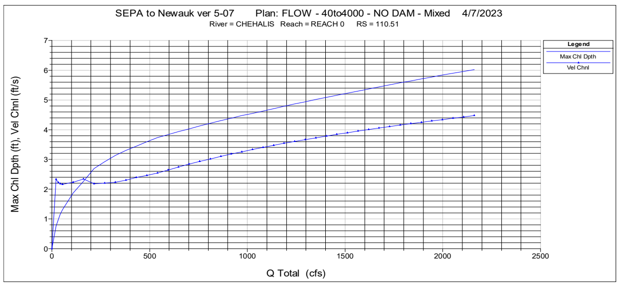

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.81 011917 PGS survey channel data
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

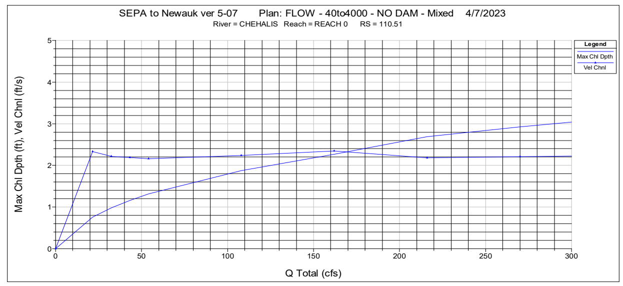

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.65 011917 added channel geo from Dube
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

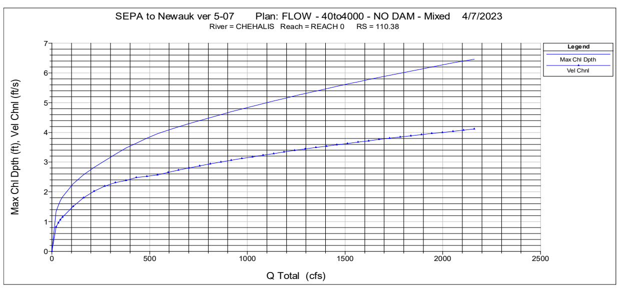

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.65 011917 added channel geo from Dube
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

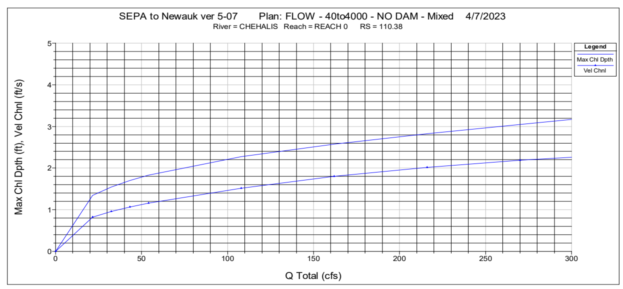

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.61 011917 added channel geo from Dube
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

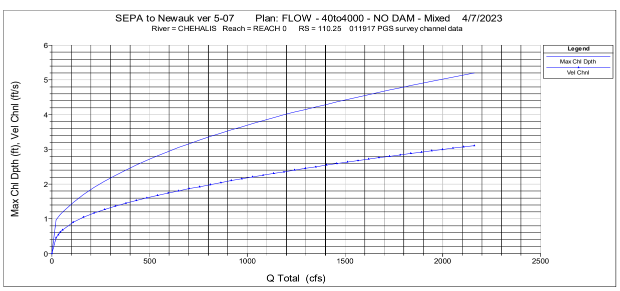

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.61 011917 added channel geo from Dube
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

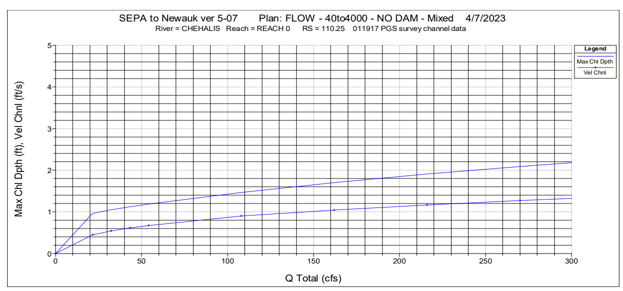

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.51
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

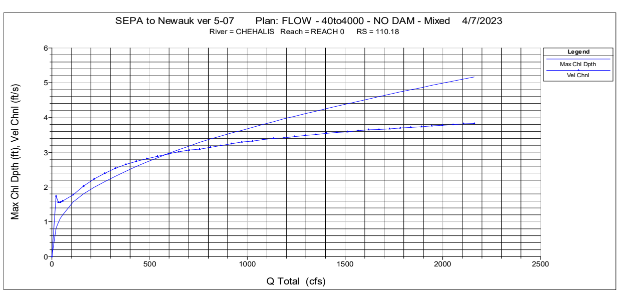

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.51
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.38
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.38
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.25 011917 PGS survey channel data
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.25 011917 PGS survey channel data
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.18
Legend
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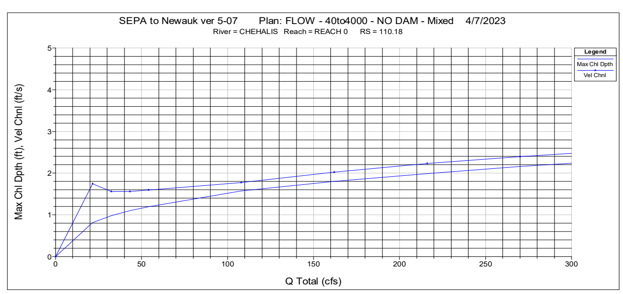
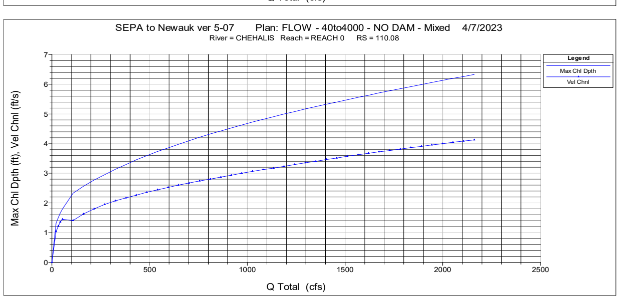
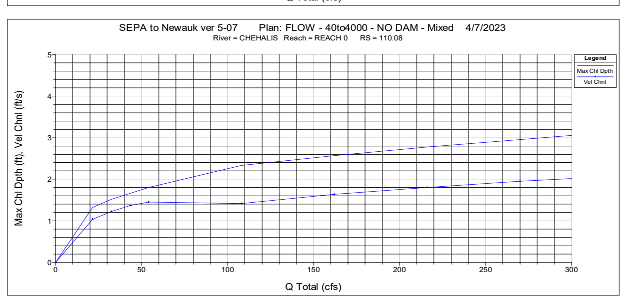
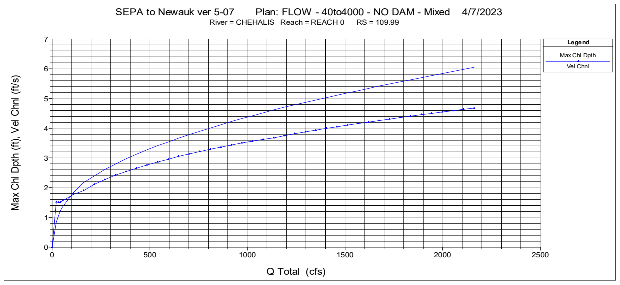
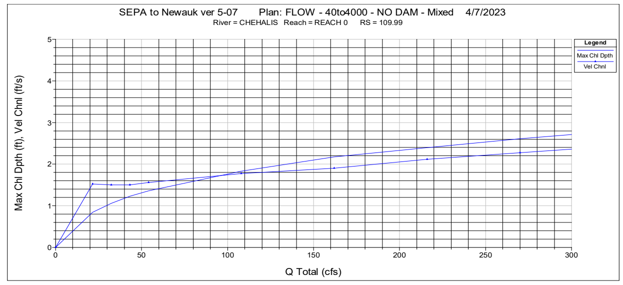
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

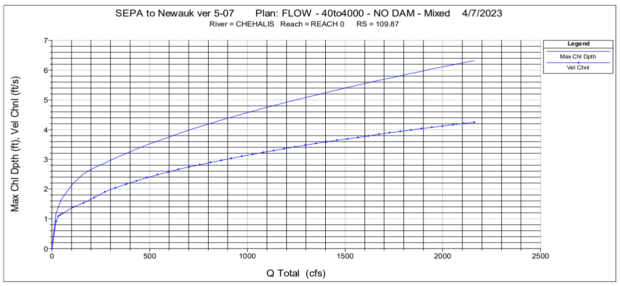

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.18
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

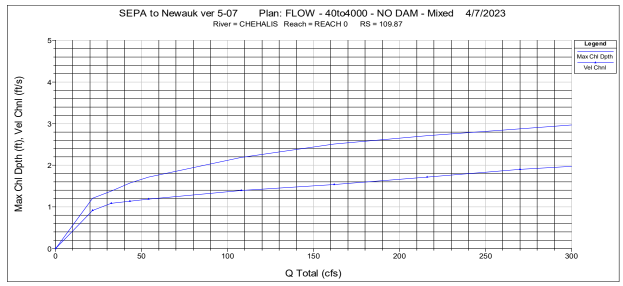

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.08
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

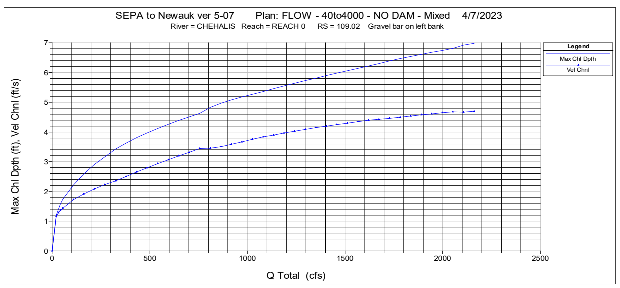

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 110.08
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

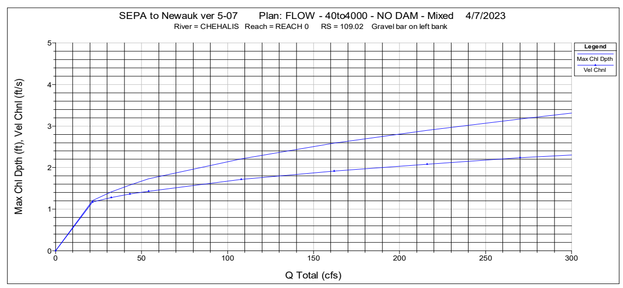

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 109.99
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

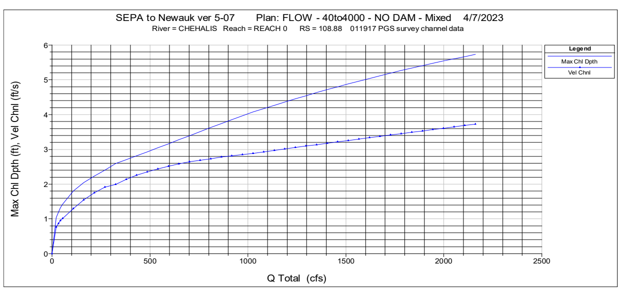

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 109.99
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

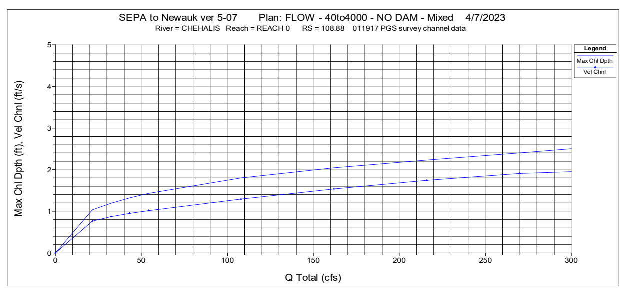

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 109.87
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

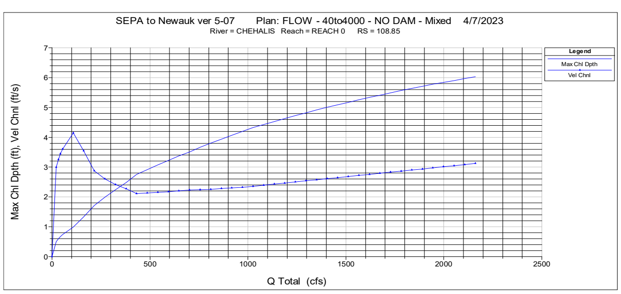

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 109.87
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

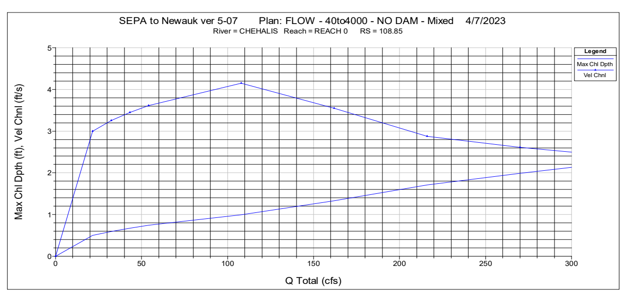

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 109.02 Gravel bar on left bank
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

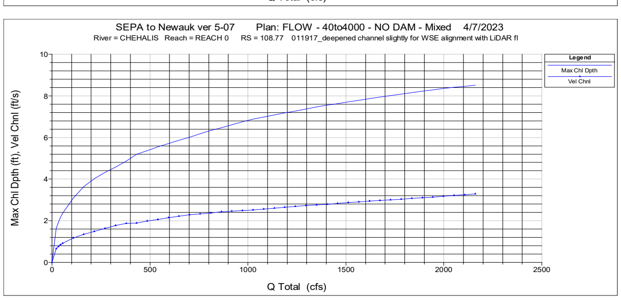

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 109.02 Gravel bar on left bank
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

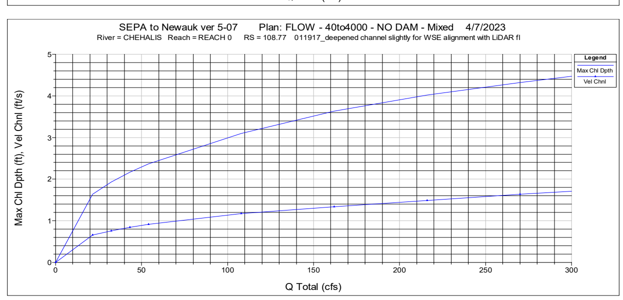

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 108.88 011917 PGS survey channel data
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

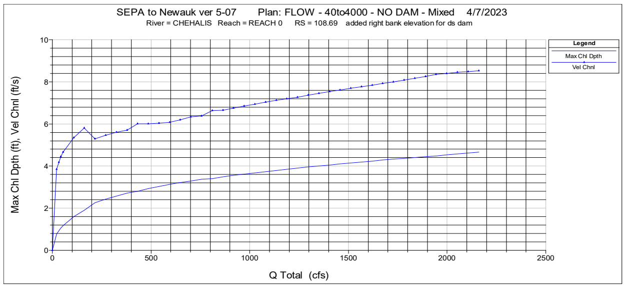

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 108.88 011917 PGS survey channel data
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

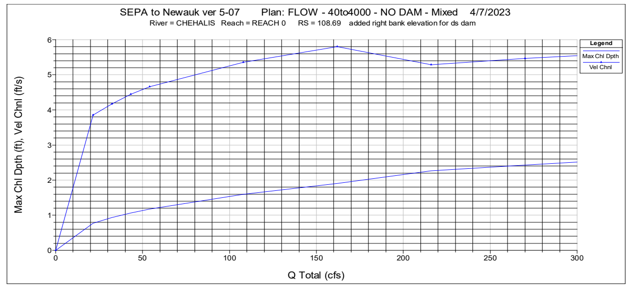

SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 108.85
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 108.85
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 108.77 011917_deepened channel slightly for WSE alignment with LiDAR fl
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 108.77 011917_deepened channel slightly for WSE alignment with LiDAR fl
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 108.69 added right bank elevation for ds dam
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)


SEPA to Newauk ver 5-07 Plan: FLOW - 40to4000 - NO DAM - Mixed 4/7/2023
River = CHEHALIS Reach = REACH 0 RS = 108.69 added right bank elevation for ds dam
Legend
Max Chl Dpth
Vel Chnl
Max Chl Dpth (ft), Vel Chnl (ft/s)
Q Total (cfs)

ATTACHMENT 2

MAINSTEM CHEHALIS RIVER SPAWNING HABITAT MAPPING DATA (2023)

Table B-1

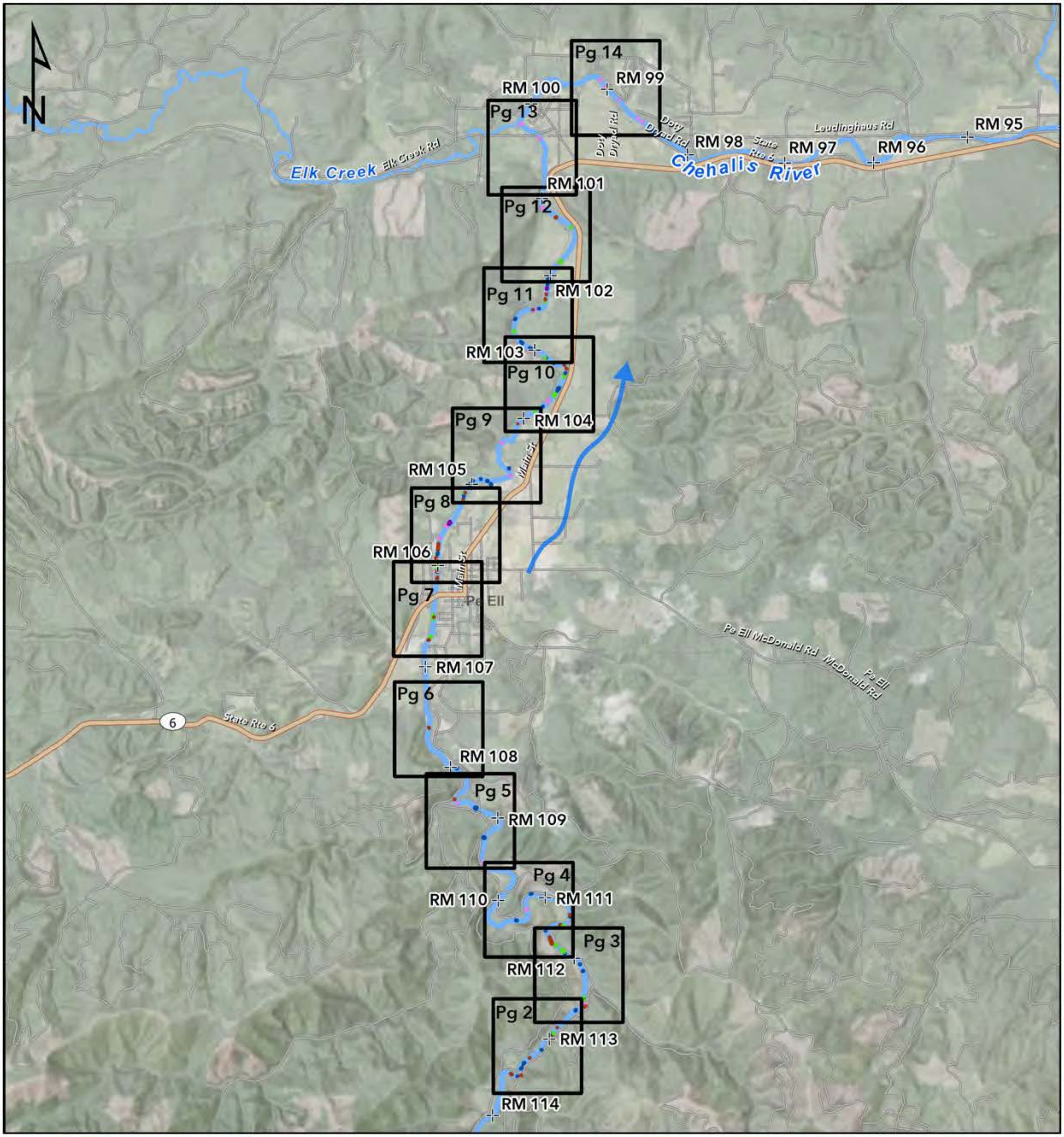
Summary of Spawning Habitat Mapping Data Collected in Mainstem Chehalis River in 2023.

RIVER MILE	DATE	MESOHABITAT	AREA (SQ FT)	SUBSTRATE		SCOUR RISK	COVER NEARBY	WETTED DEPTH RANGE (FT)		NO. REDDS OBSERVED	
				DOMINANT	SUB-DOMINANT			DEEPEST	SHALLOWEST	LIKELY ACTUAL	POSSIBLE FALSE
113.53	08/29/2023	Side Bar	472	LG	SC	High	No	0.5	-1.0	0	0
113.46	08/29/2023	Pool Tail	72	LG	SG	High	Yes	1.5	0.5	0	0
113.44	08/29/2023	Side Bar	111	LG	SG	Medium	Yes	1.0	-1.0	0	0
113.37	08/29/2023	Pool Tail	423	SG	LG	High	Yes	1.5	1.0	0	0
113.34	08/29/2023	Pool Tail	70	LG	SG	Low	Yes	2.0	0.5	0	0
113.32	08/29/2023	Pool Tail	274	LG	SC	Low	No	1.5	1.0	0	0
113.26	08/29/2023	Side Bar	102	SC	LG	Low	Yes	0.0	0.5	2	0
113.13	08/29/2023	Pool Tail	167	LG	SG	High	Yes	1.0	0.2	3	0
113.00	08/29/2023	Side Bar	74	LG	SG	Medium	No	0.5	-0.1	0	0
112.96	08/29/2023	Side Bar	199	LG	SG	Low	No	1.3	-1.0	0	0
112.95	08/29/2023	Pool Tail	159	LG	SC	Low	No	0.8	0.3	2	1
112.94	08/29/2023	Riffle	229	SC	LG	Low	No	0.7	0.2	4	0
112.87	08/29/2023	Side Bar	32	SC	LG	Medium	No	0.8	-0.3	0	1
112.62	08/29/2023	Pool Tail	307	LG	SC	Medium	Yes	1.5	-0.8	0	0
112.52	08/29/2023	Side Bar	451	LG	SC	Medium	Yes	1.2	0.5	0	0
112.48	08/29/2023	Riffle Crest	485	LG	SC	Low	No	1.3	-0.3	0	0
112.46	08/29/2023	Riffle	81	LG	SG	Low	No	1.3	0.5	0	0
112.43	08/29/2023	Pool Tail	104	LG	SG	Low	No	1.0	-0.5	0	0
112.42	08/29/2023	Riffle	55	LG	SG	Low	Yes	0.5	-0.5	0	0
112.16	08/29/2023	Pool Tail	276	LG	SC	Low	No	1.1	0.7	0	0
112.09	08/29/2023	Pool Tail	145	LG	SG	High	Yes	1.0	0.3	0	0
111.96	08/29/2023	Pool Tail	261	LG	SG	High	No	1.2	0.5	0	0
111.90	08/29/2023	Pool Tail	167	LG	SG	Low	No	1.2	0.5	0	0
111.88	08/29/2023	Riffle	1,067	LG	SC	Low	Yes	0.5	-0.2	0	0
111.79	08/29/2023	Riffle	487	SC	LG	Medium	Yes	0.4	-0.1	0	0
111.72	08/29/2023	Side Bar	2,586	LG	SG	Low	No	0.8	-0.8	0	0
111.63	08/29/2023	Pool Tail	103	LG	SG	Low	Yes	0.7	0.0	0	0
111.48	08/29/2023	Side Bar	524	LG	SC	Low	Yes	0.5	-1.1	0	1
111.46	08/29/2023	Riffle	202	SC	LG	Low	No	0.7	0.2	0	0
111.34	09/01/2023	Pool Tail	183	LG	SC	Medium	No	1.3	-0.5	1	0
111.32	09/01/2023	Side Bar	146	LG	SC	Low	Yes	0.7	-0.3	1	0
110.87	09/01/2023	Pool Tail	203	LG	SG	Low	Yes	0.8	0.0	0	0
110.70	09/01/2023	Riffle Crest	253	LG	SG	Medium	No	1.3	-0.3	2	4
110.51	09/01/2023	Pool Tail	468	LG	SG	Medium	No	1.2	-0.2	0	3
109.45	09/01/2023	Riffle Crest	49	LG	SG	Low	No	0.9	0.2	1	1
109.25	09/15/2023	Pool Tail	1,218	LG	SG	Medium	Yes	0.9	-0.3	0	0
108.75	09/14/2023	Pool Tail	1,168	SG	LG	Medium	Yes	1.0	-0.5	0	0
108.54	09/14/2023	Riffle Crest	120	LG	SC	Low	No	1.2	-0.1	0	1
108.49	09/14/2023	Side Bar	133	LG	SC	Medium	No	0.7	-0.5	0	0
108.07	09/14/2023	Pool Tail	257	MG	LG	Medium	Yes	0.8	0.0	0	0
107.56	09/14/2023	Side Bar	115	SG	LG	Medium	Yes	-0.3	-1.0	0	0
106.74	09/14/2023	Side Bar	233	LG	SG	Low	No	NRD	-0.5	0	0
106.69	09/14/2023	Riffle	227	SG	LG	Low	No	0.6	0.2	0	0
106.52	05/31/2023	Riffle	120	LG	SC	Low	No	1.0	0.5	0	0
106.50	05/31/2023	Side Bar	31	LG	SG	Low	NRD	0.0	0.0	1	0
106.48	05/31/2023	Riffle	357	-	-	Low	No	0.9	0.4	0	0
106.12	06/02/2023	Side Bar	333	LG	SG	Low	Yes	1.0	0.5	0	0
106.05	06/02/2023	Side Bar	776	SC	LG	Low	No	1.0	0.5	0	1
106.00	06/02/2023	Riffle	3,075	SC	LG	Low	No	1.0	0.2	0	5
105.93	06/02/2023	Side Bar	700	LG	SC	Low	Yes	1.5	0.5	1	0
105.86	06/02/2023	Pool Tail	373	LG	SG	Low	No	1.5	1.0	0	2
105.80	06/02/2023	Side Bar	1,100	SC	SG	Low	Yes	2.0	0.5	0	2
105.71	06/02/2023	Riffle Crest	112	LG	SC	Low	No	1.0	0.8	0	1
105.55	06/02/2023	Riffle Crest	246	LG	SG	Medium	Yes	1.5	0.5	1	3
105.51	06/02/2023	Run	1,688	LG	SG	Low	Yes	2.0	0.5	0	0
105.19	06/02/2023	Side Bar	173	SC	LG	Low	Yes	1.5	1.0	0	2
105.16	06/02/2023	Pool Tail	308	LG	SC	Low	Yes	1.0	0.8	0	7
105.13	06/02/2023	Riffle	54	LG	SC	Medium	Yes	2.0	1.5	0	1
105.12	06/02/2023	Side Bar	78	SG	LG	Low	No	1.0	0.5	0	0
105.02	06/02/2023	Pool Tail	380	SG	LG	Low	No	1.0	0.5	0	0
104.97	06/02/2023	Pool Tail	286	SC	LG	Low	No	2.0	1.0	1	2

RIVER MILE	DATE	MESOHABITAT	AREA (SQ FT)	SUBSTRATE		SCOUR RISK	COVER NEARBY	WETTED DEPTH RANGE (FT)		NO. REDDS OBSERVED	
				DOMINANT	SUB-DOMINANT			DEEPEST	SHALLOWEST	LIKELY ACTUAL	POSSIBLE FALSE
104.91	06/02/2023	Pool Tail	77	SG	LG	High	Yes	0.8	0.5	0	0
104.85	06/02/2023	Pool Tail	422	LG	SG	Medium	Yes	1.5	1.0	0	0
104.83	06/02/2023	Pool Tail	498	-	-	Low	Yes	2.0	0.5	2	5
104.65	06/02/2023	Riffle Crest	55	-	-	Low	Yes	2.0	1.0	0	2
104.58	06/02/2023	Pool Tail	247	LG	SC	Low	Yes	2.2	1.5	0	2
104.33	06/02/2023	Riffle Crest	151	SC	LG	Medium	Yes	2.0	1.0	0	2
104.06	06/02/2023	Side Bar	22	LG	SC	Medium	Yes	2.0	0.8	0	1
103.88	06/02/2023	Riffle	51	SG	LG	Low	No	1.0	0.5	0	2
103.87	06/02/2023	Riffle	123	LG	SC	Low	No	1.0	0.5	0	3
103.78	06/02/2023	Pool Tail	208	SC	LG	Medium	No	2.0	1.0	0	6
103.73	06/02/2023	Riffle Crest	514	LG	SG	Low	No	2.0	1.0	0	2
103.65	06/02/2023	Riffle	1,105	LG	SC	Low	NRD	1.5	1.0	0	5
103.58	06/02/2023	Pool Tail	1,694	LG	SG	Low	No	2.0	1.0	0	1
103.45	06/02/2023	Riffle	640	LG	SG	Low	No	1.0	0.5	0	3
103.42	06/02/2023	Pool Tail	183	LG	SG	Low	No	1.0	0.5	0	1
103.36	06/02/2023	Side Bar	102	LG	SG	Low	Yes	1.5	0.0	0	5
103.33	06/02/2023	Side Bar	53	LG	SG	Low	No	1.8	0.5	0	2
103.23	06/01/2023	Pool Tail	15	LG	SC	Medium	Yes	2.0	1.5	4	5
103.14	06/01/2023	Pool Tail	26	-	-	Low	Yes	2.0	1.0	0	0
103.13	06/01/2023	Riffle	29	-	-	Low	No	2.0	1.0	0	0
102.96	06/01/2023	Pool Tail	417	LG	SG	Low	No	1.5	0.8	0	0
102.86	06/01/2023	Pool Tail	735	LG	SG	Medium	No	1.5	1.0	0	0
102.73	06/01/2023	Riffle	267	LG	SG	Low	No	1.0	0.8	1	1
102.61	06/01/2023	Pool Tail	169	LG	SG	Medium	No	2.0	1.0	0	0
102.42	06/01/2023	Side Bar	62	-	-	Medium	No	2.0	1.5	3	1
102.37	06/01/2023	Riffle Crest	51	LG	SG	Low	Yes	1.0	0.7	0	1
102.35	06/01/2023	Pool Tail	41	LG	SG	Medium	No	2.5	1.5	1	0
102.25	06/01/2023	Riffle	24	LG	SC	High	No	1.0	1.0	0	1
102.23	06/01/2023	Side Bar	150	LG	SG	Medium	Yes	1.5	1.0	0	1
102.18	06/01/2023	Side Bar	148	LG	SG	Low	No	1.0	0.8	0	4
102.13	06/01/2023	Run	422	LG	SC	Low	No	2.0	1.5	0	1
102.07	06/01/2023	Pool Tail	452	SG	LG	Medium	No	1.5	1.0	0	5
102.05	06/01/2023	Pool Tail	469	SG	LG	Low	No	1.5	0.5	0	2
101.85	06/01/2023	Riffle Crest	406	LG	SC	Medium	No	1.5	1.0	0	8
101.84	06/01/2023	Riffle	153	LG	SC	Low	Yes	1.5	1.5	1	4
101.83	10/03/2023	Riffle	362	SC	LG	Medium	No	1.2	0.8	0	0
101.44	10/03/2023	Riffle	140	SC	MG	Low	No	1.2	1.0	1	0
101.35	10/03/2023	Side Bar	391	LG	SG	Low	Yes	2.1	1.1	1	2
101.11	10/03/2023	Riffle Crest	304	LG	SG	Low	No	1.6	0.9	0	2
100.44	10/03/2023	Riffle Crest	376	SC	SG	-	No	1.4	0.7	0	2
100.22	10/03/2023	Riffle Crest	217	SC	SG	Low	Yes	2.0	0.9	0	1
99.12	10/04/2023	Riffle Crest	253	SC	LG	Low	No	1.6	1.1	1	0
99.03	10/04/2023	Riffle Crest	77	SC	SG	Low	No	1.4	1.1	0	2
98.84	10/04/2023	Riffle Crest	49	LG	SG	Medium	Yes	1.7	1.0	3	0
98.59	10/04/2023	Riffle Crest	41	LG	SG	-	No	1.8	1.0	0	1
98.54	10/04/2023	Riffle Crest	68	SC	SG	Low	No	1.3	1.0	2	0

ATTACHMENT 3

MAINSTEM CHEHALIS RIVER SPAWNING HABITAT MAPS (2023)



Mesohabitat

- Pool tail
- Riffle Crest
- Riffle
- Run
- side bar

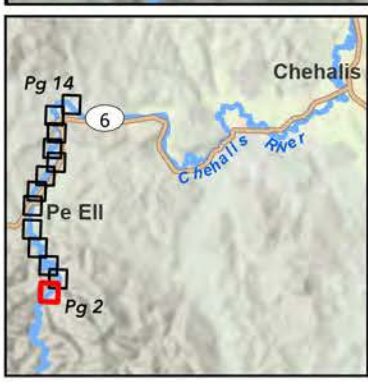
- Map Series Frame
- USGS River Mile
- Major Road
- Minor Road
- Flow Direction

0 2
Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season



Mesohabitat

- Pool tail
- Riffle Crest
- Riffle
- Run
- side bar

- USGS River Mile
- Minor Road
- Major Road
- Flow Direction

0 — 0.2 Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season

Page 2 of 14

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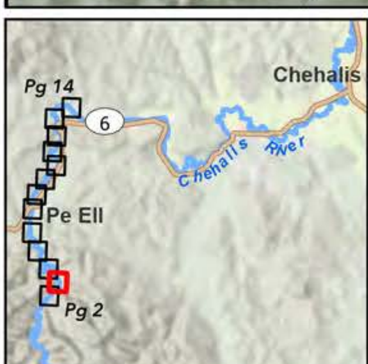


Mesohabitat

- Pool tail
- Riffle Crest
- Riffle
- Run
- side bar

- USGS River Mile
- Minor Road
- Major Road
- Flow Direction

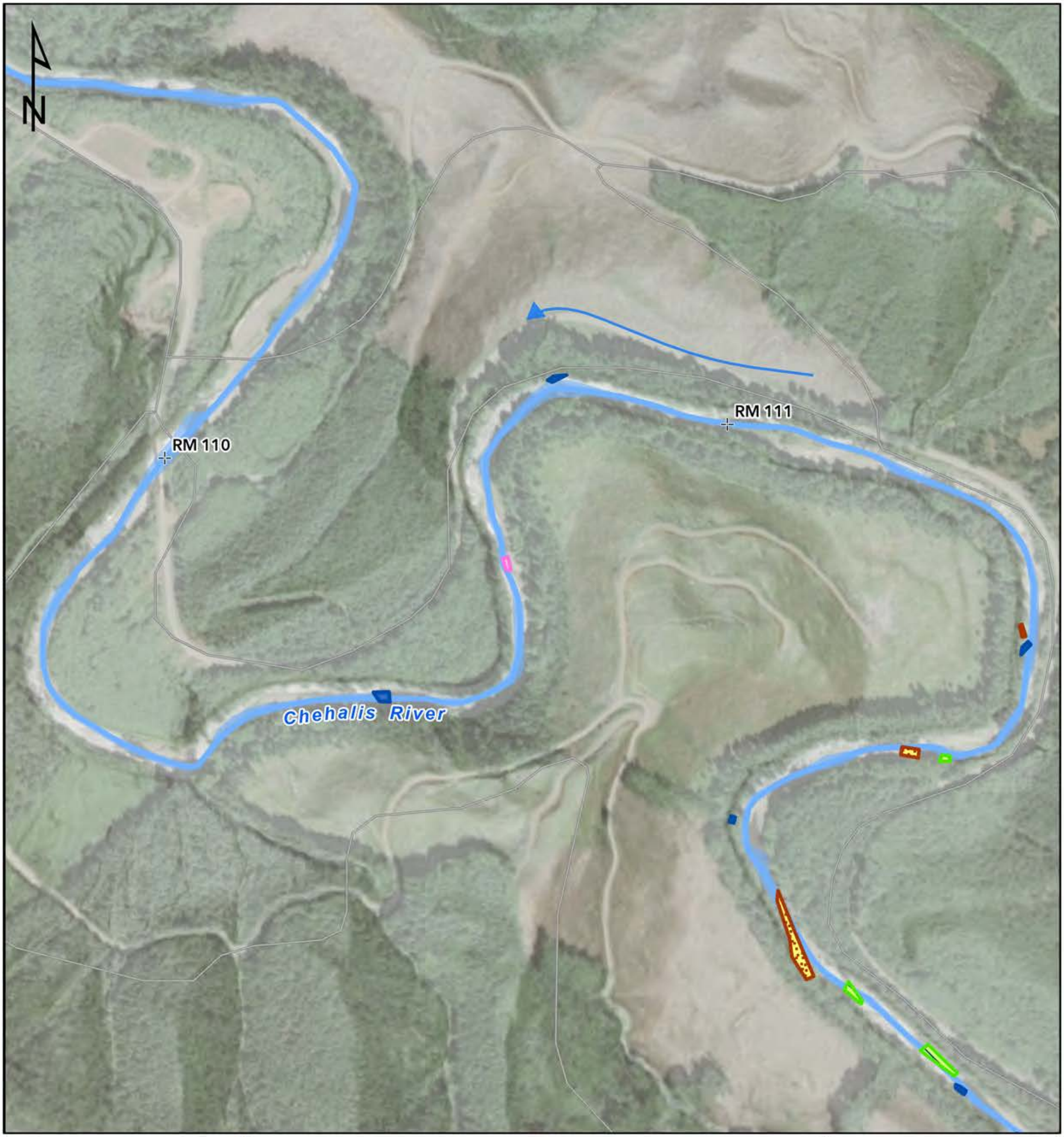
0 — 0.2 Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season

Page 3 of 14



Mesohabitat

- Pool tail
- Riffle Crest
- Riffle
- Run
- side bar

- USGS River Mile
- Minor Road
- Major Road
- Flow Direction

0 0.2
Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season

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Mesohabitat

- Pool tail
- Riffle Crest
- Riffle
- Run
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- USGS River Mile
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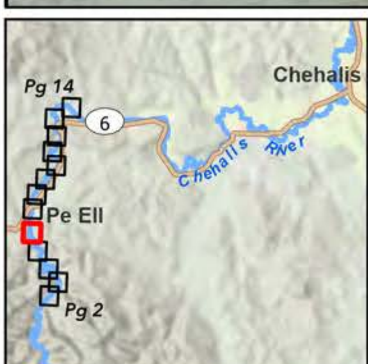
0 0.2
Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season



Mesohabitat

- Pool tail
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- USGS River Mile
- Minor Road
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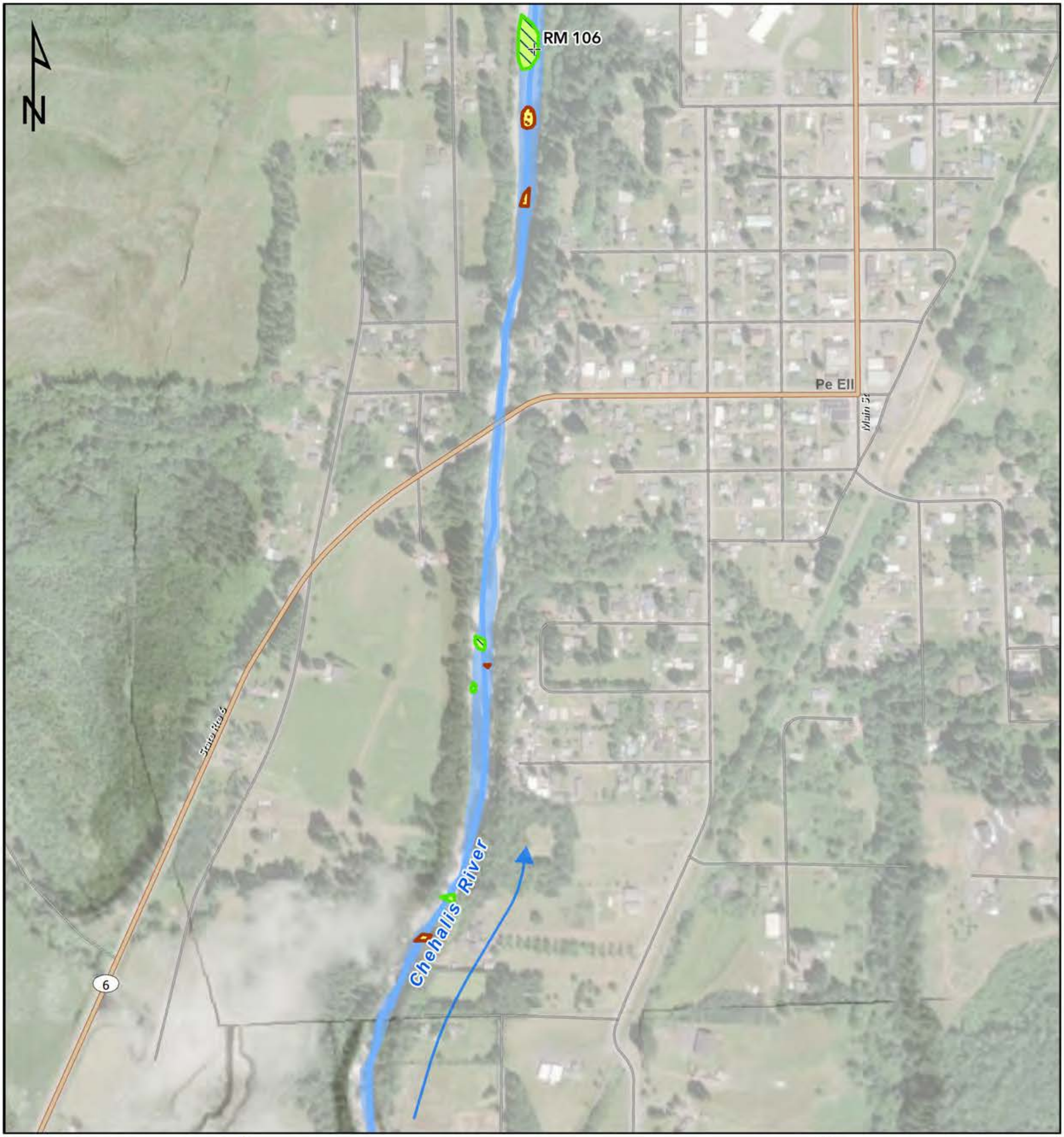
- Flow Direction

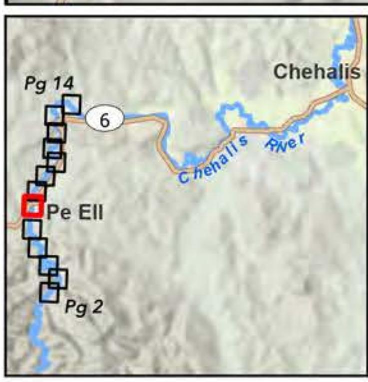
0 0.2
Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season
Page 6 of 14





Mesohabitat

- Pool tail
- Riffle Crest
- Riffle
- Run
- side bar

- USGS River Mile
- Minor Road
- Major Road
- Flow Direction

0 — 0.2 Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season

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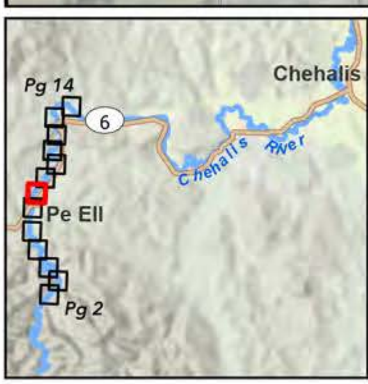

Mesohabitat
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- Riffle
- Run
- side bar

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- Minor Road
- Major Road
- Flow Direction

0 0.2
Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season

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Mesohabitat

- Pool tail
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- Run
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- Flow Direction

0 — 0.2 Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season

Mesohabitat

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0 0.2
Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season

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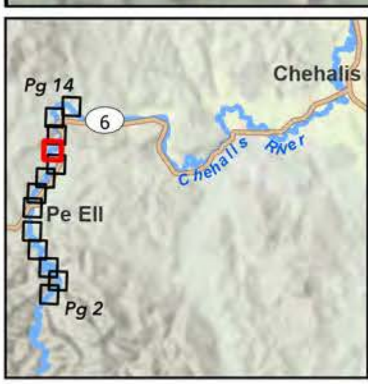

Mesohabitat

- Pool tail
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- Riffle
- Run
- side bar

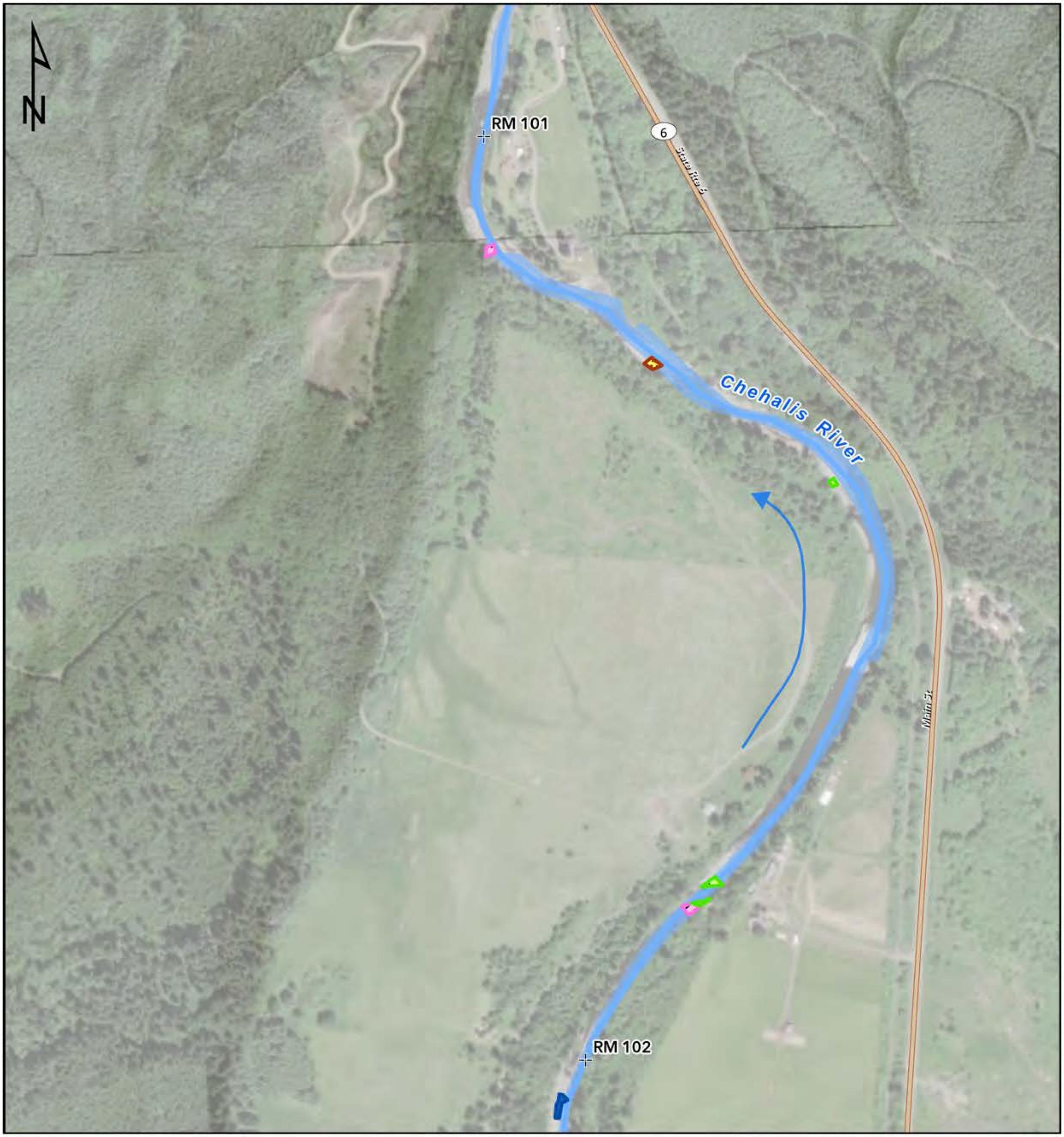
- USGS River Mile
- Minor Road
- Major Road
- Flow Direction

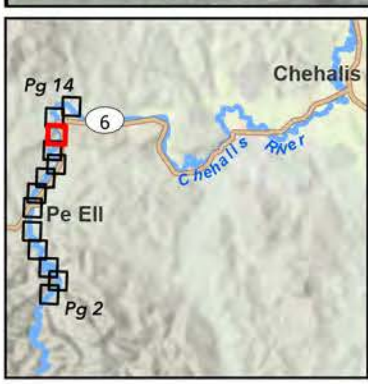
0 0.2
Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season





Mesohabitat

- Pool tail
- Riffle Crest
- Riffle
- Run
- side bar

- USGS River Mile
- Minor Road
- Major Road
- Flow Direction

0 — 0.2 Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season

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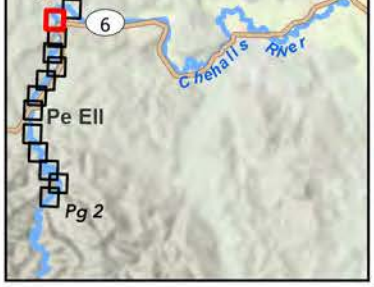


Mesohabitat

- Pool tail
- Riffle Crest
- Riffle
- Run
- side bar

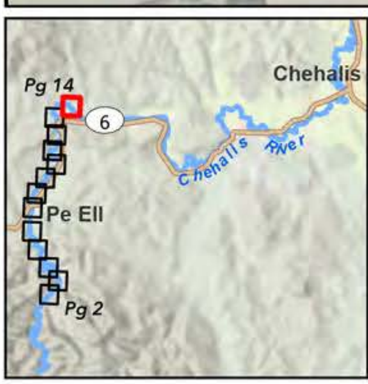
- USGS River Mile
- Minor Road
- Major Road
- Flow Direction

0 0.2
Miles

Chehalis River Basin
Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season



Mesohabitat

- Pool tail
- Riffle Crest
- Riffle
- Run
- side bar

- USGS River Mile
- Minor Road
- Major Road
- Flow Direction

0 — 0.2 Miles

Chehalis River Basin Flood Control Zone District

Kleinschmidt

Spawning Habitat Observations, 2023 Field Season

Path: Q:\Client_Data\Other\Chehalis\New folder\2_08_SpawningHab\SpawningHabitat.aprx

B2 Scour Technical Memorandum

TECHNICAL MEMORANDUM

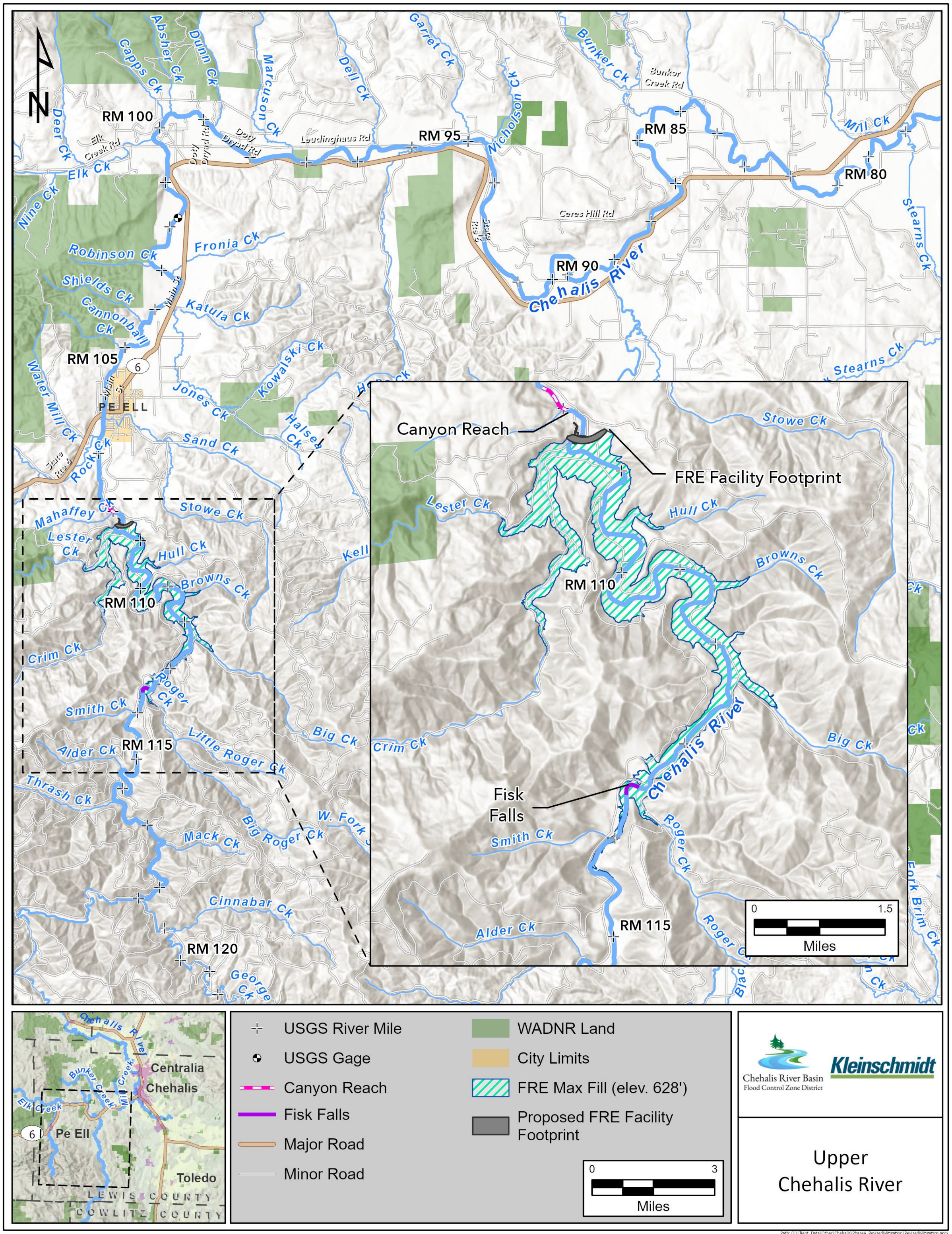
Date: July 9, 2024
To: Matt Dillin, Chehalis River Basin Flood Control Zone District
From: Paul DeVries, PhD, PE, CFP, Kleinschmidt Associates
Cc: MaryLouise Keefe, PhD and Jason Kent, PE, PMP, Kleinschmidt Associates
Re: Chehalis River 2023-2024 Scour Study Interim Report

Background

The Chehalis Basin Flood Control Zone District (Applicant) is proposing to construct a Flood Retention Expandable (FRE) facility to reduce the risk of flood damage along the mainstem Chehalis River. The proposed FRE facility is located approximately 1.7 miles upstream from the city of Pe Ell, Washington in the upper Chehalis River watershed (Figure 1). The primary purpose of the FRE facility is to reduce flooding coming from the Willapa Hills by storing floodwaters in a temporary reservoir during extreme flood events. In 2020, the two draft Environmental Impact Statements (DEISs) released for this project (by the Washington Department of Ecology [Ecology] under the State Environmental Policy Act and by the United States Army Corps of Engineers' [Corps] under the National Environmental Policy Act) projected that by temporarily storing peak flows during major or catastrophic flood events, the FRE facility operations would alter sediment transport and deposition processes and thereby impact channel forming processes and spawning habitat quantity and quality. This, in turn, was hypothesized to impact reproductive success of fish species relying on spawning habitat within the potential reservoir footprint and downstream (Ecology 2020; Corps 2020). Impacts were generally represented as occurring upstream of Elk Creek (around river mile [RM] 100).

While fall Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and steelhead (*O. mykiss*) are all found in the basin and have segments of their populations that are mainstem spawners, the DEISs expected spring Chinook salmon populations to suffer the greatest potential impact on spawning habitat. This was largely due to their restricted distribution as compared to other salmonid species in the basin. In the upper Chehalis basin, both spring and fall Chinook salmon spawn predominantly in the mainstem, with greatest concentrations of redds noted in approximately the first two miles below Fisk Falls above the proposed FRE location, and in a four-mile reach downstream of Pe Ell below where the river exits the Willapa Hills (Washington Department of Fish and Wildlife [WDFW] electronic data for 2015-2021 received from Ecology; Phinney et al. 1975; Watershed GeoDynamics and Anchor QEA, LLC [WG and Anchor] 2017; Ferguson et al. 2017; Ronne et al. 2020; Figure 2). There are few tributaries large enough in the basin with sufficient gravel deposits to provide spawning habitat for Chinook salmon and they are primarily located downstream of the proposed location of the FRE. Steelhead and coho salmon spawn more extensively than Chinook salmon in tributary habitats most of which would not be influenced by FRE operations (Ronne et al. 2020). In addition, there likely would be

Figure 1
Map of Chehalis River Study Reach, Including Location of Important Landmarks and River Mile (RM) Markers.



more locations and opportunities to mitigate for impacts to those two species by providing access to disconnected spawning habitats than there would be for Chinook salmon. Thus, the focus for mitigation of sediment impacts to mainstem spawning habitat will be most important with respect to Chinook salmon. However, analyses and data collection performed by the Applicant's team (Appendices A1, B1) indicate that scour may be an important confounding factor with respect to defining impacts of FRE operations on spawning success and any associated mitigation measures that may be required.

Spawning gravel mapping and coarse sediment transport analyses indicate that the core long-term spawning habitat for Chinook salmon is concentrated in two reaches, below Fisk Falls above the proposed FRE location and downstream of Pe Ell (Kleinschmidt 2024, Appendices A1 and B1). Field observations made during spawning gravel mapping suggested scour risk may be higher upstream of the FRE location than downstream based on visual assessment of the balance between local supply and transport of spawning sized substrates (Kleinschmidt 2024, Appendix A1). As corroboration, Weyerhaeuser's watershed analysis characterized scour risk to salmon intragravel survival as high in the mainstem Chehalis River in the reach below Fisk Falls in the early 1990s (Light and Herger 1994). The risk downstream of Pe Ell has not been characterized; it may be high given the confined nature of the river channel, yet at the same time given the lower gradient and greater abundance of spawning sized gravel and cobble, it may be lower than in the upstream reach. Limited scour data were collected in the development of the DEISs in the context of evaluating general substrate mobility during floods, but the data were not collected to address scour as a direct risk factor to intragravel survival and how FRE operation may modify that risk.

This study was designed to evaluate scour risk more directly and extensively through scour monitoring in both reaches over the winter of 2023-2024 (the study is presently underway and may be continued over the 2024-2025 winter season; this technical memorandum should be considered a work in progress). A key question of the study is whether scour risk in the proposed inundation area is sufficiently high during major floods that intragravel survival would be low under existing conditions. If this is the case, then operation of the FRE facility could provide a benefit by reducing scour in spawning areas upstream during these floods. A second key question is whether scour risk is also high downstream of the proposed FRE location and whether FRE facility operation would reduce that risk.

Study Design

The study relies on replication to evaluate specific hypotheses. A minimum sample size of six replicate scour monitors were installed in a given site, where each site was characterized as potential spawning habitat during the 2023 spawning habitat mapping effort as defined by depth ranges and general substrate sizes (Kleinschmidt 2024, Appendix A1). This sample size is a practical approximation of the asymptotic degree of freedom in the Student's t-distribution above which critical values decrease more slowly with increasing sample size when computing confidence intervals. To control potential major sources of variation, sites were differentiated based on channel mesohabitat unit type and judged risk of deep scour. The following mesohabitat types were noted to contain suitable spawning habitat in the upper Chehalis River during the spawning habitat mapping effort: pool tail, riffle crest, riffle, side bar. Scour risk was characterized qualitatively as 'low,' 'medium,' or 'high.'

Two reaches were defined that corresponded to the two, core long-term spawning reaches: one within the FRE inundation area and the other downstream in the Pe Ell valley (Kleinschmidt 2024, Appendices A1 and B1). Sites were selected according to mesohabitat type and relative risk of deep scour as judged in the field during mapping. Specific null hypotheses to be tested were:

- H_{o1}: Scour depth in spawning habitat in FRE inundation area is not significantly different than in downstream reaches; and
- H_{o2}: Scour depth in 'low risk' sites is not significantly different than in 'high risk' sites.

In addition, the visual characterization assigned during spawning habitat mapping was evaluated by comparing measured scour depths against characteristic egg burial depths (DeVries 1997), and whether the scour depth was restricted to the surface layer in low risk sites (i.e., $<2D_{90}$ of the surface armor layer, which corresponds approximately to bedload layer thickness under dynamic equilibrium conditions without scour and fill), and was deeper in medium/high risk sites (i.e., scour and fill associated with local sediment transport imbalances; DeVries 2008).

Sample Sites

Several criteria were considered in selecting sites for scour monitoring. During 2023, gravel mapping study, pool tails were mapped as the most prevalent channel unit supporting potential spawning habitat upstream of the proposed FRE location, so this mesohabitat type was sampled primarily. Two (2) replicate pool tail sites were selected for sampling for each scour risk level in each reach, for a total of eight (8) pool tail sites. However, given pool tails have a higher risk of deep scour generally compared with riffles based on sediment transport principles (DeVries 2008), a riffle was also sampled in each reach where redd activity had been recorded in previous years and where scour risk was judged to be low during the mapping effort, for comparative purposes. Accessibility for safe scour monitor installation, measurement, and retrieval was also considered during site selection. Sampled sites are depicted in Figures 2-6.

Measurement Methods

Scour depth was measured using a sliding whiffle ball scour monitor (Figure 7). The monitor was installed in the gravel using a specialized pipe assembly (Figure 8). The monitor was anchored at its bottom end with either a wooden dowel or metal washer that is held in place by gravel. Scour monitor balls should generally not move when the pivot angle between a ball and the scour depth elevation is greater than 180 degrees because substrate particles hold the ball in place. Scour of a single ball will occur when the disturbance depth falls below one-half of the ball diameter and the pivot angle becomes less than 180 degrees. The next ball underneath should not move until the scour depth reaches its half-diameter depth. The scour depth measurement error of a single monitor is thus expected to be plus or minus half the ball diameter, or ±0.8 inches (range=1.6 inches). The number of balls ending up at the end of the line has been found to be a reliable measure of scour depth (DeVries 2000).

Figure 2
Locations of Sampled Pool Tail Sites Above the Proposed FRE Location, at High Bridge Below Rogers Creek and Fisk Falls. Symbols Are Locations in WDFW's Database of Fall (triangles) and Spring (squares) Chinook Salmon Redds. Polygons Indicate Approximate River Miles (RMs) of Mapped Spawning Habitat Patches.

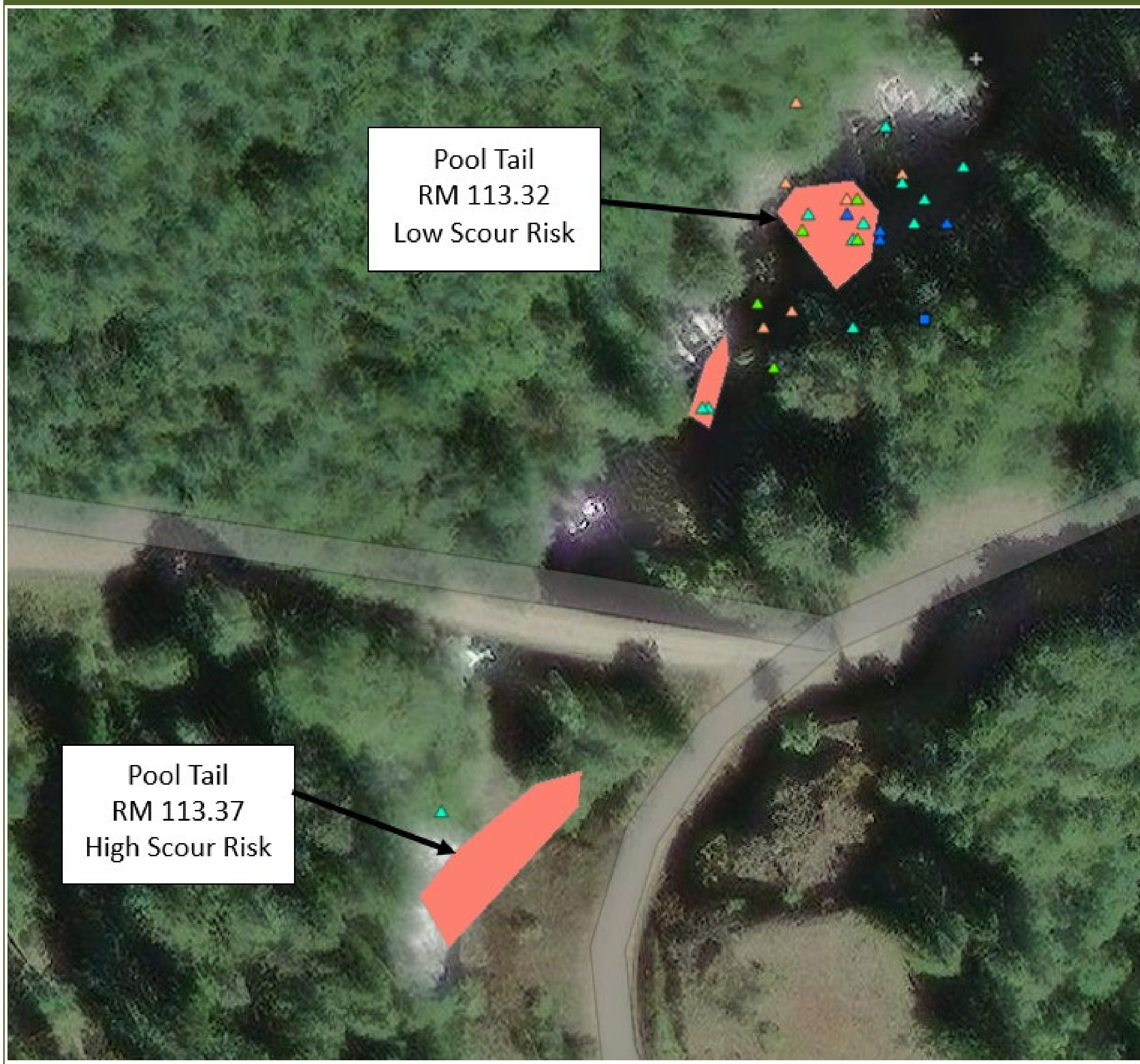


Figure 3
Locations (depicted by polygons) of Sampled Pool Tail and Riffle Spawning Mesohabitat Patches Above the Proposed FRE Location, Downstream of Big Creek. Colored Symbols Indicate Locations in WDFW's Database of Fall (triangles) and Spring (squares) Chinook Salmon Redds. Approximate River Miles (RMs) of Each Mapped Spawning Habitat Patch Are Indicated.

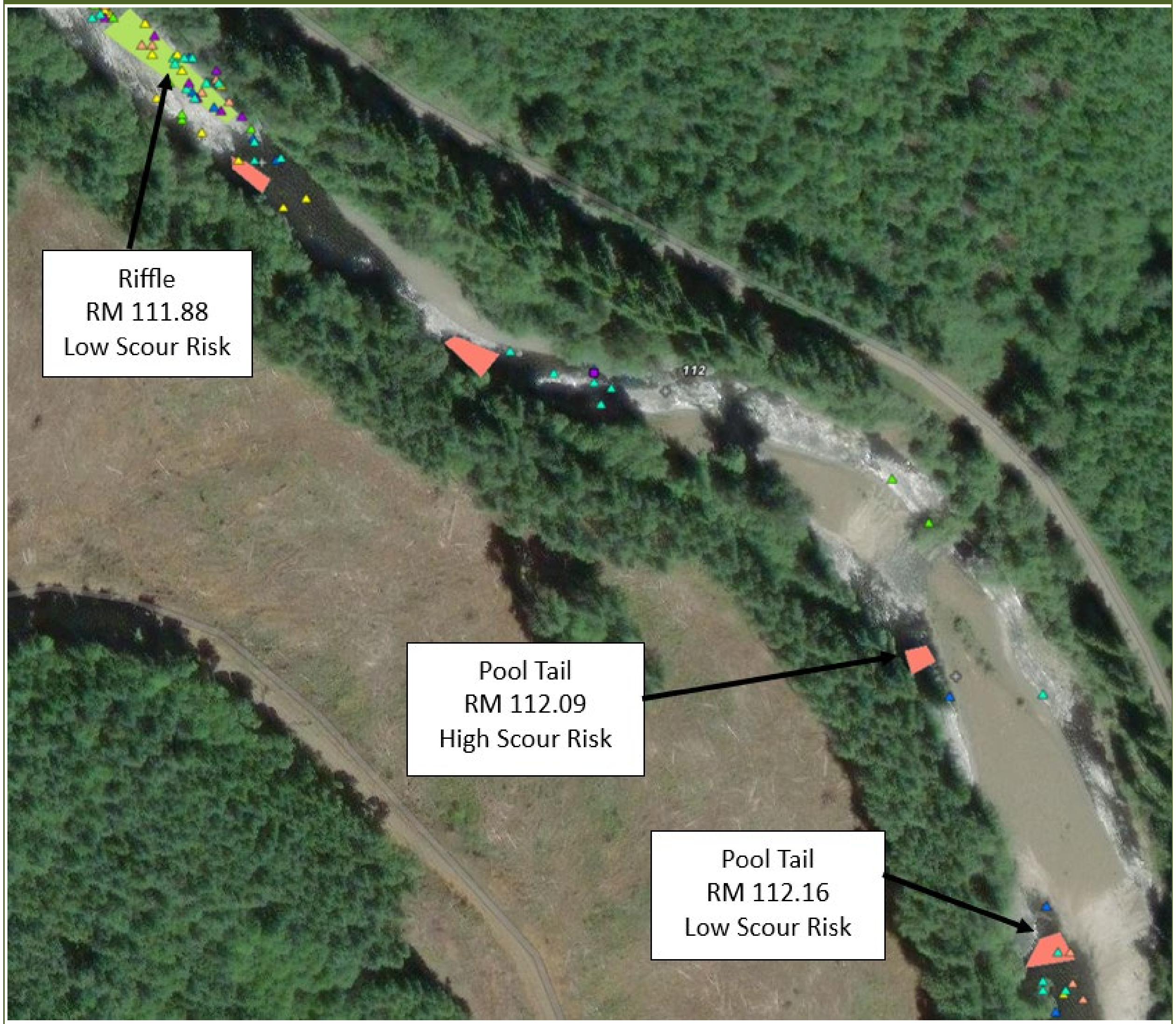
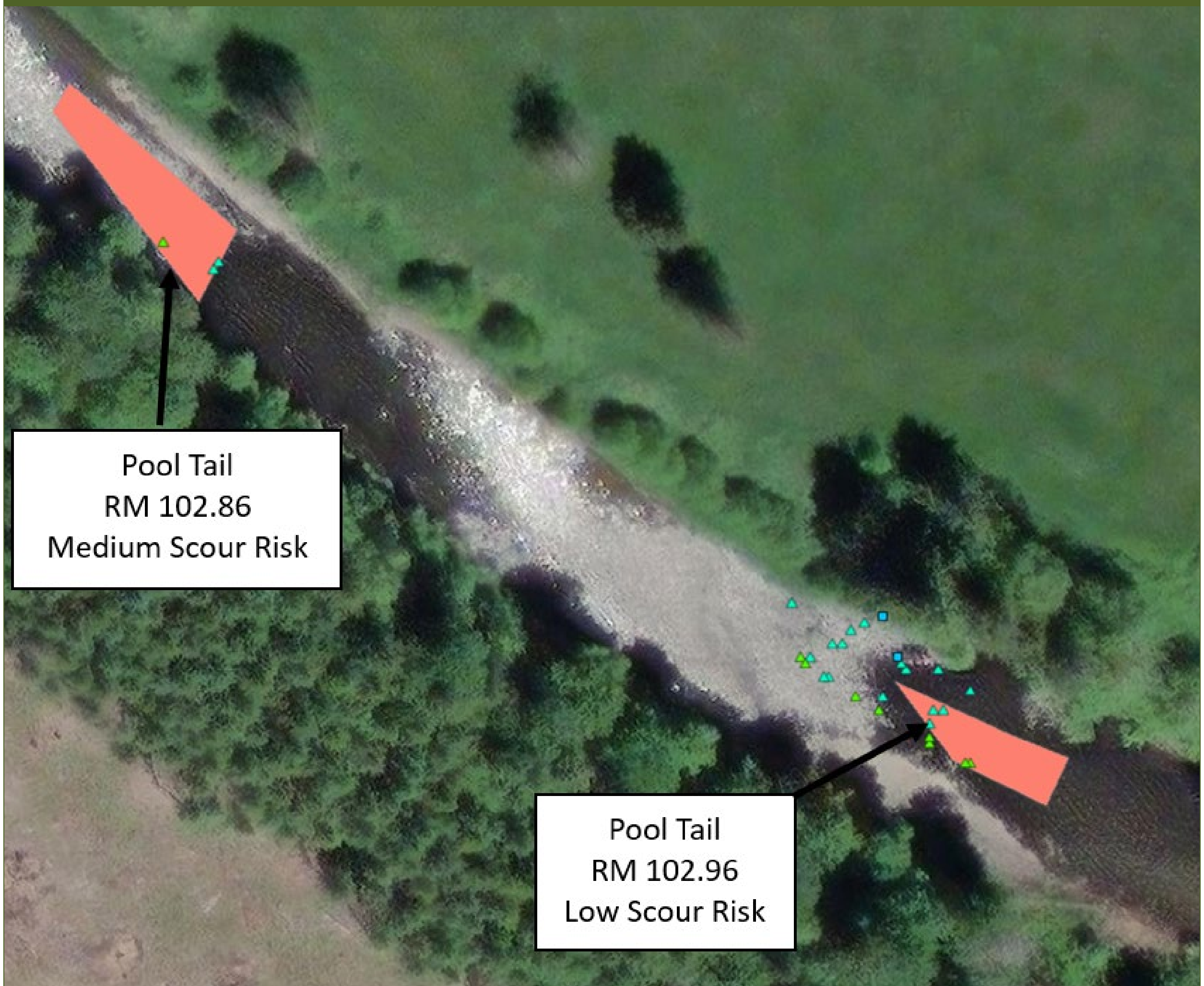


Figure 4
Locations of Sampled Riffle Mesohabitat Patch at Pe Ell. Colored Symbols Are Locations in WDFW's Database of Fall (triangles) and Spring (squares) Chinook Salmon Redds. Approximate River Miles (RMs) of Each Mapped Spawning Habitat Patch Are Indicated.

Figure 5
Locations of Sampled Pool Tail Spawning Mesohabitat Patches Below Pe Ell. Colored Symbols Are Locations in WDFW's Database of Fall (triangles) and Spring (squares) Chinook Salmon Redds. Approximate River Miles (RMs) of Each Mapped Spawning Habitat Patch Are Indicated.

Figure 6
Locations of Sampled Pool Tail Spawning Mesohabitat Patches Below Pe Ell. Colored Symbols Are Locations in WDFW's Database of Fall (triangles) and Spring (squares) Chinook Salmon Redds. Approximate River Miles (RMs) of Each Mapped Spawning Habitat Patch Are Indicated.



A number of scour monitor dimensions were measured during installation for calculating scour depth (Figure 7). The distance from the top crimp to the top washer (D_1 in Figure 7) was measured both before and after installation to ensure that the indicator balls were seated properly without any gaps occurring between balls. The combined height of the indicator balls (D_2 in Figure 7) was measured before installation because the dimension it represents is always greater than the multiple of number and average diameter of balls due to manufacturing and surface irregularities. The distances from the streambed surface to the top washer and to the top crimp (D_4 and D_5, respectively, in Figure 7) were measured to distribute potential error inherent in defining the level of the streambed surface.

Figure 7
Scour Monitor and Installation Dimensions.

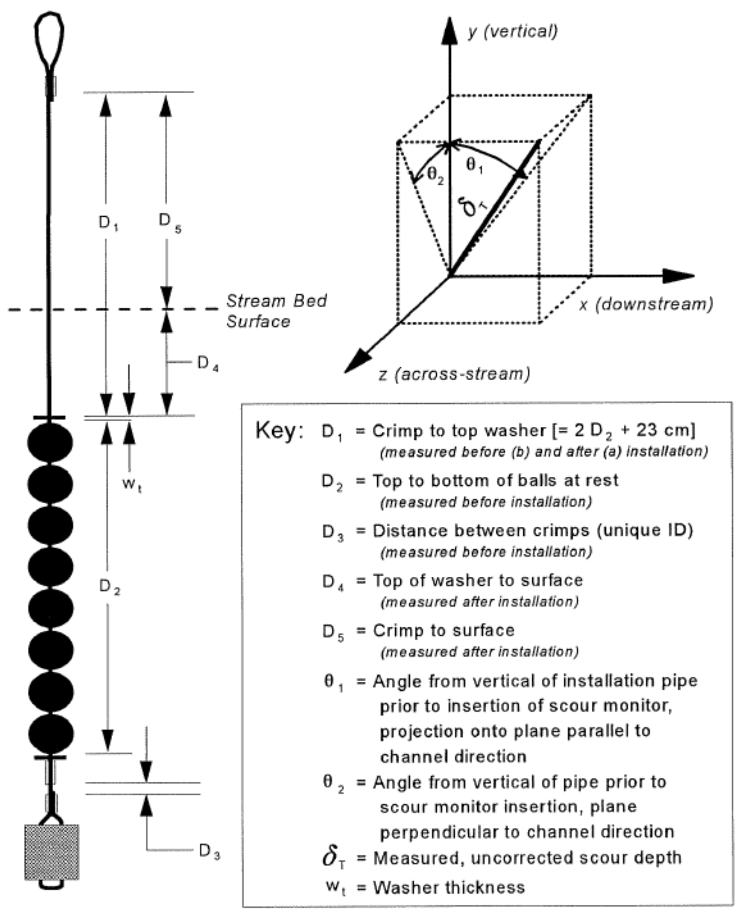
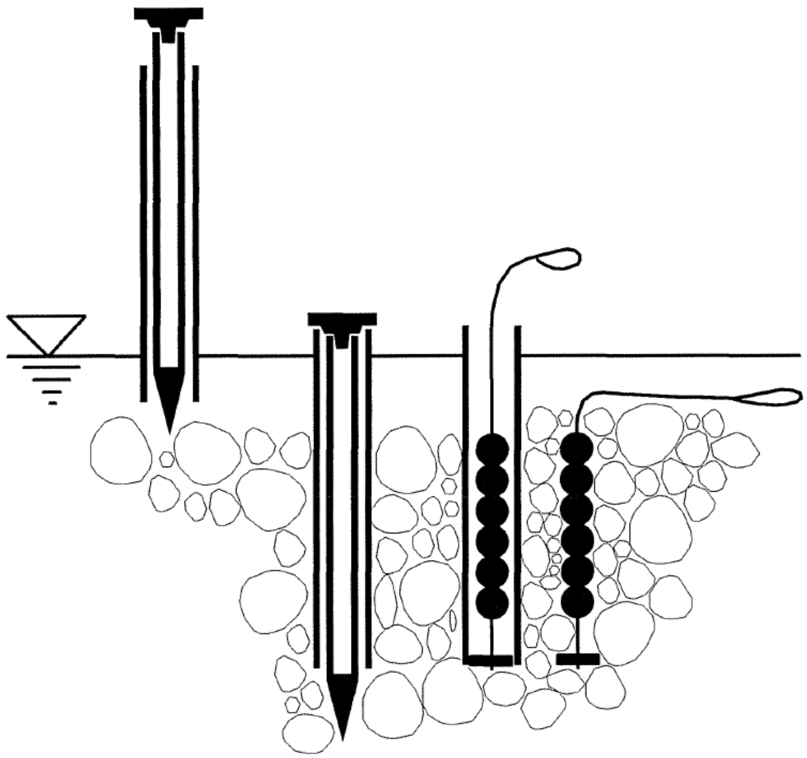


Figure 8
Schematic of Method of Scour Monitor Installation into the Chehalis Riverbed.



The inner tube of the installation device was removed and the scour monitor inserted as far as possible into the outer tube until the anchor met resistance (Figure 8). The monitor was held in place with a long steel rod with an eye-hook fastened at the lower end. The top end of the scour monitor cable was threaded through the hook, which maintained the indicator balls in their installed position as the outer tube is lifted and removed. The rod was then removed, and the top ball exposed to check whether the balls have separated by comparing the D_1 measurement before (D_{1b}) and after (D_{1a}) installation. The washer was left at the end of the cable. In a few cases the top ball lifted slightly during installation but this was corrected by either (i) pushing and working the ball down until it contacts the next ball, or (ii) pulling gently on the monitor cable to bring all of the balls together snugly. The elevation of the top ball was typically set within the lower half of the surface armor layer. The D_4 measurement was made, where the steel rod was placed across the hole to define an average bed surface elevation. Any substrate material excavated to expose the top ball was then replaced. The D_5 measurement was made subsequently, again using the threaded rod to define a bed surface elevation. Finally, the free end of the scour monitor cable was placed on the bed pointing in the downstream direction.

Monitor Placement

Six replicate scour monitors were placed in each site except the Pe Ell riffle site, where five monitors were placed (the last monitor was found to be missing at the time of installation). A mix of 8- and 10-ball monitors was used, with the longer monitors used in sites expected to have higher scour risk. Scour monitors were placed across two transects spanning the selected spawning habitat area with three monitors per transect spaced approximately equidistantly across the center of the spawning substrate area. Transects were spaced to divide the spawning patch into approximately three similar sub-areas. Transect ends were defined on both banks by stakes, steel reinforcing bar (rebar), or nails in trees. The distance across each transect was recorded for monitor relocation later.

Surveying of Bed Topography

Survey benchmarks were established at each site for redundancy in case some were lost to erosion or shifted in elevation during the study. Steel reinforcing bar (rebar) and large nails in trees and bedrock cracks were used. Benchmark elevations and cross-section elevation profiles were surveyed during scour monitor installation. A repeat survey will be performed at the time of monitor retrieval in early summer of 2024 when flows drop sufficiently for workability and access. Scour and fill depths are calculated at each monitor location using the surveyed cross-section geometry combined with the scour monitor measurements.

Substrate Grain Size

Particle grain size distributions will be measured across the spawning habitat patch via pebble counts at each site during final retrieval to avoid disturbing the vicinity of the scour monitor locations. The grain size distribution will be computed and the scour depth compared to the D_{90} to evaluate the extent to which the measured scour depths reflect (i) judged scour risk and (ii) local sediment transport rate imbalances that are controlled by availability of gravel and cobble for transport from upstream.

Data Analysis

Scour Depth

Total scour depth, δ_T, at the monitor location is indicated by the number of balls disturbed and moved to the end of the cable. It is measured as the distance down to the top of the first undisturbed ball from the original bed elevation. Following the notation in Figure 7, the measured value of total scour depth was calculated from (DeVries 2000):

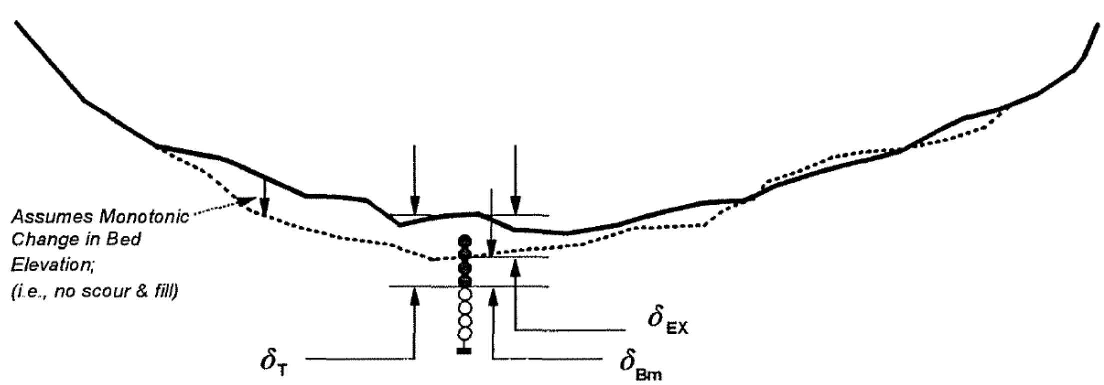
$$\delta_{T_{Measured}} = \frac{n_s}{n_T}[D_2 + (D_{1b} - D_{1a})] + D_4 + \frac{[D_{1a} - (D_5 + D_4)]}{2}$$

where n_T and n_s are the total and moved number of balls, respectively, and the washer thickness depicted in Figure 7 is ignored for this application. The equation distributes the total inter-ball spacing error equally among all balls and splits the error between the D_1 and D_5 measurements to determine the elevation of the top of the first ball relative to the uneven streambed surface (cf. DeVries and Goold 1999). In cases where the scour monitor is unavoidably installed at a notable angle, the measured scour depth was corrected following the notation in Figure 6 by:

$$\delta_{T_{Corrected}} = \sqrt{\frac{\left(\delta_{T_{Measured}}\right)^2}{1 + tan^2\Theta_1 + tan^2\Theta_2}}$$

Net excavation scour depth, δ_{EX}, was calculated as the magnitude of the negative change in the surveyed bed elevation at a monitor location before and after a flood (Figure 9; net fill depth was calculated as the positive change in bed elevation). Maximum bedload disturbance depth, or δ_{Bm}, is estimated as the difference between the total and net excavation scour depths (Figure 9). A critical assumption is that the bed surface elevation did not proceed beyond the limits defined by its pre- and post-flood level (i.e., no additional excavation scour followed by fill; Figure 9). Instances of local degradation or aggradation are assumed to be unidirectional, affected by reach-scale loss or gain of sediment (e.g., through downstream translation and diffusion of a mass of sediment originating from upstream), or by slight shifts in thalweg location due to limited meander migration.

Figure 9
Depiction of How Total Scour Depth (δ_T), Net Excavation Scour Depth (δ_{EX}), and Maximum Bedload Disturbance Depth (δ_{Bm}) Are Estimated, Assuming That No Scour and Fill Occurred. The Pre-flood Bed Elevation Is Depicted by the Solid Profile, the Post-flood Elevation by the Dashed Profile; No Scour and Fill Occurs Below the Lower of the Two Lines. The Dark Circles Indicate Scour Monitor Balls That Were Disturbed and Moved to the End of the Monitor Cable.



Interim Results

Sites were visited on two occasions. The first visit occurred on December 15, shortly after the first and only major flood event that occurred over the winter (Figure 10). That event had a peak flow at the Doty gage of 13,600 cubic feet per second on December 5, 2023, which corresponds roughly to the 2.5-year recurrence interval event. All sites except RM 102.86 and 102.96 were accessible after the river flow subsequently receded. At these sites, the riverbed had deepened along the primary access route (along the river bank from a parcel owned by the Chehalis Tribal Trust) during the December event that, combined with thick vegetation, precluded safe access by foot; alternative access across adjacent private properties was not allowed. Only three sites (RM 106.48, 111.88, and 113.32) had all scour monitors visible (Table 1). A fourth site (RM 104.86) had only two monitors visible (scour depths of 9.6 inches and 1.8 inches). Limited excavation at that and the other sites did not find the other scour monitors that had been installed. Some sites appeared to have experienced fill, and other sites may have had all scour monitors scoured out.

The second visit occurred on March 22, 2024, at the three sites where all scour monitors were visible on the first visit. No additional scour was observed, instead additional fill had occurred at some locations.

Scour monitors will be relocated and retrieved where they have not been scoured out at all sites in early summer 2024 once flows have dropped sufficiently.

Figure 10
Chehalis River Flow Hydrograph at the USGS Gage Near Doty (Sta. No. 1202000) Over the 2023-2024 High Flow Season. The Peak Event on December 5, 2023 Is Indicated by Vertical Dashed Line and Dot (Source: USGS Website).

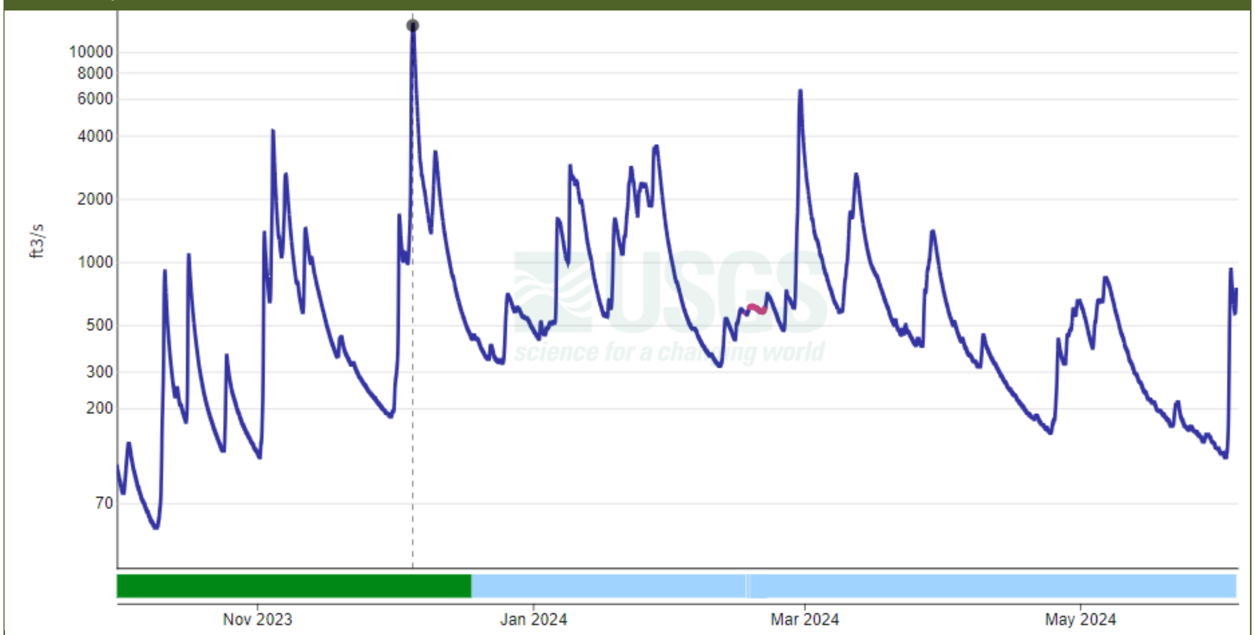


Table 1
Summary of Scour Depth Data from Sites Where All Scour Monitors Were Found Visibly Disturbed After the December 5, 2023 Peak Flow Event.

	SCOUR DEPTH (INCHES)		
STATISTIC	**RM 106.48 (RIFFLE)**	**RM 111.88 (RIFFLE)**	**RM 113.32 (POOL TAIL)**
Raw Data	5.5	10.0	10.4
	8.0	10.0	4.7
	8.8	9.7	6.5
	7.7	9.6	12.1
	7.5	10.4	7.1
	-	10.6	13.7
Range	**5.5-8.8**	**4.7-13.7**	**9.6-10.6**
Mean	**7.5**	**10.0**	**9.1**
Standard Deviation	**1.2**	**0.4**	**3.5**
95% Confidence Interval	**1.5**	**0.4**	**3.7**

Interpretation

The initial data suggest that partial scouring of Chinook salmon redds may have occurred during the December 2023 2.5-year recurrence interval event peak, which may have partially reduced survival to emergence. Typical egg burial depths for Chinook salmon range between 6 inches and 20 inches (DeVries 1997). On top of that, scouring down to egg burial depth increases the likelihood of fine sediments intruding even deeper into the redds (Beschta and Jackson 1979; Diplas and Parker 1985; Lisle 1989), which may have further reduced survival to emergence during the relatively low magnitude event that occurred. It is plausible that a larger flood would have scoured deeper in the study sites. Although flow strength is secondary to local coarse sediment supply as a primary control on scour depth (DeVries 2008), the patchy nature of spawning habitat and relatively large distances between successive deposits of gravel and cobble that are sized suitably for Chinook salmon spawning implies that, in the case of the mainstem Chehalis River, larger floods are likely associated with deeper scour (and fine sediment intrusion) than occurred during the December 2023 event.

Preliminary calculations based on scour monitor measurements also indicate the sites in Table 1 experienced fill depths averaging between 4 and 8 inches, with a maximum of approximately 12 inches during the December 2023 event. Entombment may have also adversely affected survival to emergence over the 2023-2024 intragravel phase for fish spawning in the mainstem Chehalis River (Lisle 1989; LaPointe et al. 2000). However, what maximum thickness of fill would pose a critical threshold is unknown.

These inferences are based on preliminary data and will be revisited pending final monitor retrieval, bed profile surveying, and pebble counts that will be performed this summer. Present plans are to reinstall scour monitors at selected sites over the 2024-2025 winter flood season for further corroboration, including potentially measuring scour during a larger peak flow event.

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