

## **Attachment J**

### **Hydraulics Technical Memorandum**

July 30, 2021

NHC Reference 2006723

**Parametrix**

1019 39th Ave. SE, Suite 100  
Puyallup, WA 98374

**Attention:** **Randy Raymond, P.E.**

**Copy to:** **Taya K. MacLean, MS, PWS**

**Via email:** [RRaymond@parametrix.com](mailto:RRaymond@parametrix.com)

**Re:** **Lower Satsop Right Bank Conservation Project**  
**Site Assessment and Design Alternatives Draft Report, Rev. 1**

**Dear Mr. Raymond:**

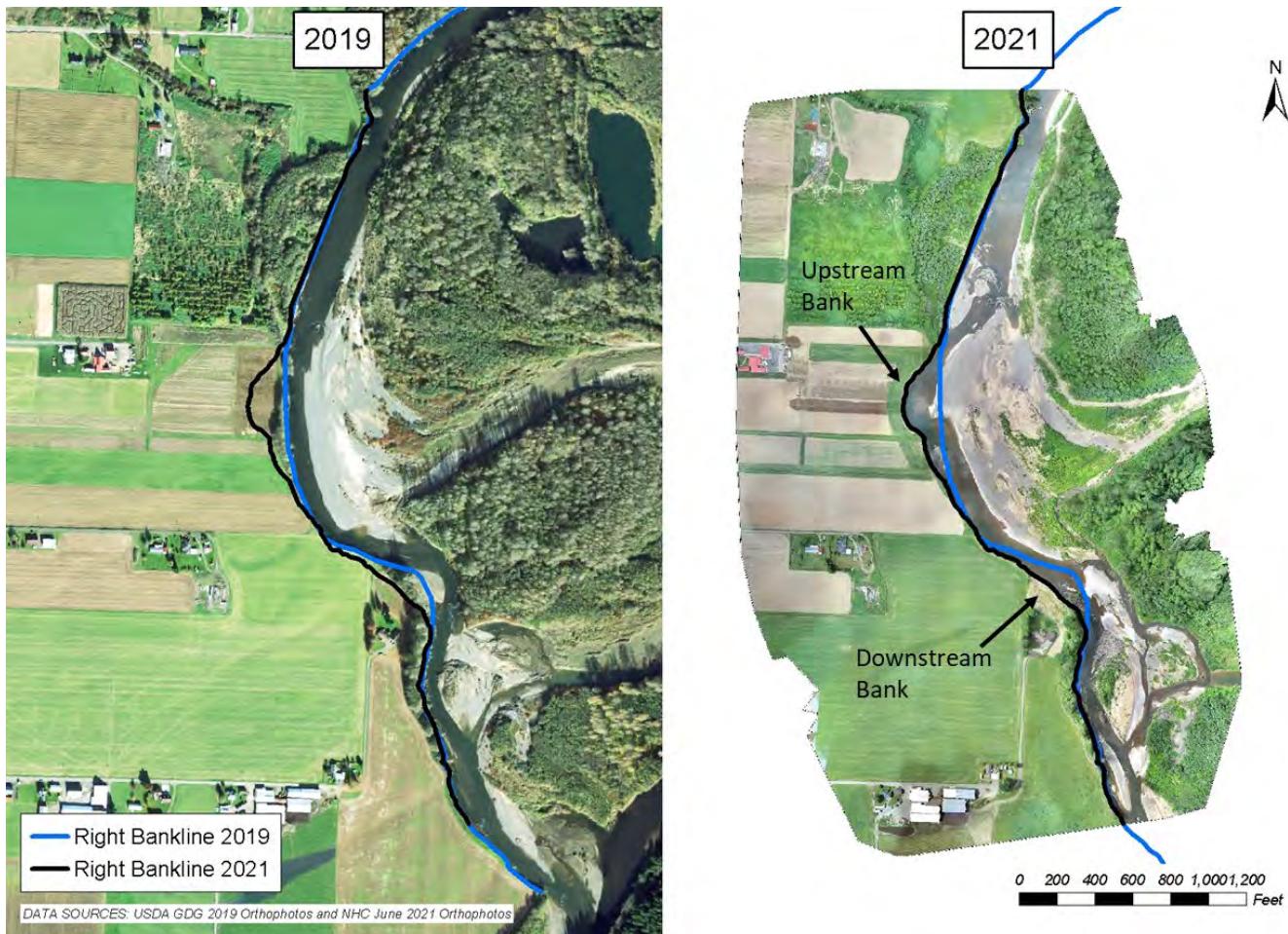
NHC is providing Parametrix with a memorandum summarizing a site assessment and design alternatives analysis for the Lower Satsop Emergency Bank Protection project. This work was performed under Parametrix Project Number 217-7132-001 and NHC project number 2006723. On July 1, Parametrix and NHC presented analysis and alternative concepts developed to-date and received feedback from Washington Department of Fish and Wildlife (WDFW), Grays Harbor County, and Lower Satsop Advisory Committee representatives on design priorities. This memo summarizes these analyses, presents preliminary design alternatives, selection criteria, and a preferred alternative for emergency bank protection at the project reach.

## **1 Site Assessment**

The Lower Satsop River is an active single thread meandering channel in Grays Harbor County, Washington. The land surrounding the Lower Satsop River at the project site is primarily agricultural. Historically, channel migration occurred in both the eastward and westward directions within the floodplain; however, the construction of Keys Road on the east side of the floodplain restricts eastward migration of the river corridor from approximately two river miles upstream of the project site to the confluence with the Chehalis River, 0.3 river miles downstream. Consequently, the channel has been migrating westward over the past few decades, eroding agricultural land along the right bank of the channel (Natural Systems Design, 2019).

In 2018, the channel avulsed at the project site, approximately 0.4 miles upstream of where the Lower Satsop River enters the Chehalis River. Due to the avulsion the reach is in a degradational state and channel shortening has occurred. It is expected that the avulsion may generate up to another three feet of vertical channel degradation. It is uncertain how much of this expected vertical channel degradation has already occurred.

Since the 2018 avulsion, the right bank of the channel has been rapidly eroding. Figure 1 compares the right bank line location in 2019 and 2021. Prior to the avulsion, vegetation on the right bank was limited to grasses and a narrow band of trees; since the avulsion, the remaining trees along the right bank have fallen into the channel as the bank continued to erode. During a site visit on June 15, 2021, NHC observed that the eroded bank comprises very silty, easily erodible material. Gravel was visible at the toe in only a few locations. The right bank is near vertical, ranging from 10 to 25 feet high, and the minimal bank vegetation has relatively shallow rooting depth.



**Figure 1 Right Banklines in 2019 (blue line) and 2021 (black line) overlaid on 2019 (left) and 2021 (right) orthophotos**

There are several mechanisms of bank failure actively occurring at the project site, including toe erosion, scour, and mass failure. Reduced vegetation, higher shear stress along the channel bends, and limited roughness elements in the channel result in substantial toe erosion along the bends at the upstream and

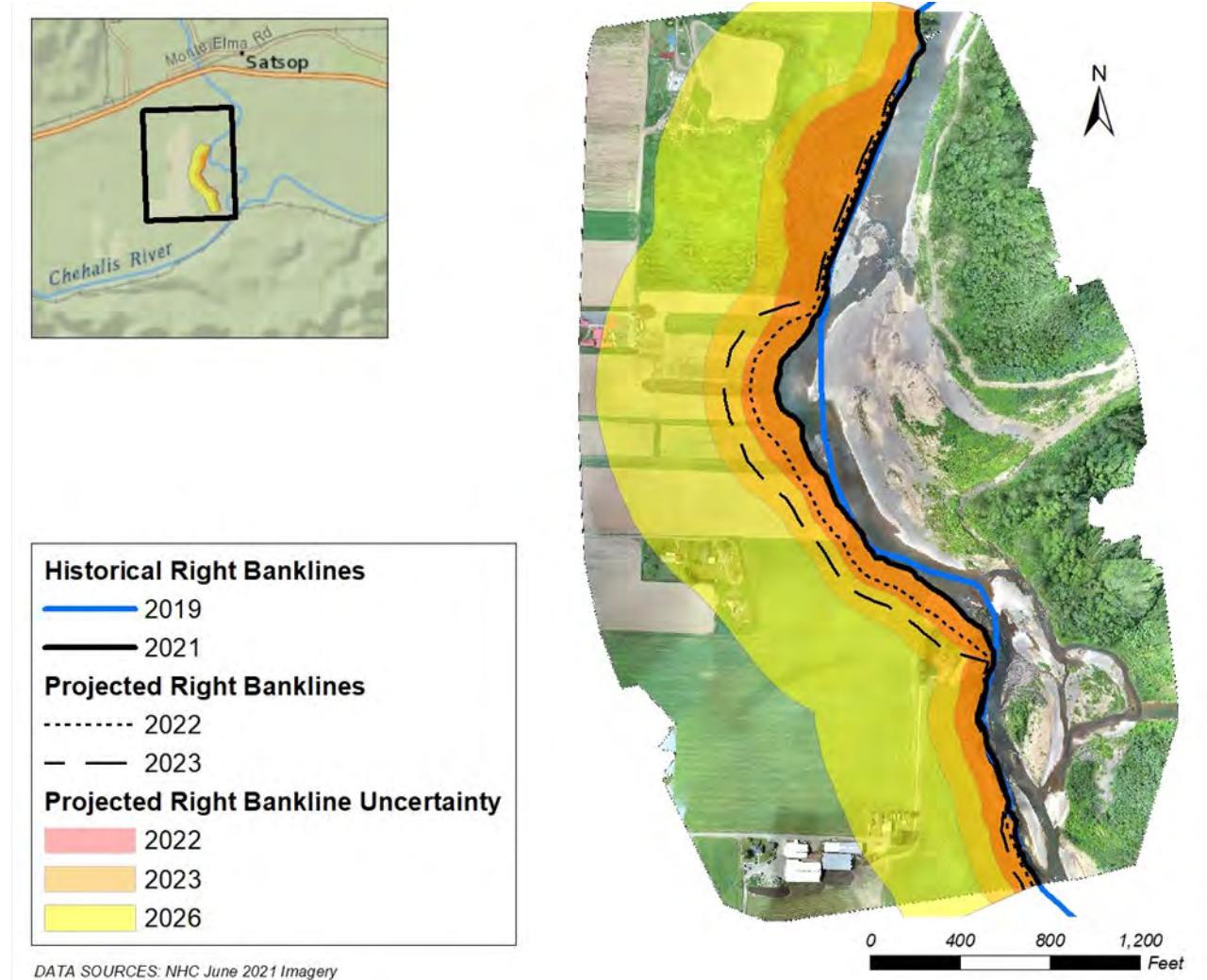
downstream banks (upstream and downstream bank locations are indicated in the right panel of Figure 2.1). The substantial toe erosion is a key driver of the collapse of the right bank of the channel. Jet scour is also occurring along the right bank at the channel bends, where flow is directed along the right bank increasing the stress and leading to increased erosion. The near vertical unvegetated banks are inherently unstable and mass failure is and will continue to occur even without further toe erosion or scour. Mass failure mechanisms likely occur both due to high flow surficial erosion and post flood geotechnical slope failures when the banks are saturated and river levels have dropped.

The abandoned meander the river flowed through pre-avulsion has extensive sediment deposition at its upper end and is rapidly vegetating in. Due to the slope advantage of the avulsion pathway it is considered likely the current river channel will remain as the primary flow path. In the center of the area there has been minimal bank erosion over the past few years. Field inspection did not reveal any apparent erosion resistant soils in this area, so the expectation is that this segment will also undergo significant erosion in the near future as the river continues to adjust to the avulsion.

## 1.1 Bank Erosion Rates

Following the 2018 avulsion, the Lower Satsop River corridor migrated westward, eroding substantial portions of the right bank. Natural Systems Design (NSD) determined historical erosion rates of 92 ft/yr for the upstream bank and 73 ft/yr for the downstream bank along the Lower Satsop River meander bends (NSD, 2019). Between 2019 and 2021, the rate of bank erosion at the upstream bank substantially increased compared to historical rates. Between 2019 and 2021, the maximum displacement of the right bankline at the upstream and downstream banks was 230 ft and 132 ft, respectively. Based on the maximum displacement of the bankline, the maximum rate of erosion between 2019 and 2021 was calculated as 115 ft/yr at the upstream bank and 66 ft/yr at the downstream bank.

The erosion rate between 2019 and 2021, local geomorphology, and modeled shear stress was used to project the future channel migration trajectory in 2022 and 2023. Figure 2 shows projected right banklines for 2022 (dotted line) and 2023 (dashed line) along with the uncertainty bands associated with these estimates. A projected right bankline was not estimated for 2026 due to the high degree of uncertainty associated with projecting five years into the future, but an uncertainty band for the 2026 right bankline projection is shown. For all years, including 2022 and 2023, there is a high degree of uncertainty about the future location of the channel.

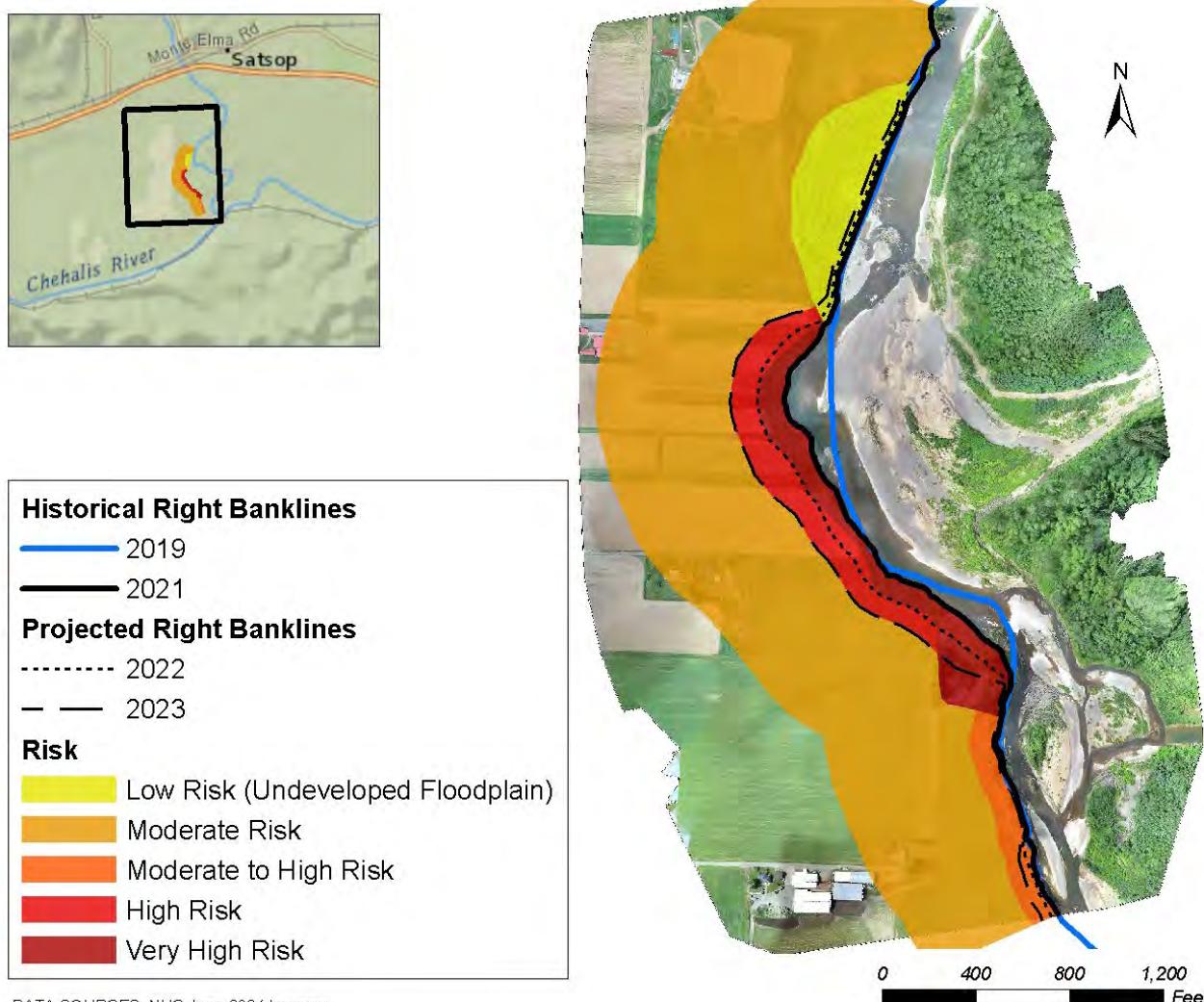


**Figure 2** Historic and Projected Right Bank Locations of the Lower Satsop River in which there is a high degree of uncertainty about the projected right bank locations

## 1.2 Predicted Risk Areas

Projected channel erosion and local geomorphology were used to delineate predicted at-risk areas for the Lower Satsop River. For the purposes of this analysis, the magnitude of risk can be defined as the product of likelihood of occurrence and consequence. For example, upstream areas of undeveloped floodplain are categorized as low risk, while the downstream area occupied by a house is categorized as high risk – due to the relative consequence of erosion in each area. Figure 3 shows predicted at-risk areas classified in five categories: low risk (undeveloped floodplain), moderate risk, moderate to high risk, high risk, and very high risk. The areas at highest and most imminent risk (very high risk category)

correspond to the upstream and downstream banks where the highest rates of erosion occurred between 2019 and 2021. Near the downstream bank, there is a house that falls within the very high risk area.



**Figure 3 Predicted At-Risk Areas for the Lower Satsop River based on projected channel erosion and local geomorphology**

## 2 Hydrology & Hydraulics

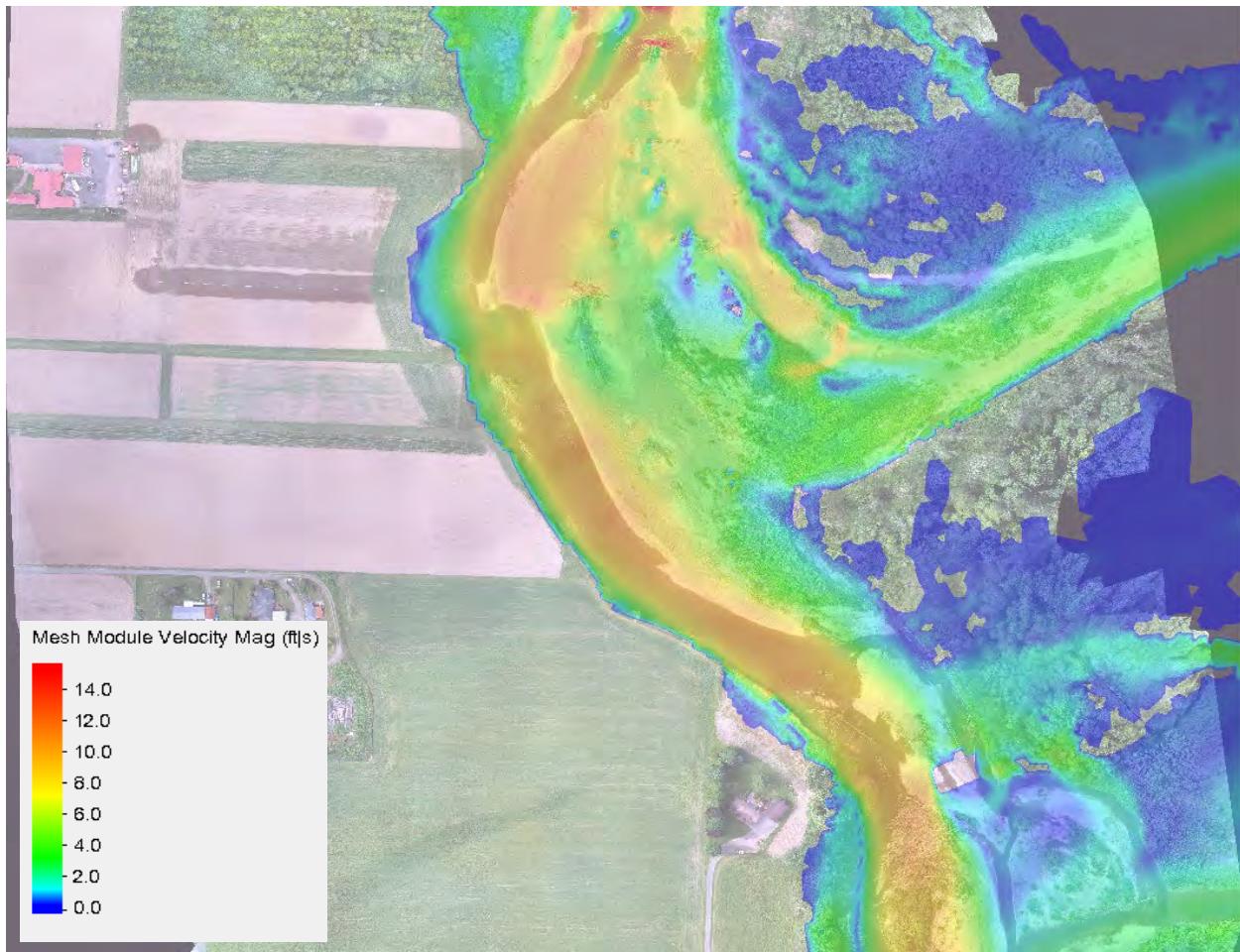
Previous hydrologic analysis and hydraulic modeling of the project reach was conducted by NSD (2019). Recurrence flow intervals were computed from a Log Pearson Type-III analysis of Satsop River flows at

USGS gage 120350000, located at the Monte Elma bridge, approximately two river miles upstream of the project site. NHC incorporated the previously calculated recurrence flow events into the development of design alternatives for the project reach. Table 2.1 shows the selected recurrence flow estimates referenced for these analyses.

**Table 2.1 – Select Recurrence Flow Estimates for Satsop River at the Project Reach (NSD, 2019)**

| Recurrence Flow Event | Satsop River Flow (CFS) |
|-----------------------|-------------------------|
| 2-yr Flow (Q2)        | 26,260                  |
| 100-yr Flow (Q100)    | 52,610                  |

Previous hydraulic modeling was conducted by NSD using computed recurrence flow events and a combination of 2017 topography and March 2019 bathymetry data to build a two-dimensional hydraulic model with RiverFlo-2D (NSD, 2019). To inform the development of design alternatives, NHC updated the existing reach-wide hydraulic model (NSD, 2019) with current topobathymetry survey data from the project reach, collected in June 2021 (Parametrix). Figures 4 and 5 show plots of output from the updated hydraulic model used in evaluation and preliminary design of alternatives.



**Figure 4 - Model Output 2-Year (Q2) velocity (ft/s)**

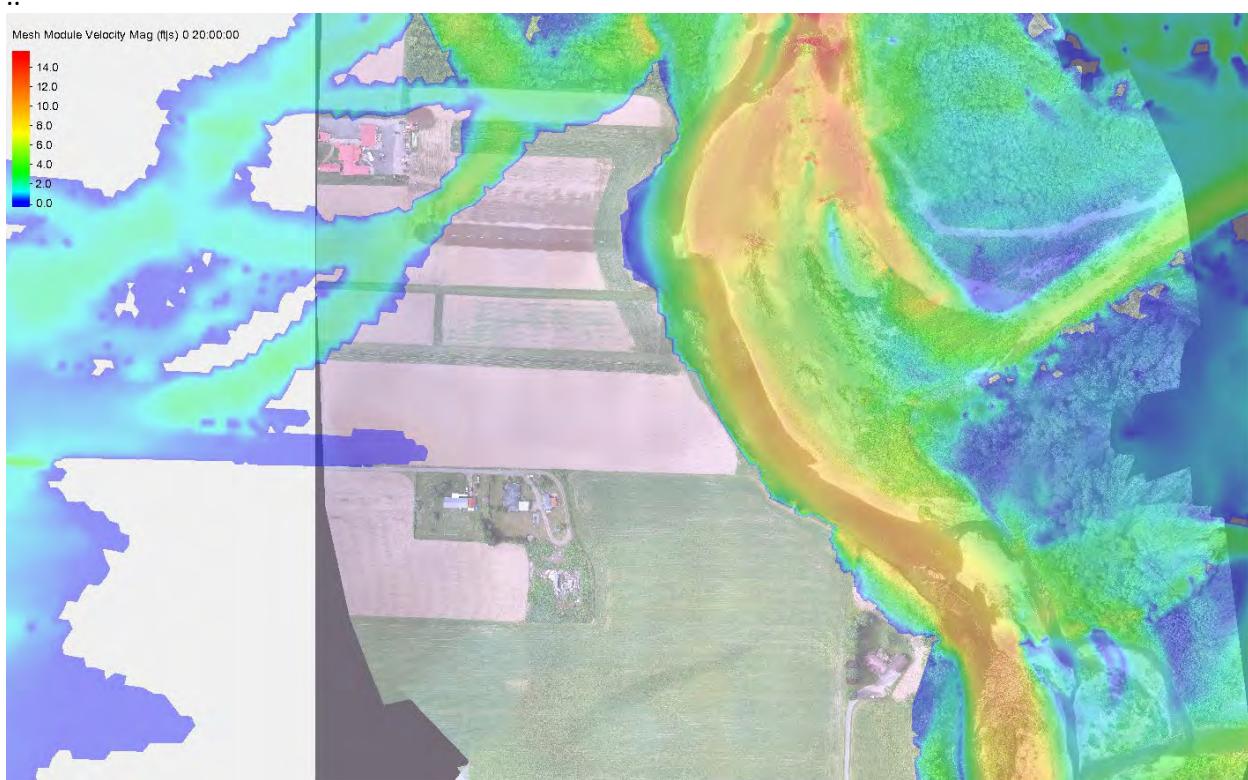


Figure 5 - Model Output 100-Year (Q100) velocity (ft/s)

### 3 Alternatives Analysis

Initial site and reach assessments were performed using Integrated Streambank Protection Guidelines (ISPG) to evaluate key erosion mechanisms and identify possible countermeasures. Following initial screening, a list of preliminary design alternatives was developed with the principal objective of reducing the rate of westward migration of the channel meander within the project area. Due to the limited timeframe available and ongoing work by others throughout the greater reach, multiple criteria were considered along with bank stability for selection of a preferred alternative.

A scoring matrix was developed to evaluate each alternative against the set of project criteria, further described in Section 4 of this report. The scoring matrix is subdivided into three sub-reaches: upper, middle, and lower, corresponding to the predicted risk areas in Section 1.2. Evaluating alternatives at each sub-reach allowed for consideration of constraints and opportunities unique to each reach.

The following project goals and constraints were included in the scoring matrix:

### Goals

- Design, permit, and construct a project this year to reduce right bank erosion during the upcoming flood season
- Maximize the area protected with the available funding and time (scalability)
- Provide compatibility with, or at least don't hinder, past and future flood control and habitat efforts in the reach
- Minimize excavation and soil haul

### Constraints

- Very limited time
- Project cost
- Stay above OHWM to facilitate permitting (OHWM in the project area is an elevation part way up the near- vertical bank)
- Construction and excavation limitations due to high, fragile bank
- Site access coordination with landowner agriculture and activities

## 3.1 ISPG Analysis

To identify possible alternatives, NHC used the Integrated Streambank Protection Guidelines (ISPG) to evaluate and rank potential solutions (Cramer et. al, 2003). The ISPG provides a structured procedure in which a designer uses a series of matrices to identify and evaluate alternatives that may be appropriate for a site. To identify possible solutions using the ISPG procedure, the designer screens alternatives based on the failure mechanism occurring at the site, how alternatives would likely perform and respond to the stream given the reach conditions, and the potential for long term habitat impacts.

## 3.2 Design Concepts

Seven conceptual design alternatives for bank protection within the project reach were identified by the ISPG evaluation procedure:

- Barbs
- Log Toes
- Roughened Rock Toes
- Woody Plantings
- Soil Reinforcement
- Bank Reshaping
- Riparian Buffer Management

NHC developed a list of alternatives similar in function to those recommended by the ISPG, with modifications to meet project goals and objectives. For example, biotechnical techniques such as installation of woody plantings were not considered due to the short timeframe available to stabilize the bank – but may be appropriate as part of future work in the reach and would be more likely to succeed once the bank approaches a more stable configuration. Similarly, ISPG does not contain a category for self-deploying design concepts; however, due to the need for an expedited permitting schedule, self-deploying concepts are considered in this alternatives analysis. All design alternatives under consideration will be constructed outside of the channel and can be divided into two categories: self-deploying and trenched, as described in the following section.

### 3.3 Self-Deploying Options

Self-Deploying designs are constructed outside of the channel and initially placed near the top of bank, where continued erosion processes cause them to slide down the eroding bank face to rest at the toe – where they provide toe protection, grade stabilization and habitat enhancement. Due to observed bank heights near 20 to 25 feet tall within the project reach, all self-deploying designs would be placed in an excavated bench at five feet below existing grade and set back approximately five feet from the edge of bank to reduce the total height of the deployment.

#### 3.3.1 Log Jacks

Log jacks are tetrahedral structures constructed from logs and boulder ballast connected by steel cables or chains. They are intended to be placed in groups to form highly three-dimensional, interlocking, and deformable structures. Slash is tied on to the structure to reduce porosity and through structure velocities. Boulder-ballasted log jacks would be placed on a shallow bench near the edge of bank. Following deployment, log jacks would decrease nearshore river velocities, and provide grade stabilization by encouraging sediment deposition near the toe of the bank. Their tetrahedral shape is stable during and after deployment, with a large surface area providing bank protection and energy dissipation both vertically and horizontally. Due to their shape and stability, log jacks can settle and continue to provide protection in response to scour. Log jacks can easily be recovered, relocated or scaled up to respond to changes in bank erosion. Log jacks installed in the project area could potentially be reused for future restoration efforts within the reach. Rootwads are not used in log jacks, both to keep buoyancy forces and hence boulder sizes down, and for the significant cost savings gained by using standard logs. In addition, a log jack with slash attached mimics the function of a large rootward to some degree.



Figure 6 – Detail View of Log Jack,  
slash not shown

Potential disadvantages of log jacks include safety concerns for pedestrians and boaters near the deployment area, lack of habitat benefits compared to other alternatives, and visual impacts.



**Figure 7 – Log Jacks immediately following installation on the Wynoochee River at Montesano WWTP (left) and one-year post installation (right.) Thalweg has shifted in the right photo.**

### 3.3.2 Continuous Log Rows

Continuous log rows consist of groups of four logs with rootwads and boulder ballast connected by steel cables or chains. Units would be constructed upland and placed end-to-end, parallel to the shoreline in a shallow excavated bench near the edge of bank. Following deployment, continuous log rows would armor the toe of the exposed bank, dissipating energy near the toe, and providing potential habitat benefits from the submerged rootwads. Additional benefits of log rows are their ability to deform and continue to provide protection in response to changes in the bank. Potential disadvantages of continuous log rows include safety concerns for pedestrians and boaters near the deployment area, and less vertical protection of the bank relative to other alternatives.



**Figure 8 - Example of Log Rows (Photo: Green River Flood Control District)**

### 3.4 Trenched Installation

Trenched designs would be constructed in an excavated trench adjacent to the bank with a bottom elevation near the thalweg of the existing channel. As erosion of the bank progresses, the buried elements would be exposed and provide armoring against further erosion. The use of trenched options throughout the site can be scaled as cost and schedule allow. Due to the required depth, trenched designs must be set back from the existing bankline and therefore would require additional bank loss before they are engaged. Trenching reduces or eliminates deployment of structures from the bank at some height and improves the quality and certainty of structure function.

#### 3.4.1 Buried Rock Spurs

Rock spurs are constructed in trenches at an angle to the bankline, projecting upstream into flow. Once engaged, flow over the spur is redirected perpendicularly to the axis of the spur and away from the eroding bank. Spurs can shelter the bankline for distances of approximately two to four times their length downstream, lowering velocities, reducing erosion and encouraging sediment deposition. Spurs constructed from angular rock riprap are a well-documented bank protection method and simpler to construct than other methods using large wood; however, the use of angular riprap is discouraged due to its displacement of existing bank habitat. Spurs are generally not appropriate in tight meander bends.



**Figure 9 – Example of buried rock spur under construction, Green River.**

#### 3.4.2 Buried Log Spurs

Log spurs are structurally similar to rock spurs and would be constructed in a trench set at an angle to the bankline, projecting upstream. Once engaged, they provide flow redirection and protection from erosive flows. Logs used in the construction of spurs would have rootwads and could be anchored with either mechanical anchors or boulder ballast; boulder ballast is preferable to reduce slack following structure settling and response to local bed scour. The use of logs rather than angular rip rap is preferred for habitat benefits; log spurs can be more effective at recruiting additional large wood relative to other alternatives. Potential disadvantages of log spurs are the cost of large wood, and additional complexity of construction compared to rock spurs.

### 3.4.3 Buried Rock Revetment

Buried rock revetment would be constructed in a long, continuous trench, running parallel to the bankline. Angular rip rap would be placed inside the trench at a stable slope, with additional material placed at the toe of the riprap slope to allow for downward movement in response to toe scour. Rip rap revetment is a well-documented method for bank protection and simple to construct; however, of the alternatives considered, rock revetments have the largest negative effect on habitat.

### 3.4.4 Buried Log Revetment

A buried log revetment would consist of logs with rootwads placed in a lattice-like structure within continuous trench. Individual logs within the lattice structure would be ballasted by boulders attached with steel cable or chains. Once engaged, exposed portions of the log lattice provide toe and bank stabilization, and energy dissipation. The added roughness of the log lattice will shift the thalweg from the toe of slope. If exposed, log lattice structures could be dismantled to allow for repurposing of high value wood in subsequent reach restoration efforts. Additionally, the exposed wood will provide habitat uplift and may recruit additional large wood. As the channel responds during high flow events, some bank adjustment is expected; logs will shift, and the connected boulder anchors will settle with the streambed and bank. Potential disadvantages of buried log revetments are the higher cost and relatively higher complexity of construction compared to rock revetments.



Figure 10 – Example of log revetment, Cowlitz River

## 4 Selection Matrix Results

Design alternatives applicable to the upper, middle and lower reaches were evaluated with a matrix to generate a refined list for consideration. The matrix evaluates the alternatives by reach relative to risk (as defined in Section 1.2, Predicted Risk Areas), constraints, and project objectives, with scoring criteria comprising priorities related to both reach benefits and design implementation. At each reach, values were assigned to priorities to represent each priority's relative importance to the respective reach. Design alternatives were designated a general performance score for each priority based on a qualitative efficacy rating of high, medium, low, or none. Alternative performance scores were then applied to the priority scores at each reach to provide a weighted performance score. Weighted performance scores for each design alternative were summed and normalized by the total possible score to determine the relative rankings of each design alternative for a given reach. Table 4.1 provides the four highest scoring design alternatives across all reaches based on matrix scoring.

**Table 4.1 - Highest Scoring Design Alternatives**

| Reach  | Recommended Treatment                                |                                  |                            |
|--------|--|----------------------------------|----------------------------|
|        | Benefits   | Implementation                   | Overall                    |
| Upper  | 1. Log Jacks   | 1. Continuous Log Rows           | 1. Log Jacks               |
|        | 2. Buried Spur Jams - Logs                           | 2. Log Jacks                     | 2. Continuous Log Rows     |
|        | 3. Buried Spur Jams - Logs                           | 3. Buried Log Revetment          | 3. Buried Log Revetment    |
|        | 4. Continuous Log Rows                               | 4. Buried Spur Jams - Logs       | 4. Buried Spur Jams - Logs |
|        | 5. Buried Spur Jams - Rock                           | 5. Buried Rock Revetment         | 5. Buried Rock Revetment   |
| Middle | Buried Spur Jams - Logs /<br>1. Buried Log Revetment | Log Jacks/Continuous Log<br>Rows | 1. Log Jacks               |
|        | Buried Spur Jams - Logs /<br>2. Buried Log Revetment | Log Jacks/Continuous Log<br>Rows | 2. Continuous Log Rows     |
|        | 3. Log Jacks   | 3. Buried Log Revetment          | 3. Buried Log Revetment    |
|        | 4. Continuous Log Rows                               | 4. Buried Spur Jams - Logs       | 4. Buried Spur Jams - Logs |
|        | 5. Buried Spur Jams - Rock                           | 5. Buried Rock Revetment         | 5. Buried Rock Revetment   |
| Lower  | Buried Spur Jams - Logs<br>1. Buried Log Revetment   | Log Jacks/Continuous Log<br>Rows | 1. Log Jacks               |
|        | 2. Buried Log Revetment                              | Log Jacks/Continuous Log<br>Rows | 2. Continuous Log Rows     |
|        | 3. Log Jacks   | 3. Buried Log Revetment          | 3. Buried Spur Jams - Logs |
|        | 4. Continuous Log Rows                               | 4. Buried Spur Jams - Logs       | 4. Buried Log Revetment    |
|        | 5. Buried Spur Jams - Rock                           | 5. Buried Rock Revetment         | 5. Buried Rock Revetment   |

## 5 Preferred Alternative Conceptual Design

NHC used the results of the selection matrix to apply the highest scoring alternatives throughout the site, taking into consideration the project objectives and constraints at each reach. The conceptual layout represents a balance between the need to reduce the rate of bank erosion and the limited time and budget available for construction, as well as the need for compatibility with future habitat restoration within the reach. NHC incorporated comments on the alternatives and conceptual design from stakeholders including USACE, Ecology, WDFW, Grays Harbor Conservation district and adjacent property owners, which are reflected in the final conceptual design. The design was also discussed with Natural Systems Design, the contractor designing the Phase 2 habitat project for the reach. NSD stated that the proposed design would not interfere with their designs for the right bank. Figure 11 illustrates the preferred alternative. Appendix B includes draft project special provisions.

The conceptual design incorporates the log jacks, continuous log rows, and log spur alternatives as described below:

- In the upper reach, continuous log rows are proposed to address toe erosion and jet scour within the short-radius bend (station 2+50 to 9+00). The log rows are connected in bundles of four log structures, which are independent of other bundles to allow for individual bundle deployment. The rows are wrapped around the upstream bend at the project to prevent flanking, but are not keyed into the slope as they are meant to deploy to the bank toe if erosion occurs.
- In the middle reach, a hybrid design combining the log jack and log spur alternatives is proposed. A relatively lower risk in the middle reach, and the larger bend radius made spurs an appropriate treatment for this area. The need for flexibility and compatibility with future phases of restoration work led to the design, in which log jacks are installed in a spur configuration, providing similar function with the ability to be repositioned later as needed. Four jack spurs are proposed, with approximately 25 jacks per spur and a length of approximately 100ft per spur. At station 10+00, a standalone grouping of eight self-deploying log jacks is proposed with the intention of recruiting and wracking native woody debris across a short width of the channel to an existing apex jam. If the recruitment is successful, woody debris could bridge to the existing apex jam, providing function similar to a spur.
- At the lower reach, continuous log rows are proposed to provide additional toe protection at the existing residence. The lower reach is also protected by the most downstream of the four spurs in the middle reach.

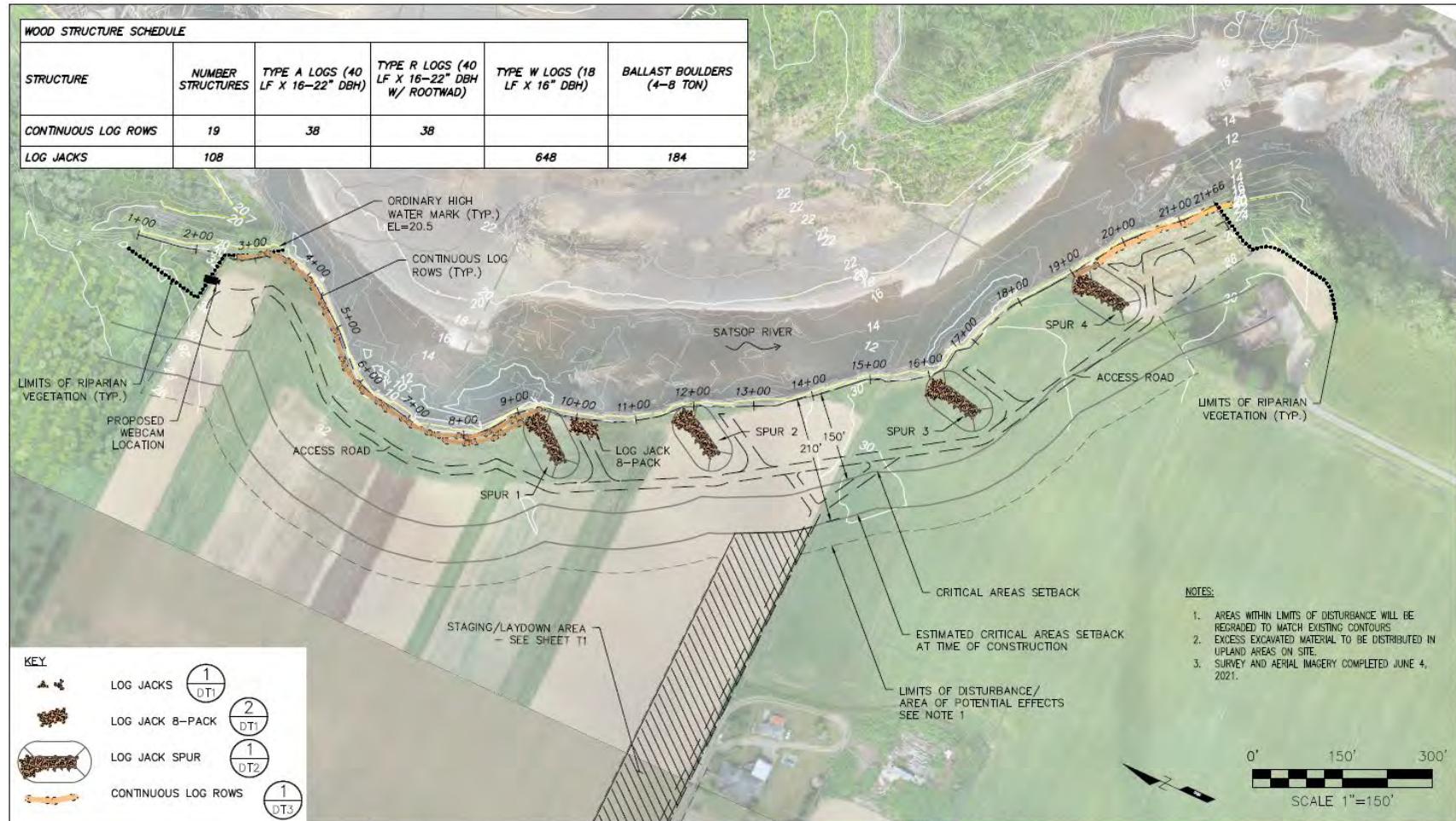


Figure 11. Preferred alternative layout

## 6 Expected Project Performance

### 6.1 Anticipated Function

The preferred alternative will be installed landward of the existing bankline, and thus is not expected to change flow regime patterns until further bank erosion occurs. The bank slope is near vertical, indicating that toe instability results in mass failure of bank material. Therefore, the log rows and jacks are anticipated to deploy into the channel at or near the resulting toe of slope. Once engaged and deployed, the bank protection elements are expected to stabilize the toe of the slope, after which the bank would be expected to regrade landward at a stable slope of 1.5H:1V. Figure 12 illustrates the anticipated ‘engaged’ locations of the bank protection elements and probable adjusted banklines following bank regrading. Once engaged and deployed, the project elements are anticipated to maintain flow patterns close to the present conditions.

Bank erosion is not strongly tied to flood flow magnitude in this reach: -comparison of the 2- and 100-year flood velocities in the model do not show significant differences. Some of the factors that likely affect bank erosion rates are duration of flows above allowable bed shear stress, rate of post flood water level drawdown, local erosion from wood racking along the bank or mid channel (especially at the downstream end), and continued adjustment from the avulsion. Due to these factors continued bank erosion at rates seen in the past few years is expected in the winter of 2021-2022 regardless of peak flow magnitude.

In the upper reach the hydraulic model results indicate that embayment near bank velocities are low during floods. With the upper stable vegetated hardpoint at Station 3+50 remaining in place, upstream sheltering from Spur 1, and the log rows deploying, erosion in the upper reach is expected to be reduced. In the middle reach erosion will need to expose 60 feet or so of the 100 ft long spurs in order for them to provide erosion protection for the bank in between them. In the lower reach, downstream of Spur 4, the combination of spur and log row protection is expected to decrease erosion rates.

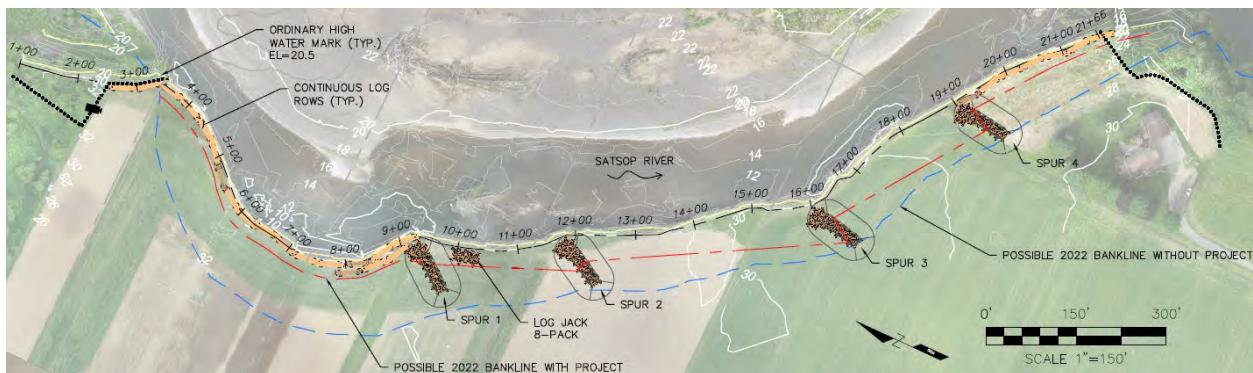


Figure 12. Anticipated 2022 bankline

## 6.2 Performance Uncertainty

There is a high degree of uncertainty in the project performance related to the project elements performance and adjusted bankline location.

The highest area of performance uncertainty is in the upstream reach. Due to the tight bend radius, log spurs are not recommended to use and thus a more linear and continuous solution is appropriate. As the channel continues to adjust around the upstream Phase I log jams, the angle of attack at the upstream project reach may change and result in more impinging flows on the project bank. The log rows will provide toe protection for this entire reach to address the unknown progression in channel adjustment and flow patterns upstream. The lower reach of log rows adds protection to that provided by Spur 4 to maximize protection of the downstream home. This will provide additional protection in response to uncertainty in flow patterns from upstream.

Log jacks have been successfully implemented in a deployable configuration on the Wynoochee River, so the connection strength has been successfully tested and the log jacks have been observed to deploy with minimal translation into the channel or downstream. The log rows have not been tested during deployment to determine the strength of the log-log and log-boulder connections under impact loading; the connection materials are well understood and are anticipated to perform and hold better than those used in the log jacks.

The proposed design was constrained by budget. Spur number and spacing is below general design recommendations, and the log rows, which are used in part due to their lower cost, have uncertainty in how they will deploy and function. Long term bank protection in this area will require additional work being designed by NSD.

## 6.3 Adaptive Management

Wet season monitoring will be a key component of the adaptive management component of this project. A webcam is proposed for installation at the upper end of the project looking downstream. High visibility erosion marker poles will be installed to allow clear indications of erosion in the webcam field of view. In addition, installation of permanent photopoints and repeat UAV mapping flights through the winter is recommended to monitor and quantify erosion.

The proposed bank protection elements are ballasted to be flexible to settle into the channel bed and banks as deformation occurs. The elements are ballasted such that they are not anticipated to be transported downstream. As such, the log rows and log jacks are recoverable and retrievable, so that they may be removed or incorporated into future phases of reach restoration or bank conservation projects. Additionally, project elements are located to optimize function within the project budget. If channel erosion is observed within the project reach at a more vulnerable location, the log rows or log

jacks may be repositioned to provide additional bank protection. The proposed temporary access road is to be left in through the winter to facilitate this work if needed.

## DISCLAIMER

This report has been prepared by **Northwest Hydraulic Consultants Inc.** for the benefit of **Parametrix** for specific application to the **Lower Satsop Right Bank Conservation Project**. The information and data contained herein represent **Northwest Hydraulic Consultants Inc.** best professional judgment in light of the knowledge and information available to **Northwest Hydraulic Consultants Inc.** at the time of preparation and was prepared in accordance with generally accepted engineering and geoscience practices.

Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only by **Parametrix**, its officers and employees.

**Northwest Hydraulic Consultants Inc.** denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents.

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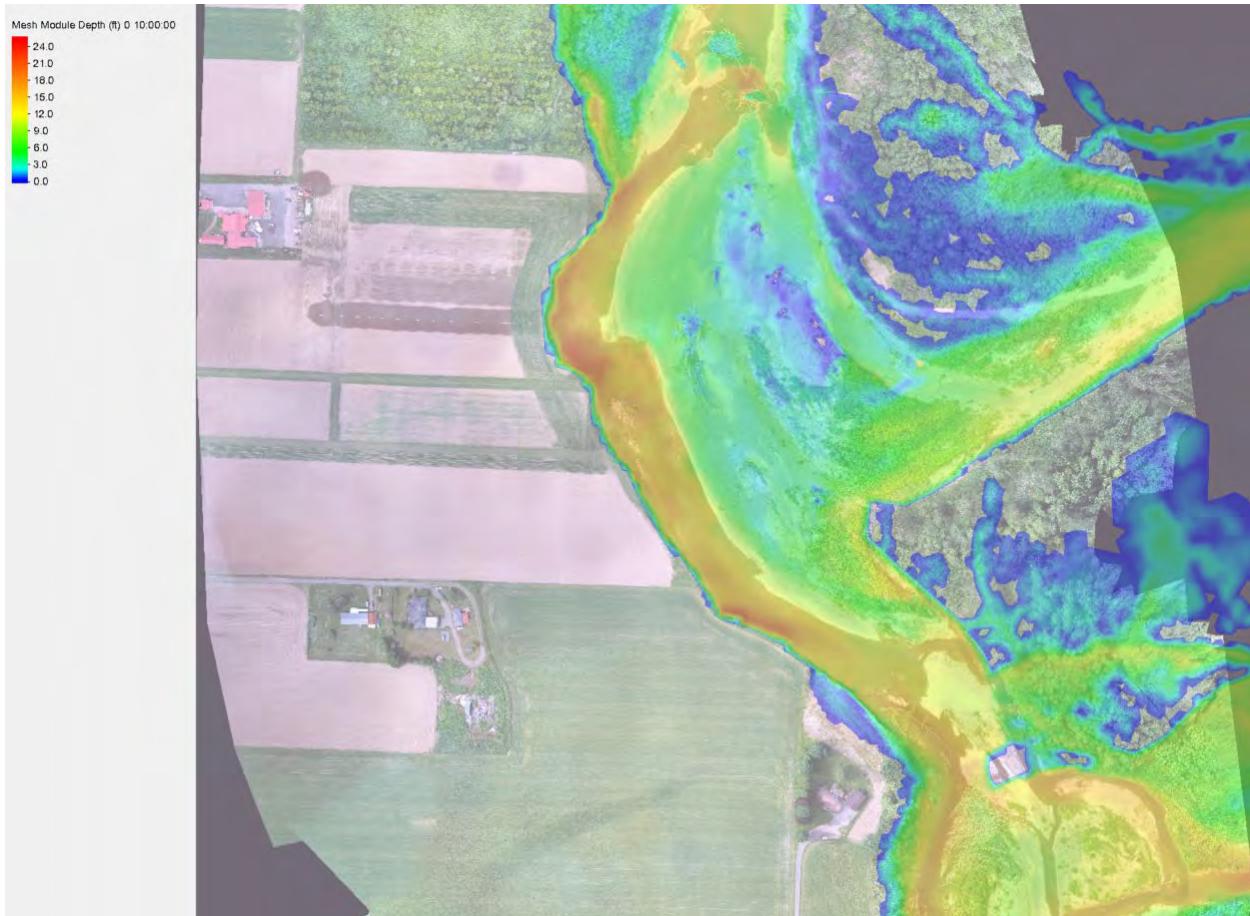
## 7 References

Cramer, M., K. Bates, D. Miller, K. Boyd, L. Fotherby, P. Skidmore, P. Hoetsma (2002). *Integrated Streambank Protection Guidelines. Washington State Aquatic Habitat Guidelines Program.* Washington Department of Fish and Wildlife, Olympia, WA.

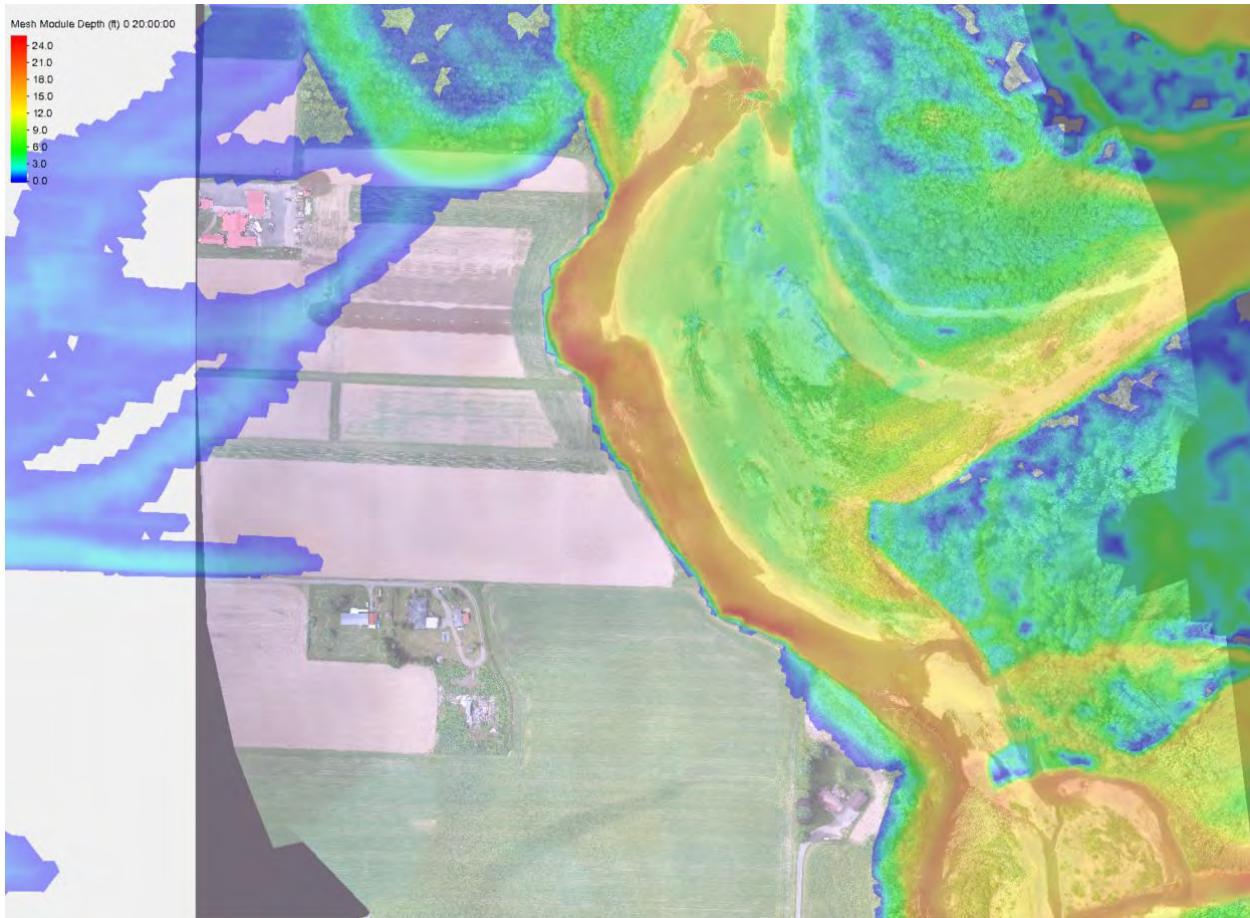
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Parametrix (2021). *Satsop RB Protection, UAV imagery, topographic and bathymetric survey* (2177132001 - Satsop RB Protection.dwg). Electronic data received June 11, 2011.

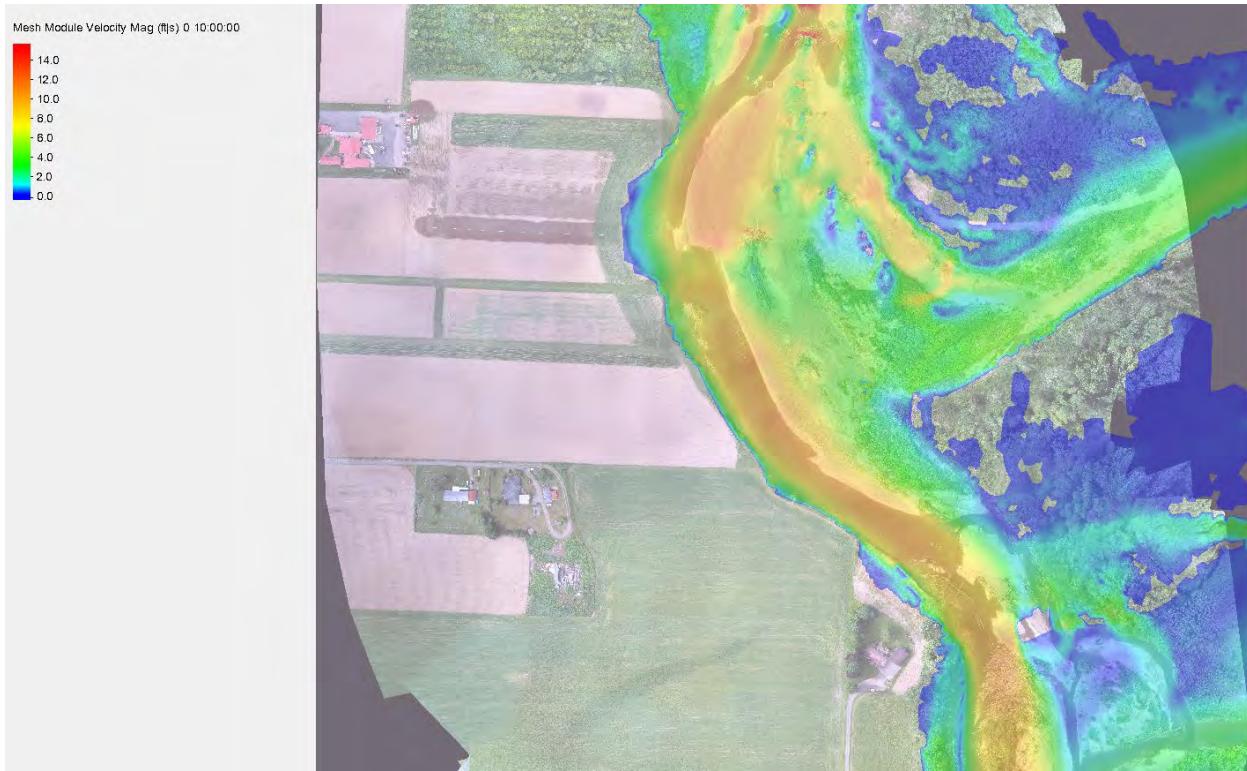
## APPENDIX A – HYDRAULIC MODEL OUTPUT



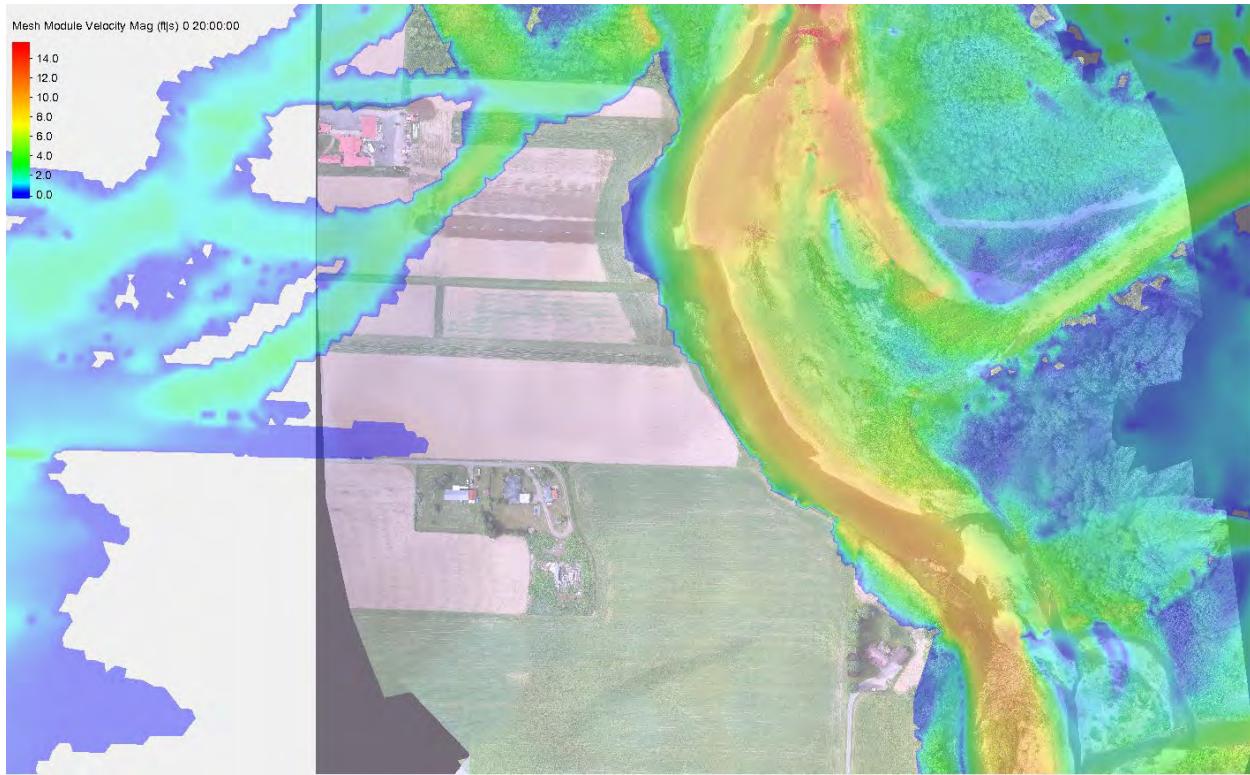
**Figure 13. Model Output Depth (2yr) (ft)**



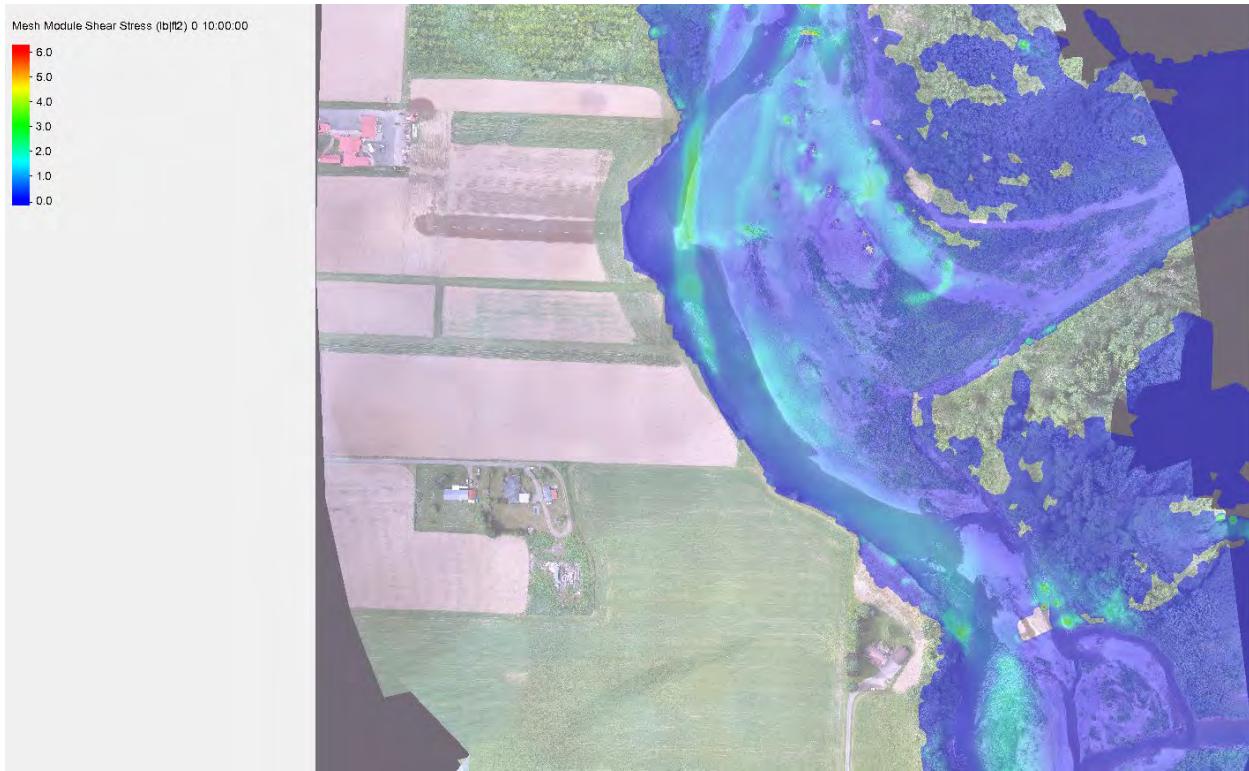
**Figure 14. Model Output Depth (100yr) (ft)**



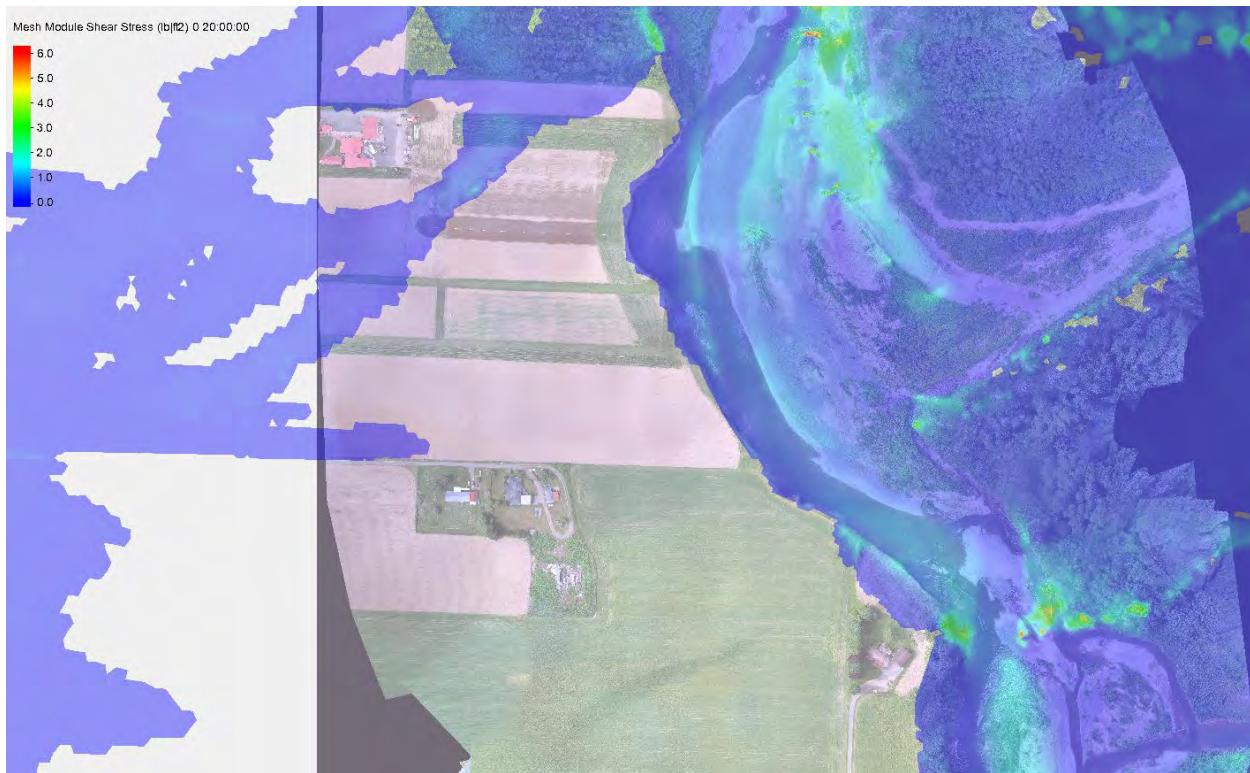
**Figure 15. Model Output Velocity (2yr) (ft/s)**



**Figure 16. Model Output Velocity (100yr) (ft/s)**



**Figure 17. Model Output Shear Stress (2yr) (lb/ft<sup>2</sup>)**



**Figure 18. Model Output Shear Stress (100yr) (lb/ft<sup>2</sup>)**

## APPENDIX B – DRAFT PROJECT SPECIAL PROVISIONS

## **8-19 Wood Structures**

### **8-19.1 Description**

This work shall consist of furnishing materials including ballast boulders, wood, and connecting hardware; and placing and installing proposed wood structures, including Ballasted Log Jacks and Continuous Log Row, as specified on the Contract Drawings, or as directed by the engineer.

### **8-19.2 Materials**

The Contractor shall submit the source of materials to the Engineer for approval at least 10 working days prior to use.

#### **8-19.2(1) Member Logs**

Wood species shall be harvested no more than six months prior to use and shall consist of Douglas Fir, Red Cedar, or Sitka Spruce trunks or trunks with rootwads unless otherwise specified. No dimensional beams or timbers, Red Alder, or other deciduous tree species shall be used for wood structures.

Minimum log diameters and lengths for each log type are provided in the structure schedules on the Contract Drawings. Log types include A, R and W.

Root wads shall be cleaned of soil, but root structure shall be retained intact. Limbs shall be trimmed to no more than 18 inches in length from stem.

#### **8-19.2(3) Slash**

Slash is composed of trees, limbs, roots, brush and tops imported or generated during site clearing activities. It shall be free from soil that would cause turbidity when placed in the water. It shall be composed of various sizes less than 6 inches in diameter with no more than 20 percent smaller than ½ inch. It shall also be free of noxious weeds per the Washington State Noxious Weed Lists and Monitor List (<http://www.nwcb.wa.gov>).

#### **8-19.2(4) Ballast Boulders**

Ballast boulders shall meet the requirements of 9-13.4 Rock for Erosion and Scour Protection and 9 13.4(1) Suitable Shape for Rock for Erosion and Scour Protection, except the gradation requirement is waived, and boulders may also be rounded in addition to angular or sub angular. Ballast boulders for Ballasted Log Jacks must weigh between 4 to 6 tons each, composed of limestone, granite or similar type approved by the engineer. Ballast boulders for Continuous Log Rows must weigh between 1 to 1.5 tons each, composed of limestone, granite or similar type

approved by the engineer. Field verification of weight determined by the formula  $W = 0.85(Md)^3$  where W=weight (lbs), M=stone density(pcf) from submitted test reports, and d= intermediate axis diameter (ft) of the boulder. All ballast boulders should be drilled with a hole large enough to accommodate the required chain or all thread. The mass of rock around the hole should be strong enough to use for lifting using a chain anchor.

### **8-19.2(5) Connections**

#### **Wire Rope and Connecting Hardware**

Wire Rope shall be galvanized, 9/16 inch, fiber core wire rope, Class 6 by 19 with a breaking strength equal to or greater than 14 tons. Steel grade shall be Extra Improved Plow Steel (EIP). Wire rope shall be secured using wire rope clips as shown in the Contract Drawings and consistent with manufacturer recommendations, or as directed by the Engineer. Wire rope clips shall be sized to fit the corresponding wire rope and shall be drop-forged galvanized steel of single (U-bolt) or double saddle clip. Wire rope terminations shall be mechanically crimped sleeves or approved equivalent. Terminations are not structural elements but shall resist a minimum of 500 pounds of force and must cover cut cable end completely.

#### **Chain and Connecting Hardware**

Chain shall be ½-inch diameter, grade 43 welded long-link chain conforming to NACM or ASTM A413 with a natural finish. Staples shall be 6-inches long, nominal 0.5-inch wire diameter, ½-inch interior width and made of steel.

#### **All-Thread and Connecting Hardware**

All-thread shall be 1 inch diameter ASTM A193 Grade B7 All-Thread Rod meeting ASME B18.31.2, plain finish. Nuts shall be ASTM A194 Grade 2H Heavy Hex, plain finish. Washers shall be 4-inch-square, minimum 1/4-inch plate thickness, Grade A36, plain finish. Screw eyes shall be drop forged steel, 3/4-inch diameter, 8-inch long, minimum of 4-inch thread, with shoulder, and of sufficient eye diameter to easily pass the wire rope.

#### **Chain and Connecting Hardware**

Chain shall be ½-inch diameter, grade 43 welded long-link chain conforming to NACM or ASTM A413 with a natural finish. Staples shall be 6-inches long, nominal 0.5-inch wire diameter, ½-inch interior width and made of steel.

### **8-19.2(6) Backfill**

Backfill shall come from onsite sources and adhere to Section 9-03.14(3) Common Borrow of the Standard Specifications unless otherwise specified in the Contract Drawings.

### **8-19.3 Construction Requirements**

All work shall be accomplished in accordance with the requirements of the Washington State Department of Fish and Wildlife HPA and other relevant permits which are attached elsewhere to these contract provisions. Logs, boulders and hardware shall be approved on site by the Engineer prior to installation.

#### **Ballasted Log Jacks**

Log Jacks shall be constructed as shown in the Contract Drawings or as approved by the Engineer. Constructed Log Jack appearance is described in the Contract Drawings along with a recommended construction sequence.

### **8-19.4 Measurement**

#### **8-19.4(1) Member Logs**

Type A Log shall be measured per each log furnished.

Type R Log shall be measured per each log furnished.

Type W Log shall be measured per each log furnished.

#### **8-19.4(3) Slash**

Slash shall be measured per cubic yard of slash furnished from off-site. Use of on-site slash shall be incidental to the Contract.

#### **8-19.4(4) Boulders**

Boulders shall be measured per each boulder furnished.

#### **8-19.4(5) Connections**

Chain shall be measured per linear foot of chain furnished.

All other connection hardware, including but not limited to, wire rope, all thread, washers, nuts, clips, screw eyes and staples shall not be measured, but shall be considered incidental to and included in the associated Wood Structure Bid Item.

#### **8-19.4(8) Ballasted Log Jack**

Ballasted Log Jack shall be measured by each Ballasted Log Jack constructed and installed.

#### **8-19.4(9) Continuous Log Row**

Continuous Log Row shall be measured by each Continuous Log Row constructed and installed.

#### **8-19.5 Payment**

Payment will be made for the following Bid Items when included in the Proposal. It shall be full payment for labor, tools, materials and equipment necessary to complete construction as described and as shown in the Construction Drawings, including but not limited to, any final field adjustment as directed by the Engineer; and all incidentals necessary to satisfactorily complete the work.

“Type A Log furnished” per each

“Type R Log furnished” per each

“Type W Log furnished” per each

“Slash furnished” per cubic yard, truck measure. No payment will be made for on-site slash.

“Ballast Boulders furnished” per each

“Chain furnished” per linear foot

“Ballasted Log Jacks, Installed” per each

“Continuous Log Rows, Installed” per each

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