SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX H

ENGINEERING

Integrated Feasibility Report and Environmental Impact Statement

US Army Corps
of Engineers®
Seattle District

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1 INTRODUCTION

The integrated Feasibility Report and Environmental Impact Statement presents the results of a U.S. Army Corps of Engineers (Corps) Ecosystem Restoration feasibility study undertaken to identify and evaluate alternatives for restoring degraded structures, functions, and processes in the Skokomish River Basin, Washington. The Corps is undertaking this action in partnership with Mason County and the Skokomish Indian Tribe.

Engineering calculations and studies were undertaken in order to support the development and evaluation of alternatives; to inform cost estimates including schedules and evaluation of risk; to provide preliminary designs for HTRW, cultural resources, and real-estate work; and to document the intended project performance. This appendix documents the results of the engineering work in accordance with ER 1110-2-1150.

1.1 GENERAL PROJECT BACKGROUND

The Skokomish River Basin is located on Hood Canal, a natural fjord-like arm of the Puget Sound and water of national significance. The Skokomish River is the largest source of freshwater to Hood Canal as it flows into Annas Bay and of critical importance in the overall health of Hood Canal. Environmental degradation can be seen throughout the Skokomish River Basin including a loss of natural ecosystem structures, functions, and processes necessary to support critical fish and wildlife habitat. Four anadromous fish species (Chinook salmon, chum salmon, steelhead, and bull trout) that use the river as their primary habitat are listed under the Endangered Species Act (ESA) and have experienced population declines. The impaired ecosystem has adversely affected riverine, wetland, and estuarine habitats that are critical to these and other listed species. The underlying need for development of a plan for ecosystem restoration in the Basin has arisen from recognition and analysis of these problems.

1.2 SITE SELECTION AND PROJECT DEVELOPMENT

As part of the planning process for the study, the Project Delivery Team (PDT), in coordination with interested stakeholders and the public, developed a series of measures and alternatives to be considered as potential elements of the project solution. To guide alternatives formulation, the study team identified the planning objectives of the study. Based on the problems identified in the study area, planning objectives include the following:

- Provide year-round passage for fish species around the confluence of the North Fork and South Fork Skokomish River for the 50-year period of analysis.
- Reconnect and restore the spawning, rearing, and refuge habitats in the study’s side channel and tributary for the 50-year period of analysis.
- Improve the quantity, quality, and complexity of native riparian and floodplain habitats in the study area for the 50-year period of analysis.

- Improve the quantity, quality, and complexity of pools in the Skokomish River to promote spawning and rearing success, as well as reduce stranding of ESA-listed salmonid species for the 50-year period of analysis.

A recommended restoration plan was selected that includes a levee removal, a side channel reconnection, placement of large woody debris in the upstream reaches of the river, and wetland restoration at two sites. This Engineering Appendix outlines key design elements for the features included in the recommended plan.

The recommended plan includes five features: (Figure 1 below and Annex A; Sheet G-003)

- Confluence Levee Removal
- Wetland Restoration at River Mile 9
- Wetland Restoration at Grange
- Upstream Large Woody Debris
- Side Channel Reconnection

These features are described in more detail in the following sections.

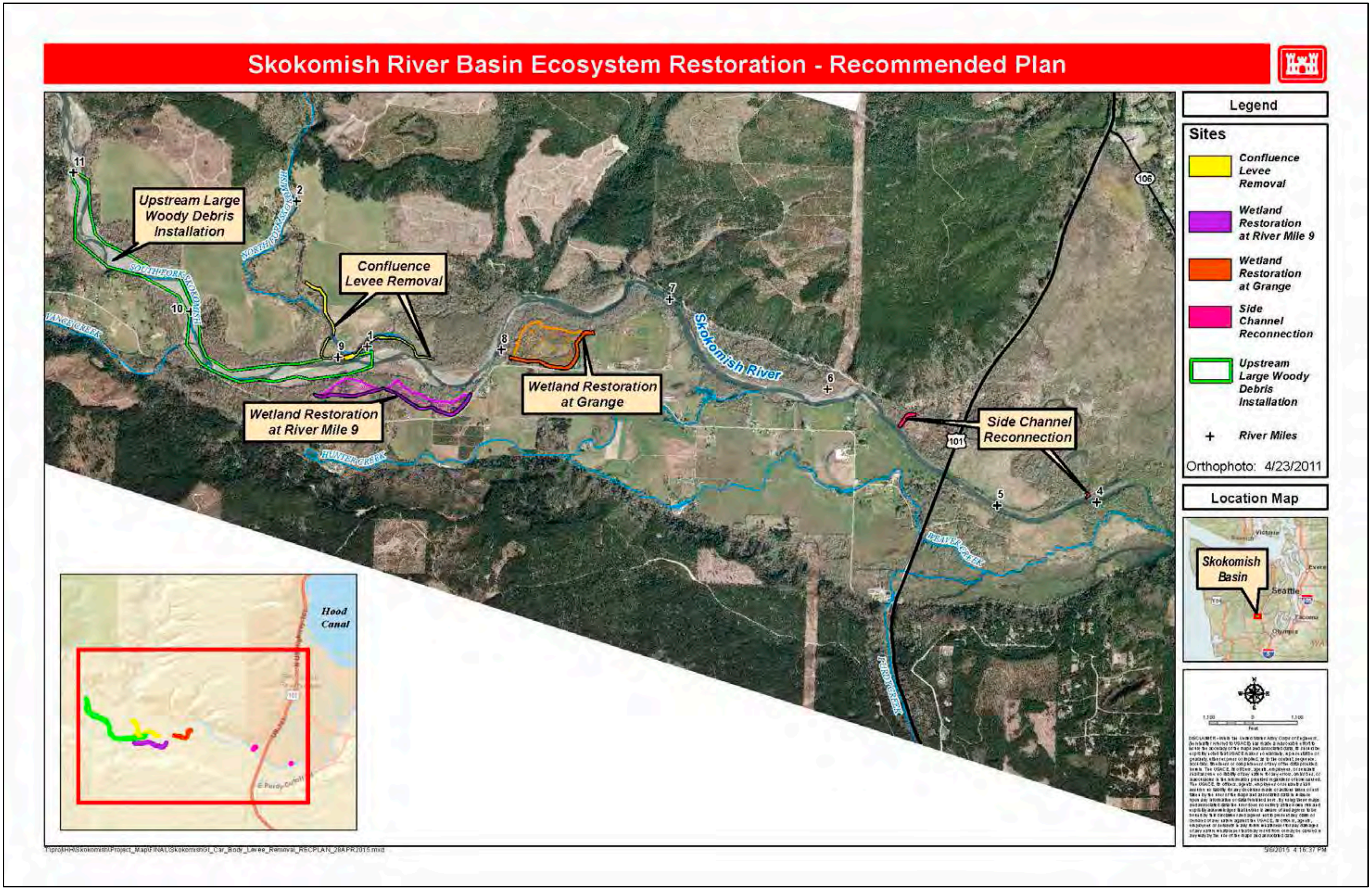

Figure 1-1. Recommended Plan

1.2.1 Confluence Levee Removal

In the vicinity of the North Fork/South Fork confluence, riverbed aggradation in the South Fork and the avulsion of the North Fork has lead to dry channel conditions developing in the South Fork during the late summer/early fall period. The dry channel stops the upstream migration of salmon returning to the South Fork. This feature addresses that problem by removing the Confluence Levee and diverting the South Fork into the North Fork near the pre-2003 confluence. The combined discharges would provide a continuous low flow channel in what is now the North Fork channel. The reach of the South Fork that goes dry in the late-summer/early-fall would be abandoned during those low flow periods.

This feature primarily addresses the study objective of restoring a continuous low flow channel near the confluence and to a lesser extent the objective of improving the quantity, quality, and complexity of pool habitat in the river. Mainstem flows would be diverted into the North Fork channel and reenter the mainstem at the present confluence location. This would bypass the subsurface flow reach and provide improved fish migration. A portion of flood flows would stay in the old channel. Installed LWD would direct flow in the new channel and improve fish habitat in the vicinity of the diversion. Periodic maintenance may be necessary to remove sediment accumulations from the new channel.

1.2.1 Wetland Restoration at River Mile 9

The Wetland Restoration at River Mile 9 increment, located at RM 8.3-9.2, is intended to reconnect and restore high quality wetland habitat. An existing agricultural berm will be breached and a new wetland embankment will be constructed landward (south) varying distances, generally around 200-300 feet. Four strategically located sections of the existing agricultural berm would be removed. These breaches would allow flood waters to flow freely within the wetland restoration area, reconnecting the riparian zone to the aquatic habitat for the benefit of salmon and many other species. The wetland embankment will improve hydraulic conditions in the reconnected wetland area and is expected to hold water within the wetland at a greater depth and longer duration, thereby improving and expanding wetland conditions. This action would place about 24 acres of riparian habitat, forest, and floodplain ponds on the riverward side of the wetland embankment. The new wetland embankment would be approximately 4,370 feet long and would contain flow during moderate winter storm events up to approximately 6,000 cfs. The wetland embankment would also be designed for shallow overtopping. This feature includes planting of native vegetation.

1.2.2 Wetland Restoration at Grange

The Wetland Restoration at Grange, located at RM 7.5-8, is intended to reconnect and restore high quality wetland habitat. Similar to the Wetland Restoration at River Mile 9 described above, an existing agricultural berm will be breached and a new wetland embankment would be constructed landward (south). This action would place about 34 acres of riparian habitat, forest, and floodplain ponds on the riverward side of the Wetland Embankment. Two strategically selected sections of the existing agricultural berm would be breached. These breaches would allow flood waters to flow freely within the wetland restoration area, providing salmon access to the riparian habitat for refuge from high velocity and turbidity during high flows. The new wetland embankment would be approximately 2,740 feet long and would contain flow during moderate winter storm events up to approximately 6,000 cfs. This feature also includes planting of native vegetation.

1.2.3 Upstream Large Woody Debris

This feature, located from RM 9-11, would include placement and installation of anchored wood and Engineered Log Jams (ELJ). Small wood clusters, single logs, as well as larger ELJ would be installed in this reach to encourage low flow channel meandering and mid-channel bar formation and provide multiple types of habitat benefits for salmon.

1.2.4 Side Channel Reconnection

An abandoned channel that lies between RM 4 and 5.6 would be reconnected to the mainstem to provide high flow refuge and rearing habitat for fish. Restoration would involve constructing improvements to the channel inlet and outlet, while most of the channel would not be disturbed. The reconnected channel would only be connected to the mainstem Skokomish River during high discharges and would not convey water year round. During high river discharges, the reconnected channel would provide low velocity refuge. During most of the year, the channel would provide pond habitat for fish rearing. Reconnecting the channel to the river could provide 45 acres of high quality, low velocity fish habitat. This feature would also include planting of native vegetation.

1.3 Design Features

Table 1-1 summarizes the project features developed in preparation of the conceptual design alternatives.

Table 1-1. Design Features

Project Feature	Description of Project Feature	Approx. Quantity
Confluence Levee Removal	Remove Existing Confluence Levee. For cost estimating purposes we are assuming the Confluence levee is comprised of earthen material and the possibilities that the levee is constructed with debris is included in the cost risk contingency	10,345 cubic yards (CY)
Existing Confluence Levee Breach	Enlarge an existing breach	7 ELJ, 26 single logs; 4,715 CY
Existing River Mile 9 Berm Breach	Breach four sections of the existing River Mile 9 Agricultural Berm to match existing grade.	7,935 CY
Wetland Embankment at River Mile 9	Construct wetland embankment at River Mile 9, RM 8.3-9.2, to provide additional floodplain habitat	17,335 CY Planting Berm 2,235 CY
Existing Grange Berm Breach	Breach two sections of the existing Grange Agricultural Berm to match existing grade.	3,790 CY
Wetland Embankment at Grange	Construct wetland embankment at Grange, RM 7.5-8, to provide additional floodplain habitat	24,960 CY Planting Berm 1,500 CY
South Fork Large Woody Debris Installation	Bar Apex ELJ are designed with no net excavated material, 5-log channel cluster placements will create a total net excavation, single log placements are designed with no net excavated material	7 ELJ, 24 clusters, 56 single logs; 11,000 CY

Side Channel Reconnection Entrance	The abandoned channel that exists between RM's 4 and 5.6 would be reconnected to the main stem to provide high flow refuge and rearing habitat for fish. Placed wood may create a small net excavation.	4 wood clusters; 3,600 CY channel; 930 CY wood excavation
Side Channel Reconnection Exit	Existing outlet will be used with no excavation planned at this stage of design. Placed wood may create a small net excavation.	2 wood clusters; 460 CY wood excavation

1.4 Hydraulic Design

Two hydraulic models were utilized for this study to evaluate measures. River and floodplain hydraulics were modeled with a two-dimensional (2-D) SMS model. Bedload transport near the confluence of the north and south forks was modeled with a one-dimensional (1-D) HEC RAS model.

In 2014, the Bureau of Reclamation utilized SMS, a 2-D hydraulic model, to model floods and measures proposed in the project area of the Skokomish River Valley (USBR, 2014). The SMS software utilizes a dynamic wave solver to route flow through independent mesh cells and can, therefore, handle multiple water surface elevations and flow paths. Model outputs include the extent and depth of flood inundation, current velocities and directions, and flow distributions. The topographic data used for the Skokomish valley was developed from several sources from the best available data. A detailed description of the model and the results are presented in the Skokomish 2-D Modeling Report (Annex H-9).

Bedload transport modeling was completed by Seattle District using HEC-RAS 4.1, which incorporates bedload transport equations into a quasi-unsteady 1-D flow model of the Skokomish River. The bedload transport function used in this model was the Meyer-Peter Muller (MPM) equation. The model was calibrated to the stage/discharge and bedload measurements at the USGS mainstem gage (RM 4.8). The HEC-RAS model used in this analysis was originally developed by KCM in 1997. It was updated by CES (1999) and WEST (2006). For this bedload analysis USACE again updated the model with new channel cross-section surveys between RMs 2 and 11 in 2007 and RM 0-2 in 2011. Lateral weirs were used along the channel to simulate the diversion of flood waters from the main river channel. Active flow areas were limited to those along the river that influenced the amount of water in the main channel. The bed material gradation is an important model input for the bedload transport calculations. The bed material gradations used in the model were collected by Reclamation in 2009. The bedload transport results were compared to measurements collected at Highway 101 in 1994 by Simons and Associates and in 2010 by the USGS. A detailed description of the bedload transport model and the results are presented in the Skokomish River Basin Flooding and Sedimentation Baseline (Annex H-7).

The project area of the Skokomish River (roughly from RM 8-11) has changed significantly from the 1930's to present. The channel is presently much narrower and has a significantly reduced wood supply from what has existed historically. Previous reports have discussed the change in historic wood loadings (Annex H-9) and historic channel migration zone (Annex H-7). Few large jams are presently located mid channel, with the majority found pinned against banks in areas of secondary flow and blocking side channels. Estimates given for present wood loading are roughly 5-6 large jams per mile between RM 1-11 (Annex H-9). It is clear that present wood loads are only a fraction of what has existed historically. Some estimates have suggested that this is 74-99% less wood than what has existed historically (TEAMS, 2009). The result of this is a channel that has significantly reduced hydraulic roughness and an absence of the complexity afforded by historic log jams. Significant opportunity exists to rehabilitate this reach with log placements, to include establishing stable scour pools and mid channel bars, re-activating historic side channels, and generally adding complexity to what is presently a stark gravel bed river. Use of mechanically placed wood in Northwest Rivers for these purposes has been widely documented (Collins 2011, Montgomery 2003, USACE 2009, USACE 2012, USACE 2014, and others). The South Fork reach of the project area is intended primarily for these rehabilitative efforts and was found to be suitable for the methods described here. Some wood is used to help direct flows through the diversion in the Confluence levee and to stabilize the side channel reconnection. The potential for reactivating side channels along the south fork depends largely on what the local sponsor is amenable to as later design phases are reached. Land along much of the historic channel migration zone is not presently available for restoration or has not yet been acquired by the sponsor. The potential exists to broaden the scope to activate historic side channels at future design phases. A similar project was undertaken much farther upstream on a steeper reach of the South Fork (TEAMS, 2009) with success. The present state of design with respect to wood placement is preliminary, with structure types, quantity, and locations selected to create localized effects within the present active channel footprint. Wood placements are planned for the South Fork between RMs 9 and 11, adjacent to the new Confluence Levee Removal channel, and at the side channel reconnection inlet and outlet. Species should mainly be conifers and Douglas Fir is specified in the design; however, Cedar can be used for increased longevity. The wood placements shall be anchored with boulders and/ or piles to prevent them from moving during bankfull discharges. Some LWD may be used to reduce the risk of harmful bank erosion and included in the design at later phases if deemed necessary from a channel migration risk perspective. Restoring historical wood loading is likely not entirely possible without bank protection. Areas of erosion risk/property loss will need to be identified and coordinated with the local sponsor. Areas that are potentially affected should have mitigation such as minimal placement of anchored wood or strategic placement of log jams to deflect flows. Several types of wood structures are presently included in the design:

- **Bar apex structure**: Located at meander crossings and at locations where minor geomorphic work is acceptable. Promote the formation of vegetated bars (existing and new) and development of deeper and narrower low flow channels to either side of the structure, increase low flow channel length, and scour pool formation. Will dissipate energy in floods, maintain large scour pools, and store woody material and gravel. This structure is anchored with piles, rootwads, and chained together. Seeding the structure and including plantings will help to provide replenishment as the structure decays.
- **5 log channel cluster:** Located along low flow channel margins and along braids formed by the bar apex structure to form low flow scour pools. Individual logs are chained to boulder anchors and interlocked. The root wad and trunk provide hydraulic shadows, feeding stations, and rearing and refuge habitat for juvenile salmonids. These structures also provide resting and refuge habitat for juvenile and adult salmonids, and aquatic insect colonization substrate and production.
- **5 log bank cluster:** Located in the channel banks to provide complex instream cover and bank protection. The elevation of the root wads off the bottom on the cover log base provides habitat partitioning that benefits salmonid rearing and refuge habitat. It also provides feeding stations in

hydraulic cover at the edge of flowing water that will provide drift feeding opportunities. The cover log base also affords easier construction to hold the top logs above the bottom during anchoring.

- **Single Anchored log:** Located along low flow channel margins and along braids formed by other structures to form low flow pool habitat. Each individual log is chained to a boulder anchor with the rootwad placed in a preformed scour pool and the trunk buried with excavated material. The root wad and trunk provide hydraulic shadows, feeding stations, rearing and refuge habitat for juvenile salmonids. These structures also provide resting and refuge habitat for adult salmonids, and aquatic insect colonization substrate and production.

The location of wood structures is preliminary at all sites and refinement is intended during the pre-construction, engineering, and design phase. Terrain used in modeling is generally poor resolution and was not significantly useful from a detailed design perspective (i.e. based hydraulic parameters). Modeling and analysis is expected to be updated at later design phases. New LiDAR when available is not expected to significantly change design concepts but will inform the location of wood. The location of wood structures will also depend upon how the river evolves (the location of the low flow channel and active channel margins) before the final designs are completed. Structure types and quantity were selected based upon preliminary guidance and may change at later phases. The overall quantity of wood is expected to allow sufficient flexibility with cost contingencies to meet project goals. The 50-year project life period may necessitate use of other wood types such a cedar or replenishment of wood as it decays and should be coordinated with the sponsor. It is desirable to use conifer species to maximize longevity of wood placements and to minimize the need to replace logs over the project life.

1.5 Civil Design

This section discusses the key elements of the civil design and determines the gross volumes associated with each feature included in the Feasibility report. The discussion includes the major components, construction, access and staging considerations.

1.5.1 Staging and Access

Based on evaluation of the site topography and predominant land use, approximately 3.7 acres of staging areas would be utilized. Staging would be anywhere within the project construction limits and the staging areas shown on the plans. Access will be at the locations shown on the plans.

1.5.2 General Construction Methodology

Specific timing restrictions will be required for in-water work to protect fish and wildlife and measures may be required under site-specific permit requirements to protect downstream infrastructure. Construction would be in the drier summer months to facilitate access and construction and to comply with regulated in-water work windows to protect sensitive fish species. Any excavated materials would be removed off-site. The erosion and water quality control plan and best management practices will be determined during Pre-construction Engineering and Design (PED). Generally the following are included:

- Existing roadways or travel paths will be used whenever possible and stream crossings minimized.

- The number of temporary access roads will be minimized and roads will be designed to avoid adverse effects like creating excessive erosion and avoiding crossing slopes greater than 30%.
- All temporary access-ways not needed for future access will be removed (including gravel surfaces) and planted by the end of the in-water work period and after project completion.
- As much as practicable, any large wood, native vegetation, weed-free topsoil, and native channel material displaced by construction will be stockpiled for use during site restoration.
- When construction is finished, the construction area will be cleaned up and rehabilitated (replanted and reseeded) as necessary.
- Prepare a Work Area Isolation Plan for all water crossing requiring flow diversion or isolation.
- Within seven calendar days of project completion, any disturbed bank and riparian areas shall be protected using native vegetation or other erosion control measures as appropriate.

1.5.3 TOPOGRAPHY

Three different data sources were used to develop a topographic surface for 2-D mesh development:

- 1994 Photogrammetric 2-ft Contour Map
  - Horizontal Datum: Washington State Plane coordinate system South zone NAD 83/91.
  - Vertical Datum: NAVD 1988
  - Source: Bell Walker & Associates
  - Description: A Photogrammetric model was built with a stereoscopic drafting station using GPS registered aerial photography. Extends upstream to approximately RM 11 on Skokomish River.
- 2002 Bare-earth LIDAR
  - Horizontal Datum: Washington State Plane coordinate system South zone NAD 83/91.
  - Vertical Datum: NAVD 1988
  - Source: Puget Sound LIDAR Consortium
  - Description: Bare-earth LIDAR containing the X, Y, Z values of all the LIDAR returns classified as ground.
- 2014 field cross sections and utility information
  - Horizontal Datum: Washington State Plane coordinate system South zone NAD 83/91.
  - Vertical Datum: NAVD 1988
  - Source: Mason County
  - Description: May/June 2014 field topography at the Confluence Levee and Channel reconnection entrance area. Utility information collected in the River Mile 9 and Grange areas.

1.6 GEOTECHNICAL DESIGN

This section presents background information for the geotechnical design and construction of the proposed environmental restoration features for the Skokomish General Investigation.

Proposed features of design include Confluence Levee degrade, wetland embankment at River Mile 9, wetland at Grange, large woody debris (LWD) structure anchors, and side channel reconnection.

Although the wetland embankment features are ecosystem restoration features, they were designed according to USACE levee design standards and text throughout this section references general design standards for levees. The Wetland Embankment elements of the wetland restoration projects will retain flood waters for a limited loading period and are designed to allow targeted reconnection to riparian wetlands during frequent, moderate storm events. The features are designed to be resilient for the 50-year study period assuming normal operations and maintenance. This standard protects the initial investment of the ecosystem restoration project.

1.6.1 Geologic Setting

The Skokomish River Valley is located at the southeastern end of the Olympic Peninsula near the southernmost extent of Hood Canal. The Skokomish River flows east from its headwaters in the Olympic Mountains and descends through narrow steep gorges and cascading pools to the Skokomish Valley, which occupies the lower most 10 miles of the Skokomish drainage basin.

The Puget Lowlands have been impacted by multiple continental glaciations during Pleistocene time. The ice excavated the valley during the Vashon stade into the older Vashon advance outwash deposits (Great Lowland Fill) and pre-Vashon deposits (Booth, 1994). Holocene fluvial erosion has exerted minimal influence on the large-scale valley morphology.

The Skokomish catchment is underlain by thick deposits of glacial till and inter-glacial gravel, which is, in turn, underlain by basalt (Carson, 1970; Tabor, 1975). The lower portions of the basin consist of till deposited by the Vashon lobe of the Fraser Glaciation approximately 15,000 years ago. In the valley of the mainstem Skokomish, interglacial gravel interfingers with Holocene fluvial deposits of the Kitsap Formation. Eocene basalt outcrops in upper portions of the basin, in the gorge. (Stover & Montgomery, 2000).

1.6.2 Local Geology

The site is located adjacent to the Skokomish River in a broad, (approximately ¾-mile wide) flat river valley about 5 miles southwest of the river's delta as it enters the Hood Canal. Geologic mapping for the site was obtained from the *Geologic Map of the Skokomish Valley and Union 7.5-minute Quadrangles, Mason County, Washington* (Polenz et al. 2010). Near-surface geology at the site is mapped as Quaternary age alluvium (Qa). Alluvium at the site typically consists of loose to medium dense, silty sand with gravel (Mason County 2014). Hills above the river valley (to the north and south) are generally mapped as glacial till (Qgt) with various ice contact deposits mapped between the upland glacial till and lowland alluvium. Occasional peat (Qp) zones are mapped in the valley, although not in the vicinity of the explorations for this study.

1.6.3 Subsurface Explorations

The subsurface exploration program for the project consisted of borings, test pits, and a hand auger along and near the proposed wetland embankment alignment. Additional explorations were performed in the area to inform a hazardous, toxic, and radioactive waste (HTRW) investigation. The subsurface explorations and testing for the Skokomish GI project site were performed in July of 2014 by Landau Associates, Olympia, Washington under contract to Mason County. The final geotechnical report can be found in Annex B-1. The Corps utilized the soil and geotechnical analytical laboratory analyses in these reports for the development of the new wetland embankment design.

1.6.4 Laboratory Testing

Geotechnical analytical laboratory testing performed on soil samples collected during the subsurface exploration program included visual classification, moisture content determinations, grain size analyses, hydrometer analyses, fines content determinations, Atterberg limits tests, organic content, and consolidation tests. The laboratory tests were conducted to evaluate index and engineering properties of the soils. Laboratory testing results can be found in Annex B-1: Geotechnical Exploration Report.

1.6.5 Soil Conditions

In general, subsurface conditions within the project area are consistent with the geologic history of the area. Based on site reconnaissance, review of information from previous geotechnical studies, and recent exploration and laboratory test programs, we conclude that to the depth of interest for the proposed work, the project sites are underlain varying layers of alluvium. Typically, for the wetland embankments, a layer of silt to silty sand overlies more coarse grained alluvial deposits of poorly graded sand or well graded gravels. Soil profiles can be inferred from sheets B-201 and B-202 in the plan set (Annex A).

The soil parameters were determined from exploration data, laboratory data, empirical relationships, and experience with similar soil types of the region. Soil design parameters listed in Table 1-2 were used for the Wetland Embankment design.

Table 1-2. Soil Parameters

Soil Type (USCS)	Unit Weight (γ, pcf)	Friction Angle (ϕ, degrees)	Cohesion (c, psf)	Hydraulic Conductivity (K, cm/s)
ML	110	30	0	5.00E-05
SM	115	32	0	1.00E-04
SP-SM	120	34	0	1.00E-02
SP	120	34	0	5.00E-02
GW/GP	120	34	0	5.00E-01

1.6.6 Proposed Wetland Embankment Fill

For wetland embankment fill, the following soil specifications are recommended as a typical levee gradation used for Northwest levee construction: USCS soil classification of SP-SM or SM, free of organics and debris, with LL<50, and a gradation meeting the following specifications in Table 1-3.

Table 1-3. Typical Wetland Embankment Fill Gradation

Sieve Designation	Percent Passing
3 inch	90-100
1 inch	70-95
½ inch	60-90
No. 4	50-85
No. 40	20-55
No. 200	10-20

Based on initial quantity calculations, the required fill for the wetland embankments will total approximately 42,500 CY. To account for losses and loose to compact soil state, these neat line quantities should be increased by 15 percent. Therefore, a total of approximately 50,000 loose CY are anticipated to be necessary to complete the construction of the wetland embankments.

Mason County has identified two nearby sources for potential borrow sources. First, approximately 40,000 loose CY of potential borrow material is stockpiled approximately 7 miles away from the proposed project sites. The source of the spoil is a roadside slope re-grade near US-101. Additional material from future WSDOT slope re-grades will be stockpiled for these purposes. The second source is a potential borrow source from the hill south of the Skokomish Valley. Site soils are of the Grove series classified as gravelly sandy loam (SM) by NRCS.

Samples from the boring logs also showed that soils in the vicinity of the project either exhibited too high of a fines content, exceeding 30 percent passing the number 200 sieve, or too coarse (<5% fines) for ideal levee construction. In addition, surface soils exhibit organic content and a high ground water table prevents deeper soils from being used because water content is much higher than expected optimum for proper compaction. Blending soil sources or creating a zoned embankment with adjacent borrow sources are considered to be less cost effective.

The degrade of the existing confluence levee may also provide a potential borrow source for material. The levee material is not overly saturated, but much of the surficial soil will need to be grubbed for vegetation and organics. In addition, 5 grain size distribution tests were performed on hand auger samples recovered from the confluence levee. Only one of those samples exhibited desirable soil properties for levee fill.

Wetland embankment construction will consist of a maximum 8” lift of soil compacted to 95% of maximum with vibratory compaction methods consistent with the coarse grained fill. With the aforementioned soil type, gradation, and compaction assumptions, the constructed soil properties used for design analysis can be found in Table 1-4.

Table 1-4. Soil Parameters for Typical Wetland Embankment Fill

Soil Type (USCS)	Unit Weight (γ, pcf)	Friction Angle (φ, degrees)	Cohesion (c, psf)	Hydraulic Conductivity (K, cm/s)
Embankment Fill (SM)	120	35	0	5.00E-04

1.6.7 Disposal Sites

No specific disposal site has been identified at this stage in the design. For cost estimating purposes, all spoil is assumed to be disposed of off-site. However, some excess spoil may be found to have re-use potential on other projects. Spoil from the removal of the Confluence Levee may potentially be used for wetland embankment fill at the wetland restoration sites or for ballast of the bar apex LWD structures.

Over excavation for foundation preparation of the wetland embankments may provide suitable material for top soil to cover wetland embankment slopes. Import material may need to be blended to provide suitable top soil mix.

1.6.8 Rock Sources for Erosion Protection

For wetland embankment locations requiring riprap armor, the following quarries are potential sources for materials. Potential quarries and the one-way haul distances to the project sites are listed in Table 1-5 below for cost estimating purposes only.

Table 1-5. Quarry Sites

Quarry	Haul Distance (Miles)
Little Creek Quarry	15
Kennedy Creek Quarry	17.5

Rock quality assessments have not been made on these potential sources. This is recommended during a later design phase.

1.6.9 Filter Blanket for Riprap Blankets

All instances of riprap protection for overtopping or riverward erosion protection will have a minimum 1-foot filter blanket beneath the riprap armor. This filter blanket will be designed in accordance with EM 1110-2-1901: Filter Design, Change 2 (USACE, 2005) based on the future selection of a levee fill material.

1.6.10 Groundwater Studies

A study entitled, "Miscellaneous Planning Studies: Skokomish River Diking Inventory" dated April 2001 and prepared by HDR Engineering, Inc. notes typical groundwater trends. "The groundwater table in the valley has been reported to be rising over the last thirty years. The groundwater level in the upper valley [upstream of Skokomish Community Church near RM 8.25] is typically 0.5 to 3.0 feet below grade." (12). During high water, the groundwater has been seen percolating from old river channels. The report continues, "current groundwater flows are away from the river and run with a light silty mud present in the water" (12).

Typical groundwater depths during the July 2014 geotechnical exploration were measured from 2.9 to 6.6 feet below ground surface. The groundwater surface was not encountered in a common water bearing stratum. Groundwater levels during these explorations can be found on the boring logs in Annex B-1.

1.6.11 Wetland Embankment Underseepage Analysis

Underseepage and seepage through the three representative wetland embankment cross sections were estimated using methods presented in USACE manuals (EM 1110-2-1913, April 30, 2000; EM 1110-2-1901, February, 2005). This analysis was accomplished using the finite element modeling program, Seep/W.

Much of the wetland embankment foundation is stratified with higher fines content soils (ML, SM) in the upper 5-10 feet with coarse grained soils (SP-SM, SP, GP, GW) in the lower foundation. Hydraulic conductivity estimates were attained through grain-size analyses using correlations and empirical equations, such as Hazen equation, as well as typical values based on soil classification. In-situ permeability testing was not completed during the reconnaissance geotechnical exploration. Prolonged seepage conditions could cause piping of the silty sand wetland embankment material. However, seepage analysis illustrates that the exit gradients experienced at the landward toe of the wetland embankment under design flood steady state seepage conditions are not conducive to seepage or piping. Maximum average exit gradients experienced at the landward toe of the wetland embankment were less than 0.3. Therefore, no seepage mitigation is recommended for the design. Foundation soils of minimal fines content such as the gravelly soils encountered beneath the upstream portion of the wetland embankment at River Mile 9 are anticipated to experience high underseepage quantities resulting in ponding landward of the wetland embankment structure similar to conditions that presently exist.

1.6.12 Wetland Embankment Slope Stability Analysis

Global stability analyses were performed for static and steady state seepage loading conditions. Slope stability of the proposed Wetland Embankment was evaluated at representative sections along the wetland embankment alignments in accordance with USACE Design and Construction of Levees, Section 6-5 (USACE, 2000). This analysis was accomplished using the limit equilibrium modeling program, Slope/W. The Factors of Safety reported are calculated using the Spencer method which satisfies both moment and force equilibrium, and considers both shear and normal interslice forces. The following loading conditions were analyzed:

1) **End of construction (Static).** End of construction analysis did not account for significant development of pore pressures in the shallow embankment soils. Foundation soils are relatively permeable and deposited in relatively thin strata. A static slope stability utilizing piezometric surface equivalent to the groundwater table at the time of the soil exploration and effective strengths of soils were used. This assumption can be confirmed in later design phases when time rate of consolidation is explored and construction phases are determined. The minimum required FS is 1.3 according to EM 1110-2-1913: USACE Design and Construction of Levees, Table 6-1b (USACE, 2000).
2) **Steady-state**. This condition represents the long-term stability where the water level on the wetland embankment is at the design high water level. Effective soil strength parameters were used for the foundation soils. Pore pressures were imported from the steady state seepage model for use in this stability model. This condition is applicable to the landside slope, the minimum required FS is 1.4 according to EM 1110-2-1913: USACE Design and Construction of Levees, Table 6-1b (USACE, 2000).
3) **Rapid drawdown.** The rapid drawdown loading condition was not analyzed. Based on indications of available wetland embankment fill sources and design permeability, the wetland embankment soils will be relatively permeable and not develop significant excess pore water pressures along the riverward slope. This assumption can be confirmed at a later design phase.

1.6.13 Wetland Embankment Settlement Analysis

For this level of design, one-dimensional consolidation theory was applied for the calculation of settlement. Consolidation settlement parameters are based on laboratory one-dimensional consolidation testing data. The consolidating layers are soft/loose layers of silt or silty sand with greater than 30 percent fine content by weight. Significant secondary compression is not anticipated due to the absence of highly organic or plastic soils. Atterberg limit testing of the soils indicated that the fines exhibited low plasticity or were non-plastic. Coefficient of consolidation and recompression were calculated based on the one-dimensional consolidation laboratory testing implementing typical Casagrande construction methods to determine the pre-consolidation stress. Five consolidation tests were completed with calculated coefficients in Table 1-6 below.

Table 1-6. One-Dimensional Consolidation Test Results

Boring	Sample	Depth (ft bgs.)	USCS	OCR	C_{CE}	C_{RE}
BH-02C	S-1	2.5	ML	5.0	.176	.008
BH-05R	S-4	12.5	SM	1.3	.116	-
BH-07R	S-1	2.5	ML	- Test Not Used -		
BH-08	S-3	7.5	ML	1.2	0.07	-
BH-10	S-3	6.5	SM	- Test Not Used -		

Normal pressure vs. strain curves from the one-dimensional consolidation tests for BH-07R and BH-10 exhibited significant sample disturbance and were not used for design. Over-consolidation ratios for soils ranged from 1.0 to 1.3; therefore, these alluvial deposits are classified as normally-consolidated. The sample from BH-02C taken at 2.5 feet exhibited over-consolidated behavior, but this can be attributed to sample disturbance or from matric suction induced by fluctuating groundwater levels. Based on primary consolidation calculations, settlement was anticipated to range from 4-8 inches.

Due to the anticipated permeability of the silt and silty sand layers, much of this settlement may occur during the construction phase. Additional time rate of consolidation estimates will occur during subsequent design phases. For design, 6 inches of overbuild was prescribed to mitigate settlement with station 35+00 to 45+00 of the wetland embankment at River Mile 9 being increased by 9 inches due to the presence of a 10-foot thick layer of soft to very soft silt in the foundation.

1.6.14 Earthquake Studies

The Skokomish River Valley has a seismic site classification of D to E based on Washington State Department of Natural Resources Liquefaction Susceptibility and Site Class Maps of Washington State, by County (2004). The DNR maps also classified the liquefaction susceptibility of the river valley as moderate to high.

Earthquake loadings are not normally considered in analyzing the stability of levees because of the low risk associated with an earthquake coinciding with periods of high water. The severity of the expected earthquake and the consequences of levee failure are considered. The saturated loose silts and silty sands composing the levee foundation have liquefaction potential, but seismic design is not anticipated for this site based on low coincident loading probability and low expected consequences.

2 Confluence Levee Removal (Annex A, Sheets C-110 through C-115)

2.1 Site Description

The Confluence Levee removal removes approximately 5,400 lineal feet of levee including enlarging an existing breach to 300 lineal feet. The levee removal includes approximately 1,625 lineal feet on the left bank and 3,775 lineal feet on the right bank. This work requires 15,058 CY of material excavation. Estimates from satellite imagery include 61 trees (smaller than 12” DBH) and 57 trees (greater than 12” DBH) removed.

2.2 Hydraulic Design

In the vicinity of the North Fork/South Fork confluence, riverbed aggradation in the South Fork and the avulsion of the North Fork has led to dry channel conditions developing in the South Fork during the late summer/early fall time period. The dry channel stops the upstream migration of salmon returning to the South Fork. This measure addresses that problem by removing the Confluence levee and diverting the South Fork into the North Fork near the pre-2003 confluence. The combined discharges would provide a continuous low flow channel into what is now the North Fork channel. The reach of the South Fork that goes dry in the late-summer/early-fall would be abandoned during those low flow periods. This measure would have little effect on flooding since the existing South Fork channel would be available to convey flood discharges and both sides of the river frequently flood in this location already.

Since the 2003 North Fork avulsion, which shifted the confluence downstream about 1.5 miles, the Confluence levee has been a barrier between the North and South Fork channels. The Confluence levee is located at and downstream from the old confluence near RM 9. Aggradation in the South Fork channel has raised much of the riverbed to elevations above the North Fork at the old confluence, but the levee limits the flow diversions to the North Fork.

About 5,400 feet of the Confluence Levee, approximately 15,058 CY, would be removed. A small channel would be established to direct the South Fork flows into the current North Fork channel. The South Fork’s bedload would be diverted to the combined channel after levee removal. Little deposition has been observed in the current North Fork channel. The river channels would then be permitted to naturally evolve over time. The new connection would allow upstream migrating salmon to bypass the reach of the channel that typically goes dry in the late summer. This action would have little impact on flooding, as the North Fork floodplain near the confluence is presently heavily inundated by the South Fork flood flows.

Estimated sedimentation downstream of the diversion is further explained in the Confluence Channel Sediment Deposition annex (Annex H-7).

2.2.1 Design Considerations

The diversion through the old Confluence Levee into the North Fork was designed to pass all flow up to a typical winter flow of approximately 2,000 cubic feet per second (cfs). For greater flows than 2,000 cfs the historic south fork channel is reactivated. The diverted flows are expected to do geomorphic work downstream of the diversion for many years after the project as high flows will be split between the existing and new flow paths. The existing terrain will erode and existing vegetation will be altered as a new larger active channel forms there. This process will be allowed to occur naturally. A breach 300 ft wide with a bottom elevation of 53 ft NAVD88 was found to adequately pass the desired flows. This elevation requires excavation below the existing ground at the base of the levee. The area immediate vicinity of the breach will see an increase in water surface for the 0.01 ACE event (USBR, 2014) and is being included in the real estate takings analysis. Seven of the Bar Apex ELJ and twenty-six single logs were placed adjacent to the diversion to assist in keeping low flows in the diverted channel and to prevent the main channel from migrating around the diversion. This wood will encourage recruitment and aid in formation of the newly diverted channel. Concept graphics for placed wood are included in the annex the Engineering Appendix. Local scour at log structures was estimated from scour holes at rootwads and logs observed at the site near the confluence. Observed scour ranged from 3-5 ft typically. A value of 5 ft was used in preliminary stability analysis for placed wood.

2.2.2 Risk, Next Steps, and Future Work

As better resolution terrain is acquired the SMS model can be updated and refined to allow better accuracy in modeling diverted flows and activation of the historic south fork channel. The Bar Apex ELJ placements adjacent to the diversion were roughly incorporated in the SMS model geometry as raised grid cells. However the locations and structure size were changed slightly from what was originally modeled to make better use of the structures. This should be corrected and refined to reflect actual placements and the model re-run to verify acceptable split of high flows. Number and placement of ELJ can then be further refined as necessary. The opportunity exists to move some of the ELJ's to the downstream side of the diversion to improve the habitat quality. This should be explored with the sponsor and is an opportunity to include persistent large wood in the area that otherwise would evolve into an unstable braided channel section with no large wood. The area presently does not have any large trees. Alternately loose wood could be introduced downstream of the diversion and allowed to migrate as the new channel area forms.. Estimated local scour depths at placed wood will need further investigation based upon refined hydraulic modeling from better resolution terrain data, and anchoring methods updated to reflect estimations.

2.3 Civil Design

2.3.1 Breach

The work includes enlarging an existing breach to 200 LF long and 70 feet wide to elevation 53 feet NAVD 88 with 3 horizontal to 1 vertical side slopes. This work requires 4,715 CY of material excavation.

2.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access will be in the locations shown on the plans and will require crossing the South Fork Skokomish River. Temporary culverts and water diversion are necessary in these areas. The Confluence Levee Removal and wetland embankment at River Mile 9 share the staging area at the primary access point.

2.3.2 Construction Methodology

Construction would be in the drier summer months when the South Fork of the Skokomish River is low to facilitate access. The construction methodology is to field stake the excavation limits and walk the site with the project biologist to identify any trees to save, and any areas to modify. The area would then be cleared, and levee removed to the design profile. The excavated materials would be removed off-site. Construction of the breach may require a temporary cofferdam along the length of the north side of the breach north fork of Skokomish River.

2.3.3 Survey/GIS/Topography

The 2014 field cross section data was used for most of this evaluation. The first 1,000 feet of levee was not accessible because right-of-entry could not be obtained. This first 1,000 feet of levee removal was estimated using the 2002 Lidar information shown on the cross sections. This depicts a slightly more continuous levee than the 1994 photogrammetric topography, however, still indicates the levee may not be continuous. For estimating purposes, the first 1,000 feet was estimated using averages from the remaining left bank work.

2.3.4 Risk, Next Steps, and Future Work

During PED, the design catch point will be field staked and the project walked to determine any modifications needed for final plans and specifications. Modifications may be a change in levee removal elevation, omitting areas where the removal of trees and habitat will be more disruptive than removing the levee.

2.4 Geotechnical Design

The Confluence Levee removal involves removal of approximately 15,058 CY of soil. Based on hand auger explorations and minimal grain size analysis, the USCS classification of the levee fill includes SM, SP-SM, SP, GP-GM, and GM. Excavation of slopes for the removal of the Confluence will not exceed a 2H:1V slope to ensure stability of the slopes during levee removal.

2.5 Planting Plan

A planting plan has been developed for the Confluence Levee Removal site. Approximately 3.6 acres will be cleared for the Confluence levee removal with a total work area limit of 7.7 acres. It is assumed that approximately 4 acres will need to be replanted with the following planting considerations:

- 100% of area will have conifers 15’ on center (O.C.)
- 100% of area will have shrubs 6’ O.C.
- 100% of area will have bark mulch 6” deep

For trees, a 1-gallon size is assumed with sourcing of bare-root plants for cost savings. Bare-root trees are planted in March/April versus potted trees that are planted in fall, so this would require a second, separate planting effort outside normal construction time, after main construction is complete. Finally, Because of the Japanese knotweed present, this site will need approx 10 years of invasive species removal and maintenance.

3 Wetland Restoration at River Mile 9 (Annex A, Sheets C-120 through C-124)

3.1 Site Description

The new wetland embankment at River Mile 9 from RM 8.3 to 9.2 is expected to be approximately 6 feet in height. The total length of the wetland embankment is approximately 4,370 linear feet. The wetland embankment crest width is 12 feet wide with 2H:1V riverward slopes and 6H:1V landward slopes to allow for overtopping flows. A planting berm will be placed at the riverward toe of the wetland embankment to allow for planting of native vegetation. The entire wetland embankment would be designed for shallow overtopping similar to present conditions

3.2 Hydraulic Design

The Wetland Restoration at River Mile 9, from RM 8.3-9.2, is intended to reconnect and restore high quality wetland habitat. The wetland embankment would be constructed landward (south) varying distances, generally around 200-300 ft, from the existing agricultural berm. This places more riparian forest and floodplain ponds on the riverward side of the wetland embankment. Four strategically located sections totaling approximately 950 ft section of the existing agricultural berm would be removed. These breaches would allow flood waters to flow freely within the wetland restoration area, providing salmon access to the riparian habitat. Breaches are located at existing ground elevations to allow the area to drain with receding flows to prevent stranding. From west to east the breaches were given elevations of 60, 57, 56, and 51 ft NAVD88 respectively. The new wetland embankment would generally be lower than the existing agricultural berm. The entire wetland embankment was designed for shallow overtopping with a 6H:1V backslope. The wetland embankment between RM 8.8-9.0 (STA 10-17 and 37-43) was given a slightly lowered crest to allow flooding to occur similar to existing conditions.

3.2.1 Design Considerations

The wetland embankment was designed to improve hydraulic conditions in the reconnected wetland area. These structures will not change the existing flooding conditions in the study area. While the system is aggrading in the area of the confluence between the north and south forks, all bedload is expected to pass through the diversion in the Confluence levee and bypass the setback area. Deposition in the section of the river adjacent to the wetland embankment at River Mile 9 will be reduced significantly and is expected to consist mostly of fines. The wetland embankment was not preliminarily designed to account for future deposition. No significant change in the 0.01 ACE water surface is expected at the site. Rip rap was necessary at 3 locations on the wetland embankment face due to proximity and orientation to the main channel and estimated velocity of 4-6 ft/s at the wetland embankment face. Class 2 rock was found to be adequate from the methods provided in EM 1110-2-1601 for sizing rip rap. These methods are employed in the software application SAMW in 1.0 which was used for analysis. Results are presented in the Annex. The remainder of the wetland embankment is vegetated on the riverward and landward sides.

3.2.2 Risk, Next Steps, and Future Work

Due to the preliminary nature of the location of the wetland embankment, it may be reconfigured at later design phases. The 2D hydraulic modeling (SMS 11.1) would need to be reconfigured for any significant changes and re-run to estimate overtopping characteristics. The existing agricultural berm overtopps between a 0.99 and 0.5 ACE event. The difference between these events is likely small, but annual flows can be developed and run in the SMS model to refine overtopping and better duplicate existing flood extents if deemed necessary. High performance turf reinforcement mats (HPTRMs) or biorevetments can be investigated during future engineering and design as a viable alternative to rip rap. The wetland embankment design will need to be finalized for adequate superiority for controlled overtopping consistent with ETL 1110-2-299.

3.3 Civil Design

The area includes approximately 4,370 lineal feet of new wetland embankment with a planting berm. This work requires 17,335 CY of wetland embankment material, 2,235 CY of planting berm material, 1,370 CY of topsoil, 3,076 CY of stripping, 662 CY of wearing course, 141 CY of riprap and 102 CY of filter material.

3.3.1 Breach

The work includes 4 breaches, 70 feet wide (totaling 935 lineal feet) of the existing agricultural berm, totaling 7,935 CY of excavation. Two areas adjacent to the proposed breaches of the agricultural berm will require erosion protection on the riverside. These are shown on the plans.

- 100’ long x 70’ wide, elevation 60 NAVD 88
- 180’ long x 70’ wide, elevation 57 NAVD 88
- 290’ long x 70’ wide, elevation 56 NAVD 88
- 365’ long x 70’ wide, elevation 51 NAVD 88

3.3.2 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access will be in the locations shown on the plans. The Confluence Levee Removal and Wetland Restoration at River Mile 9 share the staging area at the primary access point.

3.3.3 Construction Methodology

Construction would be in the drier summer months to facilitate access and construction. The area would then be cleared, and the Wetland Embankment constructed to the design profile. Some excavated materials would be used to construct the planting berm, with any excess material removed off-site.

3.3.4 Survey/GIS/Topography

The 1994 photogrammetric topography was used here, supplemented by 2014 utility information.

3.3.5 Risk, Next Steps, and Future Work

There are two areas close to the breaches that are treated with riprap for erosion protection. These areas and the tie-in require additional refinements during PED.

3.4 Geotechnical Design

The wetland embankment at River Mile 9 is approximately 4,370 linear feet in length and varies in height along its alignment from 4-6 feet in height. The wetland embankment was designed for overtopping and incorporates a sod covered 6H:1V landside slope to protect against shallow overtopping for short durations.

3.4.1 Subsurface Explorations and Soil Classification

Subsurface explorations were completed at approximately 1000 linear foot intervals along the proposed wetland embankment setback alignment except where significant vegetation removal would be required. The upstream portion of this wetland embankment was defined by boring BH-01, which indicated a coarse grained foundation consisting of well graded gravel for nearly the entire depth of the boring. The remaining portion of the wetland embankment portrayed a low plasticity silt (ML) confining layer underlain by varying layers of more coarse grained alluvial deposits. No specific depositional layering was evident in these random alluvial deposits. The wetland embankment foundation consists of three distinct layers of varying thickness. First, the upper confining layer is a silty sand (SM) to silt (ML) confining layer ranging from 5-10 feet in thickness. Atterberg limit testing indicates low plasiticity with a maximum PI of 11 (BH-09R). The underlying layer includes 10-20 feet of poorly graded sands (SP or SP-SM) with varying percentages of fines. The final layer evident in borings BH-09, BH-10, and BH-07R at the downstream end of the wetland embankment is a permeable well graded gravel layer of 7-15 foot thickness.

3.4.2 Design Considerations

Wetland embankment design indicates that a typical section with 2H:1V riverside and 6H:1V landside slopes and 12-foot crown width would be sufficient to meet seepage and stability design criteria. Additional design criteria details are listed in the following sections. The landside slope was developed to allow for shallow and short duration overtopping.

3.4.3 Seepage

Seepage results for the typical 2H:1V riverside and 6H:1V landside computed for the wetland embankment at River Mile 9 were attained for two varying foundations at the upstream end and downstream end of the wetland embankment. First, a typical wetland embankment section at station 2+00 was used to represent the upstream coarse grained foundation conditions. (See Figure B-3 of Annex B-3). Second, a typical wetland embankment section at station 25+00 was selected to represent the critically thin silt confining layer and represent the critical condition for underseepage and piping for the downstream portion of the wetland embankment. (See Figure B-6 of Annex B-3). For the gravel foundation section, the average vertical exit gradient taken over two feet below the landward toe of the wetland embankment is equal to 0.05. Assuming a unit weight of 120 pcf for the gravel layer, the factor of safety against seepage is equal to 18.5. For the silt foundation section, the average vertical exit gradient taken over two feet below the landward toe of the wetland embankment is equal to 0.27. Assuming a unit weight of 110 pcf for the confining silt layer, the factor of safety against seepage is equal to 2.8. No additional seepage mitigation measures are recommended at this design phase. However, gravelly soils with limited fines content encountered beneath the upstream portion of the wetland embankment at River Mile 9 are anticipated to experience high underseepage quantities resulting in ponding landward of the wetland embankment structure similar to conditions that presently exist.

3.4.4 Slope Stability

Slope Stability results for the typical 2H:1V riverside and 6H:1V landside slope indicate the wetland embankment design meets required factors of safety for loading conditions. The stability analysis of the landward slope was designed to meet a 1.4 factor of safety for long term steady state seepage and 1.3 for static loading. (See Figures B-1, B-2, B-4, and B-5 of Annex B-3).

3.4.5 Settlement

Based on available soil information and one-dimensional consolidation test data, settlement for the wetland embankment at River Mile 9 is estimated to be less than 6 inches except at the upstream and downstream ends of the wetland embankment. At the upstream end of the wetland embankment, only coarse grained soils exist that would experience negligible settlement during construction. A consolidation test for the very soft silt layer in BH-02 (Station 10+00) indicated a steep modified compression index (C_{CE}). Although the laboratory testing of the sample indicates a significant degree of overconsolidation, the recent alluvial deposit was conservatively estimated to be normally consolidated. When this compression index is applied to a thick layer of soft silt near station 35+00, computed settlement increased to approximately 9 inches. Settlement predictions for the wetland embankment at River Mile 9 are listed by project station in Table 3-1 below.

Table 3-1. Predicted Total Primary Settlement

Station	Expected Settlement (inches)
0+00	0
10+00	4.5
24+00	4.5
35+00	9
45+00	9

Time rate of consolidation analysis will be performed at a later time. Initial correlations based on liquid limit (LL) indicate that 90% settlement would be reached within 75 days of the full load being applied.

3.4.6 Transition to Existing Agricultural Berms

The wetland embankment will need to tie in to the existing agricultural berms at the upstream and downstream end of the proposed alignment. The existing agricultural berm is of unknown construction and materials and has a significantly narrower section that is not designed for overtopping. The existing agricultural berms will not be improved because the project goal is for environmental restoration. The agricultural berms are currently at risk of overtopping breach and potentially other geotechnical failure modes prior to breach. A goal of this project is to not increase the likelihood of overtopping upstream or downstream. The wetland embankment is expected to have no change to performance and level of protection.

3.4.7 Wet Weather Considerations

In the Puget Sound region, wet weather generally begins about mid-October and continues through about May, although rainy periods could occur at any time of the year. Thus, it would be advisable to schedule earthwork during the drier weather months of June through September. Soil with fines contents higher than 5 to 8 percent is highly susceptible to changes in water content and tends to become unstable and difficult or impossible to compact if the moisture content significantly exceeds the optimum. During wet weather months, the groundwater levels could increase, resulting in seepage into site excavations. Performing earthwork during dry weather would reduce these problems and costs associated with rainwater, trafficability, and handling of wet soil. Placing and compacting fill for the new Wetland Embankment may not be practicable during wet weather.

3.4.8 Wetland Embankment Planting Plan

The wetland embankment is designed with a vegetation planting plan. The minimum wetland embankment prism as described above will be planted with only sod cover. For ecological benefits, the riverside slope of the wetland embankment will be overbuilt with agricultural berm breach spoils to form a planting berm of approximate dimensions of 7 feet wide and 3.5 feet in height. (See Annex B-6). This berm will be planted with tree species with mature heights of 10 – 20 feet. Assumptions were made that trees would be planted a maximum of 2 feet from the hinge point of the planting berm (5 feet from the catch point of the wetland embankment section). If plantings can be placed within the slope of the planting berm or closer to the hinge point on the berm crest, the amount of spoil required for construction could be reduced.

3.4.9 Risk, Next Steps, and Future Work

Time rate of consolidation analysis is planned for the next engineering design phase. In addition, further exploration into end of construction slope stability loading conditions is recommended. Finally, continued coordination and analysis is required to finalize the preliminary embankment planting plan requirements and the planting berm dimensions.

3.5 Operations and Maintenance

The proposed wetland embankments were designed in accordance with applicable USACE engineering manuals. Operation and maintenance of these structures will be necessary to ensure proper functioning of the wetland embankment structures to maintain ecological benefits at the site. Maintenance zones should extend 15 feet from both the riverward and landward wetland embankment toe. This maintenance zone is visible on the feasibility-level design plan set and should remain free of unwanted vegetation and unauthorized encroachments. Sod cover and riprap maintenance will be necessary to ensure proper functioning of erosion protection; especially at overtopping locations.

At the completion of the Wetland Restoration projects, an operation manual detailing proper maintenance practices will be provided to the local sponsor. The wetland embankment will not be eligible for rehabilitation assistance under the PL84-99 program due to inability to meet the minimum level of protection guidelines.

3.6 Planting Plan

A planting plan has been developed for the Wetland Restoration at River Mile 9 site. The new wetland embankment area will have approximately 5 acres planted with only grass. A planting berm will be constructed from materials excavated from the breached sections of existing agricultural berm at River Mile 9 and potentially from the Confluence Levee. This berm will be approximately 4’ to 6’ wide and 2’ to 3’ tall. The berm will be planted with grass and will be planted with one row of short willow species 6’ O.C. In addition, the staging area (approximately 14,000 square feet) will be replanted with grass. The breach areas (approximately 2 acres) will also be replanted with grass.

4 Wetland Embankment at Grange (Annex A, Sheets C-130 through C-133)

4.1 Site Description

The new wetland embankment at Grange from RM 7.5 to 8 is expected to be approximately 5 - 10 feet in height. The total length of the wetland embankment is approximately 2,750 linear feet. The wetland embankment crest width is 12 feet wide with 2H:1V riverward slopes and 6H:1V landward slopes to allow for overtopping flows. A planting berm will be placed at the riverward toe of the wetland embankment to allow for planting of native vegetation. The entire wetland embankment would be designed for shallow overtopping, but two lengths of wetland embankment between station 5+00 to 9+00 and 15+00 to 18+00 would be a designed overflow section, with a 1.5 foot higher crest, in the area of homes. These area would have a 3H:1V landward slope with an 18” thick riprap layer.

4.2 Hydraulic Design

The wetland restoration at Grange, RM 7.5-8, is intended to reconnect and restore high quality wetland habitat. The wetland embankment would be constructed landward (south) up to 1,200 ft from the existing agricultural berm. This would place about 40 acres of riparian habitat, forest and floodplain ponds, on the riverward side of the wetland embankment. Two strategically selected sections of the existing agricultural berm summing to approximately 800 ft would be breached. These breaches would allow flood waters to flow freely within the restored wetland area, providing salmon access to the riparian habitat. Breaches are located at existing ground elevations to allow the area to drain with receding flows. From west to east the breaches were given elevations of 49 and 44 ft NAVD88 respectively. The new wetland embankment would generally be lower than the existing agricultural berm.

4.2.1 Design Considerations

The wetland embankment was designed to improve hydraulic conditions in the reconnected wetland area. These structures will not change the existing flooding conditions in the study area. While the system is aggrading in the area of the confluence between the north and south forks, all bedload is expected to pass through the diversion in the Confluence Levee and bypass the setback area. Deposition in the section of the river adjacent to the wetland embankment at Grange will be reduced significantly and is expected to consist mostly of fines. The wetland embankment was not preliminarily designed to account for future deposition. No significant change in the 0.01 ACE water surface is expected at the site. Rip rap was necessary near the west end due to proximity to the main channel and estimated velocity of 4-6 ft/s at the wetland embankment face. Class 2 rock was found to be adequate from the methods provided in EM 1110-2-1601 for sizing rip rap. These methods are employed in the software application SamWIN 1.0 which was used for analysis. Results are presented in the Annex. Rip rap is used from STA 21-26 on the face, and on both sides where overtopping occurs from STA 15-18 on a 3H:1V slope. The remainder of the wetland embankment is vegetated with a 6H:1V backslope.

4.2.2 Risk, Next Steps, and Future Work

Due to the preliminary nature of the location the wetland embankment may be reconfigured at later design phases. The hydraulic modeling (SMS 11.1) would need to be reconfigured for any significant changes and re-run to estimate overtopping characteristics. The existing agricultural berm overtops between a 0.99 and 0.5 ACE event. The difference between these events is likely small, but annual flows can be developed and run in the SMS model to refine overtopping flows and better duplicate existing flood extents if deemed necessary. High performance turf reinforcement mats (HPTRMs) or biorevetments can be investigated during future engineering and design phases as a viable alternative to rip rap. The wetland embankment design will need to be finalized for adequate superiority for controlled overtopping consistent with ETL 1110-2-299.

4.3 Civil Design

The area includes approximately 2,750 lineal feet of new wetland embankment with a planting berm. This work requires 24,960 CY of wetland embankment material, 1,500 CY of planting berm material, 1,037 CY of topsoil and 2,847 CY of stripping, 444 CY of wearing course, 1598 CY riprap and 1107 CY filter material.

4.3.1 Breach

The work includes 2 breaches, 40 feet wide (totaling 880 lineal feet) of the existing agricultural berm, totaling 3,789 CY of excavation.

- 280’ long x 40’ wide, elevation 49 NAVD 88
- 600’ long x 40’ wide, elevation 44 NAVD 88

4.3.2 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access will be in the locations shown on the plans. The staging area is sited near beginning and the end of the Wetland Embankment at Grange. These will be refined during final plans and specifications.

4.3.3 Construction Methodology

Construction would be in the drier summer months to facilitate access and construction. The area would then be cleared, and Wetland Embankment constructed to the design profile. Some excavated materials would be used to construct the planting berm, with any excess material removed off-site.

4.3.4 Survey/GIS/Topography

The 1994 photogrametric topography was used here, supplemented by 2014 utility information.

4.3.5 Risk, Next Steps, and Future Work

Portions of the alignment are in dense brush resulting in inaccurate survey information. Comparison with the 2002 LIDAR indicates the 1994 photogrametric information is probably more reliable. Rights of entry could not be obtained to update the topographic information. Should this feature be carried into PED updated topographic data is required.

4.4 Geotechnical Design

The wetland embankment at Grange is approximately 2,750 linear foot long with a height ranging from 5 to 10 feet in height. The wetland embankment was designed for overtopping and incorporates a sod covered 6H:1V landside slope to protect against shallow overtopping for short durations. The wetland embankment section adjacent to homes was overbuilt 1.5 feet to provide structure superiority and encourage incipient overtopping in uninhabited areas. This design consideration is intended to minimize life safety concerns associated with embankment construction near adjacent homes.

4.4.1 Subsurface Explorations and Soil Classification

Due to right of entry issues, the upstream portion of this wetland embankment was not accessible for subsurface explorations. The explorations completed for this design phase began near station 15+00 and continued downstream. The wetland embankment foundation consists of three distinct layers of varying thickness. First, the upper confining layer is a silty sand (SM) to silt (ML) confining layer ranging from 5-10 feet in thickness. Atterberg limit testing indicates low plasiticity with a maximum PI of 11 (BH-09R). The underlying layer includes 10-20 feet of poorly graded sands (SP or SP-SM) with varying percentages of fines. The final layer evident in borings BH-09, BH-10, and BH-07R at the downstream end of the Wetland Embankment is a permeable well graded gravel layer of 7-15 foot thickness.

4.4.2 Design Considerations

Wetland embankment design indicates that a typical wetland embankment section with 2H:1V riverside and 6H:1V landside slopes and 12-foot crown width would be sufficient to meet seepage and stability design criteria. Additional design criteria details are listed in the following sections. The landside slope was developed to allow for shallow and short duration overtopping.

4.4.3 Seepage

Seepage results for the typical 2H:1V riverside and 6H:1V computed for wetland embankment at River Mile 9 are considered applicable for foundation conditions present at the wetland embankment at Grange. (See Figure B-6 of Annex B-3). The atypical overtopping section with a 3H:1V landside slope and riprap armor was analyzed. The average vertical exit gradient taken over two feet below the landward toe of the wetland embankment was equal to 0.17. (See Figure B-9 of Annex B-3). Assuming a unit weight of 115 pcf for the confining silty sand layer, the factor of safety against seepage is equal to 5.0.

4.4.4 Slope Stability

Slope stability results for the typical 2H:1V riverside and 6H:1V landside slope computed for the wetland embankment at River Mile 9 are considered applicable for foundation conditions present at the wetland embankment at Grange. (See Figures B-4 and B-5 of Annex B-3). The atypical overtopping section with a 3H:1V landside slope and riprap armor was analyzed. (See Figures B-7 and B-8 of Annex B-3). Overtopping sections of the wetland embankment at Grange were designed with a 1 foot granular filter blanket and 1.5 foot layer of class II riprap to prevent overtopping erosion and scour damages. The stability analysis of the landward slope was designed to meet a 1.4 factor of safety for long term steady state seepage prior to the addition of the riprap. The riprap erosion protection may be replaced with another overtopping protection measure in later design phases. Therefore, the wetland embankment section was flattened to a 3H:1V slope to remain stable should another method be utilized.

The downstream approximately 1000 linear feet of wetland embankment is overlying very soft silts and very loose silty sands with blow counts of 0 for the upper 5-10 feet below ground surface elevation. If the current alignment is taken forward into preliminary engineering design, this section will need to be evaluated for during and end of construction slope stability. During the next geotechnical exploration phase, a combination of in-situ testing and laboratory testing is recommended to determine undrained shear strengths. Field tests such as vane shear and laboratory undrained triaxial tests on relatively undisturbed samples can be performed. Time rate of consolidation will also be necessary to determine rate of consolidation and impacts to construction sequencing. At this time, significant cost inflation for end of construction slope stability mitigation measures is considered unlikely.

4.4.5 Settlement

Based on available soil information and one-dimensional consolidation test data, settlement for the wetland embankment at Grange is estimated to be less than 6 inches. Time rate of consolidation analysis will be performed at a later time. Initial correlations based on liquid limit (LL) indicate that 90% settlement would be reached within 75 days of the full load being applied. Pore pressure monitoring using piezometers and settlement plates may be required during construction if a staged construction is determined to be necessary. Pore pressure dissipation may control the construction staging intervals.

4.4.6 Transition to Existing Agricultural Berms

The wetland embankment will need to tie in to the existing agricultural berms at the upstream and downstream end of the proposed setback alignment. The existing agricultural berm is of unknown construction and materials and has a significantly narrower section that is not designed for overtopping. The existing agricultural berms will not be improved because the project goal is for environmental restoration. The existing agricultural berms are currently at risk of overtopping breach and potentially other geotechnical failure modes prior to breach. This project is designed to have no change in the flooding conditions in the study area.

4.4.7 Wet Weather Considerations

In the Puget Sound region, wet weather generally begins about mid-October and continues through about May, although rainy periods could occur at any time of the year. Thus, it would be advisable to schedule earthwork during the drier weather months of June through September. Soil with fines contents higher than 5 to 8 percent is highly susceptible to changes in water content and tends to become unstable and difficult or impossible to compact if the moisture content significantly exceeds the optimum. During wet weather months, the groundwater levels could increase, resulting in seepage into site excavations. Performing earthwork during dry weather would reduce these problems and costs associated with rainwater, trafficability, and handling of wet soil. Placing and compacting fill for the new Wetland embankment may not be practicable during wet weather.

4.4.8 Wetland Embankment Planting Plan

The wetland embankment is designed with a vegetation planning plan. The minimum wetland embankment prism as described above will be planted with only sod cover. For ecological benefits, the riverside slope of the wetland embankment will be overbuilt with agricultural berm breach spoils to form a planting berm of approximate dimensions of 7 feet wide and 3.5 feet in height. (See Annex B-6). This berm will be planted with tree species with mature heights of 10 – 20 feet. Assumptions were made that trees would be planted a maximum of 2 feet from the hinge point of the planting berm (5 feet from the catch point of the wetland embankment section). If plantings can be placed within the slope of the planting berm or closer to the hinge point on the berm crest, the amount of spoil required for construction could be reduced.

4.4.9 Risk, Next Steps, and Future Work

A significant portion of the proposed wetland embankment alignment subsurface was not able to be explored due to inability to acquire rights of entry. Additional subsurface exploration will be required to characterize the foundation soils along the proposed alignment, especially in locations where the wetland embankment section will be constructed within existing saturated low land areas. These locations may require additional stability or settlement mitigation due to the presence of soft soils.

Additional soil information, time rate of consolidation analysis, and end of construction slope stability analysis is required for the downstream end of the Wetland Embankment proposed to be constructed on soft foundation soils. This information will inform the construction schedule of the wetland embankment. Finally, further analysis and coordination is required to finalize the preliminary embankment planting plan requirements and the planting berm dimensions.

4.5 Operations and Maintenance

The proposed wetland embankments were designed in accordance with applicable USACE engineering manuals. Operation and maintenance of these structures will be necessary to ensure proper functioning of the wetland embankment structures to maintain ecological benefits at the site. Maintenance zones should extend 15 feet from both the riverward and landward wetland embankment toe. This maintenance zone is visible on the feasibility-level design plan set and should remain free of unwanted vegetation and unauthorized encroachments. Sod cover and riprap maintenance will be necessary to ensure proper functioning of erosion protection; especially at overtopping locations.

At the completion of the wetland restoration projects, an operation manual detailing proper maintenance practices will be provided to the local sponsor. The wetland embankments will not be eligible for rehabilitation assistance under the PL84-99 program due to inability to meet the minimum level of protection guidelines.

4.6 Planting Plan

A planting plan has been developed for the Wetland Restoration at Grange site. The new wetland embankment area will have approximately 4 acres planted with only grass. A planting berm will be constructed from materials excavated from the breached sections of existing wetland embankment at Grange and potentially from the Confluence Levee. This berm will be 4’ to 6’ wide and 2’ to 3’ tall. The berm will be planted with grass and will be planted with one row of short willow species 6’ O.C. Breach areas (approximately 1 acre) will be replanted with grass. Staging areas will have the following planting plan:

- 100% of area will have conifers 10’ O.C.
- 100% of area will have shrubs 6’ O.C.
- 100% of area will have bark mulch 6” deep

5 Upstream LWD (Annex A, Sheets C-140 through C-1410)

5.1 Site Description

This increment, located from RM 9-11, would include placement and installation of large woody debris. Small wood clusters as well as larger ELJ’s would be installed in this reach to increase low flow channel meandering, encourage mid channel bar formation, and provide multiple types of habitat benefits for salmon. The volume of added wood will improve the quantity, quality, and complexity of pools in the Skokomish River to promote rearing success and provide year round fish passage. Formation of mid channel bars will Improve the quantity, quality, and complexity of native riparian and floodplain habitats. Existing natural log jams are primarily located on the outside of bends with loose wood parked upon gravel bars and located in areas where it can persist without being swept away at higher flows. The river crosses from one side of the active channel width to the other frequently (perhaps decadal) and there is little wood in the channel to create long term stability. The existing wood load has reduced significantly from historic images dating back to the 1930’s.

5.2 Hydraulic Design

The South Fork of the Skokomish River presently has a significantly reduced supply of the wood load from what has existed historically. Three of the wood structure types discussed in section 1.4 are included in the design: Bar apex ELJ, 5 log channel cluster, and single log placements. These are intended to restore much of the missing habitat and channel complexity afforded by the historical wood load. The function of each type was discussed in section 1.4, with the general purpose being to encourage low flow channel braiding and complexity, and to form scour pools and provide in-stream cover along low flow channel margins. A target of 64 LWD pieces and clusters per mile was selected for the South Fork, with a minimum of 21 per mile being acceptable (Fox and Bolton, 2007). Individual logs should be 2-3 ft diameter and 15-30 ft long, and should have a rootwad. The individual logs and clusters would be placed parallel to flow, with larger ELJ's placed along the center of the active channel to minimize the hydraulic disturbance to the overall channel footprint. All placed wood has the potential to recruit additional wood from upstream sources and grow in size and impact, however because the diminished upstream wood load has not been well quantified recruitment is difficult to predict. The potential exists for the active channel width to change with any wood placement. Existing log jams were located in orthographic photos and their formed mid-channel bars were measured to characterize the potential for this geomorphic work. Bars were found to be between 200-300 ft long behind log jams of similar size to the bar apex ELJ. This footprint was used as a template for preliminarily locating the structure in areas away from bends to minimize the impact to the active channel width.

5.2.1 Design Considerations

All placed wood is designed to be stable through bankfull flows with safety factors between 1.3 and 2. Only the largest structure (bar apex ELJ) required the use of piles and was preliminarily designed with a safety factor of 2. The Bar apex structure is anchored with 10 piles driven to a depth of 12-20 ft, two large logs buried with rootwads inverted and angled in the downstream direction for lateral bracing, and excavated material replaced as ballast. Twenty-seven logs of varying length and 36 CY of logging slash are specified for this ELJ at a total of 7 locations. The Bar Apex ELJ is expected to be planted with Conifers to provide stability as mid channel bars form behind it and to supplement future wood supplies to the reach. The 5 log channel cluster and the single log placements are anchored with 4-5 ft boulder anchors buried directly under the log trunk with a total of 24 clusters used. Single logs are placed at a total of 56 locations. This total number of placements (80) is slightly greater than the approximately 64 pieces and clusters estimated to be needed at earlier design phases. This "buffer" of approximately 20% was used to allow some flexibility in placement at later phases of design due to the poor resolution of terrain data used for feasibility. Additionally, in application the low flow channel will migrate with time and it will likely not continually contact all wood placements. As the channel changes before later design phases there is sufficient quantity accounted for to place wood across the active channel width. As the low flow channel moves some existing habitat may be altered or degraded while new habitat forms. The process will likely be evolving for some time as the river adjusts to the new wood placements. Wood placements were reflected in the 2d SMS model geometry by global roughness increase and raised grid cells (Annex H-8). Local scour at log structures was estimated from scour holes at rootwads and logs observed at the site near the confluence. Observed scour ranged from 3-5 ft typically. A value of 5 ft was used in preliminary stability analysis for placed wood.

5.2.2 Risk, Next Steps, and Future Work

All wood included in the South Fork has been preliminarily located and designed with stable anchoring. SMS Modeling for the south fork channel area was developed from poor resolution terrain data and was not generally suitable for use in quantifying the potential for geomorphic work resulting from wood placement. Once better LIDAR and channel surveys are collected the results can be improved. Further analysis is suggested using the depth-velocity product for evaluating and refining specific locations based upon the potential for desired scour pools to form at structures and wood clusters. Similar projects on the White River have been successful at locations with values ranging from 60-80 (USACE, 2012). The model geometry should be updated with grid cells modified for wood specific ELJ placements and refined roughness. This will allow for more accurate estimation of changes in the 0.01 ACE water surface over the reach. The locations of the Bar Apex ELJ, 5 log channel cluster, and single log placements will need to be refined based upon the location of the low flow channel at later design phases. Specific locations of wood needs to be based on the location of the low flow channel (i.e. 2000 to 4000 cfs on the south fork) and its elevations, rather than on bars where it could be undercut. Designs need to be further evaluated for flow attack from all directions. Stability calculations for the Bar Apex ELJ were preliminary and assume pre-drilled piles which are likely conservative. Greater pull out strength can be realized if piles are driven and only pre-drilled if necessary. Simplified methods of estimating the maximum pile working load were used (Broms and EM 1110-2-2906) and needs to be refined using more advanced methods such CLM for final design. The only available boring at RM 9 indicates that conditions are favorable for driving piles and piles have been widely used in similar rivers in the district. If bank protection is authorized at later design phases the Bar apex ELJ can be added to either of the two large bends in the reach to take advantage of bend hydraulics to create scour pools against a hardened bank. Additionally, estimated local scour depths at placed wood will need further investigation based upon refined hydraulic modeling from better resolution terrain data, and anchoring methods updated to reflect estimations. As mentioned earlier, the potential for reactivating side channels along the South Fork depends largely on what the local sponsor is amenable to as later design phases are reached. A supplemental approach to be considered at later design phases may be to introduce loose logs at the upstream end of the reach and allow for migration and tracking. This would help to replenish deteriorated anchored wood and augment the reduced upstream wood supply.

5.3 Civil Design

5.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access will be in the locations shown on the plans and will require crossing the South Fork Skokomish River. Three water crossings are anticipated; the size and location is dependent on the river flows and location. Temporary culverts and water diversion are necessary in these areas.

5.3.2 Construction Methodology

Construction would be in the drier summer months when the South Fork of the Skokomish River is low to facilitate access. The majority of excavated material for wood placement is reused as fill for ballast.

5.3.3 Survey/GIS/Topography

1994 photogrammetry topography was used.

5.3.4 Risk, Next Steps, and Future Work

This covers a 2 mile stretch of the south fork, and will require crossing the river in a few places. The river access and refined placement of the LWD structures will be refined in PED.

5.4 Geotechnical Design

Based on initial hydrology and hydraulic pile design for lateral loads and scour depth, the pile depth is anticipated at approximately 20 feet below ground surface.

5.4.1 Subsurface Explorations and Soil Classification

Boring log BH-15 through the in-channel deposits along the left bank of the South Fork of the Skokomish River was used to develop pile design criteria. The log of BH-15 generally indicates a 20 foot layer of medium dense gravel. Visual classification of the bed substrate indicates a significant cobble fraction. The boring layer between approximately 20 and 30 feet below ground surface indicates a very dense poorly graded sand layer. Both soil conditions, gravels and cobbles as well as very dense soils, present a risk to successfully driving piles to the target depth.

Bedrock has not been observed in the main channel within the project limits based on the existing geotechnical explorations and knowledge of geologic process. Bedrock conditions are not expected to constrain the construction and function of the ELJs. Log pile embedment depths are not expected to reach bedrock throughout the project site.

5.4.2 Design Considerations

The existence of boulders or cobbles within foundation layers can present driving problems and hinder determination of ultimate axial capacity of a single pile. (EM 1110-2-2906, 2-8). The Seattle District has successfully driven timber piles in similar gravel and cobble substrates on past ecosystem restoration projects. Methods utilized diesel powered hammers to drive piles. Based on the alluvial deposits encountered in BH-15, there is confidence that driving timber piles in this environment will also be successful. Piles should have steel driving shoes as well as steel bands to protect the timber pile during driving.

Without additional site specific boring logs to provide additional data points on the substrate conditions, pre-drilling should be considered as a contingency plan. Pile installation could be accomplished by pre-drilling within 2 feet of the planned tip elevation. The diameter of the pre-drill should be approximately the diameter of the timber pile tip or slightly larger. Additional explorations into site specific pile locations during later engineering and design phases can confirm that traditional pile driving is possible, but planning should anticipate utilizing a contractor that should be prepared to pre-drill. The geotechnical explorations for this design phase did not encounter significant heave, but this condition is likely given the coarse grained soils and high groundwater table. A slurry mix can be used to resist caving in the hole prior to pile driving.

If the piles cannot be driven to their design embedment, the Government Engineer on site will be required to adjust deign in the field to add additional pilings or increase ballast/rock anchors. The number of additional piles needed would be determined during construction on a case-by-case basis and would depend on how many piles do not reach the intended embedment and by how much. The construction budget for pile installation should have a contingency to account for additional piles installed. The contract plans and/or specifications should also include language stating that additional piles may be required if the intended embedment is not reached.

For the pile design, the soil blow counts were corrected to a $(N1)_{60}$ corrected blow count depending on the effective stress at the SPT elevation below ground surface. The normalized blow counts for each layer were translated to relative density. Correlation of the relative density for USCS soil classifications to dry unit weight and angle of internal friction (U.S. Navy) provided information for pile design. Geotechnical parameters for medium dense gravel and very dense sand are tabulated below in Table 5-1.

Table 5-1. In-Channel Deposit Soil Parameters

Soil Unit (USCS Classification)	Depth (Feet)	Dry Unit Weight (γ_{dry})	Friction Angle (°)
Medium Dense Gravel (GW)	0-20	125	33
Very dense Sand (SP)	20-30	115	38

Single pile pull-out capacity was calculated for use in hydrology and hydraulics ELJ superstructure calculations. The pull-out capacity is tabulated by depth in Annex B-5. For this design phase, only 25% of the available pull-out capacity was assessed due to the possibility of installing piles using pre-drilling methods. Based on the above assumptions, the single load pile capacity is estimated to be approximately 3,000 lbf.

Ballast for engineered log jam design can likely be taken from excavation required to install some anchored logs and boulders. The gravelly channel deposits are anticipated to provide sufficient unit weight and relative erosion resistance. Given the width of the alluvial valley, overtopping of the ELJ structures is not a significant concern.

5.4.3 Risk, Next Steps, and Future Work

Site specific subsurface analysis at the proposed locations of the apex bars should be accomplished to determine the suitability of wood pile design.

A wave equation analysis for pile driving was not completed for this phase of engineering and design, but is recommended for the next preliminary engineering and design (PED) phase. This analysis is used to assess which pile driving methods and equipment can be used without overstressing the piles.

5.5 Operations and Maintenance

Placed ELJ are expected to be stable at design conditions, however attrition is possible for single log placements due to estimated local scour depths possibly exceeding the actual size of the boulder anchor. The same applies to the 5 log channel cluster, although to a lesser degree because the logs are chained together into a rigid structure. In the event that logs break free of anchoring they would likely imbed elsewhere in the channel. A contingency of 20% was added to the total placed wood volume to account for some potential loss. Future modifications to the design may include introduction of loose tagged wood into the South Fork, in which the maintenance plan would need to be modified. There are no bridges or other structures in the channel where migration is possible that could be harmed, and no additional effort is required to account for loose wood beyond the monitoring plan.

6 Side Channel Reconnection (Annex A, Sheets C-150, C-151 and C-157)

6.1 Site Description

An abandoned channel that exists between RM's 4 and 5.6 would be reconnected to the main stem to provide high flow refuge and rearing habitat for fish. The 1935 Skokomish River Valley map shows this channel was an overflow channel, connected to a downstream meander that was later cutoff from the river. Restoration would involve constructing improvements to the channel inlet and outlet, while most of the channel would not be disturbed. The reconnected channel would only be connected to the river during moderate discharges and would not convey water year round. Reconnecting the channel to the river could provide 45 acres of high quality, low velocity fish habitat.

6.2 Hydraulic Design

The existing channel is narrow and sinuous, with plentiful riparian vegetation and adjacent wetlands. The existing highway 101 bridge is estimated to be adequate in width and height to convey flows. Restoration would involve constructing improvements to the channel inlet and outlet, while most of the channel would not be disturbed. The area presently floods heavily from several locations along the main river for a 0.5 ACE event and larger. So no significant change is expected in the 0.01 ACE water surface at the site. The channel would be reconnected to the river for lower flows than what is presently able to enter. The inlet elevation would be located to allow discharges greater than a moderate winter storm (approximately 4000-6000 cfs) to enter. The channel would not convey water year round, however the interior wetland would be wet year round from backwater at the outlet and groundwater. During high river discharges the reconnected channel would provide a low velocity refuge. The entrance will be placed too high for bedload to enter from the main river, however fines are expected to continue to enter the side channel at high flows as they presently do. During most of the year the channel would provide ponded habitat for fish rearing. Reconnecting the channel to the river would provide 45 acres of high quality, low velocity fish habitat.

Improving the hydraulic connection of the channel to make it more accessible for fish would involve improvements to both the inlet and outlet. The inlet would be designed with buried wood to create hardened banks and located to prevent the river from "capturing" (permanently diverting into) the channel. At the downstream end, the channel would be reconnected to the old meander through an existing outlet that presently backwaters at the lowest flow. Use of this outlet will preserve existing water levels and prevent the wetland from dewatering.

6.2.1 Design Considerations

The inlet location was placed to provide for a stable connection to the main river that is not likely to accumulate significant wood. However prediction of recruitment is not entirely possible given the dynamic nature of the river. The inlet was located a few hundred feet directly downstream from a large natural log jam at RM 5.7 that is located in a depositional zone for wood and sediment. If this existing jam remains stable the inlet should remain clear of loose wood and stable as well. The excavated channel sections have a 50 ft bottom width, with 2H:1V side slopes. The depth of cut would vary from 0-5 ft and be a few hundred ft long. The constructed inlet bottom elevation would be roughly 31 ft NAVD88 to activate at the desired flow. The existing outlet bottom elevation is estimated to be about 23 ft NAVD88. Six of the 5-log bank clusters were placed at the inlet and outlet to provide for stable banks and refuge for salmonids. Individual logs can be either anchored with boulders or chained to existing trees on the bank for stability. Concept graphics for placed wood are included in Annex H-4 to the Engineering Appendix.

6.2.2 Risk, Next Steps, and Future Work

The side channel reconnection measure needs to be ultimately modeled as a separate reach incorporating better resolution LIDAR and field survey. One-dimensional modeling such as HEC RAS is suitable for this due to the low gradient and extent of ponded water. Terrain data used for feasibility design was very poor quality in this area. Better resolution terrain data for the inlet and outlet is needed for later design phases. This will enable fine tuning of inlet elevation (and outlet if necessary) and estimating interior stages at design flows. The capacity of the existing highway 101 bridge was discussed with the sponsor and estimated to be of adequate size to convey side channel flows. This bridge would need to be incorporated into modeling to verify that its capacity and design is adequate.

6.3 Civil Design

The entrance requires approximately 550 lineal feet of channel, 50 feet wide requires 3,600 CY excavation with 2 horizontal to 1 vertical side slopes 3 to 4 foot in depth.

6.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans.

The entrance channel reconnection area will require a temporary road through a treed area, and crosses the old channel. The old channel is fed by the Skokomish River and runoff from the hillside. While the inlet elevation at the Skokomish River inlet is not known, observation of water from the hillside from a culvert just upstream of the project area, and the flow in the old channel would indicate most of the flow is from the culvert during the drier summer months or when the Skokomish River elevation is low.

The exit channel reconnection area is accessed via an abandoned gravel road which was covered with water in numerous locations in early October as shown on the plans. At this time the source of the water is unknown; culverts and road raises are anticipated for access. The remainder of the access is via another abandoned trail overgrown with trees and brush. The work area crosses a secondary channel and the primary channel.

Access will be in the locations shown on the plans and will require crossing the mainstem Skokomish River. Three water crossings are anticipated the size and location is dependent on the river flows and location. Temporary culverts and water diversion are necessary in these areas.

6.3.2 Construction Methodology

Construction would be in the drier summer months when the South Fork of the Skokomish River is low to facilitate access. The construction methodology is to provide a temporary crossing across the existing channel. Working from the river landward, excavate the new channel. The final connection would be at the existing channel. The excavated materials would be disposed of off-site.

The exit channel work could divert the main channel through a culvert to the secondary channel to facilitate crossing the main channel. The main river may require some cofferdam technique depending on final the location and elevation of the LWD structures.

6.3.3 Survey/GIS/Topography

A combination of 1994 photogrametric topgraphy, 2002 bare-earth LIDAR information, and 2014 field cross-sections was used to site and obtain the excavation quantities for the proposed entrance channel. The topographic information at the exit is not useful. Field reconnaissance indicates the topography does not indicate the channel at the exit. The channel is well pronounced in this location and little or no channel work is required.

6.3.4 Risk, Next Steps, and Future Work

The location of the LWD structures at both the entrance and exit structures may require fish exclusion and temporary cofferdams. This may require additional detailed survey in these areas. Additional survey may be required in areas adjacent to and along the channel.

6.4 Geotechnical Design

No subsurface explorations were performed in the vicinity of the side channel reconnection. All channel slopes were designed to mimic naturally occurring slopes of the existing channels. Site specific exploration and confirmation of channel design slopes shall occur at a later design phase.

Proposed large woody debris shall be installed and anchored within the design recommendations and constraints previously described in Section 5.

6.5 Operations and Maintenance

The inlet and outlet should both be monitored for wood accumulation, and removal of trapped wood may be necessary to sustain desired connectivity to the main river. It is not possible to predict the occurrence of this, and judgment will be required to evaluate how much wood accumulation is tolerable.

6.6 PLANTING PLAN

A planting plan has been developed for the Side Channel Reconnection site. The channel inlet area is approximately 1 acre and will have the following planting plan:

- Conifers planted in 1 row, 10-15' O.C. for 550' length both banks
- Shrubs planted in 1 row, 6' O.C. for 550' length both banks
- Stakes planted 2' O.C. for 550' length that is approx 4' wide, both banks

The access route to inlet channel is approximately 10' wide X 200' long and will have the following planting plan:

- 100% of area will have conifers 10-15' O.C.
- 100% of area will have shrubs 6' O.C.

The outlet channel will have the following planting plan:

- Conifers planted in 1 row, 10-15' O.C. for full length both banks
- Shrubs planted in 1 row, 6' O.C. for full length both banks
- Stakes planted 2' O.C. for full length that is approx 4' wide, both banks

The access route to the outlet channel is approximately 10' wide X 1,000' long and will have the following planting plan:

- 100% of area will have shrubs 6' O.C.
- 100% of area will have bark mulch 6" deep
- During PED, the study team will consider creating hummocks with high spots for conifers; this planting approach would require slightly more soil material and additional conifers to add to project cost.

7 HAZARDOUS, TOXIC AND RADIOACTIVE WASTE (HTRW)

A Phase II HTRW investigation was complete in July 2014. There were no sampling results that warranted further evaluation or investigation within the footprint of the recommended plan, including the Confluence levee site. Please refer to Appendix I – HTRW, for additional information.

8 PLANTING PLAN

A feasibility-level planting plan has been developed for cost estimating purposes as well as Endangered Species Act (ESA) consultation requirements. A summary of the planting plan for each site included in throughout the Engineering Appendix. The following plant species will likely be used based on site-specific considerations:

- Grass species mix
    - 40% creeping red fescue

- 40% perennial ryegrass
- 10% white clover
- 10% highland colonial bentgrass

- Stake species
  - Willow
  - Red osier dogwood
- Shrub species
  - Snowberry
  - Serviceberry
  - Twinberry
  - Pacific Ninebark
- Conifer species
  - Western Red Cedar
  - Hemlock
  - Sitka Spruce

9 Cost Considerations

Cost estimates have been developed for the recommended plan. Please refer to Appendix K – Cost Engineering, for additional information.

10 Schedule for Design and Construction

The pre-construction, engineering and design (PED) phase will include additional refinements of design (65%, 95%, 100%) and associated analysis (e.g., additional survey data, LiDAR, etc.) for features included in the recommended plan. It is anticipated that this phase will last approximately 2 years.

Construction will likely be completed in two phases over two to three years:

- Phase I: Wetland Restoration at Grange, Wetland Restoration at River Mile 9, Confluence Levee Removal and diversion, and Side Channel Reconnection
- Phase II: Upstream LWD and Confluence Levee diversion LWD

11 Outline Of Specifications

The following information outlines the specifications that will be included in the contract documents during PED:

DIVISION 0 PROCURMENT AND CONTRACTING

00 01 15 List of Drawings
00 41 00 Bid Schedules

DIVISION 1 GENERAL REQUIRMENTS

01 11 00 Summary of Work
01 14 00 Work Restrictions
01 00 10 Supplementary Requirements
01 00 50 Site Specific Supplementary Requirements
01 02 50 Measurement and Payment
01 03 50 Modification Procedures
01 06 00 Water Quality Standards
01 06 10 Environmental Protection
01 35 26 Government Safety Requirements
01 35 40 Environmental Management
01 45 00 Quality Control Systems (QCS)
01 32 00 Project Schedule
01 33 00 Submittal Procedures
01 57 20 Environmental Protection
013 56A Storm Water Pollution Prevention Measures
01 45 10 Contractor Quality Control
01 50 00 Construction Facilities and Temporary Controls
01 56 00 Diversion and Care of Water
01 57 23 Temporary Storm Water Pollution Control
01 56 10 Dust Control
01 56 50 Construction Spoils Handling
01 74 19 Construction and Demolition Waste Management
01 62 35 Recycled/Recovered Materials
01 7 0 20 As Built Records and Drawings
01 70 30 Warranty of Construction
01 78 00 Closeout Submittals

DIVISION 31 EARTHWORK

31 00 00 Earthwork
31 05 19 Geotextile
31 05 21 Geogrid Soil Reinforcement
31 11 00 Clearing and Grubbing
31 32 11 Soil Surface Erosion Control
31 32 39 Bioengineering Practices for Stream Bank Stabilization
31 62 19 Timber Piles

DIVISION 32 EXTERIOR IMPROVEMENTS

32 92 19 Seeding
32 92 23 Sodding
32 92 26 Sprigging
32 93 00 Exterior Plants

32 96 00 Transplanting Exterior Plants

DIVISION 35 WATERWAYS AND MARINE CONSTRUCTION

35 41 19 Stone, Channel Protection for Structures

35 41 00 Levee Construction

35 44 00 In-stream and Floodplain Habitat Construction

Note: Annexes are available electronically and are not included in printed versions of Appendix H.