FINAL DESIGN REPORT
PROJECT AREA 15
TUCANNON RIVER, RIVER MILES 37.15 TO 35.35

Prepared for

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LIST OF ACRONYMS AND ABBREVIATIONS

BMP	best management practice
CCD	Columbia Conservation District
ELJ	engineered log jam
ESA	Endangered Species Act
GPS	global positioning system
HEC-RAS	Hydraulic Engineering Center–River Analysis System
LiDAR	Light Detection and Ranging
LWD	large woody debris
OHWL	ordinary high water line
PA-15	Project Area 15
RM	river mile
SRSRB	Snake River Salmon Recovery Board
TESC	Temporary Erosion and Sediment Control
WDFW	Washington Department of Fish and Wildlife

1 INTRODUCTION AND PROJECT PURPOSE

Anchor QEA, LLC, was retained by the Snake River Salmon Recovery Board (SRSRB) to develop final designs for salmonid habitat restoration within Project Area 15 (PA-15) of the Tucannon River as delineated in the Conceptual Restoration Plan (Anchor QEA 2011a) from approximately river mile (RM) 37.15 to 35.35. The Tucannon River basin is located in southeast Washington State, in Columbia and Garfield counties (Sheet 1).

Enhancing and restoring instream habitat in the project area will be accomplished through a variety of treatment actions in the main channel, along the banks, and within the left bank floodplain. These treatments include construction of instream habitat features such as engineered log jams (ELJs), large woody debris (LWD) placements, activation of a floodplain side channel, and modification of existing bank stabilization infrastructure to enhance instream and riparian habitat conditions in the project area as well as promote natural geomorphic processes and watershed recovery. A description of the project site and existing natural processes and habitat conditions is provided, along with the specific physical and biological objectives that the proposed restoration features are expected to achieve. In addition, the project's contribution to the overall watershed-scale restoration plan is described. Construction considerations and best management practices are also described for the proposed treatment actions to minimize disturbance of existing habitats and species.

The system-wide restoration objective for the Tucannon River is to improve habitat conditions for Endangered Species Act (ESA)-listed species for all life history stages. Previous efforts have identified the habitat-limiting factors associated with the decline of ESA-listed populations (CCD 2004; SRSRB 2006). Existing physical, hydrologic, and habitat conditions were synthesized within the geomorphic assessment, as well as a variety of geomorphic parameters. The assessment results are characterized for 10 geomorphic reaches between the river mouth and near RM 50 at Panjab Creek (Anchor QEA 2011b). Reach-scale restoration actions based on this basin-scale assessment were developed at a preliminary level for RM 20 to 50 in the Conceptual Restoration Plan (Anchor QEA 2011a), which identified 28 conceptual project areas organized into a tiered prioritization approach, based upon selected evaluation criteria.

PA-15 was selected as a Tier 1 (highest priority level) project for early implementation by the SRSRB and Columbia Conservation District (CCD). This project will increase instream habitat complexity and promote natural channel processes by strategic placement of LWD, modification or enhancement of existing infrastructure, and excavation to reconnect a former channel. Collectively, the project elements target retention of mobile wood and sediment, side channel development, and increased connectivity between the river and the adjacent floodplain. A summary of PA-15 in regards to the four evaluation criteria utilized in project prioritization and tier-level development is provided in Table 1; additional details of the project prioritization and discussion of the evaluation criteria are available in the Conceptual Restoration Plan (Anchor QEA 2011a).

Table 1

Project Area 15 Evaluation Criteria Rationale

Criteria	Rationale
Expected biologic response	In the short term, the LWD placements will provide high-flow refuge, low-flow cover, and additional pools in the project area. In the long term, the project actions are expected to initiate the formation of more complex and diverse habitats for juvenile and adult fish. Increased floodplain connectivity will contribute to the recovery of ecological riparian processes.
Consistency with natural geomorphic processes	The proposed restoration actions will promote the retention of LWD and sediment and increase floodplain connectivity to initiate the development of a complex channel network through project area. These actions will contribute to the recovery of natural processes in the project area.
Benefit-to-cost ratio	The project is expected to have a moderate benefit and a low relative cost. The restoration treatments should provide some immediate benefit from the placement of LWD structures and increased side channel connectivity in the left floodplain; the desired geomorphic response will likely take place on a longer time line that will provide increased benefits as complexity develops in the project area.
Reach priority	The project area is located in Reach 8, which is a Priority 1 reach.

Notes:
LWD = large woody debris
Source: Anchor QEA 2011a

1.1 Previously Completed Studies

The following report updates the information presented in the *Final 30 Design Report for Project Area 15* (Anchor QEA 2012). In addition, the following studies were completed in support of Reach 8 and PA-15 restoration:

- *Tucannon Subbasin Plan* (CCD 2004)
- *Snake River Recovery Plan for SE Washington* (SRSRB 2006)
- *Conceptual Restoration Plan, Reaches 6 to 10* (Anchor QEA 2011a)
- *Tucannon River Geomorphic Assessment and Habitat Restoration Study* (Anchor QEA 2011b)

2 PROJECT AREA DESCRIPTION

The project area is located within a portion of the river valley that is primarily owned by the Washington Department of Fish and Wildlife (WDFW). Approximately 900 linear feet of the right bank are privately owned near the upper end of the site, as well as approximately 750 linear feet near the lower extent of the project area. The valley area adjacent to the low-lying floodplain contains a private residence and open space in the publicly owned parcels. An abandoned homestead is located within the lower WDFW site. Plan views of existing features can be seen on Sheets 3 through 5 of the Construction Drawings.

The historical (pre-settlement) channel condition of the Tucannon River is a dynamic, anabranching channel across the floodplain with multiple split flow paths and active erosion processes that establish diverse hydraulic conditions throughout the low-lying floodplain and maintain habitat. The channel and floodplain are at times naturally confined by alluvial fans or bedrock along the valley walls. The present condition of the channel in the project area is primarily a single-thread and plane-bed channel form with low sinuosity and limited split flow and off-channel habitat. Within some local areas of the project reach, there is evidence of active channel migration, riparian recruitment, and other habitat features that are valuable for salmonid habitat. However, confining infrastructure is also present that contributes to adverse hydraulic conditions and local incision. These features confine the channel and the accessible floodplain corridor, limiting natural processes such as channel migration, temporary sediment storage, and side channel development that would otherwise naturally sustain habitat features. In addition, spoil piles in the floodplain indicate previous management activities associated with straightening and deepening of the channel.

Russell Springs, a spring-fed channel, is located within the east portion (right bank) of the floodplain that contains cool, flowing water that is heavily used by juvenile fish. An existing pond is located on the private property east of the channel near Station 37+00. The pond is spring-fed and drains into a channel that coalesces with the Russell Springs channel east of Station 27+00. An ephemeral tributary is located within the west floodplain, a majority of which is diverted to a ditch that is no longer in use since WDFW purchased the property. WDFW currently accesses the property from the west side of the river to treat the area for noxious weeds.

The project area and the project design are described herein as two subareas, 1 and 2. The following sections provide a detailed description of existing physical conditions in each subarea.

3 PROPOSED RESTORATION DESIGN

The proposed restoration actions are described within each subarea, including the physical description and construction details, as well as brief summaries of the expected biological and physical benefits. Detailed descriptions of the general benefits of restoration actions on both a local- and watershed-scale, including how these actions address habitat limiting factors, are provided in several existing documents. For additional information, see Section 5 of the Geomorphic Assessment (Anchor QEA 2011b) and Section 3 of the Conceptual Restoration Plan (Anchor QEA 2011a).

The proposed restoration design is shown on Sheets 7 through 10. Design details for LWD, ELJs, and other typical restoration details are shown on Sheets 11 through 22. For the purposes of describing the site-specific benefits of the design elements, the proposed structures are described within the respective subareas. However, the proposed design is intended to function collectively throughout the overall project area in order to achieve a reach-scale geomorphic response and optimum biological benefit in the long term.

3.1 Subarea 1, Stations 42+50 to 20+00 (Existing Main Channel)

The primary objectives for salmonid habitat restoration within Subarea 1 are to promote retention of mobile wood and sediment, establish hydraulic diversity, provide cover, protect existing valuable habitat in Russell Springs, and promote floodplain connectivity. The proposed restoration actions within this subarea are shown on Sheets 7 and 8 and include the following actions:

- Construct two ELJs (bar apex and channel grade) along with some groupings of single logs in the main channel to direct flow to the relocated main channel alignment (former historical main channel) through the low-lying left-bank floodplain (near Station 31+50).
- Construct five sediment retention LWD structures in the former main channel between Stations 28+00 and 20+00.
- Construct two bank barb LWD structures (right bank) in the former main channel between Stations 22+00 and 20+00.
- Construct a wood entrapment LWD structure along the right bank at Station 26+00.

Near Station 31+50, one channel grade ELJ, and one bar apex ELJ will be constructed near existing armor rock and LWD revetment. The channel grade ELJ would be placed on the channel bed in front of the structure and would not require any modifications to the existing structure. In the short term, the ELJs will dissipate high velocities that occur along the face of the armored bank during high flows and will create hydraulic refuge and diversity in the channel. Collectively these ELJs area placed to collect debris and wood to help direct flow into the relocated main channel alignment through the west bank floodplain. The bar apex ELJ will promote flow through the relocated main channel alignment during all flow regimes. Immediately following construction a majority of the flows (greater than 75%) will still be conveyed through the existing main channel. In the long term, the three ELJs will also retain sediment in this locally incised section of the channel to promote bed aggradation and increased connectivity to the relocated main channel alignment through the left floodplain. With subsequent flood events, it is expected that the proportion of flow entering the relocated main channel alignment to the left of the bar apex ELJ will increase and become more frequent, eventually leading to this alignment serving as the main channel with an anastomosing channel pattern long term.

Between Stations 28+00 and 20+00, five sediment retention LWD structures are proposed in the former main channel. These structures will slow water velocities and promote localized deposition at and in the vicinity of the structures. In addition, the structures will promote hydraulic complexity and create planform diversity by their placement.

At approximately Stations 20+60 and 21+80, two bank barb LWD structures are proposed along the right bank. These structures will provide cover and hydraulic complexity along this bank segment and help reduce water velocities along the bank. These structures are located such that high flows directed at the right bank exiting the left floodplain channel would be dissipated, minimizing the potential for channel migration into the existing spring channel in the short term. The spoil piles on the right bank floodplain near Station 24+00 will be left in place to minimize the risk of channel migration into Russell Springs.

3.1.1 Relocated Main Channel Alignment (Stations 14+00 to 1+00)

The habitat restoration objectives are to relocate the main channel alignment through the west (left) bank floodplain. The proposed restoration actions are shown on Sheets 8 and 10 and include the following:

- Relocation of the main channel through the west floodplain down a former main channel alignment. Excavation along portions of this alignment through the west floodplain will be necessary to provide preferential conveyance relative to the existing main channel.
- Construction of three channel barb LWD structures along the right bank of the relocated main channel alignment at approximately Stations 13+00, 9+75, and 3+25, respectively.
- Construction of one side channel-spanning LWD structure at a floodplain channel outlet from the relocated main channel alignment at Station 9+20.
- Construction of three bank barb LWD structures along the banks of the relocated main channel alignment.
- Twenty (20) single logs will be threaded through the existing floodplain trees. These logs will be field placed throughout the relocated main channel alignment.

The channel excavation is proposed to take place from Station 14+44 to Station 5+00 and from Stations 2+75 to 1+00. The proposed channel cut has a 40-foot bottom width and 1:1 side slopes from Station 14+44 to Station 5+00, and a 20-foot bottom width and 1:1 side slopes from Station 2+75 to Station 1+00. No cut is proposed from Stations 5+00 to 2+75. The channel cut alignment will follow the existing low areas throughout the excavation.

Multiple types of structures are proposed throughout the relocated main channel alignment to improve habitat. The channel barb and bank barb LWD structures are proposed to add complexity and roughness along the relocated main channel. In addition, these structures will help direct the flows through the floodplain within the new channel alignment. The placement of the single pieces of LWD will help promote localized complexity and habitat structures such as scour pools and local depositional bars. The side channel spanning LWD structure will be constructed in an existing floodplain flow channel. This flow path connects the relocated main channel with the existing main channel. This structure will help to maintain the main channel alignment through the west (left) bank floodplain.

3.2 Subarea 2, Stations 20+00 to 0+00 (Existing Main Channel)

Subarea 2 extends from just upstream of the confluence of the existing main channel and the relocated main channel alignment (Station 19+00) to the downstream extent of the project area (0+00). The primary habitat restoration objectives in Subarea 2 are to establish hydraulic diversity, reduce channel confinement and incision, provide cover, and protect existing valuable habitat in Russell Springs. The proposed restoration actions within the subarea are shown on Sheets 8 and 9 and include the following:

- Construction of one wood entrapment LWD structure at Station 20+00 at the main channel confluence with the relocated main channel alignment (relocated main channel alignment Station 2+00).
- Construction of a bank roughness LWD structure within the existing riprap bank between Stations 18+00 and 19+00 (right bank).
- Construction of two channel barb LWD structures in a right bank side channel.
- Construction of one channel-spanning roughness LWD structure at Station 17+00.
- Construction of five bar apex ELJs in the main channel downstream of the new channel relocation confluence between Station 14+00 and Station 1+00.
- Removal of an existing spoil pile berm in the left floodplain between approximately Stations 3+00 and 5+60 as needed for structure backfill.

One wood entrapment LWD structure is proposed near the confluence of the main channel and the historical main channel (left bank floodplain). In the near term, the structure will provide habitat complexity and cover throughout the flow regime and will provide hydraulic refuge during high flows.

Along the right bank of the main channel near Station 19+00, the existing armor rock and LWD revetment will remain in place. However, the existing structure will be augmented with LWD along its entire length. LWD will add hydraulic and habitat complexity along the existing armored bank. The majority of the armor will remain in place, although some armor rock lining the bed and banks of the constructed side channel and portions of the existing revetment along the main channel will be removed and re-used on site as ballast for LWD and ELJ structures. A channel spanning LWD structure is proposed downstream of the confluence of the main channel and the relocated main channel alignment (Station 17+00). This structure will add hydraulic complexity, reduce river velocities, and help to aggrade the overall channel bed, as well as rack additional wood. All these elements will help to improve habitat and hydraulic complexity.

Five bar apex ELJs are proposed between Stations 14+00 and 1+00. These ELJs will also have immediate benefits by providing cover and complexity in the main channel. Three of these bar apex ELJs will be constructed on existing gravel bars to split flow and help form mid-channel islands. The downstream most bar apex ELJs will be constructed along the channel margins and the space between the ELJs will be limited to promote large woody debris racking over time and left bank floodplain connectivity. To provide native backfill for the bar apex ELJs an existing spoil pile located between Stations 5+60 and 3+00 in the left floodplain will be reused down to the elevation of surrounding floodplain grade.

In the long term, the LWD and ELJ structures in this subarea will collectively promote formation of mid-channel islands, aggradation of the bed, continued development of channel migration into the left floodplain, increased channel sinuosity, and other desired effects such as recruitment of riparian trees and increased channel shading.

4 PROPOSED STRUCTURES

Eleven LWD and ELJ structure types are proposed throughout the project area. These structures vary from single pieces of large wood to large multiple layer structures. The structure types and locations will target specific habitat, hydraulic and geomorphic goals throughout the area. Each structure is described in detail below.

4.1.1 Channel Grade ELJ (n=1)

One channel grade ELJ is proposed in the existing main channel at the inlet to the relocated main channel alignment. This structure will be built in the existing main channel along the right bank immediately adjacent to the bank bar apex ELJ at the entrance to the relocated main channel alignment. The intent of this structure is to direct flow into the relocated main channel alignment. This structure is one of the two structures that will be built near the inlet to the relocated main channel alignment to direct flows into the relocated main channel alignment.

The channel grade ELJ will consist of 16 logs and 6 layers. This ELJ is a gravity structure and will be built without piles or vertical logs. The rootwad logs will consist of one size class: 20 feet in length with an 18-inch diameter. The log poles (without rootwads) will consist of two classes: 40 feet in length with a 24-inch diameter and 20 feet in length with an 18-inch diameter. The structure will be 40 feet long, 20 feet wide, and 10.5 feet high.

4.1.2 Bar Apex ELJ (n = 6)

Five bar apex ELJs are proposed in the main channel (between station 14+00 and 1+00) and one bar apex ELJ is proposed at the inlet to the relocated main channel alignment. This ELJ is a gravity structure and will be built without piles or vertical logs. The three main channel structures will split channel flows to create a more anastomosing channel planform throughout the project reach. The bar apex ELJ at the channel inlet is placed to direct flows into the relocated main channel alignment.

The bar apex ELJ will consist of 50 logs and 11 layers. The rootwad logs will consist of one size class: 25 feet in length with an 18-inch diameter. The log poles will consist of three size classes: 35 feet in length with a 24-inch diameter, 35 feet in length with an 18-inch diameter, and 25 feet in length with an 18-inch diameter. The structure will be 35 feet long, 20 feet wide, and 17 feet high.

4.1.3 Channel Barb LWD (n=5)

Three channel barb LWD structures are proposed within the relocated main channel alignment. Two more channel barb LWDs will be located in a right bank side channel downstream of the relocated main channel alignment. The channel barb LWD structures will consist of 12 logs and 5 layers. This structure is a gravity structure and will be built without piles or vertical logs. The structures will provide high flow refuge and cover for juvenile salmonids, as well as promote local deposition. The structures will be just below grade and backfilled with alluvium. The structures will consist of eight rootwad logs that are 15 feet in length with a 12-inch diameter and four log poles that are 15 feet in length with an 18-inch diameter. The structure will be 15 feet long, 15 feet wide, and approximately 7.5 feet high.

4.1.4 Bank Barb LWD (n=5)

Three bank barb LWD structures are proposed in the relocated main channel alignment, two along the left bank and one along the right bank. Two more bank barb LWDs are proposed in the existing main channel. The bank barb structures will consist of seven logs (including the buried log piles) and three layers. The structures will be built on grade. Three logs will have rootwads and be 30 feet in length with an 18-inch diameter. These structures will be supported by four buried log piles that are 15 feet in length with a 18-inch diameter. The height of the structure will be approximately 4.5 feet. Wire rope will be used to secure the rootwad logs to the buried log piles.

4.1.5 Wood Entrapment LWD (n=2)

Two wood entrapment LWD structures are proposed, one at the entrance to an existing high-flow side channel near Station 26+00, and one near the downstream extent of the relocated main channel alignment near Station 20+00. These structures will promote the retention of mobile woody debris. The structures will provide cover and refugewithin the structures' void spaces. The wood entrapment structures will consist of sixteen logs (including the buried log piles) and three layers. The structures will be built on grade. Eight logs will have rootwads that will be 30-feet in length with an 18-inch diameter. These structures will also have eight buried log piles that are 25 feet in length with an 18-inch diameter. The height of the structure will be approximately 4.5 feet. Logs will be secured to piles with wire rope and hardware.

4.1.6 Side Channel-Spanning LWD (n=1)

One side channel-spanning LWD structure is proposed along a floodplain flow pathway between the relocated main channel alignment and the existing main channel. This structure is a gravity structure and will be built without piles or vertical logs. The structure will be built on grade. This structure will provide hydraulic refugia for salmonids and other species, as well as provide cover and hydraulic refugia within the structure's void spaces.

The structure will consist of 19 logs total with 9 logs having rootwads. The rootwad logs will be 40 feet in length with a 24-inch diameter. The structures will have 10 log poles. These log poles will be 30 feet in length with an 18-inch diameter. Wire rope will be used to secure the structure logs and boulder ballast together. The structure will be 40 feet long, 50 feet wide, and 8.5 feet high.

4.1.7 Channel Spanning Roughness LWD (n=1)

One channel-spanning roughness LWD is proposed in the main channel downstream of the relocated main channel alignment. This structure type is designed to help raise the grade of the main channel and add hydraulic and habitat complexity to the channel. This structure will be porous, with river flows passing through the structure during all flow scenarios.

The structure will consist of seven logs total with three logs having rootwads and will be built on grade. The rootwad logs will be 50 feet in length with a 24-inch diameter. The structures will have four log poles. These log poles will be 40 feet in length with a 24-inch diameter. Wire rope will be used to secure the structure logs and boulder ballast together. The structure will be 50 feet long, 60 feet wide, and 4 feet high.

4.1.8 Bank Roughness LWD (n=1)

One bank roughness LWD structure is proposed in the existing main channel along the right bank within an existing riprap bank. The structure will add hydraulic roughness along the right bank.

This structure will consist of 12 rootwad logs buried into the right bank. The structure will be built on grade. The rootwad logs will be 15 feet in length with an 18-inch diameter. The structure will be 80 feet long, 15 feet wide, and 3 feet high.

4.1.9 Channel Sediment Retention LWD (n=3)

Three channel sediment retention LWD structures are proposed in the existing main channel, to help retain and sort sediment.

The sediment retention structures will consist of twelve logs (including the buried log piles) and four layers. The structures will be built on grade except for a buried sill log just below grade. Four logs will have rootwads, with two at 30 feet in length and two at 40 feet in length; all will have 18-inch diameters. These ELJs will also have three log poles that are 15 feet in length with a 15-inch diameter. Each structure will also have five buried log piles that are 20 feet in length with an 18-inch diameter. The height of the structure will be 5.5 feet. Manila rope will be used to secure the logs and log pole piles together.

4.1.10 Bank Sediment Retention LWD (n=2)

Two bank sediment retention LWD structures are proposed in the existing main channel. These structures will provide hydraulic refugia and cover for juvenile salmonids and other species. The structures will promote sediment retention and bar development in the lee of the structures.

These structures will consist of three logs with rootwads. Two of the rootwad logs will be 25 feet in length with an 18-inch diameter and one will be 35 feet in length with an 18-inch diameter. The structures will have two log poles with a length of 15 feet and 18-inch diameters. The structures will have four buried log piles. These buried log piles will be 15 feet in length with 18-inch diameters. Wire rope will be used to secure the structures together.

4.1.11 Single LWD

Placement of 53 single LWDs are proposed throughout the main channel and the relocated main channel alignment. These structures will be placed to provide hydraulic refuge and cover for juvenile salmonids. They will also be placed in conjunction with several of the other LWD and ELJ structures to add to the initial complexity of the structure. They will consist of one rootwad log that is 25 feet in length with an 18-inch diameter. The structures may be anchored between existing trees, buried into the banks, or placed against other structures. The structures may be secured together using a limited amount of synthetic fiber manila rope.

5 HYDRAULIC ANALYSIS

5.1 HEC-RAS Model

A reach-based, 1-D Hydraulic Engineering Center–River Analysis System (HEC-RAS) hydraulic model (Brunner 2010a, 2010b) was developed by Anchor QEA for PA-15 and an area immediately downstream of PA-15 (Stations -21+00 to 42+18). The results of this HEC–RAS model were used to support the structure design calculations and scour calculations presented in this report. The model was run for the design hydrology shown in Table 2. The design hydrology provided a thorough understanding of hydraulic conditions over a wide range of discharges.

Table 2
Design Hydrology, Project Area 15, Tucannon River

Discharge (cfs)	Return Period
350	1-year
860	2-year
1,920	5-year
2,950	10-year
4,700	25-year
6,380	50-year
8,430	100-year

Notes:
1. Hydrology was developed by Anchor QEA as part of the geomorphic assessment and habitat restoration study (Anchor QEA 2011b)

cfs = cubic feet per second

The detailed hydraulic model was extended downstream of the project area to RM 34.95 (2,100 feet downstream of project area) to evaluate concerns related to existing infrastructure and property (The Ranchettes). All structure design analyses, as well as risk assessments, used the results from this model.

The HEC-RAS cross-section station elevation data was taken from a 3-D existing conditions surface developed by Anchor QEA for the project area. The 3-D surface used the bare earth data from a 2010 aerial Light Detection and Ranging (LiDAR) survey (provided by CCD). Cross-sections and other model geometries were drawn and exported in AutoCAD and imported into the 1-D HEC-RAS model. Cross-sections in the model were located to capture significant changes in channel and floodplain planform, as well as changes in channel gradient, with the spacing of cross-sections varying in proportion to planform complexity of the channel and floodplain. Channel and floodplain roughness values were estimated using typical values for the land use and channel condition observed in the field and as identified from 2010 aerial photography. Existing levee features and known ineffective flow areas were also added to the model to appropriately confine and restrict flow.

A proposed conditions model was developed as part of this design phase. The design analysis for the proposed main channel required a split flow analysis to fully evaluate proposed conditions. The model analyzed the split flow between the existing main channel and the relocated main channel alignment. The result of the split flow analysis at the head of the proposed main channel is presented in Table 3 below.

Table 3
Split Flow Results at Head of Relocated Main Channel Alignment

Total Discharge (cfs)	Proposed Main Channel Discharge (cfs)	Existing Main Channel Discharge (cfs)	Percentage of Flow in Proposed Main Channel	Return Period
350	230	120	66%	1-Year
860	542	328	63%	2-Year
1920	1175	745	61%	5-Year
2950	1873	1087	63%	10-Year
4700	3272	1438	70%	25-Year
6380	4627	1753	73%	50-Year
8430	6236	2194	74%	100-Year

Note:
cfs = cubic feet per second

Smaller LWD structures, such as single LWD, were accounted for in the model using increased roughness values within the cross-section. Larger structures, such as the bar apex and channel grade ELJs were represented by blocked obstructions and ineffective flow areas. The side channel-spanning LWD near Station 9+00 was represented using a lateral structure with gates to simulate a flow-through structure to model flows returning to the existing main channel. Table 4 shows the flows returning to the existing main channel through the side channel-spanning LWD; note that a negative discharge signifies flow from the existing main channel to the proposed main channel.

Table 4
Discharge Results through Side Channel Spanning LWD[1]

Total Design Discharge (cfs)	Proposed Channel Discharge Upstream of Side Channel-Spanning LWD (cfs)	Discharge through Side Channel-Spanning LWD (cfs)	Proposed Channel Discharge Downstream of Side Channel-Spanning LWD (cfs)	Existing Channel Discharge Downstream of Side Channel-Spanning LWD (cfs)	Percentage of Flow in Proposed Main Channel Downstream of Side Channel-Spanning LWD	Return Period
350	230	53	176	174	50%	1-Year
860	542	176	365	505	42%	2-Year
1920	1175	355	824	1096	43%	5-Year
2950	1873	622	1252	1708	42%	10-Year
4700	3272	1237	2051	2659	44%	25-Year
6380	4627	1780	2845	3535	45%	50-Year
8430	6236	2465	3787	4643	45%	100-Year

Notes:
1. Relocated main channel alignment Station 9+00
cfs = cubic feet per second
LWD = large woody debris

The channel-spanning roughness LWD is a flow-through structure that was represented in the model with a large increase in roughness values. A Manning's "n" value of 0.4 was used for the channel at the channel-spanning roughness LWD HEC-RAS Station 16+95 .

5.2 Results

The HEC-RAS modeling results were used to predict changes in water surface elevations (feet) and velocities (feet/second) throughout the project site, as well as upstream and downstream of the project. Hydraulic modeling was completed for the 10-year and 100-year events, with a peak 100-year event of 8,430 cubic feet per second. The model assumes fixed cross-section conditions. The model does not evaluate scour, deposition, or erosion that may occur as the channel responds to placement to the ELJs and LWD structures. For purposes of this discussion, HEC RAS model cross-sections are referred to as Stations throughout the project area.

5.2.1 Water Surface Elevations

Upstream at the model boundary conditions (Station 42+00) and downstream to Station 33+00, no changes in water surface elevation are predicted. Based on the modeling results for the 100-year return period, water surface elevations in the main channel upstream of the split at Station 31+50 are predicted to increase for proposed conditions from the placement of wood in the channel.

Under proposed conditions, the water surface elevations generally decrease for the first 300 feet and generally increase the remaining 650 feet of the existing main channel for the 100-year return period. This is due to more flow splitting into the relocated main channel alignment at the upstream end, and then spilling back into the existing main channel through the side channel spanning LWD. The average decrease in water surface elevation is 1.8 feet in the existing main channel; the average increase is 0.4 feet. The largest decrease in water surface elevations for the 100-year return period through the existing main channel is 2.7 feet at Station 28+00. Water surface elevations generally decrease through the proposed main channel, with a few localized increases. This is due to the flow having more area as a result of the channel excavation. The largest decrease in water surface elevation through the proposed main channel is 1.7 feet at Station 8+30. The largest increase in water surface elevation through the proposed main channel is 1.93 feet at station 8+73. This increase is due to side channel spanning LWD structure located between the proposed main channel and the existing main channel. This is an area targeted for increased floodplain connectivity, therefore modeled results indicate project objectives are being met.

Other localized changes in water surface elevations are seen for the 100-year return period downstream of the confluence between the existing and proposed main channels. This is because of local hydraulic influence of the proposed structures. The largest increase in 100-year water surface elevation of 1.3 feet is seen at Station 1+47, the location of proposed Bar Apex ELJs #5 and #6. However, this increase is likely to only exist during the incoming limb of the first flood hydrograph. Once flood conditions exist, the local bed conditions will adjust to the structure and increases in water surface elevation are likely to be undetectable.

The water surface elevations for the 100-year return period for existing and proposed conditions converges near Station 0+00, the downstream extent of the project area, and remain the same to the downstream extent of the model, Station -21+00. There are no increases in water surface elevations near the existing infrastructure located near Station -10+82.

5.2.2 Water Velocities

For the 100-year return period water velocities increase under proposed conditions are predicted through the relocated main channel alignment due to more flow passing through this area. The largest increase in velocity through the proposed main channel is 8 feet/second located at Station 8+30, just downstream of the side channel-spanning LWD, because of a large decrease in water surface elevation compared to the existing conditions. As the flow area decreases, the velocity increases.

Water velocity decreases are predicted under proposed conditions through the existing main channel. The largest decrease in velocity of 6.3 feet/second is predicted at Station 26+65, which is located just upstream of where the side channel-spanning LWD is proposed. This large decrease in velocity is due to reduced flows in the existing main channel.

Downstream of the confluence between the existing and proposed main channels there are localized decreases in velocity near proposed structures, as the channel will be constricted by the proposed structures, which causes the water surface to increase. As the water surface increases there is more flow area, so the velocity decreases.

Downstream of the project area there are no increases in velocity greater than 0.1 feet/second. Near the existing infrastructure at Station -10+82 there is no increase in velocity.

6 DESIGN ANALYSES

The design analyses completed for the proposed structures include scour, stability, and pile analyses. Forces considered in these analyses include log buoyancy, log weight, upstream and downstream hydrostatic forces, friction, velocity, drag, ballast, and the resisting forces of the substrate. These design calculations were used to set footprint elevations, determine the stability of each of the structures and the resulting factors of safety that apply to the structure. The factor of safety can generally be defined as a ratio of the structure's holding strength to the modeled applied load.

6.1 Scour Analysis

Bed scour at the bank barb, channel barb, wood entrapment, and bank sediment retention structures was estimated using an equation originally presented by Liu et al. (1961) for scour at bridge abutments. This equation has since been recommended by others, including Drury (1999), for use in calculating scour at bank LWD and ELJ structures. The equation relates flow conditions (i.e., flow depth and velocity), obstruction dimensions, and Froude number to maximum scour depth below existing grade. Approach velocity, water depth, and Froude number were obtained from the hydraulic output of a HEC-RAS steady-state model completed by Anchor QEA.

Bed scour at the bar apex, channel grade, and channel sediment retention structures was estimated using the simplified Chinese equation (Landers and Mueller 1996) developed for bridge piers in coarse bed rivers. The equation relates flow conditions (i.e., flow depth and velocity), obstruction dimensions, and sediment grain size distribution to maximum scour depth below existing grade. Values for the required hydraulic parameters were obtained from output of the HEC-RAS steady-state model completed by Anchor QEA. Estimates of the channel bed grain size distribution were made based on site visit observations.

Results of this analysis were used to determine the maximum probable depths of bed scour that could potentially undercut the structures. However, final footprint elevations and log pile installation depths were determined based on scour estimates and professional judgment.

6.1.1 Scour Equation (Liu et al. 1961)

The Liu et al. (1961) scour equation was selected for use at the bank barb, channel barb, wood entrapment, and bank sediment retention structures. This equation was originally intended to estimate scour at abutments where the groins are placed perpendicular to the flow. The equation was developed from laboratory tests in a flume and prototype measurements, and was subsequently verified with field experiments. Results of the study indicated that the contraction ratio and approach flow depths are the critical parameters. This equation is recommended for when the ratio of effective length (L_e) of the ELJ protruding into the flow divided by the upstream hydraulic depth (d_1) is less than 25.

$$d_s = 1.1 \cdot {\frac{L_e}{d_1}}^{0.4} \cdot Fr^{0.33} \cdot d_1$$

where:

d_s = scour depth (predicted)

L_e = length (effective)

d_1 = upstream hydraulic depth

Fr = Froude number (dimensionless number), where

$$Fr = \frac{V}{\sqrt{g \cdot d}}$$

V = flow velocity

g = gravitational acceleration

d = flow depth

6.1.2 Simplified Chinese Equation (Landers and Mueller 1996)

The simplified Chinese pier-scour equation was used to estimate scour for the bar apex, channel grade, and channel sediment retention structures. This equation is applicable to coarse-bed rivers and is based on laboratory and field data from China (Landers and Mueller 1996, as cited in Chase and Holnbeck 2004). The equation accommodates clear-water scour and live-bed scour.

$$y_s = 0.95 \cdot K_s \cdot b^{0.6} \cdot y_o^{\,0.15} \cdot D_{50}^{\,-0.07} \left(\frac{V_o - V_{ic}}{V_c - V_{ic}} \right)^{c} \quad \text{for live-bed scour } (V_o > V_c)$$

where:
y_s = depth of scour below bed, feet
K_s = pier shape coefficient
b = pier width, feet
y_o = existing depth in channel before contraction scour, feet
V_o = approach velocity upstream of the pier, feet/second

$$c = \left(\frac{V_C}{V_o} \right)^{8.20 + 2.23 \log D_{50}}$$

D_{50} = median particle size, feet
V_c = critical velocity (incipient motion) for the D_{50}-sized particle, feet/second

$$V_c = 3.28 \left(\frac{y_0}{D_{50}} \right)^{0.14} \cdot \left[8.85 \cdot D_{50} + 6.05 \cdot 10^{-7} \left(\frac{10 + 0.3048 \cdot y_o}{(0.3048 \cdot D_{50})^{0.72}} \right) \right]^{0.5}$$

V_{ic} = approach velocity corresponding to critical velocity at the pier, feet/second

$$V_{ic} = 0.645 \left(\frac{D_{50}}{a} \right)^{0.053} V_c$$

6.1.3 Results

The maximum probable scour was estimated for the bar apex and channel grade ELJ structures over a range of flows up to the 100-year event. The maximum probable scour was estimated for the bank barb, channel barb, wood entrapment, channel sediment retention, and bank sediment retention structures over a range of flows up to the 10-year event. Table 5 presents probable scour depths based on both the results of this analysis and professional judgment.

Table 5
Probable Maximum Scour Depths for the Proposed Structures

Feature or Structure[1]	Flow Event	Equation	Scour Depth (feet)
Bar Apex	100-year	Simplified Chinese Equation (Landers and Mueller 1996)	8.3
Channel Grade	100-year	Simplified Chinese Equation (Landers and Mueller 1996)	7.7
Channel Barb	10-year	Liu et al. 1961	4.7
Bank Barb	10-year	Liu et al. 1961	5.1
Wood Entrapment	10-year	Liu et al. 1961	8.5
Bank Sediment Retention	10-year	Liu et al. 1961	6.7
Channel Sediment Retention	10-year	Simplified Chinese Equation (Landers and Mueller 1996)	6.2

Note:

1. Results are reported for the feature or structure location with the highest calculated scour depth (for that feature or structure). A common structure design was used even though scour may be less at other locations.

The probable maximum scour depth for the bar apex and channel grade ELJs are similar as their width (*b*), at the channel grade, is nearly the same. The major difference between these two ELJ structures is how they are designed to handle to scour.

- The bar apex ELJ structure is embedded into the channel bed to a depth just above the probable maximum scour depth. Embedding the structure into the bed reduces the likelihood that scour under the structure would result in differential settling, thereby compromising the stability of the structure.
- The channel grade ELJ structure is essentially placed at the existing channel grade with only minor excavation for the rootwad mass to allow good ground contact along the length of the logs in the bottom layer. The front of the structure, where maximum scour depth is anticipated, is set forward of the enclosed portion of the structure containing the ballast material. This configuration limits the likelihood that scour would undermine the structure and cause differential settling. Additionally, the enclosed portion of structure is backfilled with large boulders rather than native material. The size of the boulders greatly improves the retention of the ballast

required for stability even if the structure experiences deferential settling and distortion.

Scour was not evaluated at the side channel-spanning, and channel-spanning roughness. These structures are designed to be flexible and settle into any scour local to the rootwad logs and boulders. In addition, scour was not calculated for the single pieces of LWD that will be placed throughout the project reach or for the bank roughness LWD. The single logs will either be embedded into the bank or braced between existing trees within the floodplain. The bank roughness LWD will be embedded within an existing riprap bank.

The probable maximum scour depth for the bank barb and channel barb structures is considerably less than the other structures for the following reasons:

- The design discharge is the 10-year flow event
- The structures' low profile causes the effective length (L_e) into the flow used in the calculations to be reduced as the structure becomes further submerged at higher discharges
- The flow contraction and acceleration is expected to be both horizontal and vertical for discharges overtopping the structures

The probable maximum scour depth for the pile supported structures is used to determine the unsupported length of the log piles (see Section 7.2).

7 STRUCTURE STABILITY

7.1 Ballasted Structures

The ballasted structures stability analysis evaluates the sum of all the forces acting on the structure to determine the horizontal and vertical factor of safety against displacement. The forces driving and resisting structure displacement are:

- The upward vertical force on the structure from the buoyancy of the submerged wood
- Downward vertical forces from the weight of the un-submerged wood and the ballast material secured to or within the structure
- Driving horizontal forces from drag and differential hydrostatic pressure acting on the structure
- The resisting horizontal force caused by friction between the bottom of the structure and the river bed

The factors of safety presented in Table 6 (for both vertical and horizontal forces) are for structures just after construction. Calculations assume that the LWD density is equal to the average green weight of wood and bark for the lowest density species allowed in construction. Over time, much of the wood within the structure can become saturated, thereby increasing the log's density and increasing the overall weight and resisting force of the structure. Calculations also assume the bulk porosity of the backfill material placed as ballast is 0.30. For structures where boulders are used as ballast, the rock mass specific gravity is assumed to be 2.5 to account for variability in rock type density.

Table 6
Gravity Structure Stability Factors of Safety

Structure	Design Flow Event	Design Flow (cfs)	Design Velocity (fps)	Horizontal Factor of Safety[1]	Vertical Factor of Safety[2]
Bar Apex	100-year	8430	10	2.5	3.2
Channel Grade	100-year	8430	10	2.4	8.6
Side Channel-Spanning	100-year	1717	9.5	2.4	1.8
Channel-Spanning Roughness	100-year	8430	10.5	1.3	6.0
Channel Barb	10-year	2231	10.5	1.6	3.9
Single Log	10-year	2231	7	1.7	2.4

Notes:
1. Horizontal factor of safety is the friction force divided by the drag force.
2. Vertical factor of safety is the downward vertical force of the ballast and logs divided by the upward vertical force of the submerged wood logs.

cfs = cubic feet per second
fps = feet per second

Structure buoyancy calculations were not completed for the pile-supported or tree-braced structures. See Section 7.2 for pile-supported structure stability calculations. See Section 7.3 for an explanation of tree-braced structures and the structures' expected stability.

7.2 Pile-supported Structures

Pile stability analyses were completed for the channel and bank sediment retention structures, wood entrapment, and bank barb structures. The pile stability analyses examined the size of the structure, the number of log piles, the depth of the log piles, and the hydraulic load applied to the structure. The number of log piles needed for each structure is based on the structure length and width (structure geometry) and the hydraulic load applied to the structure. The hydraulic load is transferred from the above grade rootwad logs to the log piles. Results of the log pile analyses are presented in Tables 7a and 7b.

A resulting factor of safety was determined for the pile-supported structures. The factor of safety is the ratio of the structural capacity of the pile system to the design load. The factor of safety increases as the number of piles or the pile diameter increases because the structural capacity of the pile system is increasing as the load remains constant.

Table 7a
Pile-supported Structure Design Summary and Resulting Factors of Safety

LWD Structure [1]	Bank Sediment Retention	Channel Sediment Retention
Design Event	10-year	10-year
Velocity[2], V (fps)	8.3	8.3
Scour Depth (feet)	6.7	6.2
Log Pile Embedment[3], L (feet)	6.0	6.0
Pile Depth BEGS (feet)	13.0	13.0
Log Pile Diameter[4], B (inches)	18	18
Number of Log Piles, n	4	5
Minimum Pile Bending Stress Capacity[5] (psi)	650	650
Factor of Safety Log Pile Overturning	**1.5**	**1.5**
Factor of Safety Log Pile Bending Strength	**2.0**	**2.0**

Notes:

1. See design plans for additional details regarding LWD structure design and construction.
2. Velocity is determined using the HEC-RAS hydraulic model for the indicated design event.
3. Log pile embedment is the depth below the design analysis scour depth (see Section 6).
4. Log pile diameter is measured at the mid-point of the log pile. Diameter does not include bark.
5. Specified minimum bending stress is the starting design value before strength reduction factors are applied per timber pile design methods.

BEGS = below existing ground surface
fps = feet per second
psi = pounds per square inch

Table 7b
Pile-supported Design Summary and Resulting Factors of Safety

LWD Structure [1]	Wood Entrapment	Bank Barb ELJ
Design Event	10-year	10-Year
Velocity[2], V (fps)	7.3	10.4
Scour Depth (feet)	8.5	5.1
Log Pile Embedment[3], L (feet)	6.5	6.4
Pile Depth BEGS (feet)	15.0	11.5
Log Pile Diameter[4], B (inches)	18	18
Number of Log Piles, n	8	4
Minimum Pile Bending Stress Capacity[5] (psi)	650	650
Factor of Safety Log Pile Overturning	**1.5**	**1.5**
Factor of Safety Log Pile Bending Strength	**1.6**	**1.7**

Notes:
1. See design plans for additional details regarding LWD structure design and construction.
2. Velocity is determined using the HEC-RAS hydraulic model for the indicated design event.
3. Log pile embedment is the depth below the design analysis scour depth (see Section 6).
4. Log pile diameter is measured at the mid-point of the log pile. Diameter does not include bark.
5. Specified minimum bending stress is the starting design value before strength reduction factors are applied per timber pile design methods.

BEGS = below existing ground surface
fps = feet per second
psi = pounds per square inch

7.2.1 Soil Strength

The soil strength resisting pile overturning was calculated for the pile supported structures. These calculations represent the condition where the soils (substrate) supporting the log piles fail and the log piles overturn before the pile strength is exceeded (Section 7.2.2), resulting in structure deformation. The soil strength is calculated using published methods for estimating ultimate lateral soil resistance to timber piles in cohesion-less soils. The soil strength calculations assume the design maximum scour depth for effective pile embedment depth and also assume the structures are subject to the highest modeled channel velocity in the vicinity of the structure. Furthermore, calculations assume a homogenous channel substrate.

7.2.2 Pile Bending Strength

The pile bending strength was calculated for the pile supported structures. These calculations represent the condition where the log piles yield and break in bending under the applied load. These calculations assess each log pile as a cantilevered beam subject to the hydraulic loads of the design flow event. The calculations assume the design maximum scour depth for determination of the unsupported pile length. The pile bending strength factor of safety was evaluated to exceed the soil strength for each structure.

7.3 Single LWD Using Existing Trees

A specific stability analysis for LWD structures braced against existing standing trees was not completed. The stability of each LWD braced against existing standing trees will depend largely on the size, species, and health of the trees that the hydraulic forces are transferred to, as well as the approach angle of hydraulic forces and the changes in these forces over time.

During construction, the engineer will identify trees that can be used to brace LWD structures. The trees will be selected based on their size, species, and health to provide the best possible stability at that location. Bracing structures against existing standing trees may increase the risk that the trees could be brought down during a high-flow event. However, this risk will generally be reduced over time as the rootwads making up the structure become more saturated and as the standing trees continue to grow. It is expected that structures braced against existing trees will be capable of withstanding moderate discharge events. The hydraulic forces and the potential for channel migration caused by a 100-year event may cause the structures to shift significantly or dislodge entirely.

8 RISK ASSESSMENT

Results of the HEC-RAS hydraulic model were used to determine potential changes in channel and floodplain water surface elevations and erosion throughout the project reach, as well as upstream and downstream of the site. Placement of the structures within the channel and floodplain area will alter flood inundation areas and flood flow depths. The placement of structures may also alter the rate and location of lateral bank erosion locally at and near the structures. The excavation and increased activation of the relocated main channel alignment will alter the existing flow paths from the existing main channel alignment through this left bank floodplain area.

8.1 Localized Changes at Structures

Structures placed within channel flow change local hydraulics at and near the structures as they locally obstruct flow. Channel deposition may occur upstream of the structures as the water velocities are slowed due to the flow obstruction, as well as downstream in the slackwater or lee of the structures. Directly at the face of the structure, localized turbulence will scour a horseshoe-shaped pool upstream of the ELJs, tailing out around the side of the structures. This turbulence and energy dissipation is reflected in the water surface elevation results for the proposed condition, as the structures create localized increases in water depths (see Section 5, Hydraulic Modeling).

8.2 Water Depths and Floodplain Extents

Placement of the structures will alter the existing water surface elevations (water depths) within the project extents (Stations 33+08 to -21+00). Predicted changes in water depth as a result of the project are summarized below.

8.2.1 Upstream Model Boundary Conditions (Station 42+00 to Station 33+08)

Based on the HEC-RAS modeling results, no measurable changes in water surface elevations (i.e., flood flow depths) or in floodplain inundation are noted near the model boundary (Station 42+00) and downstream to Station 33+08 as a result of the project.

8.2.2 Project Reach (Station 32+59 to Station 0+00)

Water surface elevations are predicted to vary from existing conditions throughout the main channel. At Stations 32+22 and 30+99 the model predicts an increase in water surface elevations of, 0.2 feet and 1.6 feet, respectively. This increase is predicted at and near the location of the most upstream ELJs at the inlet to the relocated main channel alignment. These predicted increases in water surface elevation are expected to decrease overtime as the relocated main channel alignment carves its channel through the left bank floodplain lowering water surface elevations throughout its alignment and upstream of relocated main channel alignment inlet (Station 30+00) in the main channel.

Downstream of the split into the relocated main channel alignment (from Station 30+50 to Station 27+50), water surface elevations are predicted to drop in the existing main channel due to the activation of the new channel. This decrease is predicted to range from 1.3 feet to 2.7 feet. Between Stations 27+00 and Station 21+27 water surface elevations are predicted to increase in the main channel between 0.1 and 0.8 feet. Based on these results, slight increases in floodplain inundation would be likely in the existing main channel alignment as a result structure placement. However, these changes are not expected to be widespread.

Downstream of the confluence of the existing main channel and the relocated main channel alignment, water surface elevation increases are predicted at structure locations. These increases are predicted at the cross-sections associated with structure placements in the main channel. Most of these predicted increases are local and widespread impacts from changes in flood depths are not predicted to occur at a result of the project.

8.2.2.1 Relocated Main Channel Alignment

With the activation of the relocated main channel alignment, the 100-year water surface elevations along this alignment generally decrease. WSELs throughout this channel are predicted to mostly decrease through this alignment due to the excavation of this channel. The largest predicted change in WSEL is at Station 2+50, where the proposed condition WSEL is predicted to decrease by 1.8 feet. Sporadic increases in WSEL are predicted throughout this channel, with the largest predicted at Station 8+73 where an increase of 1.9 feet is predicted. However, most of these predicted increases are expected to be local with widespread impacts from changes in flood depths not predicted to occur throughout the relocated main channel alignment.

8.2.3 Downstream Project Reach (Station 0+00 to Station -21+00)

Changes in WSELs are not predicted downstream of the project site (Station 0+00 to Station -2+89). The model predicts slight fluctuation in water surface elevations in the range of -0.02 to 0.01 feet between Station -3+38 and Station -21+00. These numbers are within the background range of the model error and are not considered a notable change over existing conditions.

8.2.4 Downstream of the Project

Water depth changes (over the baseline condition) downstream of the project are not expected as result of project. Downstream of the project (downstream of Station -21+00), existing natural processes that control flood extents, occurrences, and events will continue with or without the upstream project actions.

8.3 Water Velocities

Based on the hydraulic modeling results for the project reach, peak flow velocities are predicted to change as a result of structure placement (Station 33+08 to Station -21+00). Model water velocity results may be used as an indicator of potential erosion and deposition. Where predicted, increases in water velocity may indicate areas where erosion may increase over the existing conditions. In addition, in areas where water velocities are expected to decrease over the existing condition, deposition may occur, resulting in aggradation of the channel in the long term.

8.3.1 Upstream Model Boundary Conditions (Station 42+00 to Station 33+08)

Based on the hydraulic modeling results, existing and proposed water velocities do not differ upstream at the model boundary (Station 42+00) and downstream to Station 33+08. Impacts resulting from changes in water velocity are not predicted at and downstream of the upstream model boundary as a result of the project.

8.3.2 Project Reach (Station 32+59 to Station 0+00)

Immediately above and downstream of the split into the relocated main channel alignment (between Stations 32+22 and Station 26+65), water velocities are predicted to decrease in the existing main channel due to the activation of the relocated main channel alignment with the exception of one cross-section (Station 28+00) where the velocity is predicted to increase slightly (increase of 0.26 feet/second). Widespread decreases in water velocities within this reach may result in some deposition and channel aggradation over the long term, targeting a habitat goal within this reach to reduce the overall channel incision and promote aggradation. Increases in water velocities are predicted in the main channel between Station 26+65 to the confluence with relocated main channel alignment. The largest increase is predicted at Station 20+42 of 2.21 feet/second. Based on these modeling results, widespread adverse impacts from the project are not predicted within the existing main channel alignment as a result of the increase in velocities.

Downstream of the confluence of the existing main channel and the relocated main channel alignment, water velocities are predicted to mostly decrease or remain similar to the existing condition. The only notable increase in velocity is predicted at Station 13+55, where the velocity is predicted to increase by 2.3 feet/second. This is in the vicinity of the placement of a bar apex structure in the main channel at Station 14+00. Decreases in water velocities are predicted by the model as well. The largest decreases in velocity are predicted at the downstream most structure where water velocities are predicted to decrease by 7.1 feet/second at Station 16+95 from the placement of the channel spanning LWD structure.

The predicted changes in water velocity (both increases and decreases) are localized at the cross-sections associated with structure placements in the main channel. Within the channel, these predicted increases are local and widespread impacts from changes in flood flow velocities are not predicted to occur throughout the greater channel and floodplain area as a result of the project.

8.3.3 Relocated Main Channel Alignment

As the relocated main channel alignment is activated in areas where banks have been cut or graded (exposed alluvium), minor erosion is expected. Velocities within the relocated main channel alignment are predicted to mostly increase in the upstream extent and mostly decrease in the lower extent relative to existing conditions. Erosion through the relocated main channel alignment will likely be temporary as the channel is activated with increasing flows. Any erosion should decrease overtime as the channel stabilizes and reaches equilibrium. Long-term erosion through the relocated main channel alignment as a result of the increase in water velocities is not expected.

8.3.4 Downstream Project Reach (Station 0+00 to Station -21+00)

Changes in velocities are not predicted between Station 0+00 and Station -21+00. Therefore, changes from the baseline condition are not predicted within this reach. Existing natural processes that affect erosion and lateral channel migration will continue in the future.

8.3.5 Downstream of the Project

Water velocity changes (over baseline conditions) downstream of the project are not expected as result of project. Downstream of the project (downstream of Station -21+00), existing natural processes that control flood extents, occurrences, and events will continue with or without the upstream project actions. Therefore, changes from the existing conditions downstream as a result of the project are not expected.

Table 8
Summary of Predicted Water Surface Elevation and Flow Velocity Changes from the Existing Condition for the 100-year Flood in Tucannon River Project Area 15 based on HEC RAS Modeling Results

Selected Reach or Feature	Location	Water Surface Elevation (feet)	Flow Velocities (feet)
Upstream Model Boundary Condition and Upstream Project Extent	Stations 42+00 to 33+08	Changes are not predicted	Changes are not predicted
Relocated Main Channel Alignment (new excavated channel)	Stations 12+00 to 2+00	Overall predicted general decrease in water surface elevations.	Overall predicted increases (upstream extent) and decreases (downstream extent) in water surface elevations.
Existing Main Channel	Stations 32+59 to 20+00	Water depths generally decrease in upper extent and increase in lower extent. (see Section 8.2.2 for details)	Water velocities generally decrease in upper extent and increase in lower extent.
Downstream Project Extent[2]	Stations 20+00 to 0+00	Localized increases from existing conditions are predicted[1]	Localized changes from exiting conditions are predicted. Most notable decrease is at a channel spanning structure (>7 feet per second) at Station 16+95
Downstream of the Project and Downstream Model Boundary	0+00 to -21+00	Changes are not predicted from existing condition [1]	Slight fluctuations from existing condition[1]

[1] Modeling results within +0.02 to -0.02 (feet or feet per second) are considered within model error, and not reported as an increase or decrease from the baseline condition.

9 CONSTRUCTION ACTIONS

Construction of this restoration project is expected to occur in summer 2014. Dewatering procedures, best management practices (BMPs), and strategic construction sequencing will be specified and provided to the contractor to minimize disturbance to existing habitat to the extent practicable.

9.1 Construction Sequencing

The following is a general outline of the construction sequencing for the project. Potential access roads and staging areas are shown in Sheet 6. The sequencing is based on prior experience with similar projects and serves as recommendations. Final construction sequencing and methods is ultimately up to the contractor.

- Temporary Erosion and Sediment Control (TESC) measures shall be completed as outlined in the TESC plan before mobilizing or moving equipment
- Staging areas and access routes shall be laid out in a manner that minimizes disturbed area
- Access to the site shall be from Tucannon Road on the right bank of the Tucannon River
- The left bank of the river shall be accessed by a temporary crossing of the channel to place LWD and to excavate the relocated main channel
- Care of water plan shall be implemented before any instream work begins (and will be developed by the selected contractor)
- All excavated materials being stockpiled for later use shall be staged above the ordinary high water line (OHWL)
- All equipment shall be stored above the OHWL
- Excavation for ELJs shall be to the design depth of the structure
- LWD and ELJs placed at the bank shall be done in a manner that minimizes disturbance of the bank
- Structures located furthest from access routes shall be constructed first, backing equipment out as structures are constructed
- As construction is completed, access routes shall be restored to pre-project condition

9.2 Mobilization and Project Area Preparation

Mobilization and project area preparation includes transporting equipment to the area, clearing for construction access and staging, and installing silt fencing and other project-specific BMPs. Any trees and brush cleared for access and staging will be side cast and used during decommissioning of the project area or integrated into other project components. Construction fencing will be placed along the perimeter of the staging areas and access roads to protect adjacent areas from disturbance.

9.2.1 Temporary Access

Temporary access roads may be constructed to access the project area from the east side of the river. Proposed access routes and staging areas are displayed in Sheet 6. In addition, temporary channel crossings may be installed to access bar/island components of the project and structures along the west bank. Temporary crossings should be conducted as specified in the project plans to minimize channel disturbance. Site access may require some clearing of immature deciduous trees and shrubs. Any trees and brush cleared during this process will be stockpiled in the project area and used to decommission the access routes or integrated into other project components. Unvegetated gravel bars that are exposed during the construction window will be used as access routes between project area locations to minimize riparian impacts. For this reason, these areas may also be used as staging areas.

9.2.2 Weed Control/Prevention

To minimize the establishment and colonization of weeds and invasive plant species in the project area, several preventative measures can be implemented:

Pre-construction

- A survey for invasive/weed species should be conducted in the entire project area and upstream of all contributing waters prior to construction, planting, or soil-disturbing activities
- Invasive/weed species that are found should be documented on a map or noted by global positioning system (GPS) coordinates for annual inspection
- Invasive/weed species should be removed during or before flowering to prevent the spreading of target species seeds

- In removal areas, soil disturbance should be minimized by cutting the invasive/weed at the stem
- Removed invasive/weed species should be collected and taken away from the project area

During Construction

- The root systems of woody invasive/weed species should be removed if in the footprint of the designated soil-disturbance area
- Disturbed soils should be stabilized and covered with a seed-free mulch or anti-erosion material once final grade is established
- Established corridors of travel by construction and support vehicles should be minimized to prevent disturbance of soil and carrying invasive species/weeds into the project area
- All staged or delivered materials (rock, soil, mulch, plants, and LWD) should be inspected upon arrival to minimize the introduction of invasive seed sources and plant material

Post-construction

- All disturbed soils, including soil at planting areas should be protected with seed-free mulch or compost to suppress invasive/weed species and to retain moisture
- Revisit pre-construction invasive/weed species survey areas to look for regeneration and suppression (document findings)
- If plantings require irrigation, use a localized drip system instead of a broadcast system to minimize benefit to invasive/weed seed sources
- Establish an annual or biannual monitoring plan to identify and address the problem of invasive/weed species

9.3 General Earthwork

Earthwork involves excavation, hauling, and backfilling of native materials, including streambed materials. Earthwork associated with a majority of the LWD and ELJ structures will likely be in coarse gravel/cobble material with a variable sand and organic fraction.

Generally, a majority of the excavation may be efficiently accomplished using a tracked excavator with an appropriately sized bucket. A bucket with a clamp would be advantageous for working with larger sized material, including boulders. Material hauling within the project area may be accomplished with a dump truck (standard or articulating depending on the condition of the haul route) or a front-end loader. Generally, a majority of backfill could be efficiently accomplished using a tracked excavator.

9.4 Earthwork for Relocated Main Channel Alignment

The relocated main channel will be excavated in the position and to the grades shown in the Construction Drawings. The final alignment of the channel may be modified on site under the direction of the supervising engineer or authorized representative. Trees and shrubs may be removed in order to excavate the channel; however, it is preferable that the channel alignment is modified such that mature riparian trees or other desirable vegetation is avoided. Any vegetation removed may be re-used on site by distributing on the floodplain or incorporating into structures. The excavated material may be distributed within the floodplain or used as structure backfill.

9.5 Large Woody Debris

This activity involves placing LWD of various types throughout the project area. Once the placement locations have been surveyed and, if required, field-adjusted by the engineer, placement would begin at the location farthest from the staging area and progressively work toward the staging area. Installation of LWD could be accomplished by using an excavator with a bucket equipped with a clamp (or a grapple) for log placement and a skidder (or similar machine) to ferry materials to the placement site. Before construction begins, all necessary material would be staged in an area on the floodplain or gravel bar adjacent to each LWD location so that the materials are within reach of the excavator once it is in a position to build the LWD. Some LWD types will require excavation for installation. If excavation extends below the water table, turbid water will be generated. Any dewatering required for installation of the LWD will be carried out in accordance with the BMPs for water control (Section 9.8.2). Each LWD placement will be completed before the start of construction of another unless enough equipment is present to work concurrently.

9.6 Engineered Log Jams

This activity involves construction of ELJs throughout the project area. Final locations for the ELJs will be determined by the engineer in the field following the objectives described previously in this document. All necessary material will be staged in an area on the floodplain or gravel bar adjacent to each ELJ location before construction of each structure such that the materials are in reach of the excavator once it is in a position to build the ELJ. ELJs will be founded at the specified elevation to minimize undermining from scour after completion. Construction will involve excavation of the footprint of the structure and subsequently backfilling the structure with the material excavated for the footprint. All materials excavated for the placement of the ELJ will be used for backfill. Minimal off-site disposal or redistribution of excavated materials is expected. Once the initial logs are placed at the necessary elevation, the structure can be constructed rapidly. Each ELJ will be completed before construction begins for another ELJ, unless enough equipment is present to work concurrently. Construction of ELJs could be accomplished by using an excavator with a bucket equipped with a clamp (or a grapple) for the log placement and a skidder (or similar machine) to ferry materials to the placement site. Because the ELJs will be constructed below the water table, turbid water will be generated. Any dewatering required for installation of the ELJs will be carried out in accordance with the best management practices for water control (Section 9.8.2). The contractor shall be responsible for dewatering the excavations and pumping water to a location suitable for natural infiltration and approved by the engineer and in compliance with any permits and regulations.

9.7 Project Area Decommissioning

The contractor will break down any equipment and clean any remaining areas that need decommissioning. Water and sediment control structures will be left in place until all construction activities within the river have been completed and any temporary surface erosion control measures are in place. Once construction is complete, these components will be broken down and removed by hand, and the rest of the project area will be decommissioned before leaving the project area. Any temporary access routes and staging areas will be regraded to blend into the adjacent topography and revegetated with a native seed mix to minimize erosion of materials disturbed during construction.

9.8 Best Management Practices

9.8.1 Surface Erosion Control

Surface erosion control during construction is an important turbidity control measure for the project. Removal of vegetation may temporarily leave areas exposed and vulnerable to erosion before re-establishment of vegetation. Silt fencing around the perimeter of areas where vegetation is removed is recommended to capture sediment and delineate the construction disturbance limits. During project area decommissioning, straw mulch should be placed to minimize erosion of materials as vegetation is established. Silt fencing should be removed by hand once temporary surface erosion control measures are in place or vegetation is established in the disturbed areas.

9.8.2 Water Control

Water control during construction is the most critical turbidity control measure for the project. Installation of many project components will require excavation below the water table, and turbid water will be generated. The following section provides a brief description of the recommended water control procedures for project structure requiring significant water control. However, the contractor will be responsible for developing the final water control plan. Additionally, the contractor will be responsible for dewatering the excavations as required for constructability and pumping water to a location suitable for natural infiltration as approved by the engineer. The contractor will provide sufficient equipment to accommodate changes to the water control plan required by project area conditions during construction as directed by the engineer.

9.8.2.1 Large Woody Debris and Engineered Log Jam Construction

Many of the LWDs and ELJs will be placed in the active channel (or in areas with a surface water connection to the active channel during construction). For these locations, any required excavation will be conducted within temporary gravel berms, silt curtains, or other temporary flow separation method to minimize the dispersion of turbid water into the active channel. For structures in or near the main channel, water entering the excavation will be of a significant volume. We recommend pumps (of sufficient size and quantity) to partially dewater the excavation. Water would be pumped from the excavation area into an infiltration area. The infiltration area should be located on the floodplain to minimize the potential for overland flow back into the river and to prevent damage to sensitive habitat (wetlands and alcoves). Infiltration rates into the floodplain will be significant and we expect that only a minimum amount of turbid water pumped onto the floodplain will not be infiltrated. If the infiltration capacity is exceeded, overland flow will be routed over existing vegetation to encourage suspended sediment deposition before flowing back to the river.

For LWDs and ELJs placed in the active channel that do not require a significant quantity of excavation, turbidity control is not expected to be a significant issue. For structures not requiring excavation dewatering, turbidity control is also not anticipated to be required.

9.8.3 Refueling Practices and Spill Prevention and Countermeasures

The following best management practices will be implemented for spill prevention during refueling:

- Each piece of machinery will be checked daily for leaks and any repairs will be done before work in or near water
- All vehicle staging, cleaning, maintenance, refueling, and fuel storage will take place above the OHWL in an approved staging area that is 150 feet or more from any waterbody in accordance with local, state, and federal regulations and permit conditions
- A driver/operator must be present and maintain constant observation/monitoring of the fuel transfer at all times
- A driver/operator must be trained in spill prevention, cleanup measures, and emergency procedures
- All employees must be made aware of the significant liability associated with fuel spills
- Spill containment and countermeasures must be maintained at all locations where refueling occurs; materials include non-water absorbents capable of absorbing 15 gallons of diesel fuel and drip pans
- All machinery and equipment working in or near waterbodies will maintain non-water absorbents capable of absorbing 15 gallons of diesel fuel and drip pans
- If a power generator is used during construction, the generator should be placed out of the river channel within a spill containment unit

10 REFERENCES

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CONSTRUCTION DRAWINGS