Tucannon River PA13 Basis of Design

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Preface

This document is the basis for design of Project Area 13 (PA 13). This project will improve conditions for the Tucannon River and Spring Chinook, considered the “umbrella species” for other native fish in the Tucannon Basin. The project is within the boundaries of the Washington State W.T. Wooten Wildlife Area (WTWWA). Geomorphic, hydrologic, and hydraulic assessments implemented to identify and resolve design considerations were completed. Additionally, input from stakeholders were included to improve the overall design and to meet partner beliefs and needs.

1. Project Background

The Tucannon River watershed supports ESA-listed Snake River summer steelhead (Oncorhynchus mykiss), Snake River Spring and Fall Chinook salmon (O. tshawytscha), Columbia River bull trout (Salvelinus confluentus), resident redband rainbow trout (O. mykiss), and western brook lamprey (Lampetra richardsoni). Historic grazing , agriculture, forestry, excavation and other bulk earthwork activities at various locations within the river and the 100-year floodplain have influenced the river and its geomorphic processes, floodplain connectivity, and accompanying habitat for these fish species. These activities have led to the limiting factors identified in the Tucannon River Geomorphic Assessment (Columbia Conservation District, 2011). The key limiting factors for Spring Chinook are instream and floodplain habitat complexity, degraded floodplain connectivity and riparian condition, elevated summer water temperatures, and elevated embeddedness levels. (2008 Fish Accords MOA; Columbia Conservation District, 2011).

The project reach for PA-13 is highly confined due to past land use activities and the construction of a sheet-pile weir diversion that supplies water to the Tucannon Hatchery. The weir, built in 1983, has partially starved the river below from natural bedload movement. Past maintenance practices (recently corrected) at the intake exacerbated the impact. Therefore, the focus of this project is to address bedload losses and improve floodplain connectivity throughout the reach by augmenting gravel and “building up” the streambed with alluvium and large wood structure. WDFW believes that the restoration actions proposed here directly address and enhance the interconnected nature of the river hydrology, geomorphology, floodplain connectivity, riparian community and aquatic biota by imitating or facilitating natural riverine processes and habitats. Although, WDFW intends to address these limiting factors in the project reach through direct restoration actions, we also believe that the process requires time and natural hydraulic process to achieve project goals.

1.1 Location

The project site is located on the Tucannon River, entirely in Section 27 Township 10N Range 41E, adjacent to WTWWA Rainbow Lake and the Tucannon Hatchery (Figure 1). The project reach starts above the Hatchery Dam (RM 40) down to the Hatchery Access Bridge (RM 39.2). Most of the drainage upstream is within the WTWWA and Umatilla National Forest, with relatively little land use or water diversion presently

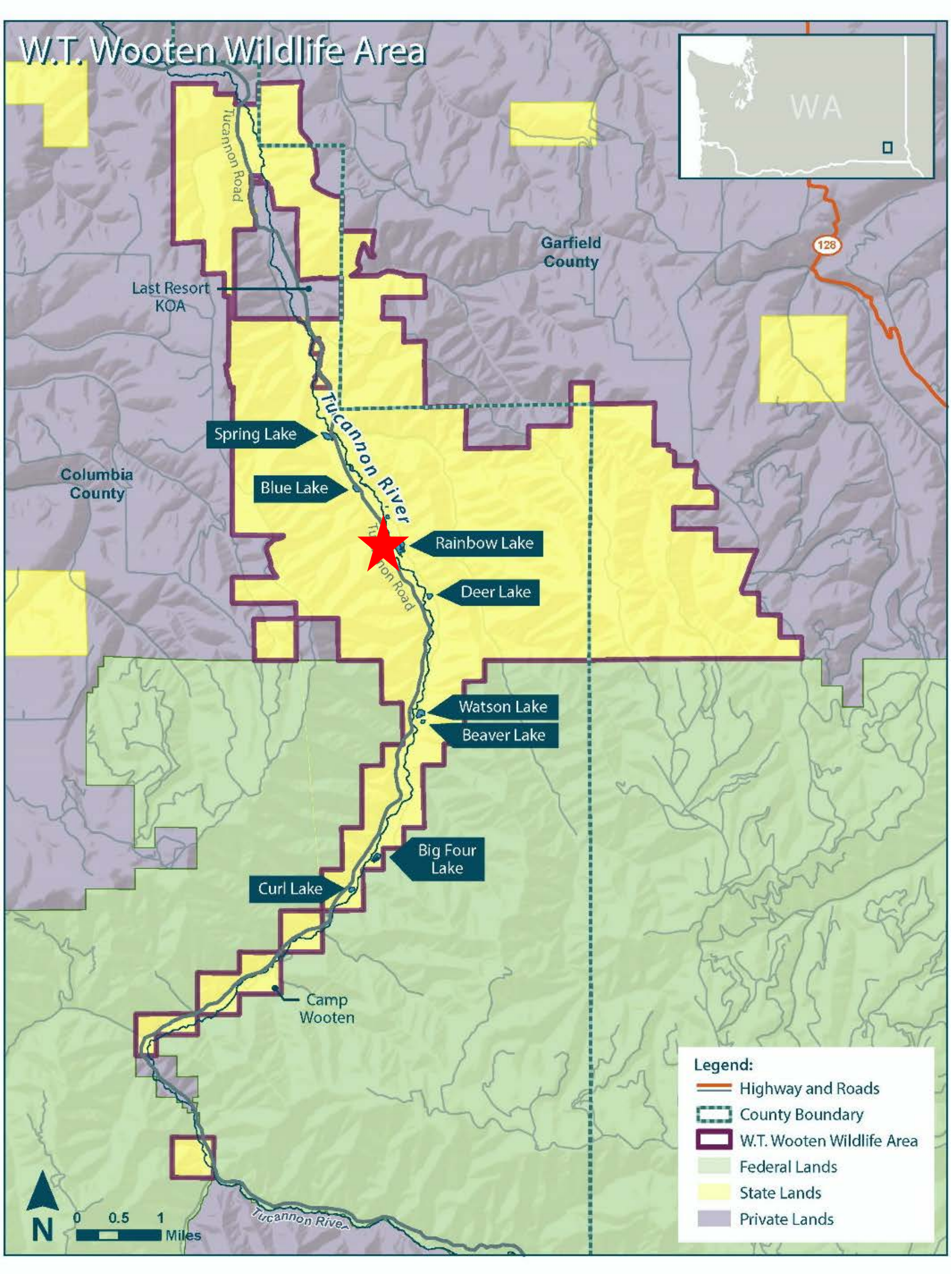

Figure 1. Project location map.

1.2 Geomorphic Assessment of River and Floodplain

The channel through PA 13 is a single-thread, plane-bed channel with forced pool-riffle and local rapid sections. The channel is typically straight, wide, and contains little complexity in much of the project area. Large levees confine the channel along the right bank from approximately RM 39.95 to 39.8, at RM 39.6, and from RM 39.5 to 39.2. The upper levee is armored with large angular boulders from the Lake Intake downstream approximately 200 meters. The project area has infrastructure that is considered in the design: (i) a lake (Rainbow Lake) for recreation use (trout fishing), undergoing restoration to increase available floodplain; (ii) an undersized bridge (replaced after the 1964 flood) that provides access to the hatchery at the downstream end of the project reach; (iii) the hatchery dam, a sheet-pile weir Intake that supplies water to the lake and the Tucannon River Hatchery. The hatchery dam at the upstream end of the project area controls the channel grade and influences bedload movement upstream from the dam and through the reach. The dam has a 4.4 – 5.0 foot drop in water surface elevation with a deep plunge pool on the downstream side. No significant active side channels or off-channel areas are in the project reach. The quality and availability of instream habitat is limited by the lack of channel and hydraulic complexity. The straight and confined channel results in hydraulic conditions that create high velocities and high transport capacity. These conditions do not support the retention of large wood (LW) and bedload so the channel lacks hydraulic complexity. A few downed logs and one logjam provide pools and cover in the actively eroding area near RM 39.7, but overall very few adequate pools for adult salmon or steelhead are available. The lack of side channels and instream gravel bars limit the amount of habitat for available for juvenile salmonids.

There is very little floodplain connectivity in this project reach. The entire reach has been channelized and straightened as a past flood control measure. Furthermore, areas that could be connected are controlled by the presence of infrastructure (levees) and lack of low-lying floodplain, except the area near RM 39.8 and 39.3, which is disconnected by infrastructure. The levees prevent channel migration and the development of gravel bars and low-lying emergent floodplain. Local channel incision exacerbates the limited floodplain availability and connection. Rainbow Lake, the public camping areas, and the access road to these areas are located atop a terrace and not within the low-lying floodplain. There is currently a project underway to reduce the footprint of Rainbow Lake and increase floodplain available to the river (2018).

The hatchery produces trout for recreation and works in cooperation with the Lyons Ferry Hatchery to raise endemic steelhead and Spring Chinook for the Tucannon River.

The riparian zone is generally in moderately good health, except for along the levees, which are populated with invasive understory species. The left side of the channel and forested areas in the right (east) floodplain contain riparian trees that are mostly deciduous, dominated by young to mature alders and cottonwood with some Ponderosa pine and older conifers. Understory vegetation is moderately diverse and includes groundcover, shrubs, and small trees that provide a moderate amount of overhanging vegetation. The levees are typically sparsely vegetated with shrubs and covered in thistle and other weedy plants that provide little overhang. The disconnected low-lying area in the east floodplain near RM 39.3 is a grassy field with some patches of sparse trees and shrubs (Tucannon Geomorphic Assessment - Columbia Conservation District, 2011).

Major project elements include:

1. Returning a roughly 1 mile reach of the river located within WDFW's WTWWA closer to its historic, naturally functioning state, and increase fish habitat complexity (quantity and quality).

2. Continue long-term gravel augmentation in the treatment reach.

3. Use the results to continue the discussion with adjoining downstream and upstream private property owners about comparable restoration actions on their own properties.

1.3 WDFW Staff Responsible for the Project

- David Karl, Project Manager/Habitat Biologist
- Bruce Heiner, WDFW Environmental Engineer

WDFW has participated in Tucannon River restoration efforts since the 1996 flood and contracted by BPA (2011) to develop restoration projects for the Tucannon River Programmatic. Funding for the projects completed by WDFW since 2011 involved combination of BPA Mitigation Funds and Washington State RCO Salmon Recovery Funds. PA 13 is located from the Tucannon Hatchery Intake (RM) downstream to the WDFW Hatchery Bridge (RM). Projects implemented include PA 10, PA 14, PA 11, and PA 6, 8, 9, all on the WTWWA. Combined they comprise almost 8 miles of river restoration.

WDFW favors a processed based approach to stream restoration as described by Beechie et.al 2010:

" *Process-based restoration aims to reestablish normative rates and magnitudes of physical, chemical, and biological processes that sustain river and floodplain ecosystems….four process-based principles that ensure river restoration will be guided toward sustainable actions: (1) restoration actions should address the root causes of degradation, (2) actions must be consistent with the physical and biological potential of the site, (3) actions should be at a scale commensurate with environmental problems, and (4) actions should have clearly articulated expected outcomes for ecosystem dynamics.*".

2. Project Actions

WDFW and other restoration partners proposed stream restoration actions in the larger Tucannon River basin based on a framework proposed by Roni et al. (2002), involving:

1. Promoting natural hydrologic and sediment routing throughout the system, allowing natural channel migration and wood recruitment.

2. Reconnecting oxbows, wetlands, and former mainstem and side channels on the floodplain.

3. Removing or modifying culverts and bridges, levees, dredge spoils, diversion dams, and grade control structures.

4. Isolating and protecting healthy riparian areas, eradicating invasive species, and planting native communities

5. Installing large individual trees and LW structures in the main channel to improve instream habitat conditions.

These actions generally address noted ecologically limiting factors in the Tucannon River such as poor riparian condition, poor habitat diversity (e.g., pool habitat and LW loading) and elevated summer water temperatures.

Restoration objectives for Project Area 13 focuses on aggrading the channel in strategic areas to re-connect floodplain and improve in-stream habitat. This will be accomplished using four large plug areas designed to lift the bed approximately 3 feet in key locations. The plugs are engineered logjams buried with designed streambed mix, and then topped with 3 inch minus gravel. Restoration actions also involve removing levees (except those necessary to maintain hatchery operations) that restrict natural floodplain connectivity and channel migration. Although some LW is present, little is being recruited within the project area or transported from upstream; therefore, LW will be placed throughout the channel. The intent of the LW is to provide areas of channel aggradation and improve bedload “residence time” throughout the reach. Additionally, LW structures will increase channel complexity and roughness, resulting in a more natural pool and riffle stream channel. Some of the LW structures will also cause channel bank erosion and provide additional bedload and large wood recruitment over time.

2.1 Geomorphic Implications

Levee removal and logjams will allow the channel to adjust via bank erosion and channel migration, establishing a more natural configuration that allows for retention of LW and sediment. These conditions will decrease channel velocities during high flows and allow pools to form and spawning gravels to collect. Reconnecting low-lying floodplain will allow dispersion of floodwaters, decreasing velocities in the main channel and allowing for dispersion of overbank sediments and mobile debris. LW placement in the project area will force pools and hydraulic variability in this dominantly plane-bed, simplified channel in the short term. Placing ELJs in strategic locations will promote side channel development through the low-lying areas in the floodplain, increasing channel complexity.

The hatchery road bridge does not appear to have influenced the local and upstream stream grade significantly. The local bed grade is in line with upstream and downstream slope in the

LiDAR-derived long profile. HEC-RAS modeling indicates that the bridge begins to backwater between the 10 and 25 year floods, but has sufficient conveyance for the 100-year flood.

2.2 Biological Benefits

Immediate biological benefits of the project include decreased instream velocities during high flows, additional instream complexity, and pool development via LW placement. In the long term, opening up the floodplain will increase complexity through the project area, providing diverse habitats for various life stages of endemic fish such as spawning substrate, holding areas, side channels for rearing, and high-flow refuge.

2.3 Potential Challenges

Site access and project actions will likely involve disturbance and removal of some existing vegetation. Any trees growing on levees to be removed will be incorporated into ELJs or other elements of the design. Levee removal will require a large amount of earthwork. The natural streambed material from the levees will be used as gravel augmentation for the project. The armor materials that compose the levee will be used in roughened channel mixtures. An infiltration gallery (spring water collection) used for hatchery operations is located in the low-lying floodplain upstream of the access bridge (right bank). This area will be maintained in its existing condition to avoid water quality problems for the hatchery. Work window timing is a concern due to Spring Chinook spawning in the reach. The project construction will be implemented in two phases to reduce in-stream impacts to Adult Spring Chinook in any one year. The preference is to complete the downstream reach of the project first so that channel changes upstream will benefit downstream habitat development. Each phase will include bypass for fish migration. The bypasses are designed to function as long-term elements of the overall project. Access pathways and disturbed areas will be re-planted with native grasses and trees. WDFW has planted trees in the past and it has been difficult to achieve survival objectives for those plantings. It is likely we may need to return and plant additional trees if conditions are not favorable.

3. Project Design

3.1 Design Objectives and Philosophy

The design addresses the following six objectives within the project reach.

- Re-connect the river to its floodplain by raising the streambed elevation locally and by removing existing levees.
- Connect/activate side channels to provide additional juvenile rearing opportunities.
- Add LW to sort and store bedload, provide habitat, and increase channel roughness and frequency of flooding.
- Add alluvium to the channel to mitigate the effects of bedload storage above the hatchery intake dam.
- Reduce the number of adult fish trying to jump over the left end of the hatchery intake dam.
- Avoid increased flooding of the hatchery spring water collection gallery.

The initial proposal for reconnecting the floodplain was to place a series of four channel-spanning LW structures (plugs) to raise the river stage. The expectation was that the structures would collect gravel and eventually raise the bed elevation 3 – 3.5 feet locally. At the same time, we wanted to use gravel from the levees being removed to replace gravel that has been intercepted for decades by the hatchery intake dam. We decided to use levee material to bury the LW structures rather than wait years for it to happen naturally. The added gravel would increase the river stage immediately as well as providing additional stability to the plugs. These structures were then designated as buried plugs.

Two additional plug structures were designed to initiate channel meandering and bank erosion in a straight section of the channel. These “partial plugs” include a constructed gravel bar that fills half the channel width, paired with a concave excavation of the opposite bank. The excavated bank will be purposely left at a steep angle to encourage erosion during high flows to expand the meander and contribute gravel. The partial plugs are adjacent to each other and on opposite banks, which will locally increase channel sinuosity.

Levee removal will improve floodplain connectivity. Existing levees will be removed in two locations, and a third levee will be breached in several locations. The levees are all on river right. The two removed levees are approximately 400 and 250 feet long, respectively.

Three remnant side channels will be activated by the project. The upstream channel (sta 20+00) will be activated by raising the water surface with a buried plug at the inlet, by removing a levee between it and the river, and by removing a minor amount of soil at the inlet. The middle, and longest, side channel (sta 16+00) will be activated with another plug in the river at the inlet, and by excavating an inlet channel for about 50 ft. The lower end of the channel requires some excavation to re-connect to the river. The downstream side channel (sta 7+35) will be activated by placing a bar apex jam next to the inlet and excavating a minor quantity of material to open the inlet.

Besides adding gravel at the buried and partial plugs, gravel augmentation will occur at four additional sites. The augmentation berms will occupy about half the channel toe width, and will be spread throughout the reach. They will add a combined total of 2285 cubic yards of gravel to the channel.

The Tucannon Hatchery uses spring water that is collected by an infiltration gallery buried in the right floodplain at the lower end of the project. Hatchery staff are concerned that increased flooding could lead to contamination of the collection gallery. HECRAS results indicate that the current levee prevents that area from flooding until a flow of approximately 3132 cfs (a 15 - 20 year flood). The proposed project will increase the flood stage in this area. To replicate the current frequency of flooding, an existing lateral berm at the upstream end of the collection gallery will be raised to the new elevation of the 3132 cfs flow.

The Tucannon Hatchery intake dam is equipped with a fish ladder and trap, and WDFW staff attempt to trap all upstream migrants. Some migrants attempt to jump the dam rather than enter the fish ladder, which is located at the right bank. Many fish jump at the left end of the dam, and it is hypothesized that they may not be finding the ladder entrance. The project includes three actions to reduce fish attraction to the left end of the dam. These include building two boulder barbs at the left bank upstream of the dam, and filling a portion of the plunge pool below the dam to reduce depth for fish attempting to jump the dam. Third, an armored bar will be constructed in the left half of the channel downstream of the dam to encourage fish to move up the right side of the river and find the ladder entrance more readily.

3.2 Hydrology

Flow records are available from three gages on the Tucannon River. Washington Department of Ecology has maintained a real-time station (#35B150) at Marengo approximately six miles downstream on the Tucannon River, since 2003. It also maintains a gage in Pataha Cr. (35F050), a major tributary of the Tucannon, near its confluence with the Tucannon River at RM 12.5. A USGS gage (#13344500) is located farther downstream near Starbuck approximately seven miles upstream from the confluence with the Snake River, with records extending back to 1914.

While the Marengo gage is closest in proximity to the project site, it is not particularly well suited to extrapolating to large flood events because of its limited period of record. With 59 annual peak flows measured between 1915 and 2015, the Starbuck gage is better suited to estimate large flood events, having recorded much higher return period events.

An instream flow study performed in 2003 at Marengo recommended minimum instream flows during the July-October period to range between 60 cfs and 90 cfs (Barber et al. 2004). Based on daily flow data at the gage, these flows are exceeded approximately 80% and 20% of the time, respectively, during those summer months (Figure 9). Accordingly, the low flow design criterion for modeling water levels at instream habitat structures was set as 60 cfs.

Climate change impacts are uncertain. The area has been characterized as tending toward a transitional rain dominant precipitation pattern in terms of the ratio of peak snow water equivalent to October-March precipitation. Large scale modeling results predict a long term reduction in April 1 snowpack and July 1 soil moisture, an increase in winter precipitation, and changes in pine species composition in the project area region (Elsner et al. 2010; Littell et al. 2010). The results suggest that peak runoff events are likely to increase in magnitude for a given recurrence interval, and summer stream flows will decrease.

Design flows for the project site were determined using hydrology modeling described in Appendix A of the Tucannon River geomorphic assessment developed by Anchor QEA, LLC (Columbia Conservation District, 2011). The Anchor evaluation included Log Pearson III analyses of peak flows using both annual and partial duration series from the Starbuck gage. Flow estimates were modeled for various un-gaged locations along the river using a basin area scaling method. Those results were further analyzed by correlating Starbuck gage flows with those from the other gage sites, and correcting the basin scaling method based on those correlations. The basin scaling method and corrected basin scaling method give low and high peak flow estimates, respectively. The corrected basin scaling method seems a more accurate, and conservative, model for the upper Tucannon and was used to estimate design flows for PA13. The following table lists design flows for various recurrence intervals for our site.

Recurrence Interval (yrs)	Design Flow (cfs)
1	286
2	697
5	1555
10	2898
25	3808
50	5169
100	6823

Table 1. PA 13 project design flows.

The other design flow of significance is the high flow during the construction season, July 15 – Aug 15. This is needed to design flow bypass channels needed to dewater construction zones. During the years, 2006-2016 thirteen spot flow measurements were taken at locations on the Tucannon between the Hatchery Bridge and Curl Lake. These flows (Q) were compared to same day flows at the Marengo gage in the form of the ratio:

$$spot\ Q/Marengo\ Q$$

The average value of the 13 ratios was 0.71. This average was then multiplied by the highest single day flow at the Marengo gage for the construction season for the period of record (136 cfs). The result, 97 cfs, is used as the construction season high design flow.

3.3 Design Feature Details

Buried plug 1 (BP1) – Sta 37+25 – 35+25

BP1 (sheet 5 of drawings) totals 200 feet in length, including 100 feet of sloped channel at 3.2% grade and 50 feet of relatively flat, backwatered gravel upstream of the sloped portion. The remaining length is transition to existing grade. The plug will raise the streambed about 3.2 feet at its crest. The flat section upstream of the buried logs was included to provide a stable location for a pit tag array that is currently deployed in the vicinity. The plug includes two constructed gravel bars on opposite banks, which will add some diversity to the relatively straight channel. They will constrict the thalweg to about 20 feet wide.

The streambed material in the sloped portion will be a stable roughened channel gradation. It will likely be a number of years before bedload is transported from upstream through the steepened channel, so the roughened channel mix together with the buried logs will maintain a stable channel profile. The material upstream of the logs will be a general alluvium mixture taken from levee excavation. The grades shown in the drawings are finished thalweg grades of the roughened channel. The entire plug will then be covered with an additional 6 – 12 inches of smaller river gravels, screened from spoils of the Rainbow lake reconfiguration project of 2017.

In the initial design, logs in the plugs were stabilized by burying them in gravel and by chaining them to large boulders. When it was determined that the use of chain or cables would not be allowed in the project, buried pilings were included to help stabilize the logs in the plugs. Boulders will still be included to buttress some logs, and some logs will be tied to boulders or pilings with hemp rope.

New meander channel

One project objective was to activate side channels or high flow channels. One of the few areas in the reach where existing topography made this feasible was around stations 32+00 to 34+00. Rather than create a high flow channel in the right floodplain it was decided to excavate a low flow channel and leave the existing channel as a high flow channel. This new channel is 140 feet longer than the existing channel. Buried plug 2 (see below) will be a hydraulic control forcing low flow into the new meander. The new meander length will be 340 feet (see sheet 12), with an overall slope of 1.1%. Channel toe width is 20 feet. Multiple log structures, stabilized by burial and log pilings, will be constructed in the new channel to provide habitat. It is expected that since the banks will not be armored, the channel boundaries will shift from scour caused by constriction at log structures.

Buried plug 2 – Sta 35+00 – 32+00

BP2 has two main functions. First, it is a hydraulic control in the main channel to ensure that low flow is directed into the new meander channel. This function is achieved using a channel-spanning structure of rootwad logs, boulder buttresses and racking logs buried in gravel, to create a control elevation about 1.7 – 2.2 feet higher than the inlet to the new meander (see sheet 5). The upper 30 feet of the plug will be constructed with a roughened channel mix to ensure an initial thalweg elevation. While all the low flow will go through the new meander, flow will go over the plug at less than a 2-yr flood.

The second function is as a gravel augmentation berm for the downstream channel. The channel will be filled with a general gravel mix 4-5 feet deep for 120 feet of length, then tapering off to match the existing bed in the downstream 50 feet. A second channel-spanning log structure midway through its length will provide additional stability to the plug. However, during high flow events the steep section at the downstream end of the plug will begin a head-cut that will supply gravel to the channel downstream.

It ultimately does not matter if the new meander remains the low flow channel or if BP2 gradually erodes and the existing channel is re-established as the low flow channel. Both channels will have logjams for habitat, flood flows will be spread between two channels and a side channel or high flow channel will be established.

Upper levee removal

The upper levee extends from station 37+00 to 32+00 and appears to be made of river alluvium. It is armored with large riprap at the upstream end for less than 100 feet. The levee will be used the first construction season as a road access for placing LW structures in the downstream left floodplain and for placing the gravel augmentation berm from station 27+00 to 23+60. Later the levee will be removed and used for gravel augmentation material and for buried plug fill. Approximately 2200 cubic yards of material will be excavated, with a footprint of 18,000 ft^2.

LW structures in active floodplain – Sta 31+50 – 28+00

This section has low floodplain on river left, and the river currently makes a sharp S-shaped meander. This is the only part of the reach where the floodplain is currently connected to the river. Six LW structures will be built in this section, with several purposes. Two buried logjams will be constructed in the floodplain (left bank) to provide habitat if the river migrates into this area. One un-anchored logjam is located on the left bank across from the outlet of the newly built meander channel. Its purpose is to reduce the potential for an immediate avulsion across the floodplain, which would reduce channel length locally. A similar structure near sta 28+00 will perform the same function on the right bank. Two other log structures will be placed in the existing channel to provide fish habitat.

Buried plug 3 – Sta 20+70 – 18+00

BP3 (sheet 7) is similar to BP1, except the first 50 feet downstream of the crest is a roughened channel at 1.4% slope, followed by 125 feet of LW-stabilized channel at 3% slope. Upstream of the crest the channel will be filled with screened gravel for 70 feet, gradually tapering to meet the existing bed. This will provide bedload to the plug at high flows and is a likely spawning location for chinook or steelhead.

The crest of BP3 is located adjacent to the head of a small right bank side channel that has been cut off by a gravel berm. That berm will be removed and it will become an active high flow channel. The crest of the plug will be 1.5 feet lower than the high flow channel inlet, and about 3 feet higher than the existing thalweg. BP3 will have three gravel bars instead of two. The downstream end of BP3 will be backwatered by BP4.

Buried plug 4 – Sta 17+25 – 14+75

BP4 (sheet 8) was originally designed with two spanning LW structures. The upstream crest is located at the proposed inlet to a left bank side channel, and provides grade control to direct flows into the side channel. During the ongoing design process, it was decided to replace the upper LW structure with an armored transverse gravel bar. The crest of the bar will be high at the right bank, with the thalweg at the left bank next to the side channel inlet. The bar will be constructed with roughened channel material, with additional 2-ft boulders added to the downstream face of the bar. The overall thalweg slope of BP4 is 2.6%.

The downstream LW structure was also altered from a full span structure to ½ the channel width. The logs will be stabilized by burying in the bed, with boulders, and with log pilings. A 25-ft wide gravel bar will be placed in the hydraulic shadow of the logjam, 1.5-ft thick and 40-ft long.

Side channels

Three existing side channels will be activated by the project. The first (sheets 7, 8) runs parallel to the channel beginning at sta 20+00. It remains a defined channel to sta 17+50 and then transitions into unconfined floodplain. The side channel is separated from the mainstem by a vegetated gravel berm. The berm will be excavated, which will allow the side channel to function as a high flow channel. Following berm removal, the bank at the inlet will be 1.5 feet higher than the crest of BP3. High flow should begin entering the side channel at ** cfs.

The second side channel will begin at sta 16+00 adjacent to BP4 and will re-connect with the mainstem above catcher's mitt structure CM5 at sta 6+10. A defined relict channel exists along the left valley wall most of this distance but it is separated from the main channel at the upstream end by a gravel berm and because of channel incision. Portions of the side channel receive groundwater inputs and flow year round. A 50-ft long starter channel will be excavated beginning at sta 16+00 to allow surface flow into the channel. The invert of the side channel inlet will be at the same elevation (2190) as the crest of BP4, so it will flow year round initially. The inlet will adjust naturally, so deposition or scour may change inlet conditions and the portion of surface flow into the side channel over time. This channel will add over 1000 feet of channel to the reach. The defined side channel ends 225 feet from sta 6+00, so a new channel will be excavated to reconnect the lower end to the river. The excavated channel will include three small pools with associated LW structures.

The third side channel is an existing high flow channel that is constricted at the inlet. It extends from sta 7+40 to 4+60. An apex logjam will be constructed on the island at the inlet to the side channel and a small amount of gravel will be excavated from the inlet to let it become active at a lower river flow. All three side channels will be used as construction flow bypass during different phases of construction. This will allow de-watering of the main channel for construction of plugs and LW structures.

Partial plugs 1&2 – Sta 14+75 – 12+80

Downstream of BP4, there is a tall levee on the right bank and the channel is well incised. This would make the concept of raising the entire bed enough with a buried plug to re-connect to the floodplain infeasible. Instead, two structures labeled partial plugs 1&2 (PP1 & 2) will be built (sheets 8, 15, 16). While they should raise the streambed somewhat, their real purpose is to start some sinuosity in a straight section of channel and to initiate bank scour to expand that sinuosity. This is achieved by filling half the channel width with gravel bar with logs buried in it, and excavating a 20-ft wide bench into the existing bank opposite the bar. The excavated bench would be left with cut banks as steep as feasible, so high flows would create erosion and supply more gravel to the river. PP1 will have the bar on the right bank and excavate into the left bank, and PP2 would be on the opposite banks. Eventually PP2 may breach the levee on the right bank. Several channel-spanning logs are incorporated in each plug to create the potential for deposition in the current channel.

Catcher's mitt structures – Sta 10+50 – 4+50

As in previous restoration projects on the Tucannon River, consideration is given for protection of existing infrastructure. The main risk in this reach is the bridge on Fish Hatchery Road. Although its span (70 feet) is wider than the logs being installed (45-50 feet), it is a constriction in the floodplain and a potential place for a logjam to form. To mitigate the risk, a group of six logjams will be constructed upstream of the bridge (sheets 9-10) as a catcher's mitt for mobile logs. They are designed to be stable during a 100-yr recurrence interval flood. While they may not catch every individual log, their location and proximity to each other will make it difficult for a collection of logs to get past them and jam up at the bridge.

Gravel augmentation berms

In addition to gravel placed upstream of each buried plug, four additional gravel augmentation berms are included in the project. They are located at stations 39+50 to 37+55, 27+00 to 23+65, 22+70 to 20+70, and 4+40 to 1+55. The estimated quantities in each are 325, 780, 430 and 750 cubic yards, respectively. They will typically occupy half of the existing channel toe width and thickness will vary depending on bank height. Their purpose is to replace some of the bedload that has been removed from flood control channelization activity done in the past and due to the hatchery diversion dam upstream. They are intended to erode during typical high flows, be deposited upstream of the buried plugs, and be sorted and create bars around LW structures. The source of materials is from levees excavated in the project or from Rainbow Lake dredging spoils, depending on suitability of material from the levees.

Fish passage modifications

Fish passage modifications are associated with the hatchery diversion dam will be implemented to help upstream migrants find the fish ladder entrance more effectively. Historically many adult fish are observed attempting to jump the dam, with particular efforts at the left end of the dam. This is the opposite bank from the fish ladder entrance. Three features have been designed to encourage fish to find the fish ladder.

First, an armored gravel bar will be built across the left half of the channel about 25 feet downstream of the dam. The intent is to keep the channel thalweg, and migrating fish, along the right bank. The bar has a relatively flat surface and will overtop between 300-400 cfs river flows. The gravel bar also provides an opportunity to place gravel for future gravel augmentation in the reach.

Second, the plunge pool along the left end of the dam will be filled with boulders and gravel, to deny fish a deep pool from which to leap. The fill would not be higher than the pool tail-out, so there would be some depth for fish dropping downstream over the dam. Filling the plunge pool also eliminates holding water on the left side of the dam, so fish should hold closer to the jet coming out of the fish ladder entrance.

The third feature is meant to decrease the quantity of water passing over the left end of the dam. The crest of the dam is lower in the center than at the edges of the river, which would normally reduce the amount of water passing over the ends of the dam. However, a central bar upstream of the dam has created a thalweg along each bank of the river. During high flows, the velocity in the left thalweg creates enough momentum that the sloped crest is ineffective at reducing flows at the left bank. The proposed solution is to construct two rock barbs at the left bank upstream of the dam to shift the thalweg toward the center of the dam and away from the left bank. Less flow going over the left end of the dam should reduce fish attraction to that side of the dam.

3.4 Construction Flow Control/De-watering

This project will be built in phases over at least two construction seasons. The entire flow will be diverted into bypass channels at four locations to facilitate construction in the main channel. In addition, work will be isolated from flowing water by temporary sandbag/super-sack dams at the four gravel augmentation sites and at several buried logjams outside the four flow bypass zones. All bypass channels will be passable to spring chinook and bull trout that may be migrating at the time of construction. In addition, fish trapping data from the Hatchery Intake indicate few fish migrating during the in-water work window.

De-watering the channel will begin with building a temporary diversion dam at the upstream end of the de-watered section one day, but it will not be sealed until the next day. The leakage through the un-sealed dam will allow fish to survive in the main channel, but the reduced flow will encourage many fish to move downstream out of the reach overnight. The following day, a block net will be placed at the downstream end of the bypass reach and the remaining fish will be collected using electro-shockers and removed from the de-watered zone. Then the upstream dam will be sealed and a second dam will be built across the lower end of the de-watered reach. A sump will be excavated downstream of the temporary diversion dam to collect seepage and leakage and pump it back to the river.

The side channel from sta 7+40 to 4+60 will be used as a bypass channel during construction of structures CM 5&6, as well as excavation of 225 feet of the lower end of the long side channel. A temporary bridge will be used to cross the lower end of the bypass channel. Temporary dams will placed as described above.

After the lower section is completed, flow can be diverted into the side channel from sta 16+00 to 6+00. This will allow construction of catcher’s mitt structures 1-4, partial plugs 1&2 and most of buried plug 4.

Prior to removal of the levee at sta 20+00 to 17+50, the river will be diverted into the adjacent side channel and returned to the river where the Rainbow lake overflow water channel enters the river (sta16+00). This will allow construction of BP 3.

The river will be bypassed around BP 1&2 in a constructed bypass channel (see sheet 13). First, the majority of the new meander channel will be constructed, leaving the upstream end isolated from the river. Then a temporary bypass channel will be excavated in the floodplain from sta 37+00 down to the new meander channel. A temporary bridge over the bypass channel will allow access to construct BP 1&2. Once buried plugs 1&2 are constructed, the plug at the upstream end of the new meander channel will be removed, and the flow returned to the mainstem. The bypass channel spoils will then be placed back in the channel together with some LW. Rather than completely refilling it, a shallow floodplain channel will be left in its footprint.

When each of the bypass channels are decommissioned, they will go through a fish removal process similar to that described for de-watering the main channel.

3.5 LW Structure Stability

Stability of LW structures is of particular concern in this reach because of the bridge at the downstream end of the project. Because the bridge span is 70 feet and the logs being used are 45-50 feet long, movement of individual logs through the bridge is low risk. If a group of logs tied together were to reach the bridge during a flood there would be higher risk of damage to the bridge or abutments. Consequently, the approach to LW stability is to not attach any logs together unless they are designed for stability at the 100-year flood. Only the buried logjams in the catcher's mitt are designed for stability during that design flow.

Single logs in other structures may be tied to individual boulders with hemp rope, but multiple logs will not be tied together with rope. Logs in buried plugs will be stabilized by being buried, by boulder buttresses, by log pilings, or by bracing against live trees on the banks.

Stability analysis of catcher's mitt buried logjams was approached by considering the balance of forces in both the horizontal and vertical axes. Uplift forces on the logjams are primarily from buoyancy. Buoyancy was determined under the assumption that the logs were completely submerged and dry. Gravitational forces resisting buoyancy are from the gravel the logs are buried beneath and from boulder ballast. Sum-of-moments analysis showed that gravitational forces would provide a factor of safety of 3.0 for vertical stability.

Horizontal forces on the logjams were evaluated in two ways. One approach is to consider the logjam to be a blunt object experiencing drag forces by water flowing past it. The other is to consider the logjam to be a dam under hydrostatic pressure equal to hydraulic head loss created by the structure. In both cases the face of the logjam was assumed to be 35-ft wide and 8-ft high. In the hydrostatic analysis, the head loss was projected to be 3 feet. Hydrostatic conditions produced the largest forces and were used for the analysis. Horizontal forces on the long buried logs are mostly axial, with relatively minor bending stresses, and are easily resisted. The shorter, upright logs were analyzed under bending stress, conservatively assuming the entire horizontal force acted perpendicular to the log cross section. Assuming 18" diameter logs, the factor of safety for bending stress was calculated to be 10.7.

The short logs were also analyzed as cantilever poles to determine the necessary burial depth to resist rotation. Based on a soil pressure of 1500 lbs/ft^2, the required burial depth is 7.2 feet.

3.6 Hydraulic Analysis

A HECRAS 1-D hydraulic model was developed for the project reach. It was based on a combination of a ground survey using a total station, and available LIDAR data. The model extends from upstream of the hatchery intake diversion dam to downstream of the hatchery road bridge. The purpose of the model was to show the impacts of the project on floodplain re-connection, to provide hydraulic data for calculating the dimensions of the roughened channel material for the buried plugs and for calculating stability of the catcher's mitt structures.

The HECRAS model was calibrated with two measured flows (77 and 191 cfs) and then the existing and proposed conditions were modeled. All the design flows in Table 1 were modeled. All changes to the channel and levees were included in the proposed conditions model, with the exception of the gravel augmentation berms. Based on observations of gravel augmentation at the hatchery bridge and downstream of the hatchery, the berms are short term features that will be mobilized at relatively low flows (< 5-yr flood). Inundation maps were developed for the 2-yr, 25-yr and 100-yr flows (Figure 1.). They show that the buried plugs and levee removals will increase inundation during the 2-yr flow at multiple locations. They also show some locations where inundation is decreased where levee removal results in lower flood elevations.

Figure 2. 2-year flow inundation map. Bright green areas are existing inundation. Dark blue areas are proposed conditions inundation. Aqua areas are overlap of existing and proposed conditions.

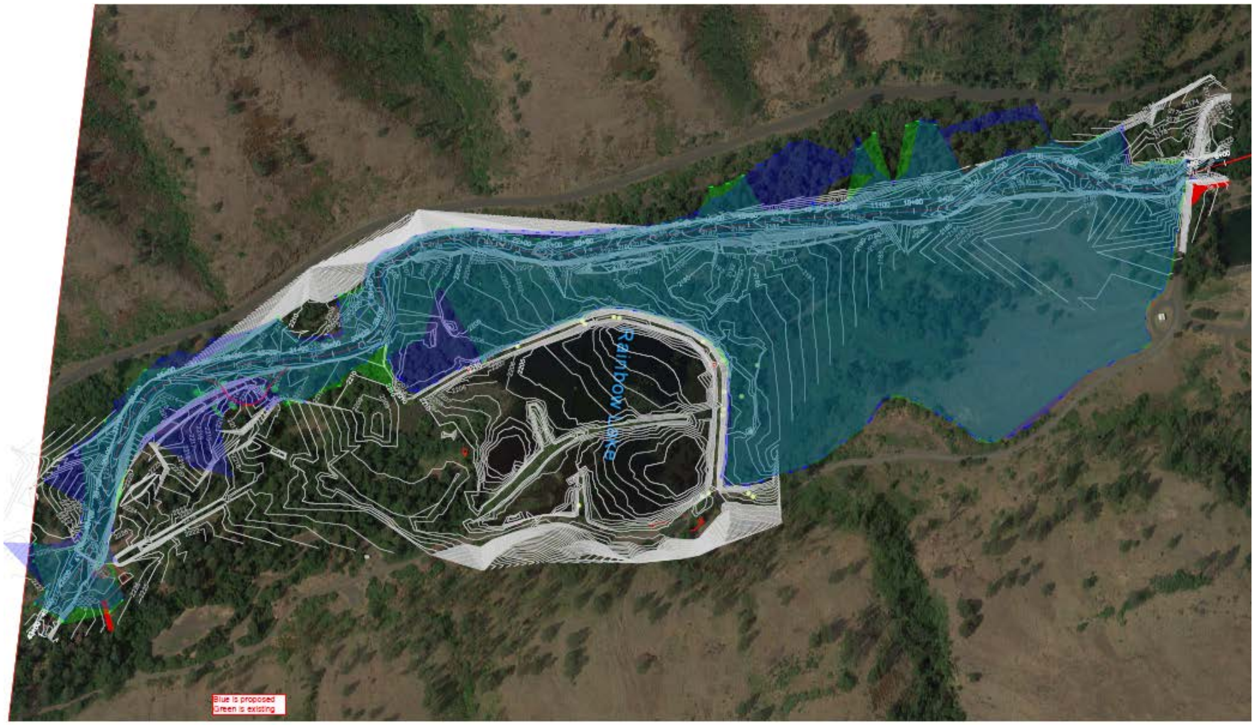

Figure 3. 25-year inundation map. Bright green areas are existing inundation. Dark blue areas are proposed conditions inundation. Aqua areas are overlap of existing and proposed conditions.

Figure 4. 100-year inundation map. Bright green areas are existing inundation. Dark blue areas are proposed conditions inundation. Aqua areas are overlap of existing and proposed conditions.

Increases in flood inudation at the 2-year flow are mainly the result of the buried plugs. Inundation at and above the 25-yr event is significantly affected by levee removal.

Hydraulic conditions of particular note in the proposed project include:

- Buried plug 1 – The right bank is topped at 400 cfs, compared to being overtopped at 1650 cfs in existing conditions. The area behind the levee is inundated at 1708 cfs whereas currently it would not be flooded by a 100-yr flood.
- Buried plug 2 – Flow tops the plug at 125 cfs, meaning flow will be split between the new meander channel and the plug during typical winter-spring flows.
- Buried plug 3 – Following levee removal the right bank overtops at 174 cfs and flow enters the existing right bank side channel. Currently that levee would be overtopped at 3760 cfs.
- Buried plug 4 – The new left bank side channel will be watered at low flows.
- Sta 7+30 – The right bank side channel will begin flowing at 390 cfs.
- Hatchery Road bridge – The 100-yr flood just contacts the upstream lower chord of the bridge in both existing and proposed conditions.

Each of the buried plugs will backwater the immediate upstream channel, allowing the deposition of smaller bed material than the current cobble/boulder bed. Modeled velocity reductions upstream of the plugs range from 1.7 – 4.5 ft/s during the 2-yr flood, and 2.2 – 5.7 ft/s during the 10-yr flood.

Roughened channel bed material gradation was developed by calculating the D_{84} dimension using the Bathurst and Corps of Engineers methods (WDFW 2013). An average dimension of 2ft diameter was calculated. Applying the bed gradation ratios in the WDFW guidelines resulted in the following gradation:

Fraction	Diameter (ft)
D_{100}	5
D_{84}	2
D_{50}	0.8
D_{16}	0.25
D_{5-10}	fines

Table 2. Roughened channel material gradation.

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