Photo credit: Megan Stites

Engineering the Calapooia River for Reduced Streambank Erosion

Presented by Streamlined Designs:

Submitted to:
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Executive Summary

This report was written to address streambank erosion of an agriculturalist's land on the Lower Calapooia River. Students in OSU's River Engineering course, under the guidance of Dr. Desiree Tullos, conducted a field survey, produced a hydraulic model, and analyzed several courses of action, or "alternatives", with the intent of stabilizing the farmer's bank while improving habitat for native species and maintaining streambank aesthetics. The combination of a streambank setback and multiple engineered log jams are recommended to achieve those objectives, after consideration of the social and financial costs associated with this site.

Introduction

In 2011, River Design Group, Inc. (RDG) and the City of Albany assessed the Willamette and Lower Calapooia Rivers to identify river restoration opportunities, with the primary intents of improving habitat for endangered aquatic species, addressing impaired water quality including temperature, and determining key natural resources for protection (RDG 2011). This year, students studying river engineering at Oregon State University utilized the work of RDG to address land erosion concerns by an agriculturalist on the Lower Calapooia. The hazelnut farmer has witnessed extreme erosion, up to 8 lateral feet per year of his property's bank. In accordance with modern practices, students assessed the causes for erosion by site- and reach-based mechanisms and produce two (2) alternatives that protect and restore ecosystem function (Biedenharn 1997; Cramer et al 2002).

The goal of this project was to provide two alternative designs for addressing streambank erosion and habitat degradation on a reach of the Lower Calapooia River for consideration by the landowner, RDG, and the City of Albany. Specifically, the project objectives were:

1) To stabilize the streambank while maintaining streambank aesthetics
2) To improve habitat quantity and quality for native fish species

Methods

A site visit provided an opportunity to analyze the site, consider the type of bank failure, assess the vegetation and soil types in the area, and learn about the experiences of the land owner. Additionally, this provided the opportunity for data collection regarding the river flow and observations that contributed to being able to place alternatives in the modeling process. A GIS analysis following the site visit provided an understand of the natural attenuation of the river through the years (Figure 1).

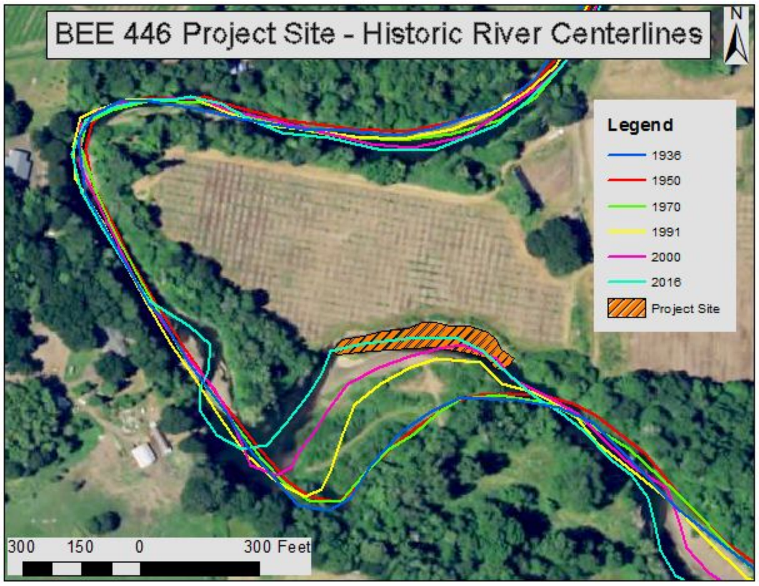

Figure 1 *Historic river centerlines. By observing the lines, it can be noted the river is naturally moving north.*

The system was modeled in HEC-RAS using a 1D, steady-state model. The model was calibrated through comparing water surface elevations as collected from the site visit to modeled values based upon discharge data from the convergence of the Calapooia and Willamette Rivers.

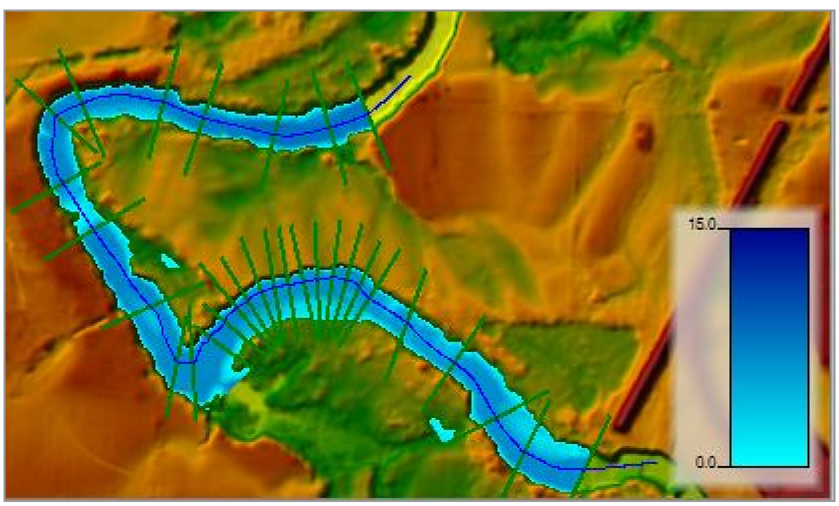

Figure 2 *Depth (ft) for the calibrated flow along the design reach, which was based upon collected water surface elevations at the end of April, 2017 (2710 cfs).*

Our alternatives were designed to withstand a 50 year flood event. This flow was based upon estimated data from a nearby, gauged system, the Mohawk River. From this estimate, 30202 cfs was the 50 year return interval of the Calapooia River (Table 1). Although estimated gauges should be used with caution, this value fell between the interpolated, measured values (36724 cfs) and Streamstats values (26900 cfs). Furthermore, designing for a 50 year event provided an additional level of safety in the face of uncertainty when estimating flood flows in a river system.

Table 1 *Several methods were used for estimating for return intervals on the Calapooia River. Estimated values are correlated from the Mohawk River. Values labelled with an asterisk (*) were interpolated using regression analysis.*

RYI	Estimated (cfs)	Measured (cfs)	Streamstats (cfs)
1	1642	2710	
2	11360	12500	10200
5	16898	19900	15300
10	19096	25800	18900
21	24468.7*	30500	22513.4*
23	23893	30540.4*	22980.2*
25	25621.1*	31204.4*	23500
42	29050.2*	32700	26069.8*
50	30202.7*	36724.0*	26900
100	34784.3*	42243.7*	30400

Both alternatives, described in detail in "Alternatives Assessment", included a streambank setback. The streambank setback was modeled in HEC-RAS by laying the slope back at a 3:1 horizontal to vertical ratio, using the toe slope (the deepest point in the channel nearest to the site of erosion) as the start of the setback (Figure 3). This modification was implemented where erosion was deemed the greatest, as determined by the field site visit between the stations 2322 and 3228.

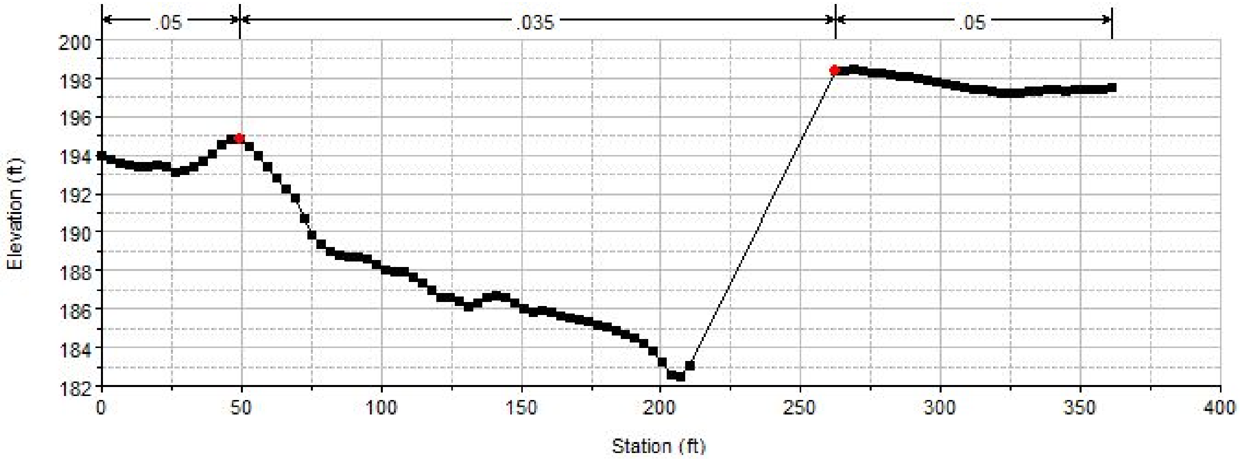

Figure 3 *This cross section, number 3022, depicts a streambank setback as modeled by HEC-RAS.*

The second alternative, which included engineered log jams, was modeled by maintaining the streambank setback as detailed above, and adding obstructed areas at two cross sections, 3022 and 2673 (Figure 4). Section 3022 represents the beginning of the erosion along the bank, and section 2673 lies approximately 350 ft downstream. This spacing was calculated using the recommended length of 3-5 channel widths (Tullos 2017). ELJs extended from the water surface elevation at the calibrated flow and to the base of the hydraulic toe, in order to maximize habitat benefits and energy dispersion, even at base flow.

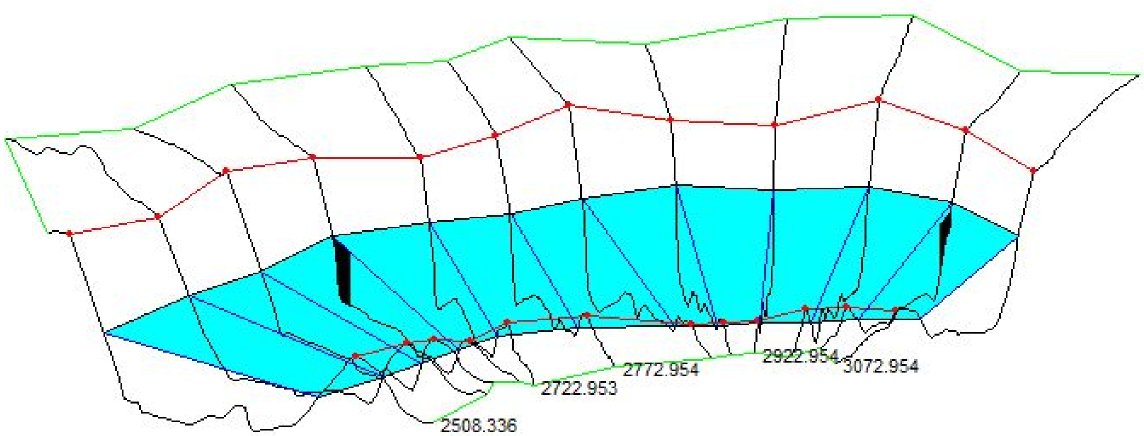

Figure 4 *Cross sections 3022 and 2673 with ELJs included. Obstructions, shown in black, were used in HEC-RAS to represent each engineered log jam.*

Model efficiency was determined by assessing the velocities and water surface elevations along the right side of the channel, both for the purpose of the design and permitting considerations.

Alternatives Assessment

Current Practice: Status Quo

This approach allows the river to flow and erode the river bank as it would naturally. The channel of the Calapooia River moves back and forth across the Willamette valley as it erodes the banks of the river, as seen in Figure 1. This is a natural process that increases sinuosity, dissipates energy, and provides a variety of habitat for the aquatic ecosystem. However, the current rate of erosion is unsustainable for the continuation of the hazelnut farm. Either the landowner needs to alter his farming practices, move, or the bank needs to be stabilized.

Alternative #1: Streambank Setback

A streambank setback reduces the angle of the bank to a 3:1 horizontal to vertical ratio. The reduced angle of the bank and root systems of the vegetation will increase stability of the bank and reduce erosion by decreasing the potential energy of the bank and increasing the roughness of the shoreline. In addition, the vegetation will create riparian areas, increase habitat for fish, and help cool water temperatures in the summer. Native grass, willows, and dogwood trees will be used to create bioengineered reinforcement of the bank (Bentrup 1998). In addition, dogwoods, a broad canopy tree, will provide shade for native riparian fauna.

A streambank setback would help stabilize the streambank and prevent future erosion to a certain extent. However, this option would provide less habitat for fish populations than Alternative #2. In addition, the vegetation described above requires several years to mature, and risks failure if large floods wipe out the newly planted seedlings in the first years after construction. Furthermore, a streambank setback may not be a permanent fix for streambank erosion, depending on the development of the riparian zone and the magnitude of future channel meandering. Although the cost savings by not including an ELJ may be attractive, its exclusion would greatly diminish the environmental benefits of a more complete restoration project.

Alternative #2: Streambank Setback & ELJ

Two engineered log jams could be constructed to direct the flow away from the shoreline, in addition to the streambank setback detailed above. By placing large logs, stacked on top of one another, into the streambank, flow is directed away from the streambank, reducing erosion. By ballasting the system with boulders and ensuring a factor of safety of at least 1.3 for both buoyancy and scour, the threat of the system floating away can be minimized (See "Engineered Log Jam Calculations" in the Appendix). The scour pools, or eddies, created behind the ELJs provide refuge from warm temperatures in the summer and from high velocities in the winter for threatened species like Oregon chub and spring Chinook salmon. The two log jams of four logs each would be placed where the erosion begins and a distance downstream, calculated by the channel width, tortuosity, or effective length of the ELJ (see "ELJ Specifications in Appendix). In this analysis, spacing was calculated using 3-5 channel widths, at 350 ft. However, designs beyond this 15% report should also investigate placing more log jams closer together (~35 ft as indicated by the channel's tortuosity and 3-5 effective lengths). Installing two (or more) ELJs would provide streambank stability, habitat, minimize erosion, and could provide a long-term solution at the local level, making it the Least Environmentally Damaging Practicable Alternative (LEDPA).

Several details should be taken into account before considering the use of engineered log jams in an river engineering project. First, ELJs present a significant safety hazard to recreationalists, like boaters and anglers. Second, Alternative #2 presents the highest cost of any course of action presented in this report. A similar project on Crabtree Creek near Albany, OR cost $133,000 (LCRD 2011). However, beyond the cost of materials (see Appendix), the sophisticated design and intricate construction of safe and effective ELJs often costs $250-$300/linear foot (Tullos 2017). At over 400 linear feet, this alternative may cost between $1,000,000 and $1,200,000. See Appendix A for further breakdown of projected costs. Careful examination of the costs vs the benefits to infrastructure and potential land use should be considered by stakeholders before proceeding with such an expensive endeavor.

Matrix Analysis:

A professional assessment of cost, environmental impacts, and social concerns are summarized in Table 2. Criteria are quantified using values between 0 (least beneficial) and 4 (most beneficial). These scores were averaged between five engineering experts, weighted by category and then normalized to 100%. As can be seen below, Alternative #2 provides the greatest benefit when considering environmental and social implications. However, it scored lowest when considering cost, as the other alternatives either have lower cost (Alternative #1) or none at all (Status Quo). The normalized results of the combined parameters results in Alternative #2 scoring 73.6% while Alternative #1 scoring 57.0% and the Status Quo scoring 40.7%. Future directions for this Matrix Analysis would be to include River Design Group, The Calapooia Watershed Council, the hazelnut farmer and other stakeholders to determine the fairest parameter weighting system.

Table 2. *Matrix analysis of alternatives.*

Project Parameters	Sub Categories	Weighted Score	Status Quo	Alternative #1 (Streambank Setback)	Alternative #2 (ELJ & Streambank Setback)
Cost (30%)	Materials	0.3	3.8	1.8	1.4
	Labor	0.4	3.8	2	1.4
	Operation & Maintenance	0.3	3.4	2	2.2
	Total	1.0	3.7	1.9	1.6
Environmental (35%)	Riparian Zone	0.2	0.6	2.8	3.6
	Fish Habitat - Winter	0.25	0.6	2.2	3.8
	Fish Habitat - Summer	0.25	1.0	2.2	3.8
	Water Quality	0.15	1.0	2.4	3.2
	Temperature	0.15	1.4	2.0	3.4
	Total	1.0	0.9	2.3	3.6
Social (35%)	Meets Hazelnut Farmers Needs	0.65	0.2	2.6	3.6
	Meets Local Needs	0.35	1.4	2.4	3.0
	Total	1.0	0.6	2.5	3.4
Normalized Assessment of Options (100%)			**40.7%**	**57.0%**	**73.6%**

Permit Analysis:

In order to conduct any engineering work along the streambank, a series of permits must be acquired. A United States Army Corps of Engineers (USACE) permit is triggered by any river engineering project, including dewatering dredged materials, cofferdams, and storage within a waterway (Zinszer and Casey 2013). Because Alternatives 1 and 2 both include a streambank setback, material will need to be dredged from the riverbank and added to the bank toe as armoring. The permits required for each of the 3 project options are summarized in Table 3. Assuming approval, these permits should take between 4-8 weeks to acquire.

Table 3. *A table of the applicability of several permits to the design alternative.*

Required Permits	Permit Name	Status Quo	Alternative #1 (Streambank Setback)	Alternative #2 (ELJ & Streambank Setback)
USACE Clean Water Act	Section 404	No	Yes	Yes
USACE Rivers and Harbors Act Section 10 Authorization	Section 10 for structures in a navigable waterbody	No	Yes	Yes
U.S. Fish and Wildlife Service (USFWS)/National Marine Fisheries Service (NFMS) Endangered Species Act Take Authorization	Section 7 “Biological Opinion” or Section 10[a] “take permit”	No	Yes	Yes
RWQCB National Pollutant Discharge Elimination System Permit	NPDES	No	No	No

Limitations

Our design was limited by the input data and modeling capabilities of a 1-dimensional model. For example, insufficient LiDAR data was collected to accurately model the floodplain boundaries. For this reason, HEC-RAS greatly overestimated the water surface elevations for flows over bankfull. As a result, water surface elevations during high flow events (including the 50 year flood) may not be trusted from the model. In addition, a 2-dimensional model would better represent the flow lines and eddies created by engineered log jams near the streambank. It is recommended that a more complex model be calibrated to the study site before implementing the alternatives listed here.

Furthermore, the success of our alternatives to improve habitat quantity and quality is limited by their suitability for native species. For example, although ELJs are designed to introduce complexity to the flow, provide habitat and improve water quality, their use by Oregon chub, spring Chinook salmon, and other native animals is dependent on animal preference and other factors beyond the control of this design. Similarly, high flow events soon after construction may alter or destroy design features like planted vegetation in a streambank setback before it is able to take hold in its new environment; uncertainty exists concerning the suitability and success of any river design project.

Recommendation

Streamlined Designs recommends the installation of two or more engineered log jams in conjunction with a streambank setback (Alternative #2) to maximize social and environmental sustainability, fish habitat, and project longevity. If intervention is deemed appropriate based on social and financial considerations, Alternative #2 provides the best solution for preventing further erosion of the hazelnut farmer’s land. Figure 5 shows the recommended site layout.

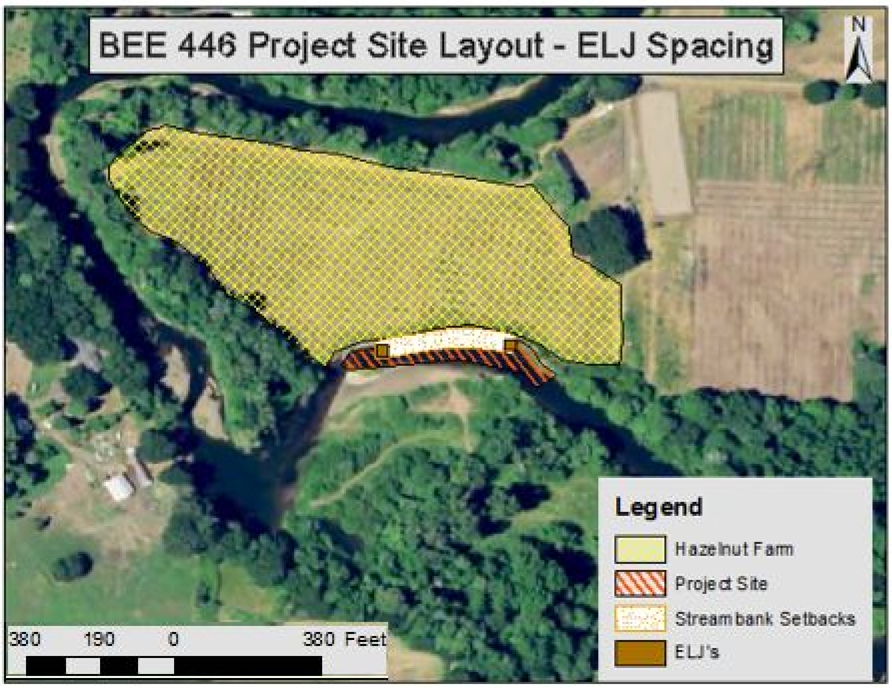

Figure 5 *Site layout of Alternative #2, including ELJ locations and streambank setback.*

Sources:

Bentrup, Gary and J Chris Hoag. "The Practical Streambank Bioengineering Guide." USDA Natural Resource Conservation Service Plant Material Center. May 1998.

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Cramer, M., K. Bates and D. Miller. "Integrated Streambank Protection Guidelines." Washington State Aquatic Habitat Guidelines Program, 2002.

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River Design Group, Inc. "Calapooia River – Albany Assessment and Project Implementation Plan – Final Report." Submitted to the Calapooia Watershed Council, 29 April 2011.

Tullos, Desiree. BEE 546: River Engineering. Lecture. Spring 2017.

Wright, Scott, P.E. "Engineered Log Jam Calculator." NRCS, Oregon, Version 1.2. Date unknown.

Zinszer, S H and J. Casey. "SLOPES V Restoration." National Marine Fisheries Service. 19 March 2013.

Appendix A:

Figure A.1 *The velocity of the channel at the status quo (unchanged), with a streambank setback (17), & with a streambank setback plus ELJ (19) with the ELJs marked (circled, in red)*

Table A.2 *A table of the materials needed for each of the two ELJs.*

Engineered Log Jam Materials				
	Log Type	**# of Logs**	**# of Boulders**	**Boulder Diameter**
Engineered Log Jam	Douglas Fir	4	2	6.0 feet

Table A.3 *A table of the cost of the materials for two engineered log jams.*

Engineered Log Jam Material Cost			
Material	**Unit Cost**	**Number of Units**	**Total Cost**
Douglas Fir	$300	8	$2400
Boulder	$186.50	4	$746
Material Cost for 2 Engineered Log Jams			**$3146**

Table A.4 *A table of the specifications for engineered log jams 1 and 2. The specifications for both log jams are identical.*

Engineered Log Jam Specifications					
	Effective Length	**Area of Waterway Obstructed**	**Percent Area of Waterway at 50-year Event**	**Percent Area of Waterway at Bank-full Discharge**	**ELJ Spacing**
Engineered Log Jam	12 ft	79 ft^2	1%	10%	350 feet

Table A.5 *A table of the specifications for the scour pools created by each log jam during the 50-year flow event.*

Engineered Log Jam Scour Pool			
	Average Upstream Flow Depth	**Froude Number Upstream of ELJ**	**Depth of Scour Pool Created by ELJ**
Engineered Log Jam 1	21.6 ft	0.19	10.7 ft
Engineered Log Jam 2	22.3 ft	0.18	10.7 ft

Table A.6 *A table of the factors of safety for both engineered log jams. The factors of safety are for the 50-year flow event.*

Engineered Log Jam Factors of Safety		
	Buoyancy FS	**Sliding FS**
Engineered Log Jam 1	2.5	3.4
Engineered Log Jam 2	2.5	4.5