Calapooia River Fish Passage

Engineering Design Report

[redacted]

Spring, 2013

Image credit: Chris Gifford-Miears

Contents

1 Background and Existing Conditions

This project was completed as a part of Oregon State University's BEE 456 River Engineering course in association with the Calapooia Watershed council. The goal was to develop a design for an alternative structure at the location of three culverts at a road crossing in the lower Calapooia River basin with consideration to fish passage. The existing culverts have been found to be a barrier to fish passage due to low water depths, high velocities, and the presence of an outlet drop.

1.1 Location

The project site is located at 31886 Oregon 99E south of Tangent, OR on the Calapooia River. The culverts are privately owned and maintained by Mr. Slate. His property spans the river, and the stream crossing is used to transport farming equipment. Mr. Slate reported that the river annually overtops the stream crossing. The landowner also stated that large debris regularly has to be removed at the crossing. In the summer boaters use this section of the river. He also expressed desire for a bridge crossing for ease of debris removal, rather than a culvert option.

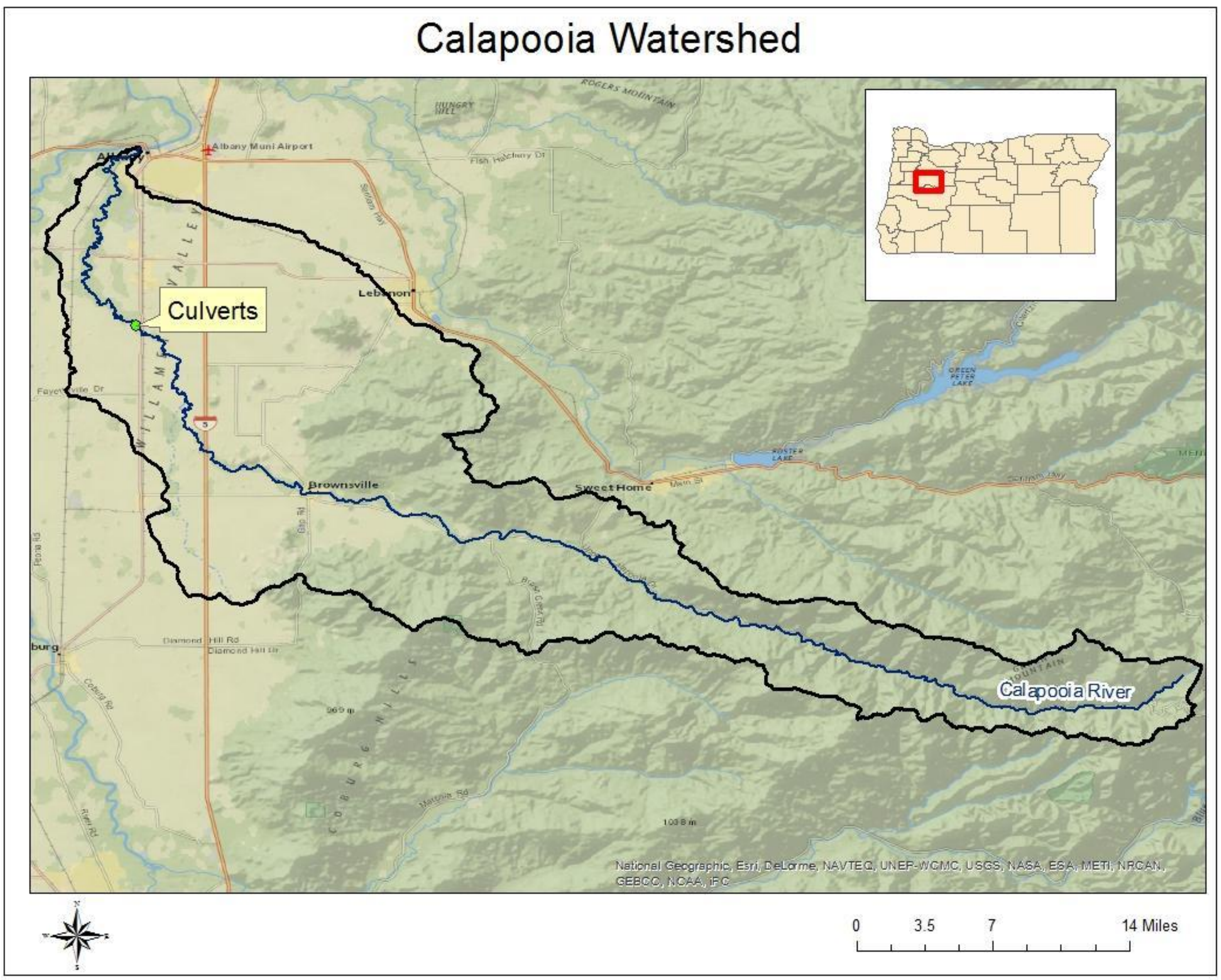

Figure 1 Location of the project site

1.2 Project Goals

The primary objective of the project is improvement of fish passability at the stream crossing, which is the last fish barrier on the Calapooia River. The crossing is required to be passable at all times by adult and juvenile Winter Steelhead (*Oncorhynchus mykiss*), Chinook Salmon (*Oncorhynchus tshawytscha*), and Pacific Lamprey (*Lampetra tridentata*). Auxiliary objectives of the project include the design of a crossing structure that reduces the amount of maintenance required by the landowner, who regularly removes debris from the existing culverts, and the ability to safely support heavy farm equipment of up to 100,000 pounds.

1.3 Watershed & Climate

The Calapooia River is one of the major tributaries of the Willamette River, running for 72 miles from its headwaters in the Cascade Mountains to its confluence with the Willamette near Albany, Oregon. Its watershed encompasses approximately 365 square miles of land, providing for a multitude of land uses and habitat for diverse species. The project site is located approximately ten miles upstream of the city of Albany, and drains about 290 square miles of the watershed, making it an important location in terms of fish passage. The moderate, oceanic climate of western Oregon characterizes the basin, with warm, dry summers and cool wet winters. The average annual precipitation in the region is 58.4 in. The basin geomorphology and its relatively steep slopes result in a somewhat 'flashy' system.

1.4 Channel Characteristics

The survey of the culvert site included downstream cross-section profiling, GPS water surface elevation surveying, and normal high flow bank height surveying. The slopes, locations and elevations of the culverts were also recorded. During this initial characterization, we could observe the culverts created a large pool at the upstream end because of its extreme outlet control and it was just at the brink of overtopping.

Figure 2 Downstream view of the channel from the river crossing
Image credit: Chris Gifford-Miears

Parameter	Estimated Value
Longitudinal Water Surface Slope	0.0845%
Bankfull Width	60 ft.
Bankfull Depth	15 ft.
Manning's n	0.045

Table 1 Estimated values of key parameters from site visit

1.5 Hydrology

The Interactive Map provided by StreamStats on the USGS website was used to determine the drainage area for the Calapooia River. The soil permeability, drainage density, mean annual precipitation, and mean elevation based on the measured drainage area were also obtained using the Interactive Map. To determine 5% and 95% flows the USGS regression equations for December and August, respectively, were calculated using the aforementioned basin characteristics (United States Geological Services, 2013).

Parameter	Discharge (cfs)	Standard Error (cfs)	Conservative Value Used (cfs)
5% exceedance (high flow)	5140	± 1140	6280
95% exceedance (low flow)	39.7	± 30.5	9.2

Table 2 Flows used in determining fish passability

1.6 Fish Presence & Use

Fish distribution data was obtained from the Oregon Department of Fish and Wildlife. The species of concern in the region are winter Steelhead, spring Chinook, Pacific Lamprey, and Oregon Chub. Distribution and swim speed data was not available for the Oregon Chub, so designs were based on data from other target species. Chinook and Steelhead have been observed in the Calapooia River and some major tributaries above the culverts. Pacific Lamprey are restricted to the Calapooia River mainstem below the culverts. Using the fish distribution data it was estimated that access to 56 miles of upstream habitat would be opened or improved by removal of the existing barriers to fish passage.

1.7 Existing Culverts

Culvert characteristics were determined at the site visit. Note that culverts were designated 1-3 from river left to river right.

	Value		
Culvert Parameter	**Culvert 1**	**Culvert 2**	**Culvert 3**
Type	Circular	Circular	Circular
Diameter (ft.)	10	6	7
Material	Corrugated metal	Corrugated metal	Corrugated metal
Entrance	Projected	Projected	Projected
Installation Type	Not embedded	Not embedded	Not embedded
Roughness[1]	0.019	0.019	0.019
Culvert Length(ft.)	41	37	50
Culvert Slope (%)	1.7	0.19	-0.55

Table 3 Culvert characteristics.

Fish passability was assessed for each culvert over a range of flows using FishXing v.3, a program designed by the US Forest Service to evaluate fish passage at culverts. The results are tabulated below. For more in-depth information on the results of the simulation (including percent passability for each species at each culvert at different flows), please refer to Appendix A.

Location	Type of Barrier
Culvert 1	Velocity
Culvert 2	Depth, Velocity, Drop
Culvert 3	Velocity

Table 4 Type of passage barrier each culvert represents to the species of interest

[1] Based on measurements of the pitch and rise of culvert 1, and the USGS Techniques of Water-Resources Investigations Report (Bodhaine, 1968)

Figure 3 Upstream inlet of the culverts
Image credit: Chris Gifford-Miears

Figure 4 Downstream outlet of the culverts
Image credit: Chris Gifford-Miears

2 Fish Passage Design

Fish passage along the Calapooia is important in providing habitat and spawning areas for native fish species. The Tangent culverts remain the last fish passage barrier along this stretch of the Calapooia River, and currently do not allow for complete passage for all fish species.

2.1 Fish Passage Criteria

Fish passage design was based on the requirements for streambed simulation options outlined in Oregon Administrative Rule (OAR) 635 Division 412 - Fish Passage. Streambed simulation strives to allow fish passage by creating a road-stream crossing that is essentially continuous with the adjacent channel with respects to hydraulics and geometry. The stream is not supposed to "see" the crossing. The streambed simulation approach was used to design the replacement bridge. Requirements for the streambed simulation bridge option are detailed in Table 5.

Criterion	Requirement
Minimum Water Depth	Same as adjacent stream
Minimum Culvert Width	1.2 x active channel width
Length	No limit
Minimum height	3 ft greater than elevation at active channel width

Table 5 Streambed Simulation Criteria

2.2 Alternatives Assessment

An alternative assessment was used to evaluate any and all possible alternatives to the culvert design including: streamed simulation, a bridge, a retrofit of the current culverts, hydraulic designs, and a "no action" design. Permitting and OAR regulations were applied for each alternative assessed and a conclusion drawn that a flat car bridge would provide the best alternate to the existing culvert design.

2.2.1 Streambed Simulation

This alternative is preferred by regulating agencies, as it allows for natural stream conditions, as described in Section 2.1. This alternative would require a single culvert to span the active channel width, however, and standard culverts do not come in sizes large enough to achieve this. Special culverts can reach spans of forty feet or more, but a still longer span would be required in order to meet streambed simulation requirements for a culvert at this site.

2.2.2 Bridge

A bridge can be either valley-spanning or floodplain-spanning. The floodplain-spanning option is preferable because it would not interfere at all with the river's natural course, but would be impractical at the site, because according to the landowner, the bulk of the property is flooded on a semi-regular basis. A more feasible option is a stream-spanning bridge, which only spans the active channel width with backfill usually spanning the floodplain. According to the OAR standards, a bridge must span 1.2 times the width of the active channel and remain 3 feet above the Ordinary High Water Line (OHWL). These requirements could be attained by the landowner's preferred alternative: a railroad flatcar bridge. These bridges are not uncommon; there are local providers available, and at least one project for a flatcar bridge installation has been installed by the Oregon Watershed Enhancement Board.

2.2.3 Retrofit

A retrofit could either entail replacing all three culverts, or replacing only the middle culvert, which has the most severe passability issues. Neither alternative is preferred, as both would be difficult to permit, and the latter option might not be possible due to the configuration of the current culverts. Additionally, the landowner would still have to provide high levels of maintenance to keep the crossing clear of debris.

2.2.4 Hydraulic Design

A hydraulic design without consideration to fish passage issues would result in a similar crossing to the one already in place, with multiple culverts at the site. The old culverts would be removed, new ones installed and embedded, and the crossing rebuilt. This would probably be difficult to permit as it would be a fish passage barrier, and it would not reduce the landowner's required maintenance at the site, so it is not a recommended solution

2.2.5 No Action

Taking no action would require no money; however similar to the retrofit or the hydraulic design, a fish passage barrier would remain at the site. This alternative is not recommended.

2.2.6 Conclusion

Considering the project goals (see section 1.2), a railroad flatcar bridge was decided to be the most appropriate alternative for the site (see Table 6 below). A stream span bridge, such as the railroad flatcar bridge, is the most effective option for meeting OAR permitting requirements while maintaining low cost. Railroad flatcar bridges are less expensive than traditional concrete or steel span bridges, and several local companies specialize in their construction. These bridges have been deemed viable for low volume and private roads (Iowa Department of Transportation, 1999). Furthermore, there is already a precedent for OWEB funding a railroad flatcar bridge (Cedar Creek bridge project in Columbia County). A bridge will also allow for more efficient debris passage than the existing culverts.

Alternative	Slope Requirements Met?	Active Channel Width Spanned?	Cost	Project Risk	Meets OAR?
Channel Spanning Bridge	Yes	Yes	$$$	Low	Yes
Floodplain Spanning Bridge	Yes	Yes	$$$$	Low	Yes
Streambed Simulation Culvert	Yes	No	$$-$$$	Low	Unlikely
Hydraulic Design	Yes	No	$$	Medium	Possible
Retrofit	Yes	No	$	Low	Unlikely
No Action	Yes	No	N/A	Low	No

Table 6: Project Decision Matrix

3 Hydraulic Design & Site Layout

3.1 Hydraulic Design

The alternative bridge options were evaluated using HEC-RAS, a one-dimensional hydraulic model produced by the Army Corps of Engineers. First, existing site conditions were used for calibration. Stream and crossing geometry was modeled using LIDAR data from the Calapooia River, detailed bathymetry from our field survey, and total station survey data of culverts. Using the existing conditions and the observed discharge the model was run while varying the value of the channel roughness until the output water surface elevations were within 0.2 feet of observed water surface elevations, at which point the model was considered calibrated. After the model was calibrated, the proposed bridge design was modeled to meet the OAR guidelines for streambed simulation crossing (see Table 5). The proposed bridge model was run for 5% flow, the 95% flow, and observed discharge on the day of survey.

Model	Minimum WSE (m)	Average WSE (m)	Maximum WSE (m)
Channel	69.00	70.59	72.96
Bridge	69.01	70.79	73.29

Model	Minimum Velocity (m/s)	Average Velocity (m/s)	Maximum Velocity (m/s)
Channel	0.01	0.99	2.85
Bridge	0.01	1.03	3.68

Table 7 Modeled WSEs and velocites at bridge crossing and natural channel

Modeled water surface elevations did not overtop the bridge at any of the simulated flows. The OAR guidelines state that water surface elevation and velocity should be similar at the crossing to the natural channel. Modeled flows with the proposed bridge crossing had only minor differences in water surface elevation and velocity compared to the natural channel at the 95% flow and observed discharge (Table 7). Water surface and velocity values were higher in the bridge crossing model for the 5% flow. Overall, we believe the water surface elevation and velocity to be sufficiently similar to the natural channel to meet the OAR requirement.

3.2 Grade Control

In order to determine whether grade control would be necessary at the site due to potential for nickpoint migration, the data collected during the site visit on water surface elevation were evalulated both up and downstream of the culvert. It is assumed that the slope of the water surface elevation matches the slope of the bed over long distances based on standard principles of hydraulics. As seen in Figure 5, there is no significant difference between slopes upstream and downstream of the culverts, meaning the risk of headcut migration is minimal. The drop in WSE near the culverts is likely due to backwatering, and should equilibrate once the culverts are removed. This assessment matches the findings of Dr. Tullos after reviewing the bedform of the channel. Though there substantial changes in bed elevation, these were characteristic of features expected in this watershed, and not determined to indicate risk of headcutting.

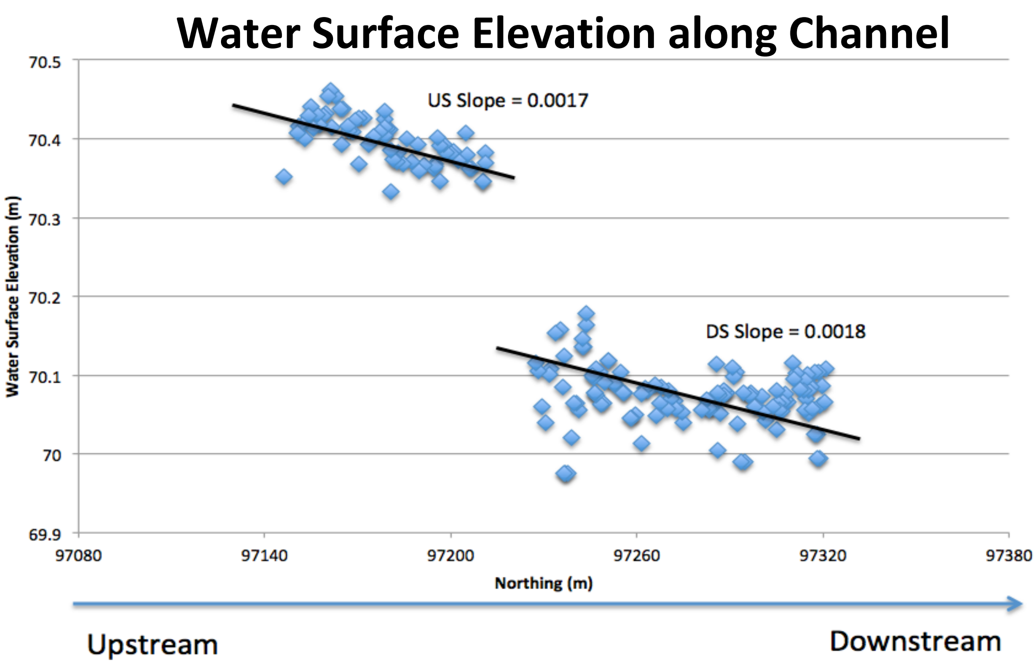

Figure 5 Water Surface Elevation versus Longitudinal Distance along the Channel

3.3 Site Layout

The rail flatcar bridge will be installed at the site of the existing culvert. It will be 89 feet long and 13 feet wide. There will need to be a moderate amount of backfill in order to raise the bridge height more than 3 feet above the OHWL, as mandated by OAR. Although there is a small amount of backfilling under the ordinary high water line, the removal of the culverts will reduce the amount of in stream fill much more than the proposed design will increase.

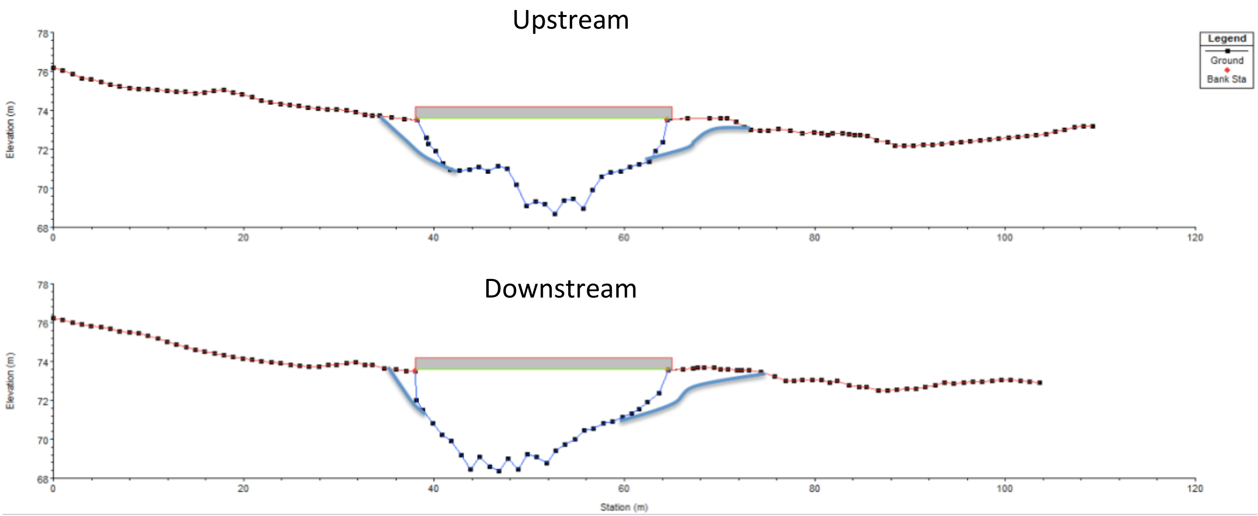

Figure 6 HEC-RAS model of stream span flatcar bridge option. Blue lines indicate the existing ground surface where additional ground fill would be required.

A secondary benefit of the bridge design is that the crossing will be usable for more of the year because the proposed crossing is at a higher elevation. An analysis of the water surface slope upstream and downstream indicated that a regrade will likely be unnecessary.

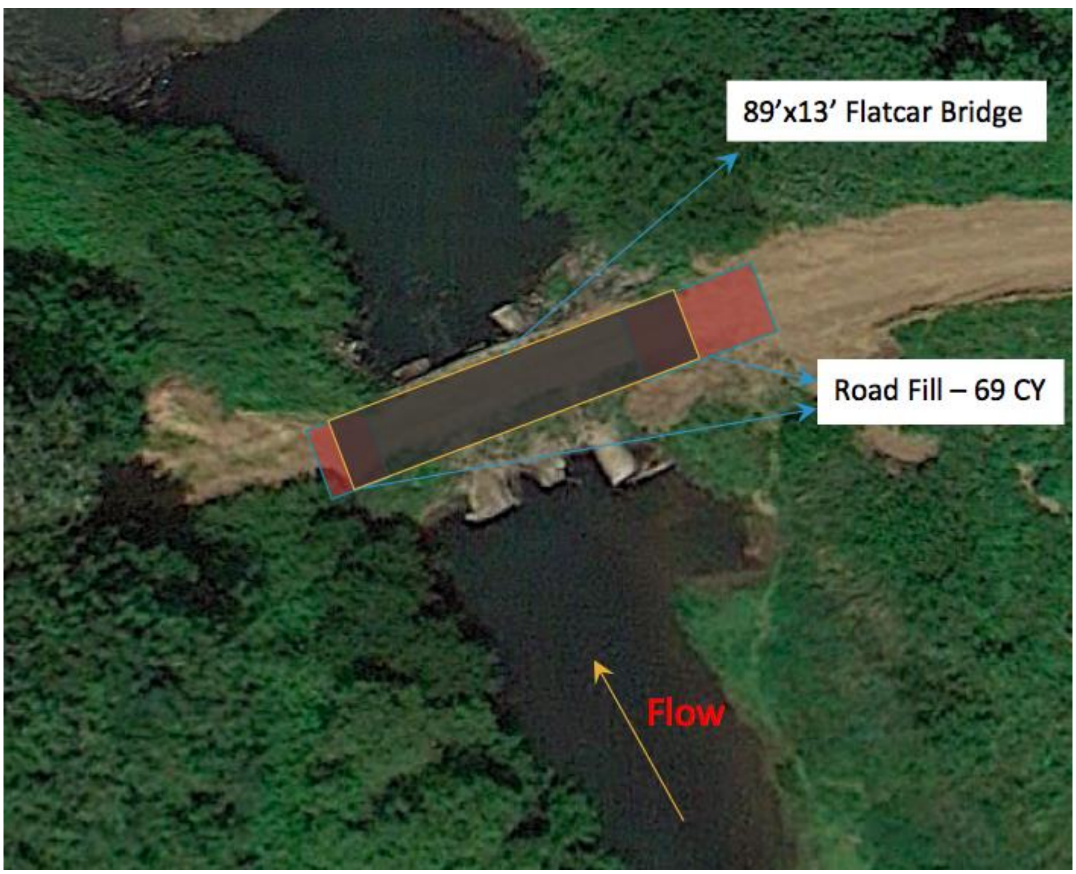

Figure 7 The above picture is a satellite photo with a plan view of the proposed design overlayed on it. The grey box represents the steel flatcar and the red represents backfill.

4 Permitting Information

Two permits are required before the proposed design can be implemented:

1) <u>Army Corps of Engineers Nationwide Permit 27:</u>

   This permit is required when conducting any "Aquatic Habitat Restoration, Establishment, and Enhancement Activities," especially when working under the ordinary high water (United States Geological Services, 2013)r level. Complete criteria for approval can be found in the attached document, but the criteria most applicable to this project are as follows:

   - It must maintain appropriate erosion and sediment controls.
   - Work must not interfere with spawning activities or destroy existing spawning grounds.
   - Construction must not interfere with the lifecycles of native organisms.
   - The structure must withstand expected high flows.
   - The permittee must submit a Pre Construction Report or PCN.

2) <u>General Authorization from Oregon DSL:</u>

   This authorization requires a separate form to obtain a "General Authorization for Fish Enhancement." but is easier and cheaper to obtain than an individual remove-and-fill permit. The specifics are found in the attached form but the main considerations are based on whether or not the permittee has fully analyzed how the proposed structure will alter the hydrology, geomorphology, and whether or not the channel changes have the potential to restore habitat functions.

A word on cultural site assessment: along with obtaining permits for construction at the site, a cultural heritage site assessment will need to be performed for the artifacts that are currently located on and around Mr. Slate's property. Proper permitting requirements and procedures will be followed in order to assess whether or not the site can be excavated or constructed upon.

5 Uncertainties & Future Considerations

Several uncertainties and/or limitations arose over the course of the project which would need to be addressed before project implementation. The 95% and 5% exceedence flows were calculated using a regression analysis tool provided by the USGS, which calculates daily average flows, due to the reach of interest being ungaged. The calculated USGS regression flows were used to determine fish passage instead of the instantaneous flows provided by StreamStats, as well as in hydraulic modeling in HEC-RAS and therefore error in that estimation would have significant effects on this design. Field data used to find the ordinary high water line were taken by non-professionals making qualitative assessments, and consisted of only 27 points with a range of 1.83 meters. Sediment qualities, standard in river engineering assessments, were not able to be determined during the site visit due to high flows. Several assumptions about the geometry of the site were used to model the culverts in HEC-RAS. Observing the culverts during low flows would allow for a more accurate depiction of how much or little the culverts are buried within the streambed. Addressing these uncertainties and limitations of the project would allow for more accurate modeling and a better understanding of the proposed bridge design.

6 References

Bodhaine, G. (1968). *Measurement of Peak Discharge at Culverts .* Retrieved April 14, 2013, from USGS Techniques of Water Resources Investigations Reports: http://pubs.usgs.gov/twri/twri3-a3/

homewyse. (2013, January). *Cost to Excavate Land*. Retrieved June 1, 2013, from homewyse website: http://www.homewyse.com/services/cost_to_excavate_land.html

Iowa Department of Transportation. (1999). *Use of Railroad Flat Cars for Low-Volume Road Bridges.* Retrieved June 1, 2013, from IDOT Website: http://www.iowadot.gov/research/reports/Year/2003andolder/fullreports/tr421.pdf

Lands, O. D. (2011, April 28). *General Authorization Notification Packet Contents.* Retrieved May 14, 2013, from Oregon State Website: http://www.oregon.gov/DSL/PERMITS/docs/GA_Notification_Packet_03232011.pdf

ODFW. (2009). *OAR 635, Division 412, Fish Passage.* Salem, OR: Oregon Department of Fish and Wildlife.

United States Geological Services. (2013). *StreamStats National Data Collection Service.* Retrieved April 12, 2013, from StreamStats Website: http://streamstats.usgs.gov/>.

US Army Corps of Engineers. (2012, March 19). *Nationwide Permit 27 Final Notice of Issuance and Notification of Nationwide Permits.* Retrieved June 3, 2013, from USACOE Website: http://www.saw.usace.army.mil/Portals/59/docs/regulatory/regdocs/NWP2012/NWP27_3-23.pdf

Washington State Departent of Transportation. (2011, July). *WSDOT Bridge Design Manual.* Retrieved May 30, 2013, from WSDOT Website: http://www.wsdot.wa.gov/publications/manuals/fulltext/m23-50/chapter12.pdf

APPENDIX A: Data and Calculations

The following charts (Tables 8 & 9) provide more detailed information on the characteristics of the current culverts at the site.

Steelhead	Length: 37 cm	Minimum Depth: 1 ft
Culvert	**Percentage Passable**	**Barrier Type**
1	100.0%	n/a
2	98.4%	Depth, Velocity
3	31.5%	Velocity

Chinook	Length: 84 cm	Minimum Depth: 1 ft
Culvert	**Percentage Passable**	**Barrier Type**
1	100.0%	n/a
2	98.4%	Depth
3	31.5%	Velocity

Pacific Lamprey	Length: 17.3 cm	Minimum Depth: 6 in
Culvert	**Percentage Passable**	**Barrier Type**
1	89.3%	Velocity
2	88.9%	Velocity, Drop, Depth
3	28.3%	Velocity

Table 8 Passability results

Culvert Diameter			
Culvert	Original Passability	+5%	+25%
1	100.0%	100.0%	100.0%
2	98.4%	98.8%	99.1%
3	31.5%	35.9%	55.9%

Culvert Slope			
Culvert	Original Passability	+5%	+25%
1	100.0%	100.0%	100.0%
2	98.4%	98.4%	98.4%
3	31.5%	31.5%	31.5%

Culvert Length			
Culvert	Original Passability	+5%	+25%
1	100.0%	100.0%	100.0%
2	98.4%	98.4%	98.4%
3	31.5%	31.5%	31.5%

Table 9 Sensitivity Analysis for Selected Parameters

APPENDIX B – Engineer's Cost Estimate for Selected Alternative

BID ITEMS	UNIT	UNIT COST LOW		HIGH ΔΔ
Structure Excavation Class A Incl. Haul				
Earth	CY	$12.00	—	$30.00
Rock	CY	$100.00	—	$220.00
Inside Cofferdam — Earth	CY	$22.00	—	$33.00
— Rock	CY	$110.00	—	$190.00

Table 10 Table of Costs for Excavation **(Washington State Departent of Transportation, 2011)**

Compact backhoe loader rental (97330 zip): $235 daily, $695 weekly, $1,935 for 4 weeks
Labor costs (97330 zip): Low = $110 / 3 hours   High = $170 / 3 hours
Side note: The cost to Excavate Land averages $299.64 - $423.77 per cubic yard in 2013.
This Land Excavation cost estimate is calculated from average material costs, unit labor productivity rates and national average hourly labor wages.
Note that the low end of the range of costs for rock was used in the assessment, as this was determined to be a conservative value for the site.

The project costs are listed below in Table 11. For the project it was assumed that excavated material could be used for the road fill. Excavated material volume was based on an estimation from the HEC-RAS dimensions of the road fill currently in the channel, including the culverts. The required volume of material for the new road fill was based on the volume of excavated material without the culverts minus the volume required to raise the ground surface to plan specifications. The cost of the new road fill material was based on the cost of 1ft rock provided by the NRCS.

Item	Rate	Quantity	Cost
Excavation	$100 / CY	289 CY	$29,000
Road Fill	$20 / ton	80.5 tons	$1,600
Bridge	$650 / ft	89 ft	$58,000
Equipment	$235 / day	2 days	$500
Labor	$140 / 3hr	20 hrs	$900
		Total	$90,000

Table 11 Engineer's Estimate of Project Cost

APPENDIX C – Supplemental Site Information

	Recurrence Interval (years)	Peak Flow (cfs)	Unit Peak Flow (cfs/sq.mi.)
Holley Gauge	2	5500	52
	5	7900	75
	10	9400	90
	25	11300	108
	50	12700	121
	100	14100	134
Albany Gauge	2	12500	33
	5	20000	54
	10	25200	68
	25	31800	86
	50	36900	99
	100	41800	112

Table 12 Calculated peak flow values on the Calapooia River by recurrence interval using the log-Pearson Type III distribution. The drainage area for the Holley Gauge is 105 mi^2 and 372 mi^2 for the Albany Gauge.

Parameter	Value	Parameter	Value
Drainage area in square miles	289	Mean maximum January temperature, 1971-2000, in Fahrenheit.	45.8
Mean Basin Elevation, in feet	1150	Mean Minimum Daily January Temperature, 1961-1990, in degrees Fahrenheit	33.4
Maximum elevation in feet.	5140	Mean minimum January temperature, 1971-2000, in Fahrenheit.	32.2
Minimum elevation in feet.	230	Average maximum air temperature, Fahrenheit	62
Relief in, feet.	4910	Average minimum air temperature, Fahrenheit	41.3
Mean basin slope measured in degrees.	10.2	Percent of area covered by forest.	41.4
Maximum basin slope in degrees.	55.9	Percentage of area covered by impervious surface area, from NOAA 1 km Sprawl impervious surfaces grid	0.64
Minimum basin slope in degrees.	0	Percentage of impervious area determined from NLCD 2001 impervious dataset	0.65
Total stream length in miles	273	Percentage of urban land cover determined from NLCD 2001 land cover dataset	2.47
Total length of streams divided by total drainage area, kilometers per square kilometer	0.59	Average Soil Permeability, in inches per hour	1.26
Mean basin precipitation, in inches.	58.4	Available water capacity of the top 60 inches of soil - determined from STATSGO data, in inches	0.14
Maximum 24-hour precipitation that occurs on average once in 2 years - equivalent to precipitation intensity index, in inches	2.36	Percent of area covered by high permeability aquifer units.	33.4
Mean Maximum Daily January Temperature, 1961-1990, in degrees Fahrenheit	45.9	Percent of area covered by high permeability geologic units.	0

Table 13 Calapooia Basin Characteristics of Area Draining to Project Site (StreamStats, 2013)