Salmon Ck at West Uncas Rd

Culvert Removal and Bridge Design

WDFW Region 6 Habitat Engineering Technical Assistance

Location

Date	2/9/09
Engineers	Bob Barnard and Ken Corwin
Road	West Uncas Rd.
Latitude	47.980441
Longitude	122.896529
Access Rating	Good

Stream and Watershed Information

Stream	Salmon Ck.
Width of Channel	24
Entrenchment Ratio	1.7 (may be revised with additional data)
Watershed area	16.5 sq. miles
Average Annual Precip.	41 inches/yr (Al says 25-30)
10% exceedance flow	121 cfs
2 year flood peak flow	310 cfs
100 year flood peak flow	1237 cfs
Regrade Potential	1 ft, depending on design
Debris Potential	Medium – forested riparian but not actively migrating
Upstream channel slope	1.4 – 1.6%
Downstream channel slope	1%
Bed material size	D50=0.21, D84=0.35, D100=0.55 ft. from a location 800 ft u/s of this crossing

Current Condition and Barrier Description

Culvert diameter/span	186” span x 114” rise pipe arch
Culvert type	CMP
Culvert length	60 ft
Culvert condition	Poor, invert rusted and in spots completely deteriorated
Fill height at mid-culvert IE	20 ft
HW/D at 25 yr. flood	0.98 at 908 cfs

	This culvert	Criteria
Outfall drop	~1 ft	0.8 feet maximum, Level
Culvert slope	0.3%	1% maximum, Level A
Low flow depth	<0.8 ft	0.8 feet at 2 yr.-7day low flow (or no flow)
Velocity at Q_{fp}	5.3 fps	4 fps, based on culvert length 60 ft

Notes: While the outfall drop is only 1 ft, the condition of the invert and the characteristics of the bed make this a significant barrier to upstream migrating chum.

Proposed Design

This report and the accompanying drawings should be considered conceptual and not suitable for construction. The level of survey used to develop the concept was minimal and it was topographic in nature. The precise location of infrastructure has not been established and no property boundaries were surveyed. The location of all features is approximate although adequate to carry out this level design.

Alternative 1: retrofit

The existing culvert is in poor condition and is likely to fail in the near future. The galvanizing has worn off the lower 2 ft and culvert bottom has rusted through in a number of places. Culverts in this condition never last very long. A retrofit for fish passage should only be considered as a short term (1 season) solution. An example of this would be two sandbag weirs immediately below the culvert outlet. Longer term retrofits (backwater with downstream grade controls, baffles, etc) should not be considered since the pipe may fail before they would.

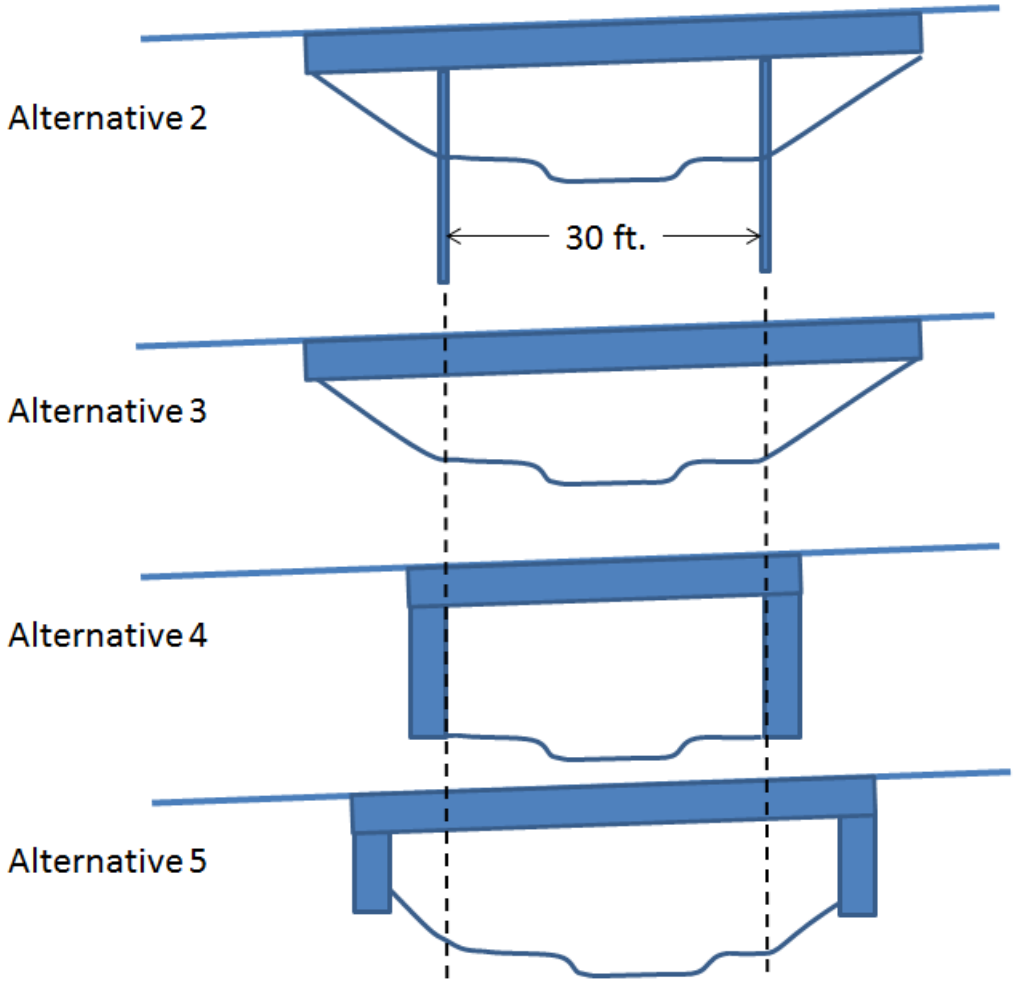
Alternatives 2-5: bridge

Generally, channels wider than 15 ft are best crossed with bridges (this channel is 24 ft wide). A culvert may still be acceptable for larger channels, but should not be the first alternative considered.

The Water Crossing Design Guidelines, WDFW 2013, bridge design section suggests that, for a confined channel, the width at the base of the abutments should be a function of the bankfull width and a factor of safety. In this reach Salmon Ck is confined by steep banks and armored in places. Under more natural conditions found in a reach 800 ft upstream of the crossing the entrenchment ratio was 1.7. It is effectively entrenched. The factor of safety should be determined by assessing the uncertainty and risk.

Salmon Ck has been studied intensively for the channel restoration project on the valley floor and for the evaluation of the bridge at US 101. We have confidence in the various hydraulic calculations and geomorphological observations. A modest factor of safety is recommended for this project, 1.25. The width between abutments would then be BFW*FS = span = 24*1.25 = 30 ft.

Any of the following alternatives are acceptable as long as an adequate width is created for the stream between abutments or piers. Unit bridge costs drive the design costs in these alternatives. The bridge type required by Jefferson Co. will affect the alternatives analysis. The alternatives are illustrated in the following figure.



Alternative 2: pier-supported bridge with jump spans
The bridge configuration shown in the plans consists of a central pier-supported bridge with a clear span of 30 ft, and two shorter jump spans to connect to the existing road. The central span is supported on pilings and the jump spans on spread footings at the top of 2h:1v sloped abutments.

Alternative 3: bridge on flow-through abutments
This alternative eliminates the piers and spans between flow-through abutments. The simplicity of the site preparation makes this an attractive alternative when bridge costs are low.

Alternative 4: bridge on vertical abutments
The third alternative is a single 30 ft clear span on approximately 13 ft tall vertical abutments of sheet pile, concrete or another acceptable retaining system. This alternative reduces the overall bridge length but increases the site work involved in constructing and back filling the vertical abutments. Depending on the type and expense of the bridge being considered, this may or may not represent a cost savings. Designers of low cost

bridges, such as modular steel bridges, find that vertical abutments are more expensive than longer spans or jump spans.

Alternative 5: bridge on shorter vertical abutments
The final alternative is a longer single span with shorter vertical abutments, say a 50 ft clear span bridge on approximately 10 ft tall vertical abutments. These abutments would be located at the top of short sections of 2:1 embankment slopes.

Additional design considerations
Some regrade is expected upstream of the new bridge, as we expect with the replacement of any undersized structure. This should not exceed a foot or so, nor should it have any significant effect on habitat or adjacent landowners. If it becomes apparent further along in the design process that more regrade is expected, its effects should be addressed.

In the proposed plan, the alignment of the stream has been shifted to the south and a gentile curve connects the up and downstream sections of stream. This will require adjusting the bed and banks of the stream outside of the road right of way. The affected landowners must agree to this work and a negotiated agreement reached before beginning this design. If the landowners do not agree with this realignment scheme, the bridge would remain centered on the stream in its current location and adjustments would be made to transition from the existing channel to new crossing. This alternative is not shown on the plans for the bridge alternative, but is shown for Alternative 6, stream simulation culvert.

Roughly 250 ft on new channel will be created in order to realign the stream. This new channel design must not reduce the productive capacity of the stream and should include appropriate habitat components, bed materials and geomorphology as would be found in a channel of this type (WAC 220-110-080). The plan shows pools, riffles, floodplain and two log jams as one means to fulfill this requirement. Many alternatives are possible. This pool-riffle structure may not persist in the long run, although we are obligated to do our best to create appropriate habitat.

As mentioned above, the bed material is D50=0.21, D84=0.35, D100=0.55 ft. at a location 800 ft u/s of this crossing. After the designer has assured themselves that this is appropriate for the slope and discharge of the stream, this gradation may be used to specify the material placed in the new channel. A slightly coarser mix may be placed in the riffle sections as a way to counteract the effects of regade.

The bankfull width of the stream is 24 ft and a channel of this width and an appropriate depth should be defined by the streambed material. In places where there is adequate width, a flood plain roughly 6 feet wide on both sides should be created. This is to be vegetated with appropriate riparian plants.

In places where the banks are cut, filled or otherwise adjusted, they should be sloped at a maximum of 2h:1v and revegetated with appropriate riparian plants.

The channel upstream of this crossing (above station 5+00) is confined by fill and rip-raped in sections. It is recommended that the sponsor of this project approach the

landowner about removing the rip rap and resloping and revegetating the banks to dimensions similar to those already mentioned for this project. It is not essential that this work be done for the success of the new water crossing, but it would improve instream habitat, particularly spawning success, and lower downstream velocity during peak flood events.

Hydraulic capacity has not been determined for this structure. Generally, sizing to the fish passage requirement means that the crossing has flood capacity. By way of comparison, the US 101 crossing of Salmon Ck is composed of a central span of 40 ft with two 40 ft jump spans on either side. A backwater model was run on that bridge and it was found to have adequate capacity, although it is tidally influenced.

Comments on drawing sheets:

Sheet 2

Tax parcel numbers and approximate right of way lines were taken from assessor's map and were not determined by ground survey. Building locations determined from aerial photographs. **These features are provided for information purposes only**. The barn and house east of Salmon Ck are not likely to be affected by the project. The house on the west side could potentially be affected if right bank reshaping is considered for habitat restoration. No underground utilities were located.

Sheet 4

Proposed channel bed profile is provided as a concept only. Two pools are shown spaced approximately 7 channel widths apart, which is typical for this type of channel. The adjacent channel is confined and is predominantly a glide, although some shallow pools do appear when forced. There will be some adjustment to this profile after the project is subject to channel changing flows.

Sheet 5

Some portions of the cross sections are approximate. They are provided to show the effects of realignment and the general shape of the proposed channel and its flood plain.

Alternative 6: stream simulation culvert

As mentioned above, bridges are typically used to cross streams greater than 15 ft BFW. Culverts are built with spans as large as 35 ft and a large concrete box or CMP multiplate could be used to cross Salmon Ck. If the culvert was the right shape and deeply countersunk, it may fit in the road fill. The cost of these structures is high and the installation complex – factors that should be taken into consideration when weighing the bridge vs. culvert alternatives.

The following is a design outline of the stream simulation method as applied to Salmon Ck.

Stream simulation application

- Stream simulation is applied to moderately confined channels with a bankfull width less than 15 ft. Salmon Ck is 24 ft wide and entrenched. The design of a culvert here might not differ significantly from a vertical abutment bridge.
- The upstream slope is 1.5% and it transitions to 1% downstream, which is probably more the equilibrium slope in this reach. The culvert is set at 1% to maintain proper sediment transport and other stream functions.
- The length to span ratio is used to determine whether a culvert is so long that the width must be adjusted to compensate for the lack of form roughness. The threshold commonly used is 10. The length to span for the proposed culvert is about 0.5 (given the design described below) which is substantially less than 10, so that this culvert can be designed without compensation for length.

Suitability of the site

- Stream simulation design requires a geomorphic assessment of stream reach. It is recommended that the designer familiarize themselves with the stream channel in a reach unaffected by the undersized culvert or other anthropogenic influences.
- The method tolerates little or no lateral channel movement and streams that are actively meandering should use a bridge. Salmon Ck is completely confined in this reach and is not expected to move laterally.
- The method tolerates moderate vertical instability. This culvert should be countersunk to accommodate any future incision.
- Culvert bed slope should not be greater than 1.25 x upstream channel slope. The proposed culvert slope is 1%, which is less than the upstream slope and within the range of equilibrium channel slope.

Culvert type and size

- Any culvert type may be used for stream simulation. Considering the fill height, a box culvert would be a good choice.
- Width of bed inside culvert = 1.2 x BFW + 2 feet = 1.2 x 24 + 2 = 30.8 ft. Usually this is rounded up to the next whole foot, but the next culvert size would be 32 ft and the added benefit would probably not be measurable. 30 ft span is recommended.

Bed configuration

- This is a low slope alluvial gravel bed stream and should be a Scenario 1, or low-slope stream simulation design. (See **Water Crossing Design Guidelines**, page 43.)
- Stream simulation culverts are countersunk 30-50% of their rise. In the case of a box culvert where the stem height is independent of the span, the actual depth of fill can vary independently from the rise. Depth of fill is important for several reasons, chief of which include extent of regrade expected and the stability of the fill. The recommended rise for this culvert is 12 ft, 4.8 of which will be filled with streambed sediment (countersunk 40%).
- This leaves a bed to crown distance of 7.2 ft. The clearance between the 100-year water surface and the crossing structure should be 3 ft for a

bridge. A simple normal flow model of 1237 cfs predicts a depth of 4.9 ft. This model does not consider backwater influences from downstream. The flood clearance would be 2.3 ft. While this is less than the recommended 3 ft, it is probably acceptable considering the size of Salmon Ck relative to the larger rivers for which the 3 ft criteria is intended.

- The culvert bed should have a pool-riffle morphology similar to that found in the adjacent channel.
- Bed structure should be built-in at the time of construction; the contractor will need good plans so that the finished project will function as planned immediately. The profile should include the slope and length of the riffles, and the depth and length of the pools. There should be cross sections of the realigned channel and culvert, showing the channel shape.

Bed material design and specification

- Stream simulation culvert bed material is similar to the natural channel. The measured sediment gradation stated on page 4 is recommended.
- Scenario 1 culverts include coarse bands of heavier material to introduce some structure to the channel cross section and profile immediately after construction.
- Sediment distribution should be well-graded, non-porous, with 5-10% fines
- Stream simulation bed materials are generally rounded, naturally-occurring materials.

Culvert layout

- The culvert is on the same alignment as the existing one but this alignment is not ideal. It is best to eliminate all skew between the culvert and the upstream channel. If agreements cannot be reached with the adjacent landowners, then the skew must be tolerated.
- The skew will create scour on the upstream left bank side of the culvert. This scour can be prevented by placing heavier streambed material along the left bank wall of the culvert. Ideally, this would be rounded boulder/cobble mix with a D100 = 1.5 ft and D84 = 0.5 ft. More careful analysis would be necessary to refine this estimate. Quarry rock could be substituted if rounded material is not available.
- The length of the culvert is based on the required roadway width, allowances for safety features, and fill slope. It is approximately 60 feet in the conceptual design drawings.
- The ends of the culvert must be skewed to fit within the ROW.

Channel realignment and profile adjustment

- It would be better to realign the stream for the culvert the same way it was for the bridge alternative.
- The channel profile will adjust to changing conditions after the culvert is replaced. There should be enough countersink to accommodate this regrade.