Phase I Effectiveness and Final Restoration Design for Lulu City Wetland

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INTRODUCTION

A key goal of the Lulu City wetland restoration is the return of the meandering Colorado River channel with a hydrologically connected riparian zone that will support a tall willow community. To evaluate the effect of reconnecting the Colorado River from Zone 3 to its historic channel in Zone 4, a temporary channel was hand dug in the summer of 2015 (Figure 1). This Phase I Channel created in the summer of 2015 was designed to concentrate river flow from north to south in one channel, and determine if it would drain the adjacent floodplain to potentially support tall willows and identify where sediment excavation is required to preclude conifer invasion. Several potential outcomes were identified prior to channel construction, each linked to specific restoration outcomes. This report provides our monitoring results from before and after the Phase I Channel was built and provides the final restoration design for the Colorado River and Lulu City wetland.

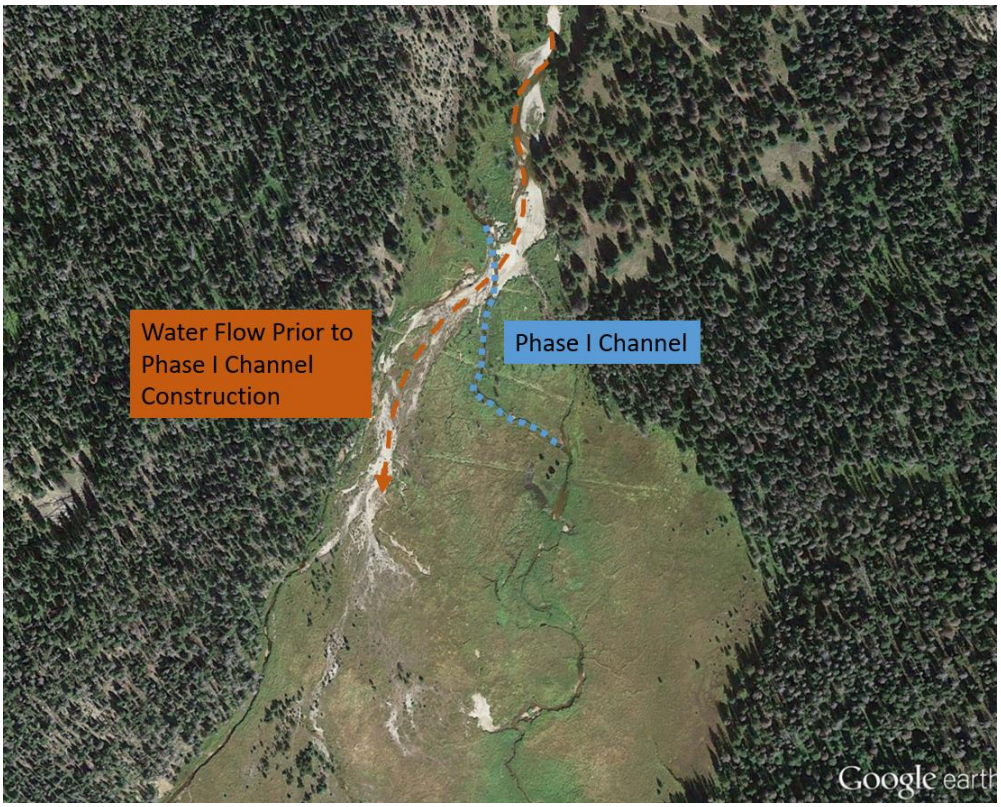


Figure 1. Lulu City wetland showing water flow prior to Phase I Channel construction as well as the channel position in 2015.

Part I. Phase I Channel Effectiveness Monitoring

Hydrologic data collection following Phase I channel construction was intended to identify which of the following potential outcomes occurred in each part of the Lulu City wetland. The first two scenarios describe the reconnection of the Colorado River to its historic channel. Groundwater monitoring would support the first scenario if no further excavation would be required to create hydrologic conditions suitable for tall willow species. The second scenario would be supported if the wetland is drained too much for tall willow species. Excavation would be required

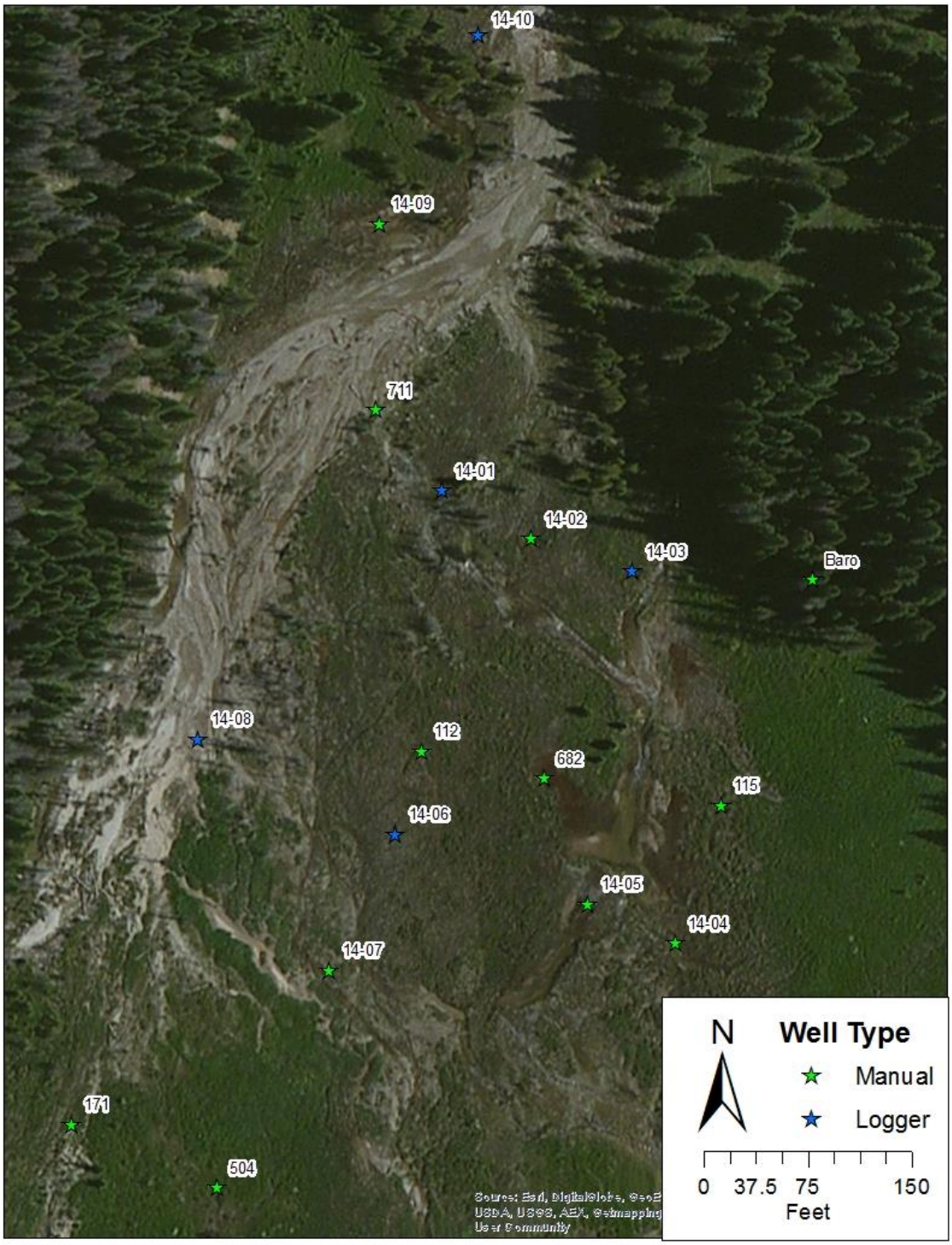
in this scenario to lower the ground surface. Should reconnection of the Colorado River not impact the water table, a new restoration approach would be needed, as described in the third scenario.

Table 1. Potential outcomes and associated restoration actions from the construction of the Phase I Channel

Scenario	Outcome	Restoration Actions
1	The constructed channel drains the adjacent floodplain and the debris zone and creates suitable conditions for tall willows	• Create an effective channel to connect the Colorado River in Zone 3 with the historic channel in zone 4. • No further excavation of the floodplain is required to create tall willow conditions.
2	The constructed channel drains the adjacent floodplain too much and creates suitable conditions for conifer invasion	• Create an effective channel to connect the Colorado River in Zone 3 with the historic channel in zone 4. • Excavation is required within the debris area.
3	The constructed channel does not drain the floodplain or the debris zone and the water table remains similar to what it was pre-pilot channel	• The type of constructed channel in phase 1 was not sufficient to drain the wetland. This suggests that a more substantial restoration plan is needed for the Lulu City wetland

Methods

Water table depths were monitored in existing groundwater monitoring wells in the Lulu City wetland (Figure 2). Automatic water level loggers were installed in six wells and recorded water table depths every six hours, and water table depths were manually measured throughout the summer in wells without automatic loggers.



Results

The wetland water tables response to construction of the Phase I Channel varied across the Lulu City wetland. The western portion of Lulu City Wetland as well as areas adjacent to the new channel had lower water tables immediately after the channel construction (Figure 2). Groundwater depths in the western and central portion of the wetland differed during spring runoff in areas further down the valley (Figure 3). Western portions of the valley had lower water tables from the year

before the Phase I Channel construction, while areas in the middle of the valley had higher water tables following the channel construction. Water table depths indicated the Phase I channel was successful in reconnecting the Colorado River from zone 3 to zone 4 and routing the water flow from its western direction after the breach towards the center of the valley, consistent with historic conditions.

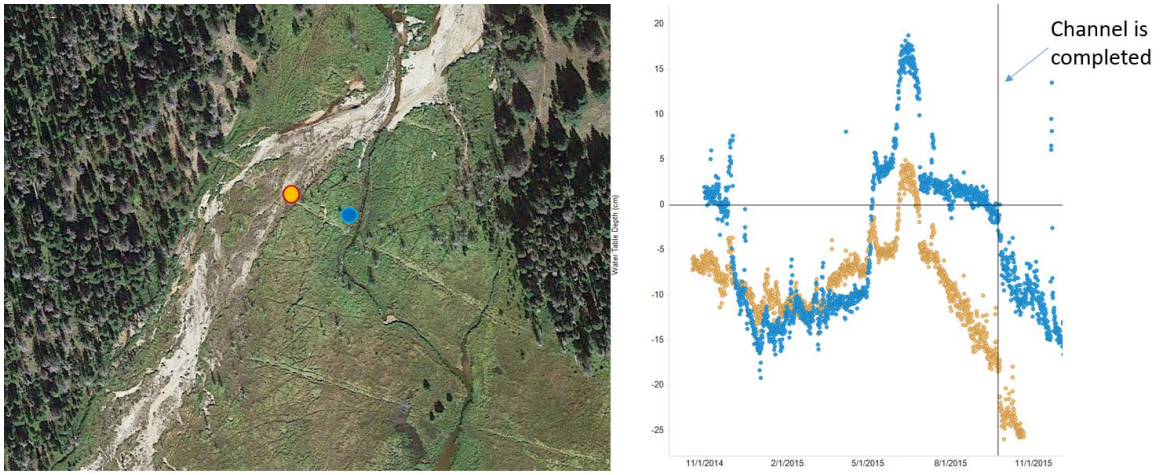


Figure 2. Groundwater depths in monitoring wells 711 (yellow) and 14-01 (blue) during 2015. The vertical line identifies when the Phase I channel was constructed. Although water tables in both wells were declining, an immediate drop in water tables is apparent following the channel construction, with resumed decline afterwards.

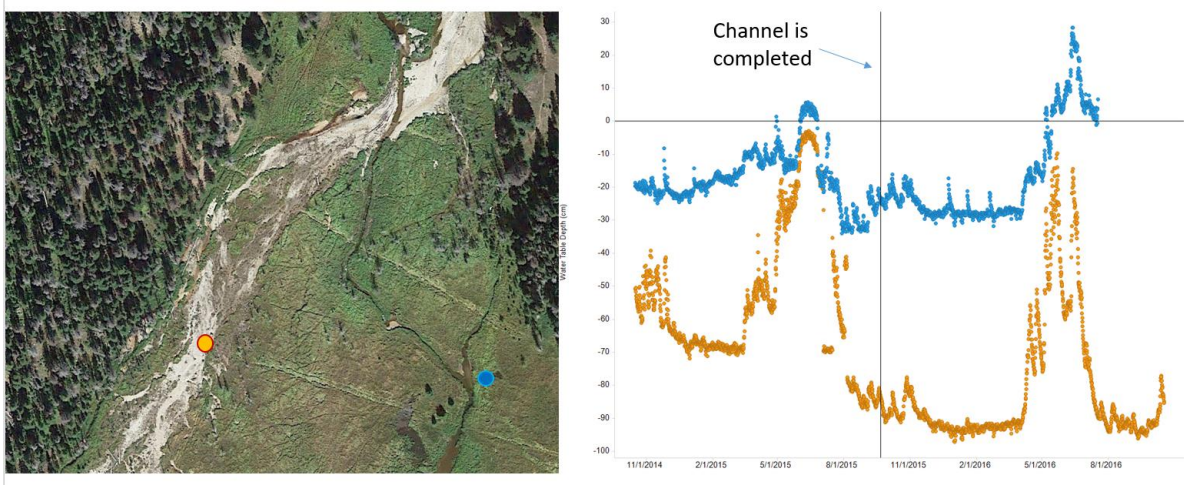


Figure 3. Groundwater depths in monitoring wells 14-08 and 14-05 during 2015 and 2016. The vertical line identifies when the Phase I channel was constructed. The spring 2015 pulse was lower in the western well, and higher in the eastern well compared to the previous year, indicating the constructed channel had partially dried the western debris flow deposits.

Discussion

A key restoration goal for the Lulu City wetland is to create a tall willow community. Tall willow species have been constrained by perennially saturated conditions, and an anticipated outcome of the Phase I channel was lowering the water tables throughout the wetland. The water table analysis indicated the success of the Phase I Channel in reconnecting the Colorado River in Zone 3 to its historic channel in Zone 4. This reconnection lowered the water table within the fan area on the western valley side, and increased discharge (as indicated by higher water tables) along the historic Colorado River channel in the center of the wetland. Lowering the water table in the wetland indicates that reconnecting the Colorado River is an effective step in developing hydrologic conditions for tall willows.

All three potential scenarios described in Table 1 occur in parts of the wetland. As described in the first scenario, reconnecting the Colorado River from Zone 3 to Zone 4 created hydrologic conditions that could be suitable for tall willows. As outlined in scenario 2, some portions of the wetland were drained too much, indicating surface excavation is required to lower the ground surface. Unfortunately, as described in scenario 3, the Phase I Channel was ineffective at draining the northwest portion of the wetland, limiting our ability to predict with certainty the outcome of creating a more robust channel. While we know that excavation along the western valley side is necessary, further monitoring will be required once the new channel is created to identify the volume of excavation required to create hydrologic conditions suitable for tall willow.

The Colorado River floodplain has many more conifers than occurred historically. A concern is the continued conifer encroachment in the wetland. There are many conifer seedlings that establishing in the bare sediment area along the western side of the wetland. Although the water table indicates suitable growth conditions for tall willow species in many areas, the bare surface and lower water tables are also conducive to conifer encroachment. It would therefore be beneficial to excavate some of the deposited sediment from the western portions of the valley to allow tall willow growth yet limit conifer invasion.

Although this report does not provide specific information on the hydraulic functioning of the Phase I channel itself, evidence from Rathburn et al. indicates that the channel constructed in Phase I was too narrow and too steep, resulting in significant bed erosion. The proposed channel in the final restoration design is thus larger in width and depth as well as shallower in bed slope.

Part II. Final Restoration Design

The restoration design considers the findings described above as well as additional hydraulic modeling detailed in the methods below. The restoration design focuses on the Lulu City wetland where Zone 3 interacts with Zone 4 and incorporates four primary components (Figure 6):

1. An effective channel to connect the Colorado River in Zone 3 with its historic channel in the middle of Zone 4.
2. Hydraulically important floodplain elevations to transport the range of expected flows.
3. The filling of the eastern channel that is eroding into a fen.
4. The creation of "terrace" floodplain elevations conducive for tall willow community development.

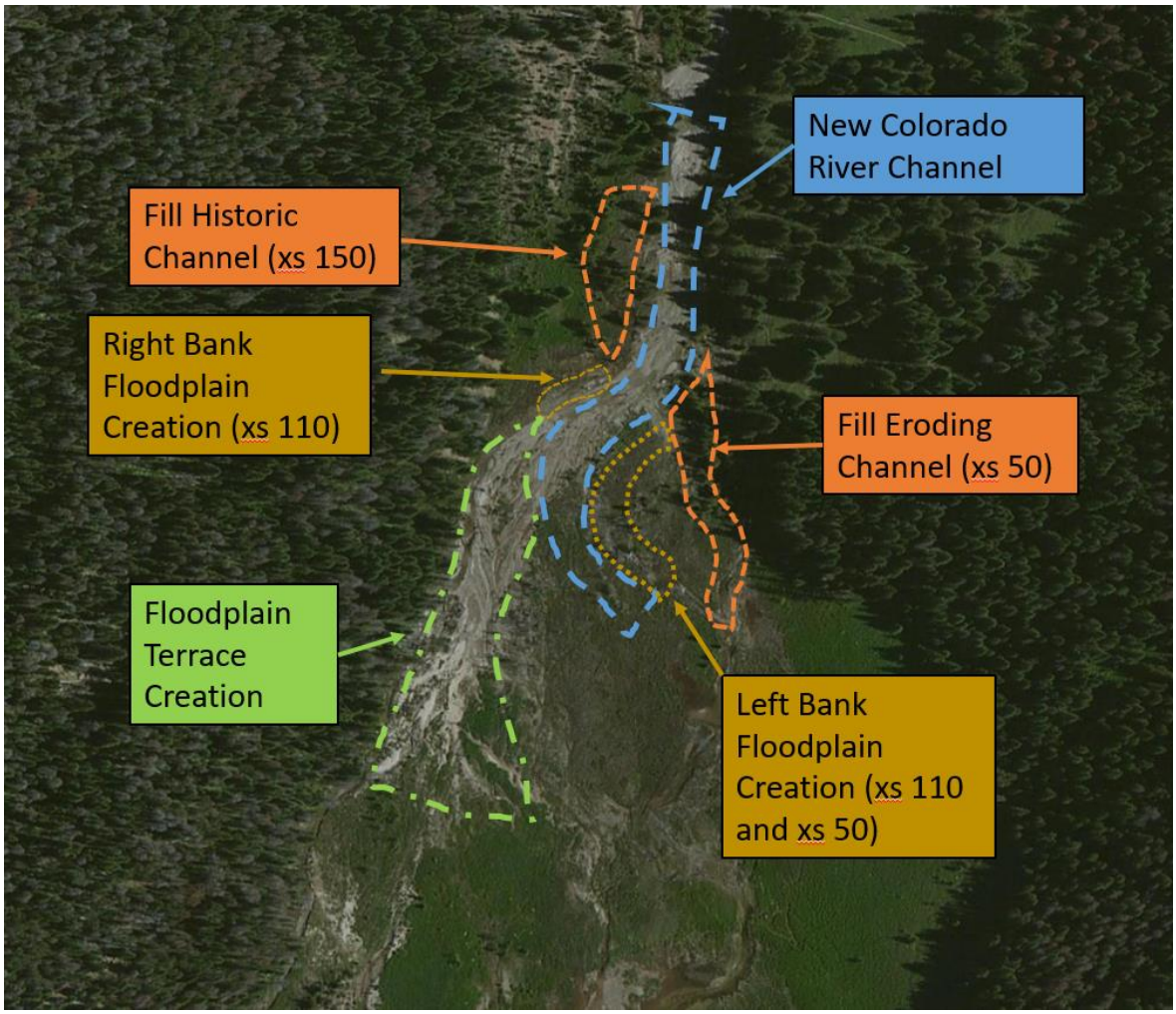


Figure 6. Focus areas for restoration to address four primary elements: creating an effective Colorado River channel, creating hydraulically important floodplain elevations near the new channel, filling the eastern channel, and creating floodplain terraces for tall willow growth. Cross sections numbers (ie. xs 110) refer to diagrams available in Appendix A.

Methods

Colorado River Channel Design

To design the final Colorado River channel, geomorphic measurements were made from the 2012 LiDAR surface within ArcMap 10.3. A reference cross section was measured within Zone 3. This area is known to be effective for sediment transport and maintains stable cross sections. The cross-section geometry from this reference area was used to design the new channel through the project area. Various channel alignments and meander patterns were evaluated with the reference cross section to identify the appropriate channel slope for the project area. Once the cross section and meander paths were identified, all river channel parameters were modeled and evaluated in HEC RAS using the range of design flows developed by Rathburn et al. 2012 for this reach of the river. The design flows included a geomorphic bankfull discharge of 3.0 cubic meters per second (cms), an effective discharge of 2.1 cms, and a 1.5-year return interval. Appropriate hydraulic floodplain elevations were added to the design to match the water surface elevation of geomorphic, bankfull flow (3.0 cms) using a 20 m wide floodplain to accommodate the highest recorded flow (4.91 cms in June of 2010).

The shear stress of the proposed channel was calculated within HEC RAS using the grain size analyses performed by Rathburn et al. (2012). Within the project reach, the D50 ranged from 20-32mm, the D85 ranged from 34-64mm, and the D100 was 192mm.

Along with the hydrologic impacts of the Phase I Channel on Lulu City Wetland, it is important to consider the hydraulic effectiveness of the newly created channel for the final restoration design. This report does *not* provide results on the hydraulic and sediment transport data collected by Rathburn et al., though their findings will be incorporated into the suggestions in this report.

Results

The reference channel cross section is a much more robust channel than the Phase I channel constructed in 2015. The proposed channel dimensions from the reference channel are approximately 8.5m wide with a bankfull depth of 0.35-0.6 m. The valley gradient through the project area is 1.43%. The proposed meander pattern creates a channel bed slope of 1.25%. Hydraulic analysis indicates the effectiveness of the proposed channel across all measured discharges within this portion of the Colorado River, and maintains a subcritical water surface throughout the design reach (Figure 4).

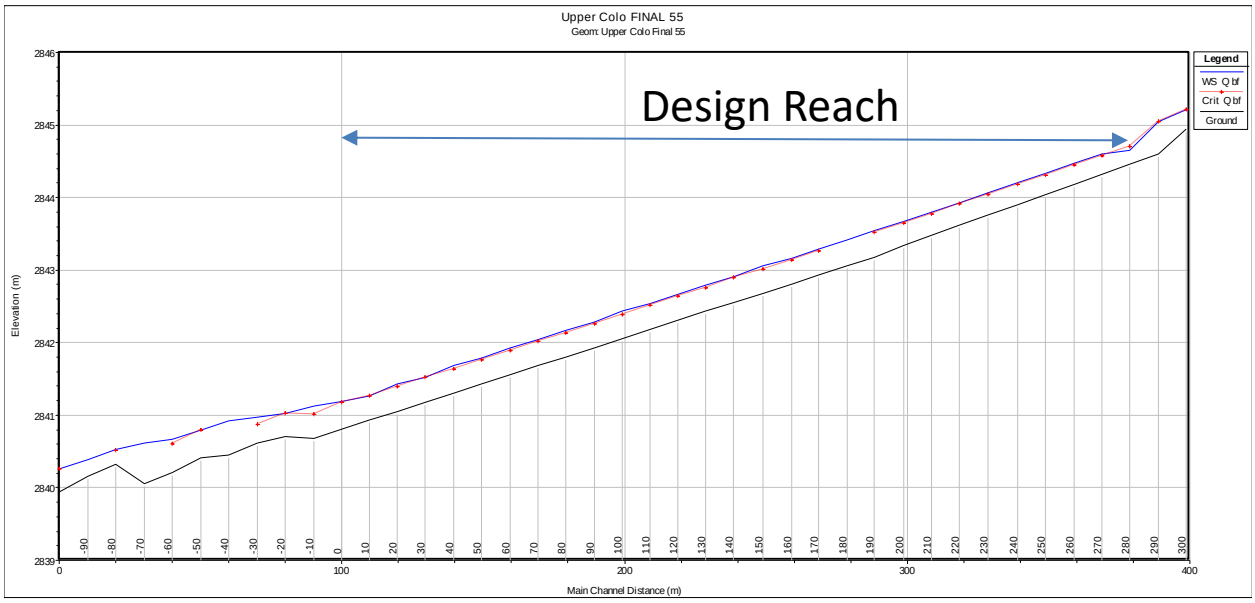


Figure 4. Bankfull flow profile analysis. The water surface remains subcritical through the design reach.

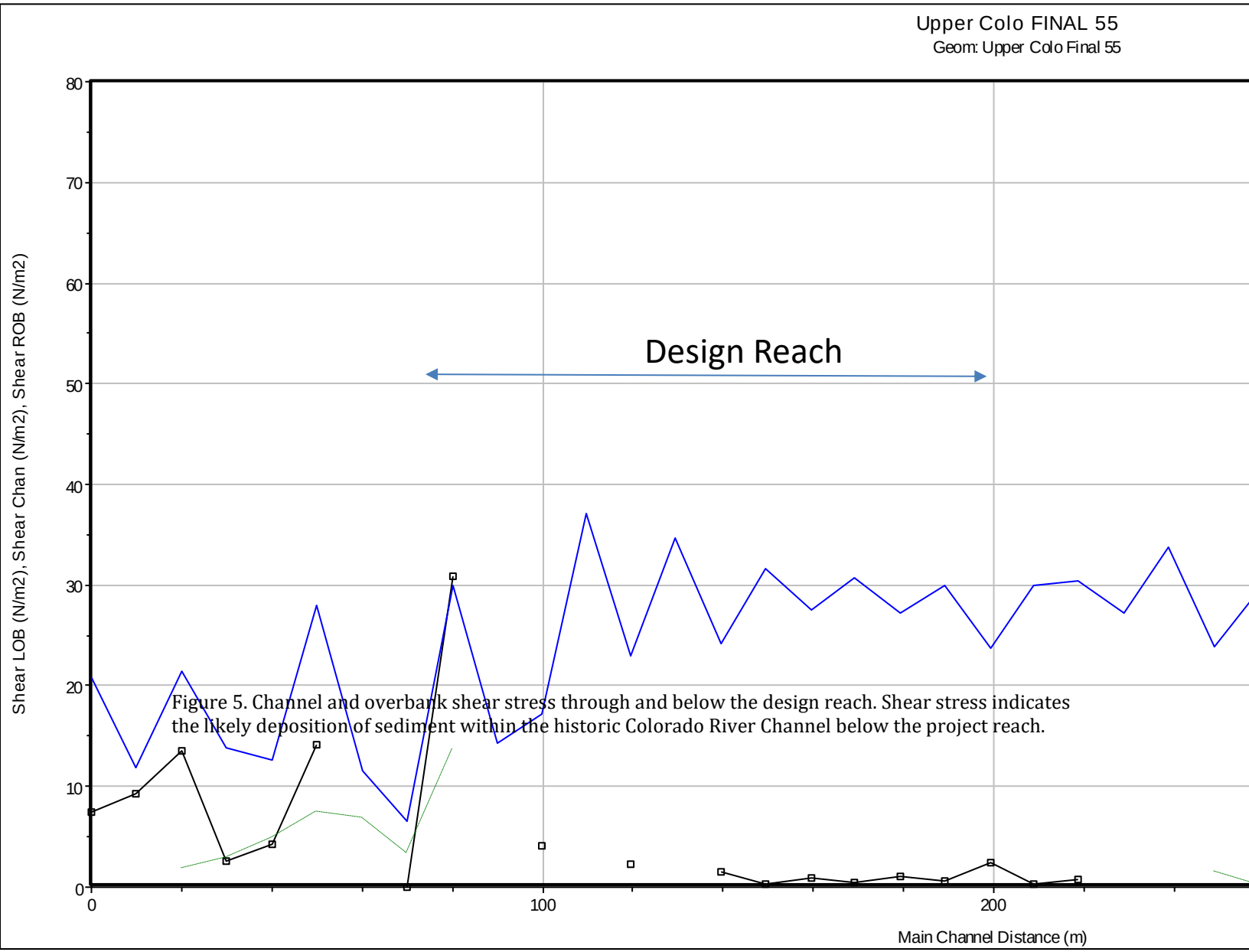


Figure 5. Channel and overbank shear stress through and below the design reach. Shear stress indicates the likely deposition of sediment within the historic Colorado River Channel below the project reach.

Discussion

Based on the effectiveness monitoring after the Phase I Channel construction as well as the hydraulic modeling described in this section, the final restoration elements of an effective channel connecting the Colorado River in Zone 3 with its historic channel in Zone 4, the creation of hydraulically important floodplains adjacent to the channel, filling the eastern channel, and creating floodplain terraces for willow growth are appropriate and achievable restoration objectives. Final restoration design plans to achieve these objectives can be found in Appendix B.

Elevations for the first three components (Channel creation, hydraulically active floodplain, filling eastern channel) are provided with a high degree of certainty based on the analyses above. While proposed elevations are also provided for the floodplain terraces, it is important to remember the need for continued monitoring of these areas once the channel is constructed to identify the appropriate amount of excavation. Effectiveness monitoring after the construction of the Phase I Channel was constrained in some areas due to the backed up water in the northwest portion of the project area. The proposed channel should drain this area more than the Phase I Channel. The terrace elevations provided here, based on groundwater monitoring after the Phase I Channel construction, can thus serve as a rough guide.

Appendix A
HEC RAS Hydraulic Modeling

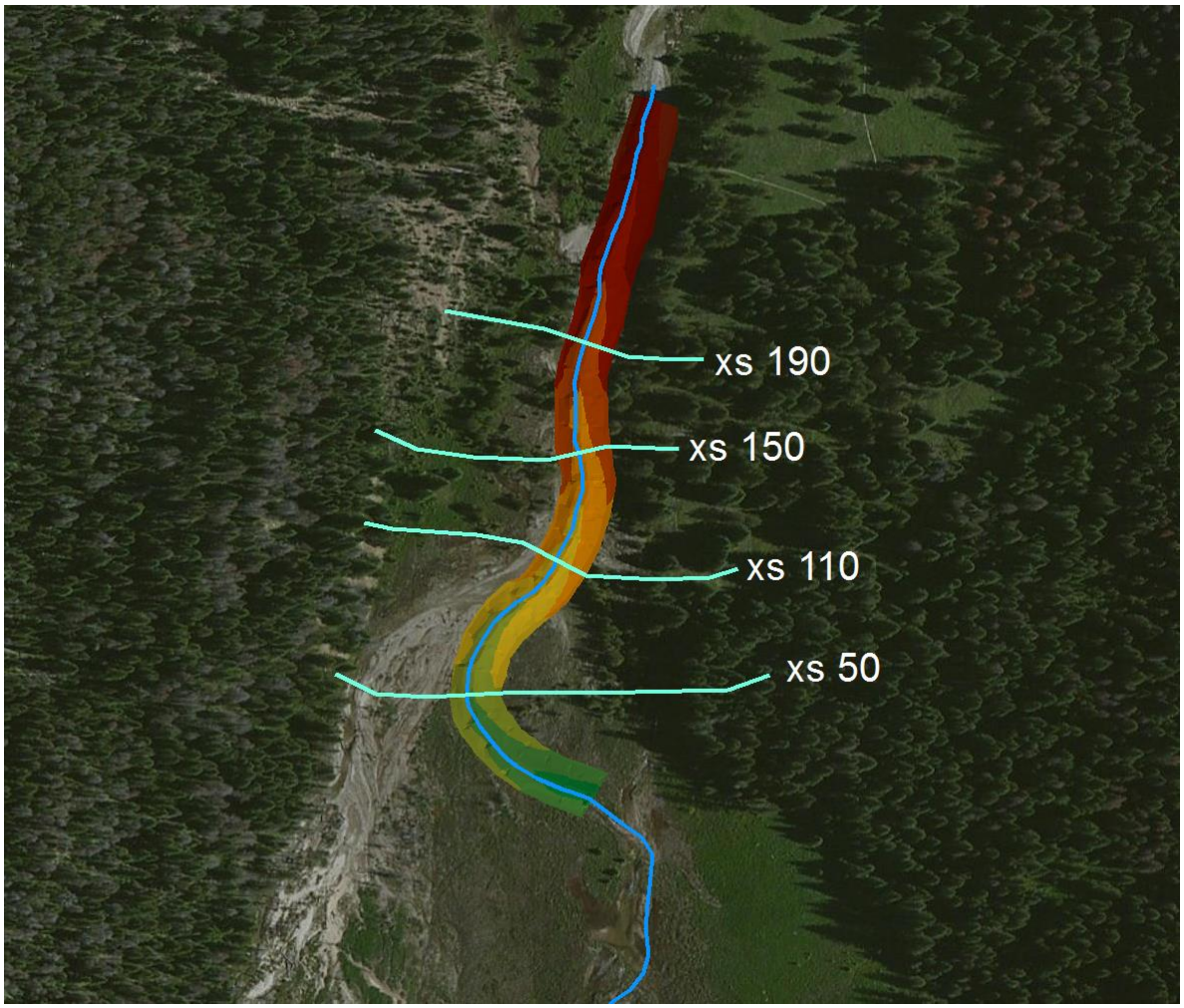


Figure A1. Aerial imagery and the proposed channel with cross section areas highlighted. The four cross section areas are further described in figures A2 through A5.

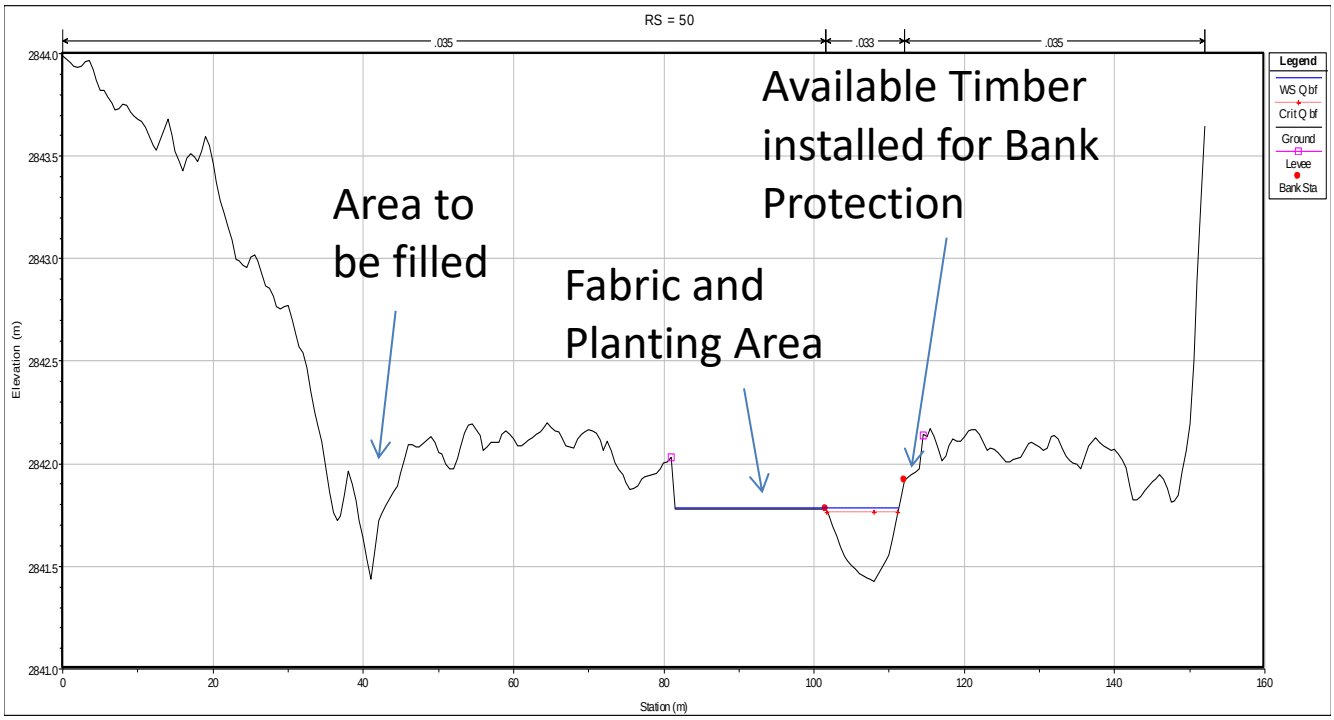


Figure A2. Cross section 50 as seen looking down the channel, with east to the left and west to the right. This cross section is entirely within the Lulu City Wetland. The eastern channel is clearly visible as the new low point in this area, requiring filling to stop further erosion. The river meanders through this cross section, requiring the construction of a floodplain on only one side. Although the western portions of this cross section are filled with debris, little to no excavation is required to create hydrologic conditions conducive to tall willow growth. The outside meander of this cross section should be protected with available timber.

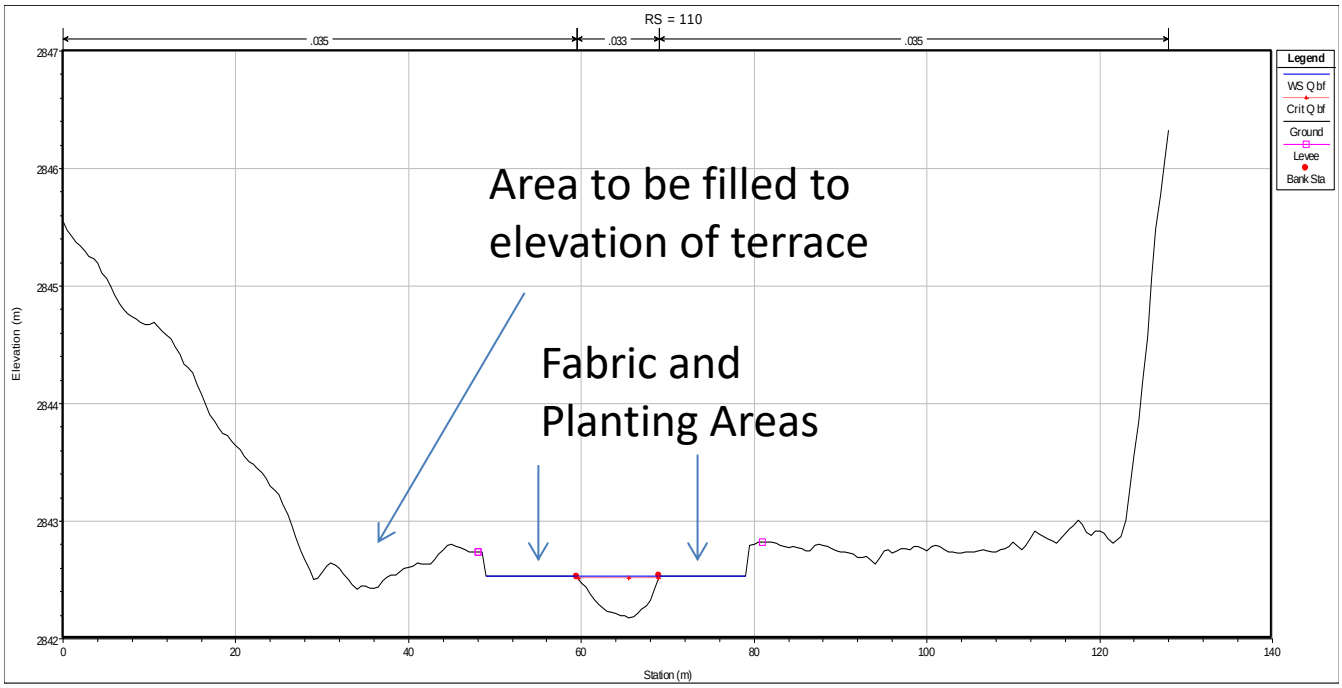


Figure A3. Cross section 110 as seen looking down the channel, with east to the left and west to the right. This cross section shows the start of the eroding channel on the east side of the valley, as well as the deposited sediment holding water back in the northwest portion of the wetland. The created floodplain on either side of the new channel will be installed with plants and fabric.

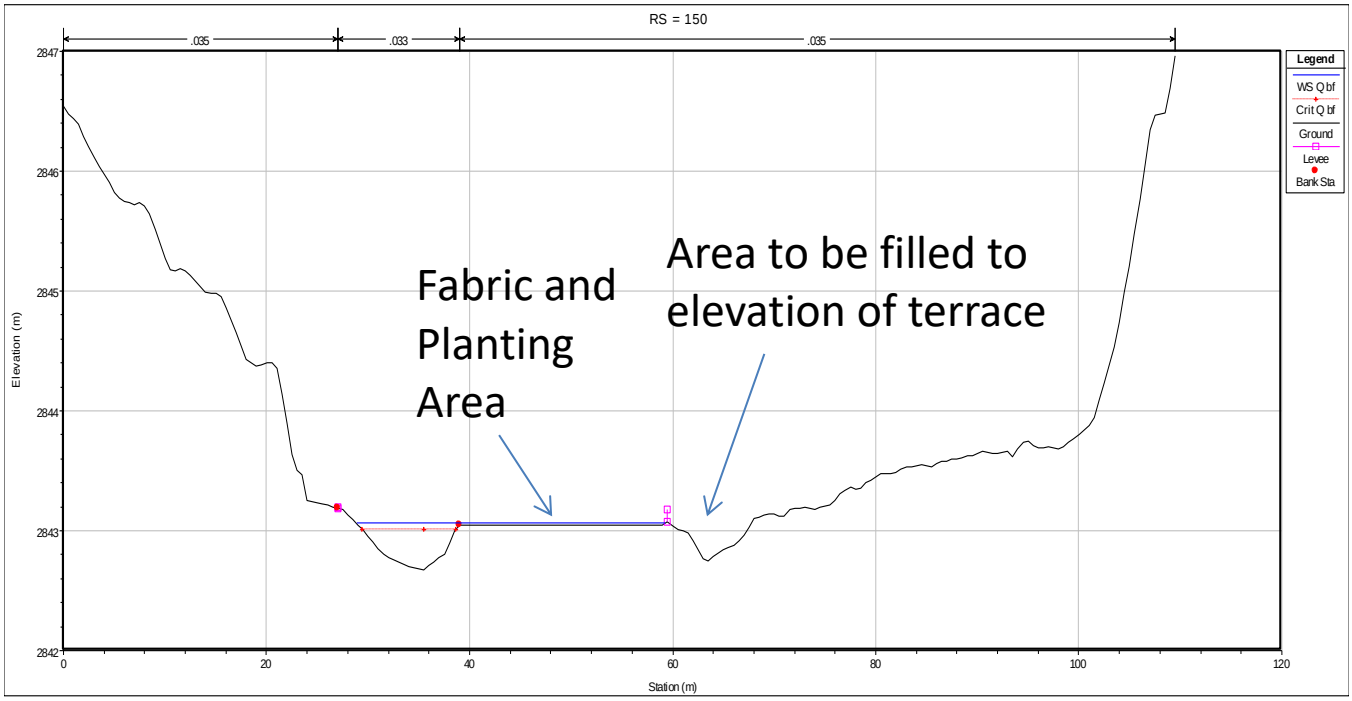


Figure A4. Cross section 150 as seen looking down the channel, with east to the left and west to the right. The bed elevation here has been elevated from deposition of the breach debris. The channel will be constructed within this deposition and the historic meander to the west of the proposed channel will be filled in to match the elevation of the floodplain terrace. Plantings and fabric will be installed in the created floodplain on the west side of the river.

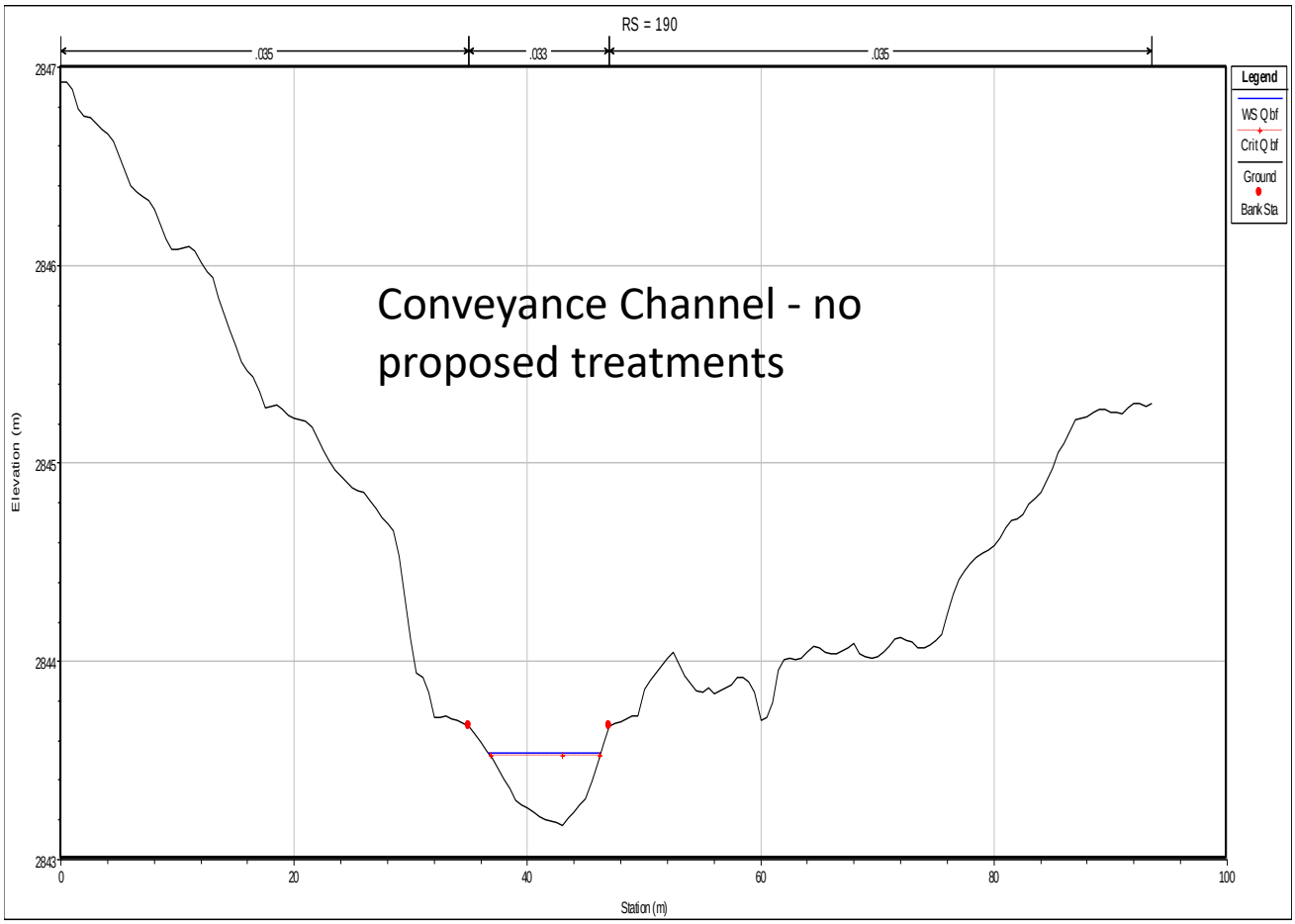


Figure A5. Cross section 190 as seen looking down the channel, with east to the left and west to the right. Transect 190 is located up stream of the Zone 3-4 interface just above the start of channel and floodplain construction. The river through this portion of the valley is constricted between the hills on either side of the river.

Appendix B
Final Restoration Plans