WEST CONSULTANTS, INC.

WWTP Protection Memo

August 31, 2017

PROJECT: City of Montesano WWTP Protection – Log Jacks

TO: Matt Kastberg, Parametrix, Inc.

FROM: Keelan Jensen, Dan Eggers, Henry Hu, WEST Consultants, Inc.

Re: WWTP Protection - Log Jacks: Hydraulic Modeling and Conceptual Design

INTRODUCTION AND PURPOSE

Ongoing migration of the Wynoochee River towards the east is threatening the City of Montesano's wastewater treatment plant (WWTP). The City and Parametrix have been evaluating temporary and permanent solutions to protect the WWTP from further channel migration. One of the temporary measures includes the placement of a series of log jacks to the north of the WWTP. These log structures are expected to protect the land behind the log jack placement from being undermined and/or eroded. In support of designing these log jacks, Parametrix has asked WEST Consultants, Inc. to perform hydraulic modeling of the conceptual design, and use the hydraulic results to provide input on the design and to assess the usefulness of the structures.

The primary purpose of this modeling was to test the effectiveness of the proposed log jack design, and to calculate the hydraulic information necessary for the conceptual design of the log jacks. In addition to the log jacks, WEST also investigated the possibility of redirecting some flow through historic channels, which could both reduce channel migration in the short term and encourage channel relocation in the long term. WEST identified an area upstream of the current project where removal of some higher ground on the right bank could allow flow to enter a relic channel and avoid the project location, and included this in the modeling. The project location is shown in Figure 1.

MODEL DEVELOPMENT AND ALTERNATIVES

WEST had previously developed a two-dimensional hydraulic model of the area using the SRH-2D modeling program. We incorporated updated channel survey data into the existing model, and then ran the model with six different scenarios: **1)** existing conditions, **2)** removal of upstream high ground, **3)** log jacks in the overbanks, **4)** log jacks and removal of upstream high ground, **5)** log jacks in this existing channel, and **6)** cutoff channel following historic channel path.

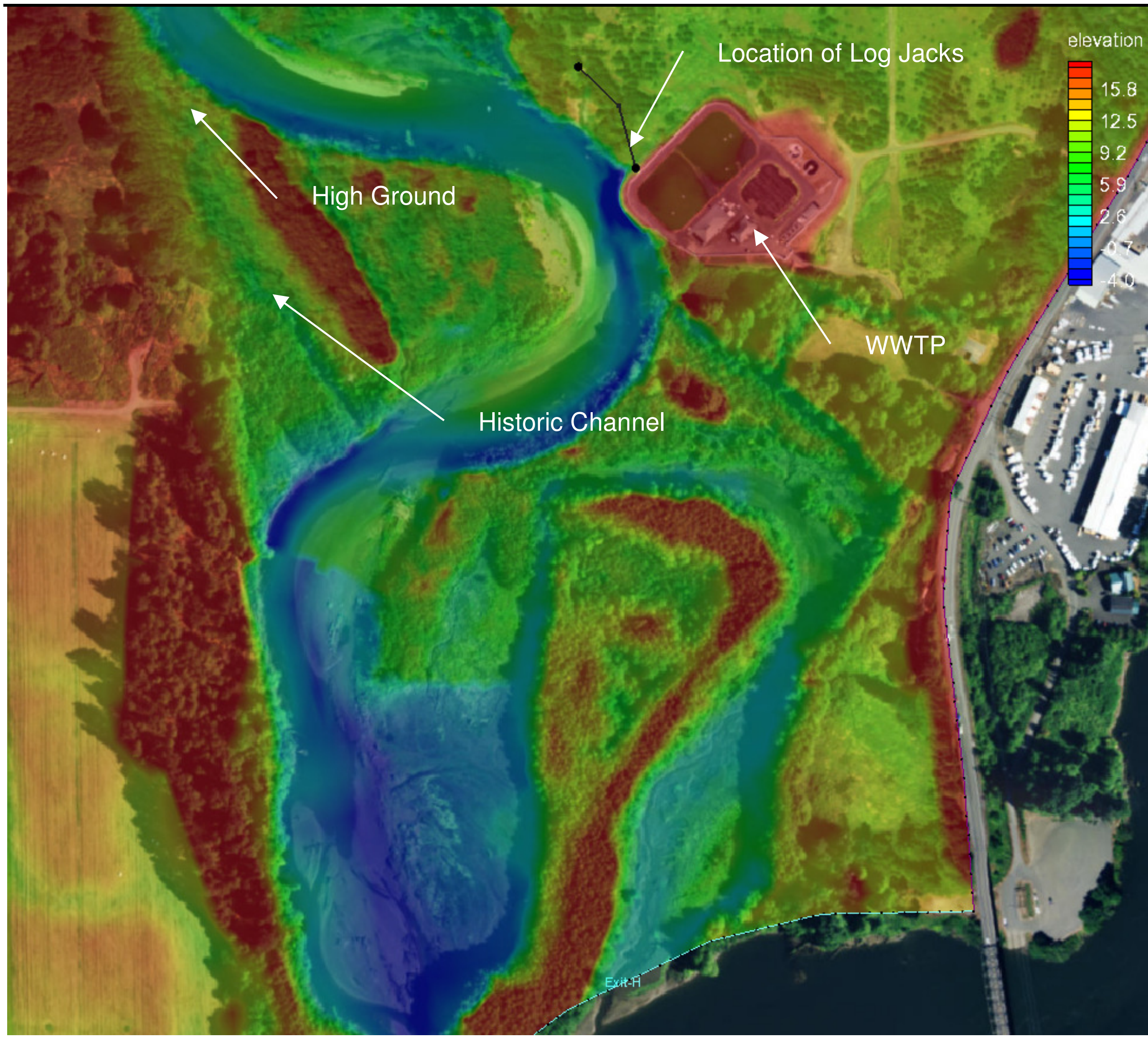

Figure 1. Project area, with elevation contours over aerial imagery.

For the existing conditions **Alternative 1**, no changes were made after the updated channel survey was incorporated. This condition was used as the base that was adjusted for all other conditions. For **Alternative 2**, we removed an area of high ground upstream from the project area, in order to open an historic channel to more flow and possibly reduce velocities in the vicinity of the WWTP. For **Alternative 3**, we simulated log jacks being added to the existing conditions model by increasing the roughness in the overbank in the area of the log jack placement. For **Alternative 4**, we included the increased roughness for the log jacks and removed the upstream high ground. For **Alternative 5**, we simulated how the log jacks would affect the channel velocities if the river migrated and the log jacks entered the main channel flow. We did this by increasing roughness along the outside of the bend, where we would expect the log jacks to settle. This assumes that the main channel of the Wynoochee River would have similar hydraulic characteristics as the existing condition, but would be shifted in plan view. Finally, for **Alternative 6** we attempted to divert more flow along the historic channel by cutting a new channel along the relic channel, in addition to removing the high ground. We simulated alternatives 1-4 using three flow events, the 2-, 50-, and 100-year recurrence interval flows. For alternatives 5 and 6 we only simulated the 100-year event.

MODEL RESULTS – EFFECTIVENESS OF LOG JACKS

After running the various alternatives and flow regimes, we found that the log jacks generally reduced velocity in their vicinity, which is expected. Comparing alternatives 1 and 3, which compares existing conditions to what conditions would be immediately after the log jacks are constructed, the velocity in the overbanks decreases due to the log jacks, and the near bank velocity increases slightly, probably due to more flow staying in the channel. When alternatives 1 and 5 are compared, the results show that the in-channel log jacks decrease flow velocity near the bank, and increase flow velocity in the center of the channel. This is likely caused by the log jacks forcing more flow away from the bank and into the center of the channel. These results are shown in Table 1.

Table 1. Flow Changes Caused by addition of Log Jacks.

	Maximum Overbank Velocity (ft/s)	Maximum Channel Velocity (ft/s)	Maximum Near Bank Velocity (ft/s)
Existing Condition (Alt 1)	2.1	7.6	4.5
Log Jacks in Overbank (Alt 3)	0.9	7.6	5.0
Log Jacks in Channel (Alt 5)	N/A	8.2	3.0

Comparing Alternatives 1 and 2, we found that removing the high ground upstream of the project area had very little effect on the flow near the waste water treatment plant. While removing the high ground did allow a little more flow to enter the historic channel, the total change of peak flow in the channel near the water treatment plant was less than 1% of total flow. Results of this comparison are shown in Table 2. Results from Alternatives 2 and 4 are similar, so Alternative 4 results are not shown here. As a note, the increase in relic channel flows does not precisely match the decrease in main channel flows. This is caused by a difference in peak times and by a dispersion of some flow into overland flow.

Table 2. Flow Changes Caused by High Ground Removal.

	Existing Conditions Flow [Alt 1] (cfs)	High Ground Removed Flow [Alt 2] (cfs)	Difference (cfs)	Difference (%)
Main Channel Flow	14,503	14,466	-37	-0.3%
Relic Channel Flow	2,004	2,058	54	2.7%

Comparing Alternatives 1 and 6, the removal of additional material along the historic channel line had a much larger effect on the flow than just removing the high ground between the existing main channel and the relic channel. Removing some of the material in the relic channel almost doubled the flow in the relic channel, while the flow in the main channel decreased by 7.5%. This comparison is shown in Table 3. The decreased flow in the main channel also resulted in lower velocities near the WWTP, as shown in Table 4.

It should be noted that the channel that was added to the terrain, representing the removal of material in the relic channel, is smaller than the existing main channel, and the larger the added channel is, the more flow will be redirected. This could be further encouraged by adding some piles or other structure to the main channel that would encourage more flow to divert down the new channel. This may, over time, encourage the channel to change its location and move further away from the WWTP.

Table 3. Flow Changes Caused by the Added Channel.

	Existing Conditions Flow [Alt 1] (cfs)	Channel Added Flow [Alt 6] (cfs)	Difference (cfs)	Difference (%)
Main Channel Flow	14,503	13,412	-1,092	-7.5%
Relic Channel Flow	2,004	3,777	1,773	88.5%

Table 4. Flow Changes Caused by the Added Cutoff Channel.

	Overbank Velocity (ft/s)	Channel Velocity (ft/s)	Near Bank Velocity (ft/s)
Existing Condition (Alt 1)	2.1	7.6	4.5
Log Jacks in Overbank (Alt 3)	0.9	7.6	5.0
Cutoff Channel Added (Alt 6)	0.7	6.9	4.4

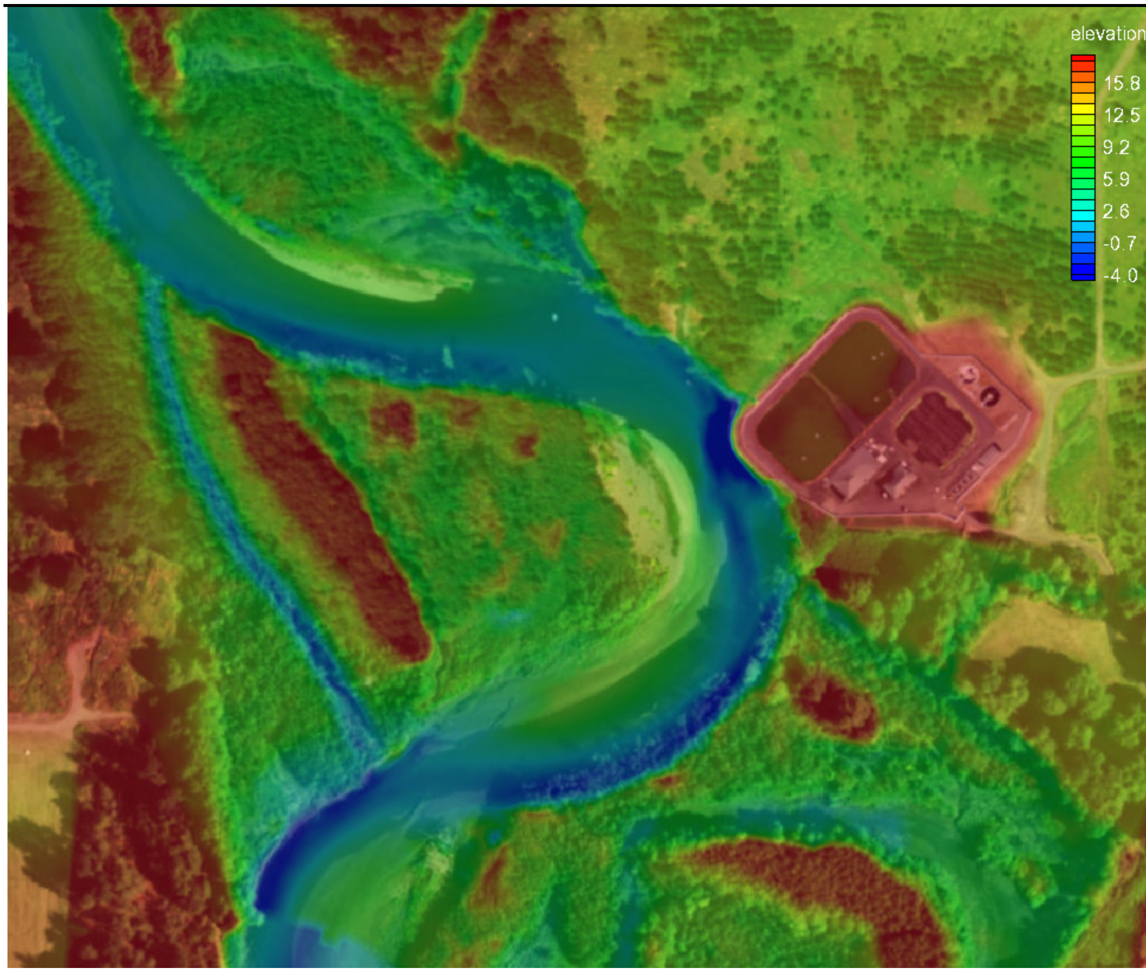

Figure 2. Project area showing removal of material in the relic channel.

CONCEPTUAL DESIGN

We used the results from the hydraulic model to test several log sizes and anchor sizes for the log jacks. Parametrix provided an initial design estimate for the log jacks, and we adjusted the design to meet safety factor criteria. In testing the conceptual design for the log jacks, we looked at the balance of forces to determine if a design would function as hoped. For the log jack to be considered stable in the vertical direction, the weight of the log jack must be greater than the buoyant force exerted on a completely submerged log jack. For the log to be considered stable in the horizontal direction, the force of friction between the jack and the river bed must be greater than the drag force exerted by the river flow on the log jack. Following recommendations for the design of large woody material structures in streams (Cramer, 2012), a minimum safety factor of 1.5 was the goal for both buoyancy and drag calculations. We performed calculations using results from the 2-year, 50-year, and 100-year events, and decided that the 100-year event was the most conservative, and was therefore used in the conceptual design recommendation.

After testing several log and anchor sizes, we decided that the optimal design would use 15 foot logs with a diameter of 18 inches. A minimum anchor weight of 16,000 lbs would be required for this design, which would require a boulder anchor with a minimum diameter of 5.7 feet (assuming a spherical rock). This combination would provide a minimum safety factor of 1.53. Due to the difficulty of finding logs with a diameter of 18 inches, a range of 16-20 inches is recommended for the logs used in the log jack design. Results from several design criteria tests are shown below in Table 5, with the final recommended design criteria marked in bold.

Table 5. Log Jack Dimension Results.

Log Length (ft)	Log Diameter (in)	Anchor Weight (lbs)	Anchor Diameter, approximate (ft)	Buoyancy Safety Factor	Drag Safety Factor
15	20	10,800	5.0	1.22	1.01
15	18	10,800	5.0	1.32	1.30
15	16	10,800	5.0	1.44	1.57
15	18	11,000	5.0	1.33	1.35
15	18	12,000	5.2	1.37	1.59
15	18	14,000	5.5	1.45	2.06
15	**18**	**16,000**	**5.7**	**1.53**	**2.54**
15	18	18,000	5.9	1.59	3.01
15	18	20,000	6.1	1.65	3.49

CONCLUSIONS AND RECOMMENDATIONS

Overall, the model results show that the log jacks should decrease flow velocity in the overbanks now, and that should the channel migrate and the log jacks fall into the channel, they will continue to decrease the velocity and divert flow away from the bank. Using the results from the hydraulic model and following standards for the design of wood structures in rivers, we recommend that the log jacks be constructed of 15 foot logs that are 16-20 inches in diameter, and that the jacks be secured with boulder anchors that have a minimum weight of 16,000 lbs.

While the results indicate that the log jacks should have at least some protective effect on the bank near the waste water treatment plant and on the area north and east of the log jacks, it is still possible that the river could migrate at a more upstream location and get around the extent of the log jack installation. In a previous study (WEST 2016), the average migration rate at the project area was estimated to be about 3 ft/yr. The channel bank is approximately 140-150 feet away from the north end of the log jack extents, so the log jacks should provide protection for more than 10 years if the channel continues to move at the same average rate. Even using the maximum calculated rate from the previous study of 17 ft/yr, the river should not reach the end of the log jack installation for at least 8 years, so the log jacks should still provide protection for the expected 5 years that are required of this temporary measure.

While the log jacks should protect the WWTP for the required amount of time, there are several additional factors that should be accounted for. Migration of the channel is heavily dependent on the basin hydrology. Because we cannot predict or forecast exactly how much precipitation the basin will receive or its distribution in the future, we cannot predict how the rate of channel migration will change. Several years of higher than normal flows could significantly increase the rate of channel migration, decreasing the effective life of this mitigation measure. Additionally, because the log jacks are going to be installed above ground, they may degrade or decay over time, depending on the weather conditions. This could decrease their effectiveness in providing bank protection. With this in mind, any mitigation measures such as log jacks should be monitored during and after high flow events, as well as on a somewhat regular basis to ensure the structural integrity of the jacks.

REFERENCES

Cramer, Michelle L. (2012). *Stream Habitat Restoration Guidelines*. Washington State Department of Fish and Wildlife. Olympia, WA.

WEST Consultants, Inc. (2016). City of Montesano WWTP Protection Geomorphology Memo. May 5, 2016.