Effects of Spacing between Engineered Logs Jams on Flow, Scour, and Bar Patterns

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Abstract

Large Woody Debris (LWD) assembles in natural streams and rivers and affects the fluvial geomorphology. LWD contributes to the development of scour pools, bars, and floodplains; furthermore, these fluvial formations are necessary to many ecosystem habitats. Recently, many stream restoration projects have used structures, called engineered log jams (ELJ) similar to LWD to stabilize banks and create ecological habitats. Many engineering firms have implemented these structures; however, in many cases, the methods of design are trial and error (Shields et al 2004). Detailed flow lines, velocity gradients, and local sediment scour and deposition patterns around log structures are not well known. In a flume scaled experiment using sand sized sediments, the geometries of the scour pools and the bars were dependent on the spacing between two parallel logs.

Background

Channel straightening and land use modifications in the early and mid-20th century have degraded river health and increased bank erosion. Natural vegetation, such as trees, are used as more natural and less costly structures to restore stream reaches. These structures designs have little theoretical basis for their configurations.

Design and Methods

- The ELJ design consisted of two parallel rooted logs faced upstream to the flow (*Figure 1*).
- D = 0, 1, 2, 4, 6 inches (0, 2.54, 5.08, 10.16, 15.32 cm)
- Single rooted log used as a control.
- Flume (20 m long and 50 cm wide); Q_{avg} = 7.11 lps; $Slope_{avg}$ = 0.0032; v_{avg} = 0.342 m/s; Froude # = 0.548.

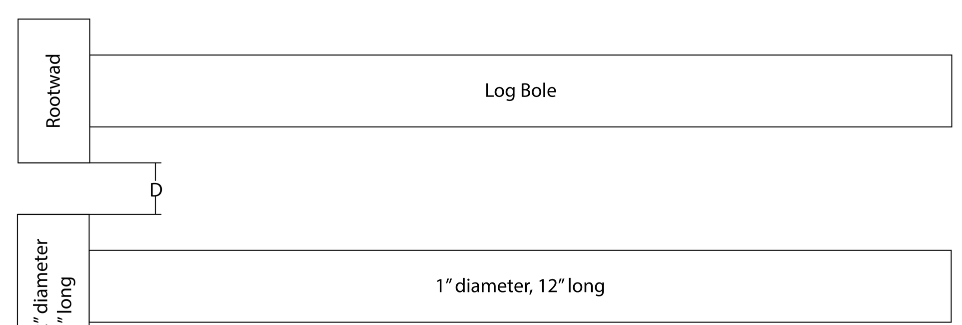

Figure 1: A generalized depiction of the ELJ model.

The bed topography was measured before and after each log structure was place in the flow for 30 min. Last, particle image velocimetry (PIV) was performed using a Phantom 9.0 high-speed camera and PIVLab.

Results

- As the logs moved apart, the scour pool and bar structures became much smaller (*Figure 2 & Table 1*). There was additional scour from flow constrictions between the two logs narrow spaced ELJ. At the wider spaced ELJs, the bars separated and became independent of one another.
- The flow constriction was quantified in the PIV analysis (*Figure 3*).

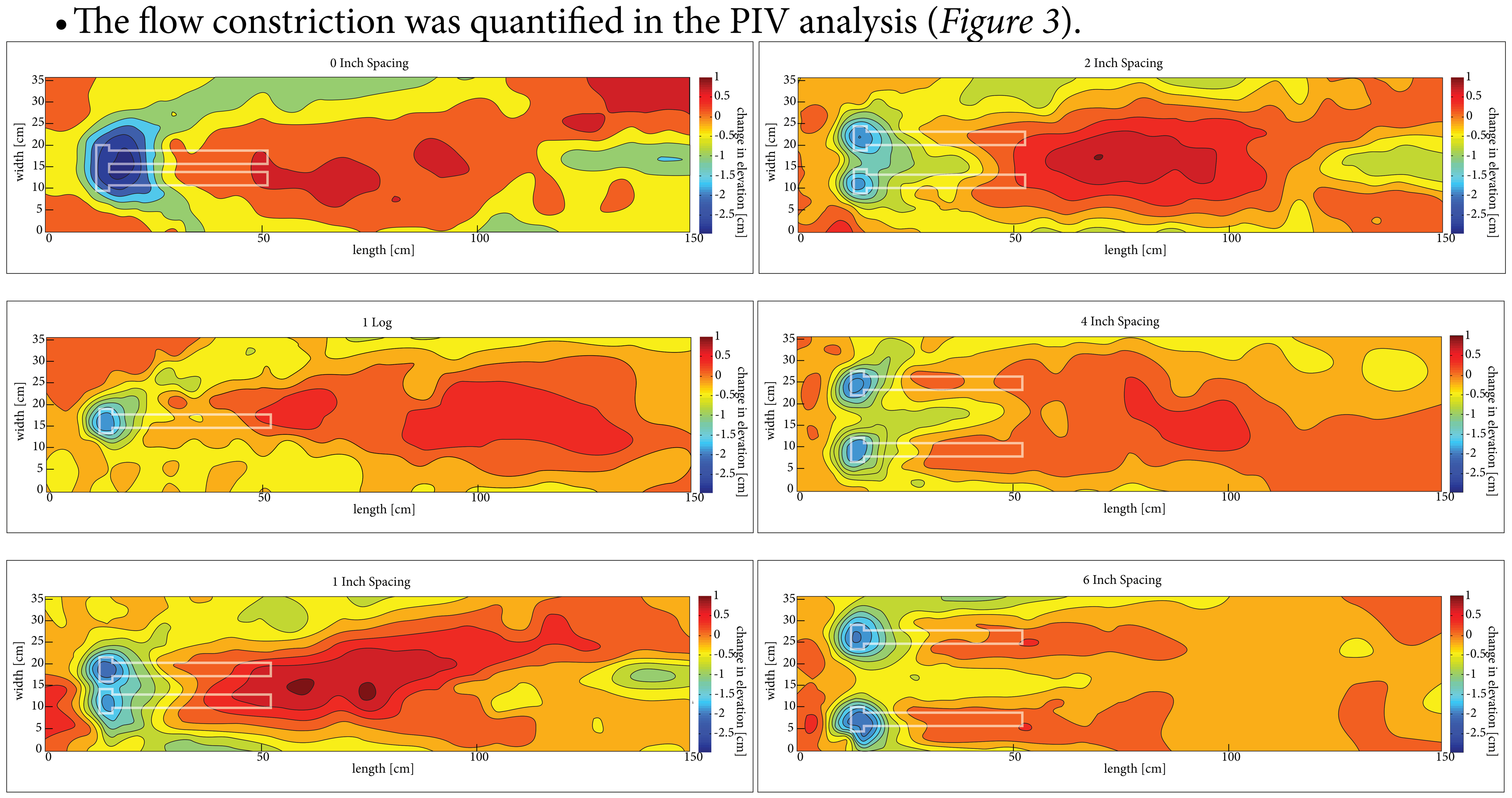

Figure 2: The change in bed topography for the control and five ELJ tests.

Table 1: Bed topography change of the six tests.

Test	Δ Elevation [cm]		Area [cm²]		Volume [cm³]	
	Minimum	Maximum	Scour Pool	Deposited	Scour Pool	Deposited
single log	-3.492	0.877	193.8	2269.3	332.9	853.0
0 Inch ELJ	-5.322	1.544	1038.1	2667.6	2011.7	1656.2
1 Inch ELJ	-3.836	1.592	688.2	2348.3	1143.8	1351.3
2 Inch ELJ	-3.506	1.505	738.0	2326.4	1131.7	1185.8
4 Inch ELJ	-3.472	1.222	473.6	2249.8	793.5	631.8
6 Inch ELJ	-3.752	0.675	511.0	1334.7	955.5	217.3

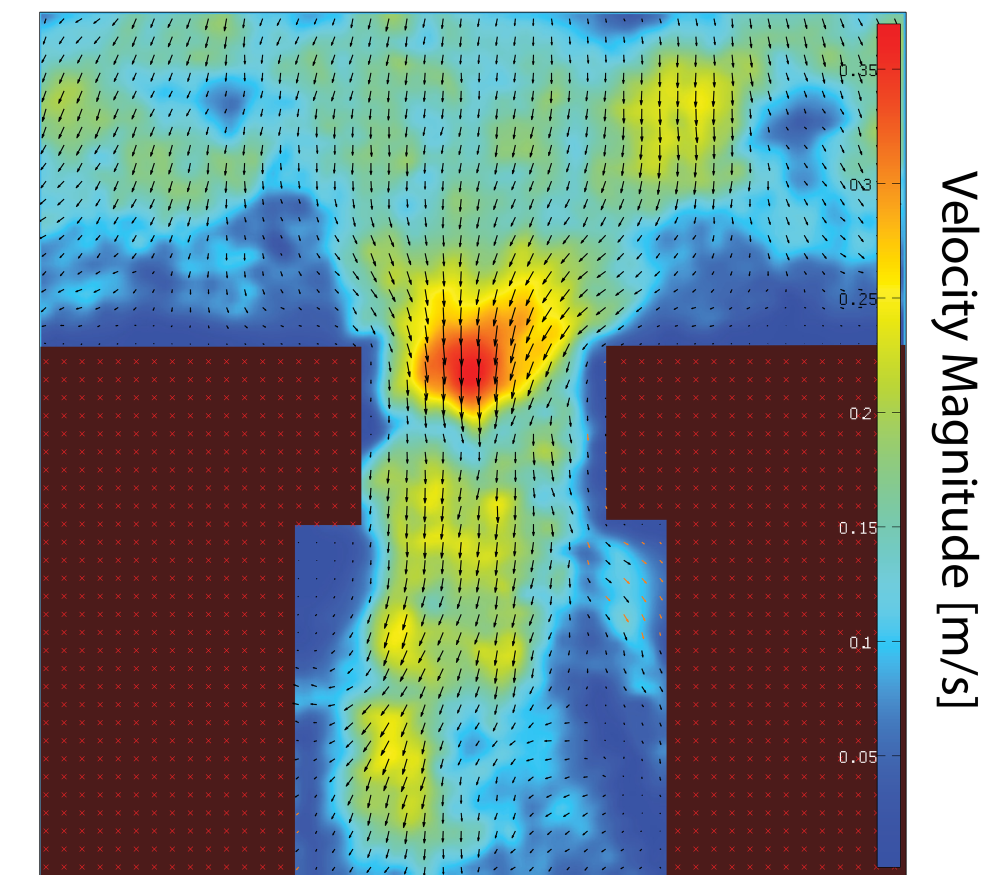

Figure 3: PIV analysis of the flow constriction between the 1-inch spaced ELJ.

Discussion

With our data quantified, we modeled the trend between the formation geometries and the spacing of the ELJ (*Figure 4*). The parameters and variables are listed in *Table 2*.

- The model was in the form of an exponential decay: $y = ae^{-bx} + c$.
- Variables: x, spacing and y, dependent variable.
- Parameters: a & b, fitting parameters and c, the convergent point set by the control test.

Table 2: Variables and parameters of each non-linear fit.

variable		parameter		
x	y	a	b	c
Spacing [cm]	Maximum Negative Elvation Change [cm]	1.832 cm	0.677 cm^{-1}	3.492 cm
Spacing [cm]	Area of Scour Pool [cm^2]	609.3 cm^2	0.156 cm^{-1}	387.6 cm^2
Spacing [cm]	Void Volume of Scour Pool [cm^3]	1280 cm^3	0.252 cm^{-1}	665.8 cm^3

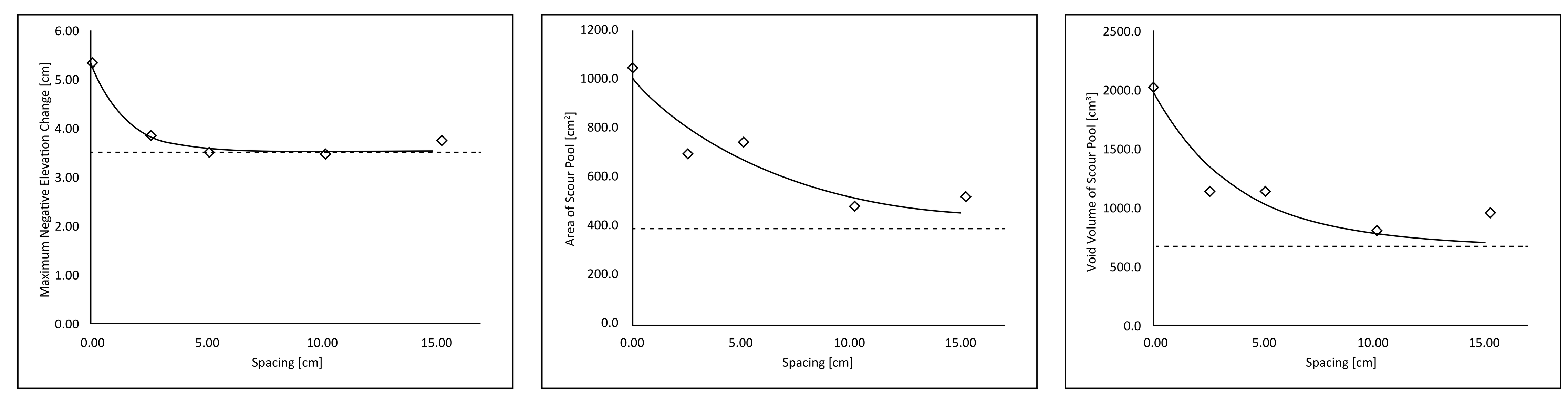

Figure 4: Non-linear models fit to the experimental dat for maximum elevation change, scour pool area, and void volume of the scour pool as a function of spacing. The diamonds are the data points, the solid lines are the non-linear models, and the dashed lines are the convergence parameters.

There were a few sources of error that caused uncertainty:

- Deposition did not follow the exponential trend due to its increased sensitivity to edge effects.
- The slope was not constant throughout the experiments because the flume was not fed with sediment. Slope can increase the amounts of shear stress and, therefore, sediment transport.

Future studies can explicitly investiagate the effects of slope amounts of scour and deposition around ELJs. Last, more studies using PIV on the local flow velocities around ELJ structures can explain the structures locations.

Conclusion

Simple models of ELJs and their associated patterns of scour and deposition can be studied in flume scale experiments. This opens an opportunity for research that can create a systematic basis for design using woody debris in stream restoration.

Acknowledgments

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References

Shields, F., N. Morin, and C. Cooper (2004), Large woody debris structures for sand-bed channels, *J. Hydraul. Eng. -ASCE, 130*, 208-217.