3. Preliminary Results of the Hydraulic Effects of Beaver Dams at Fanno Creek at Greenway Park

By James White[1], Erin Poor[1,2], Cassandra Smith[1], Stewart Rounds[1], and Krista Jones[1]

[1] U.S. Geological Survey, Oregon Water Science Center, Portland, OR [2] Portland State University *Residence-time correspondence: cassandrasmith@usgs.gov *Modeling correspondence: jameswhite@usgs.gov *Continuous wetted cross-sectional area correspondence: epoor@usgs.gov

Goals and Objectives

Beaver dams and ponds fundamentally alter how water moves through a stream reach. Semi-porous dams can impound water, leading to backwatering, floodplain inundation, and overall changes in wetted area, depth, and velocity.

For this part of the study, USGS: 1) assessed hydraulic changes caused by beaver dams across a range of flows using a hydraulic model, 2) assessed the rate-of-change of continuous wetted area during storm events, and 3) estimated water residence time with continuous conductance data. These findings will be helpful for evaluating the effects of beaver dams and ponds on stormwater run-off and habitat diversity.

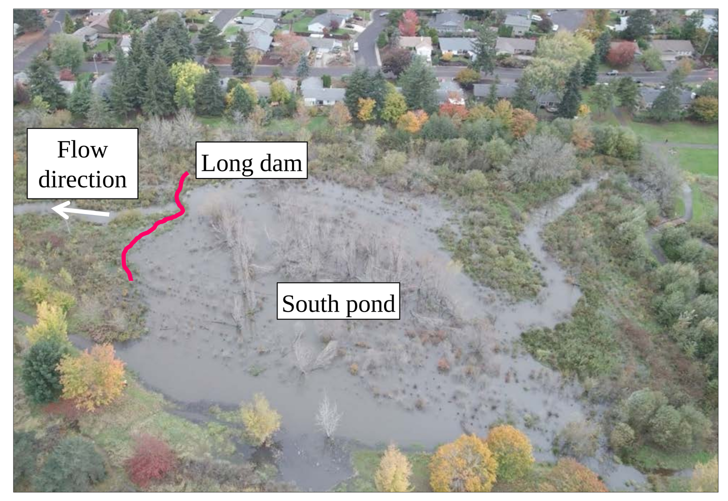


Figure 1. Photograph of the long dam and south pond created by its backwater in the Fanno Creek at Greenway Park reach. Courtesy of R. Poor.

Methods

Hydraulic Modeling with and without Beaver Dams

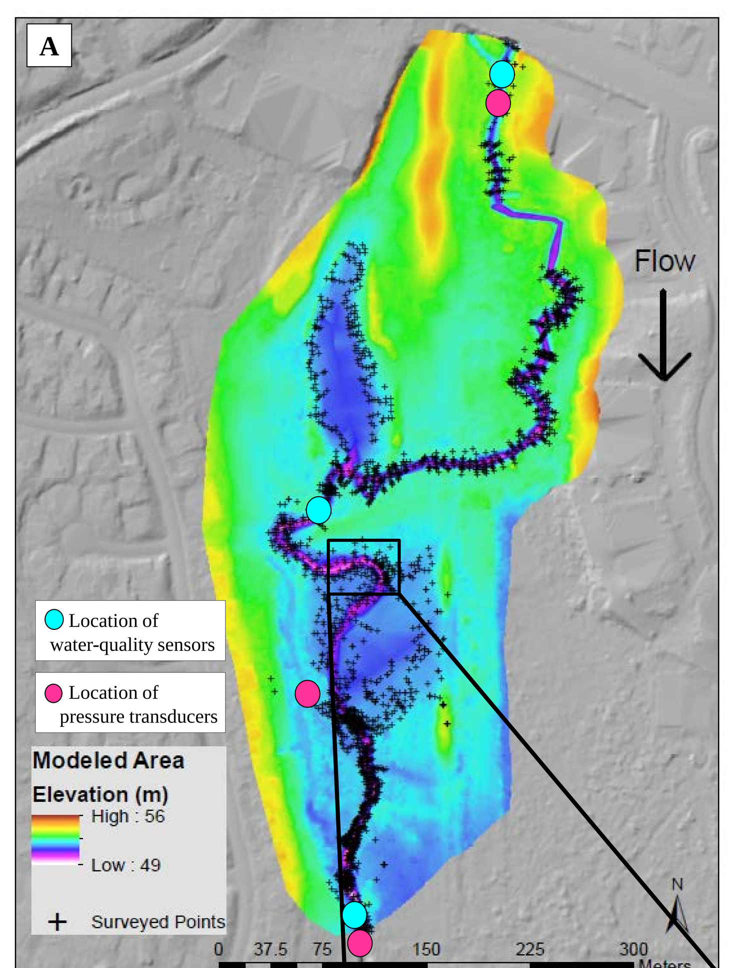
- The Delft-3D model was used with a flexible computational mesh to simulate flow, depth, and velocity for a 1-km reach with three dams of various heights and lengths (figs. 1-2).
- The model was calibrated using discrete water-level elevation data collected at low and high flows (fig. 2) and also with continuous water levels. Boundary conditions were developed from continuous water levels and discrete discharge measurements.
- Simulations were run with dams, without dams by removing the dams from the topographic data, and for three storm events of increasing magnitude.

Storm Flow Rates-of-Change using a Continuous Wetted Cross-sectional Area Analysis

- Continuous surface-water stage data were collected above and below the beaver reach. Stage time series were combined with channel cross sections to create continuous wetted cross-sectional area datasets. These datasets are surrogates for continuous stream discharge, and have been found to be useful when assessing hydrologic change.

Water Residence Time with Conductance Analysis

- Five summer events (when specific conductance was elevated) and five winter events (when specific conductance was lower) were analyzed to assess the travel time of the water between water-quality sensors.



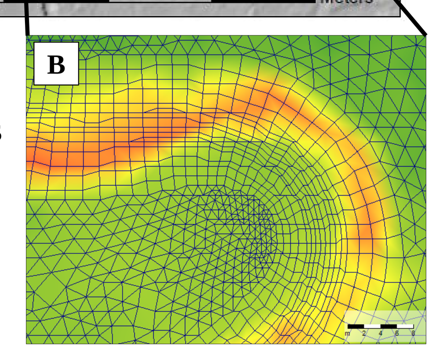


Figure 2. Images of the modeled reach showing A) locations of dams, water depth loggers, and water-quality sensors, and B) flexible mesh modeling grid.

Hydraulic Model Validation Results

1. Modeled inundation mostly matched observed edges of water (fig. 3A-B), with some areas of underestimation.
2. The model more accurately captures channel dynamics at high flow than at low flow (fig. 4A-B). Overall results suggest the model simulates hydraulic dynamics associated with the beaver dams reasonably well (table 1).

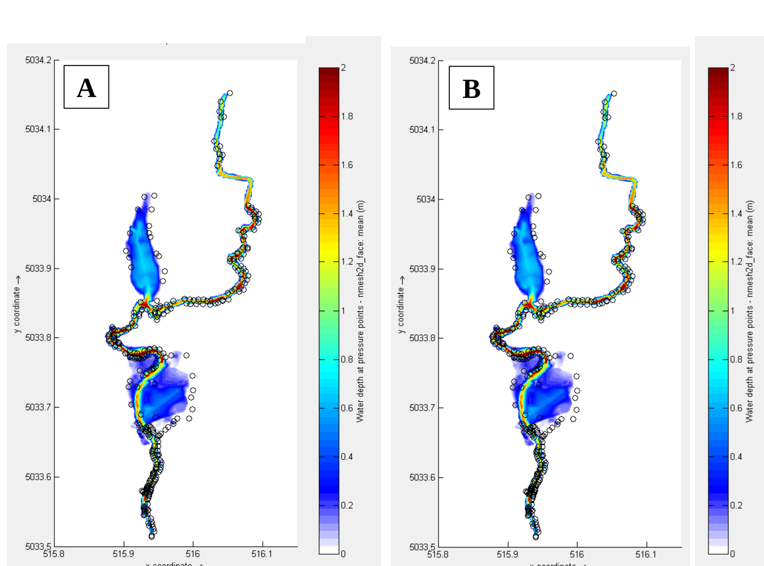


Figure 3. Modeled water depth and observed edge of water during: A) low flow (6 ft³/s), and B) high flow (240 ft³/s).

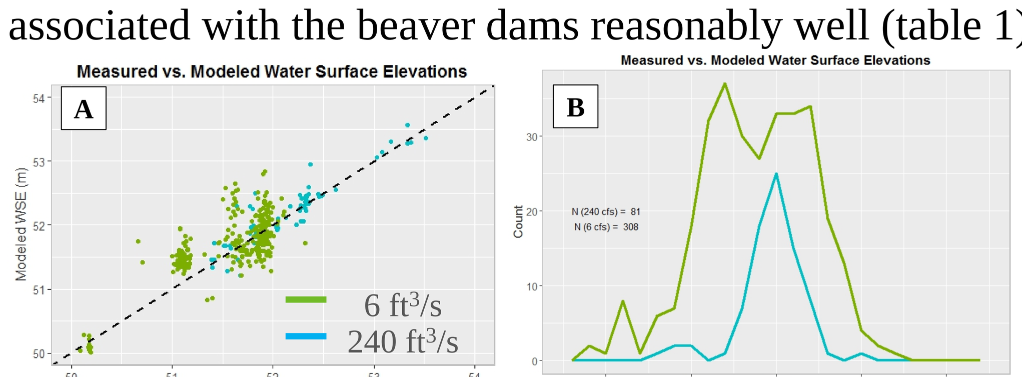


Figure 4. Plots showing: (A) observed and predicted water-surface elevations at low (6 ft³/s) and high flows (240 ft³/s), and (B) smoothed histograms of model water-surface elevation error.

Table 1. Model performance metrics for low (6 ft³/s) and high flow (240 ft³/s).

	Mean Absolute Error (ft³/s)	Nash-Sutcliffe	Percent Bias	R^2
High Flow	0.03	0.84	-0.07	0.86
Low Flow	0.12	0.49	-0.22	0.64

Hydraulic Modeling Results

1. Simulations with dams store more water than those without dams (fig. 5; tables 2-3). This storage results in a slight reduction of peak flows and a shift in peak timing (upstream to downstream), but minimal change in hydrograph shape.
2. Simulations with and without dams have different depth and velocity distributions at low flow (fig. 6A-B). However, the distributions converge as flows increase.
3. Shear stress is highest in the main channel of the simulations without dams (fig. 7A-B). It is lower and distributed laterally and longitudinally in the channel and floodplain in simulations with dams.

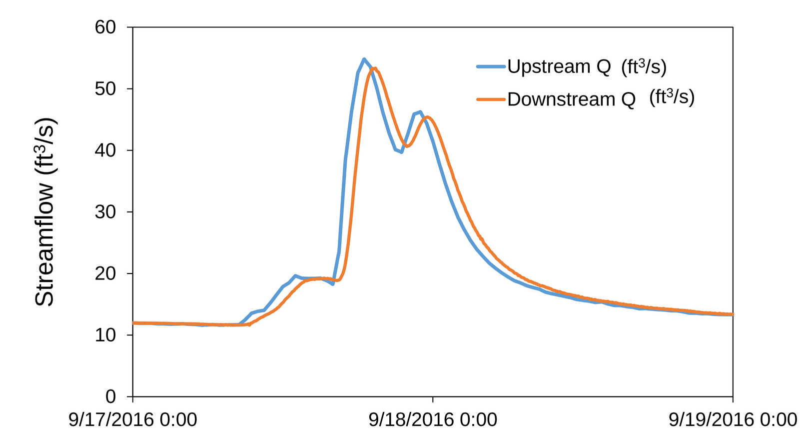


Figure 5. Hydrograph comparison at upstream and downstream cross sections in a small (55 ft³/s) storm.

Table 2. Volume and discharge differences at peak flows between the simulations with and without dams.

Peak discharge (ft³/s)	Discharge reduction (ft³/s)	Volume temporarily stored (ft³)	Total storm volume (ft³)
55	-0.3	15,000	2,651,000
175	0.6	294,000	38,137,000
210	0.3	337,400	21,380,000

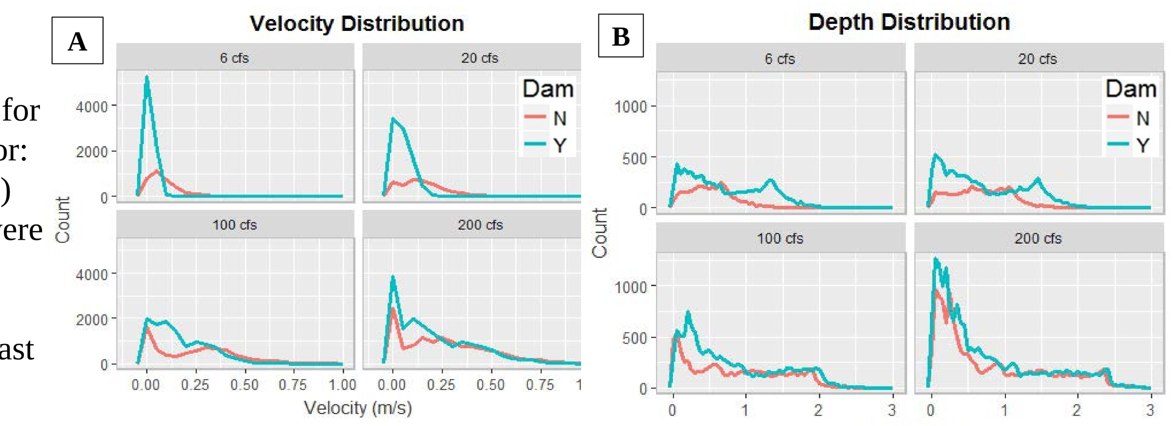


Figure 6. Distributions with and without dams for a range of flows for: A) velocity, and B) depth. All flows were simulated using steady state discharges of at least 24 hours.

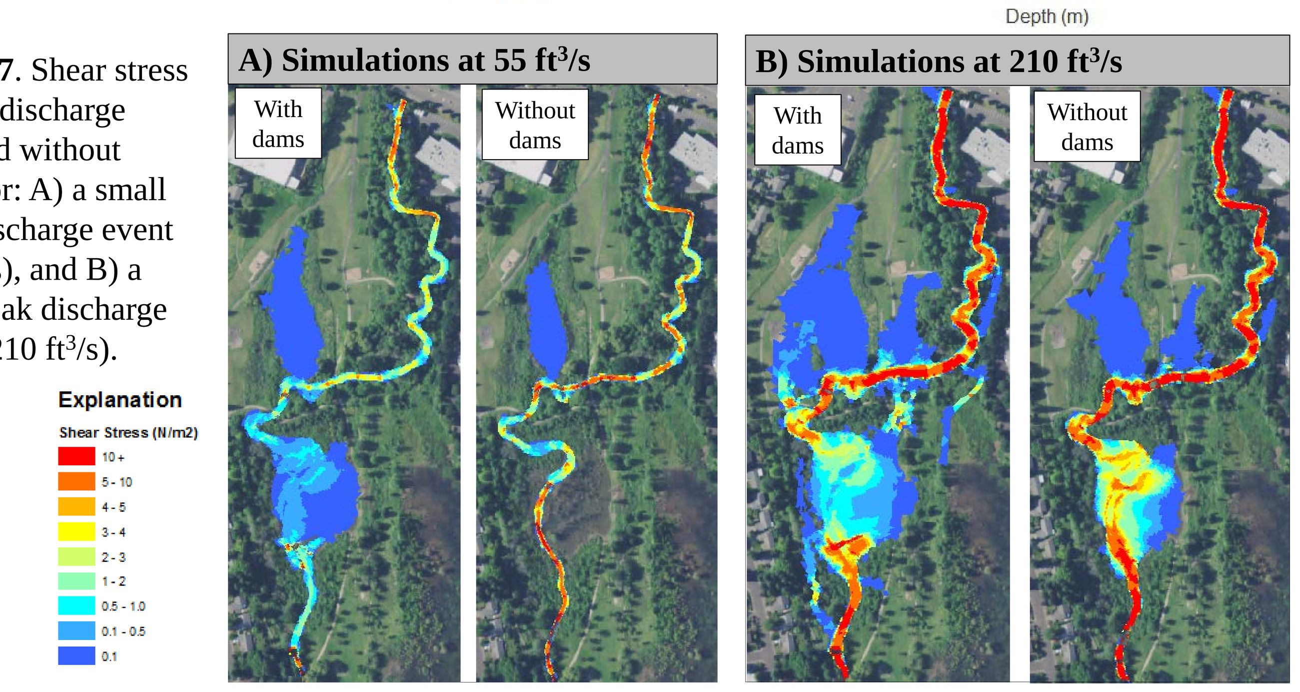


Figure 7. Shear stress at peak discharge with and without dams for: A) a small peak discharge event (55 ft³/s), and B) a large peak discharge event (210 ft³/s).

Table 3. Area and volume changes with and without dams for a range of flows. All flows were simulated using steady state discharges of at least 48 hours.

Discharge (ft³/s)	Area Increase (ft²)	Area Increase (%)	Volume Increase (ft³)	Volume Increase (%)
6	125,300	211	272,500	278
20	140,000	186	275,300	177
100	119,000	69	232,600	57
200	166,400	54	231,200	34

Storm Flow Rates-of-Change Results

1. Fig. 8 illustrates the conceptual basis of this analysis.
2. Up- and downstream differences in rising limb rates were variable at Fanno Creek, but consistently lower at Stoller Creek (fig. 9A-B). This indicates a potential reduction in storm flashiness at Stoller Creek.
3. Up- and downstream differences in falling limb rates were consistently lower at both Fanno and Stoller Creeks (fig. 9C-D), potentially indicating the storage and slower release of water over time because of ponding.

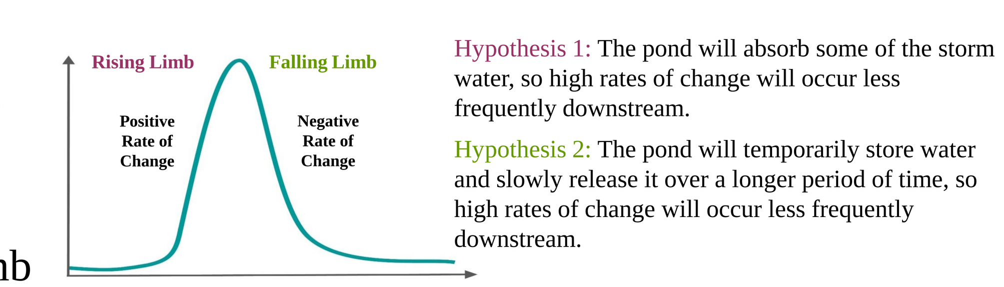


Figure 8. Conceptual basis of the continuous wetted cross-sectional area analysis.

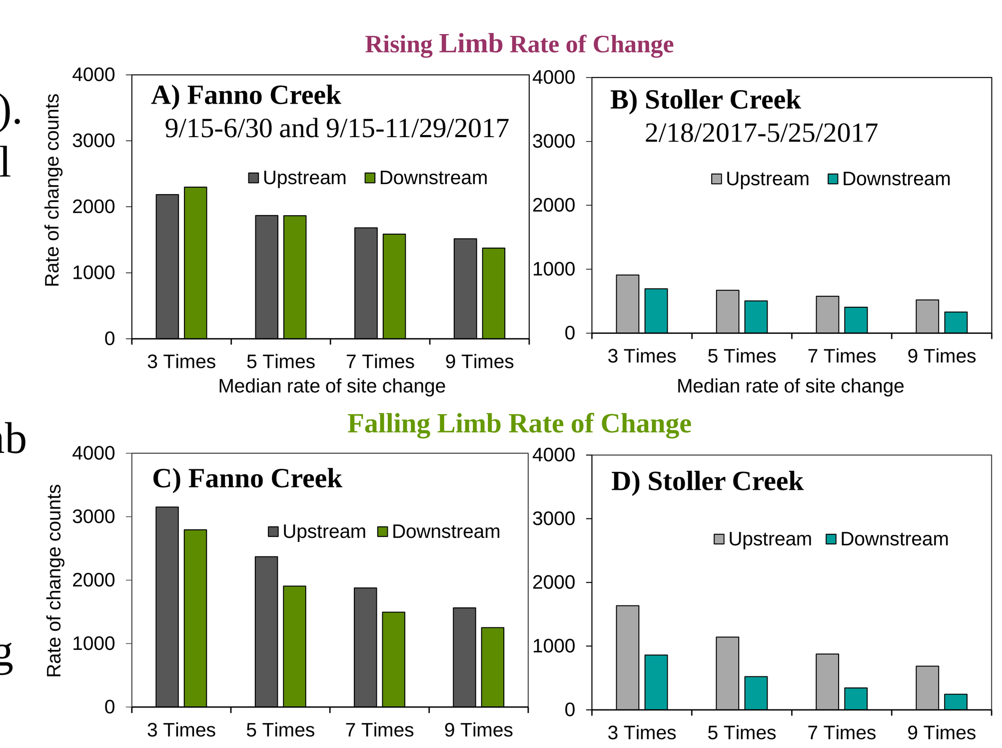


Figure 9. Counts of wetted cross-sectional area rates-of-change using four levels of median rates-of-change for the rising limbs (A-B) and falling limbs (C-D) at Fanno and Stoller Creeks.

Next Steps for this Study

- Complete/update Fanno Creek at Greenway Park modeling and analyses.
- Complete Bronson Creek modeling and analyses.
- Model longer time periods to allow calculation of Richards-Baker flashiness index for the Fanno and Bronson reaches with and without beaver dams.
- Finalize continuous wetted cross-sectional area analyses and evaluate effects of beaver dams on hydrographs during storm events.

Water Residence Time Results

1. During dry summer months, it can take over 6 days for water to travel 0.5 miles from the upstream to the downstream sensor (fig. 10).
2. During high flows in winter months, water moves through the reach in about 3 hours. The large south pond did not appear to increase travel time under these conditions (fig. 10).

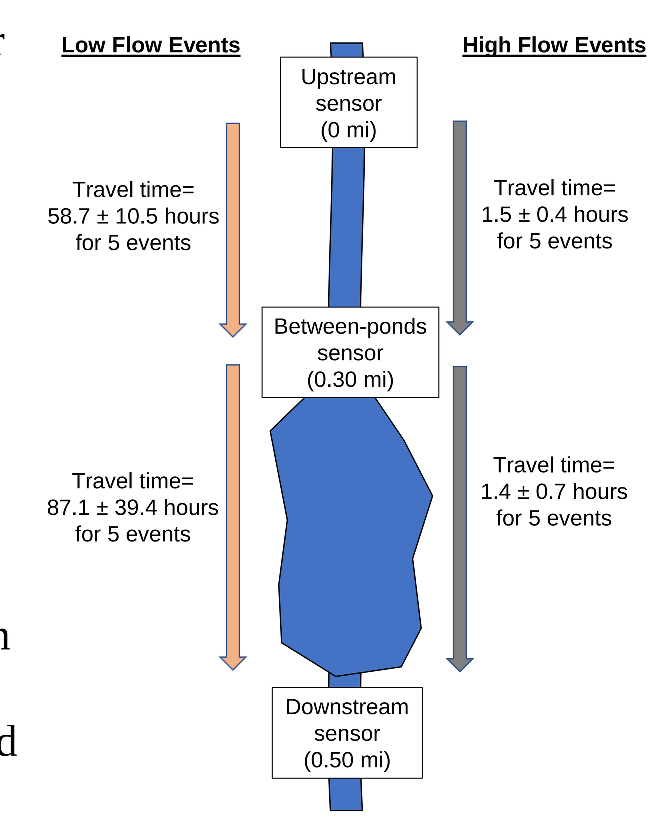


Figure 10. Conceptual image of the travel times determined from continuous conductance data for five low- and five high-flow events.

Considerations for Future Studies

- Simulate the evolution of beaver dams and ponded areas by applying a morphodynamic model.
- Evaluate lifespan of dams and associated changes in hydraulic and sediment retention effects over time.
- Evaluate effects of beaver dam management strategies (such as piping) on the hydraulic and sediment retention effects of beaver dams.

White, J., E. Poor, C. Smith, S. Rounds, K. Jones, 2018, Tualatin Beaver Poster 3 - Preliminary Results of the Hydraulic Effects of Beaver Dams at Fanno Creek at Greenway Park.

All data and findings are provisional and subject to change.