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Temperature and hydrological impacts of beaver-based stream restoration: hypotheses, models and data and the way forward with low tech process based restoration.

Restoring natural hydrological and transport processes is a fundamental objective of beaver-based stream restoration practice. Returning the simplified stream reach state to a beaver dominated state means that the hydrological dynamics of a simplified, pre-restoration reach are altered to dramatically increase lateral and vertical connectivity. That is, groundwater elevation and extent and groundwater - surfacewater coupling are greater post-restoration, thereby strongly affecting surface water flow patterns and temperature. Although anecdotal evidence supports this process, few studies provide quantitative evidence of these altered dynamics associated with beaver-based stream restoration. From 2006 to 2017 we monitored water table elevation and temperature in two groundwater well fields on Bridge Creek, an incised tributary to the John Day River in northeastern, OR, USA. In 2009, beaver dam analog (BDA) structures were installed to increase the number and lifespan of beaver dams adjacent to one well field, while the reach in the second well field remained untreated. Post-restoration monitoring measured large increases in surface water extent and water table elevation at the BDA-treated well field site relative to the untreated well field site. In addition, groundwater and surface water temperature

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patterns became more similar, a function of increased hyporheic exchange, post restoration relative to the pre-restoration conditions. The time-history of these changes also supports our application of a process based conceptual framework in that the post-restoration changes occurred rapidly, but then stabilized, indicating a state transition of the treated stream reach. Results demonstrate BDAs can be successfully utilized to raise groundwater tables and increase surface-groundwater exchange by altering the hydrological and transport processes that govern the movement of water through stream reaches. These results will also be discussed in the context of observations and some data from other examples of process based stream restoration based on beaver dam like structures. A developing methodology for approaching low tech process based stream restoration is emerging from practitioners across the northern hemisphere, but the acceptance in the scientific and management realm is lagging, so coordination, documentation and collaboration is necessary within the restoration community to ensure the long term viability of these methods.