Long-Term Impact of Exploitative Logging on Forest Watershed Hydrology in the Missouri Ozarks

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BACKGROUND

Stream channels adjust to human-induced landscape disturbance by expanding to accommodate increases in runoff. Headwater stream channels in the Ozarks show signs of instability as bank erosion, incision, and bed aggradation are common even in watersheds that are mostly forested. This study explores the idea that stream channels are adjusting to the reduction in shortleaf pines in the region contributing to increased runoff in the winter and early spring. Shortleaf pines intercept 3x more rainfall than bare deciduous tree and runoff is slowed by decreasing throughfall and stem flow rates (Figure 1). Implications are that climate change could exacerbate instability as the number of high intense rainfall events is increasing in southeast Missouri (Figure 2).

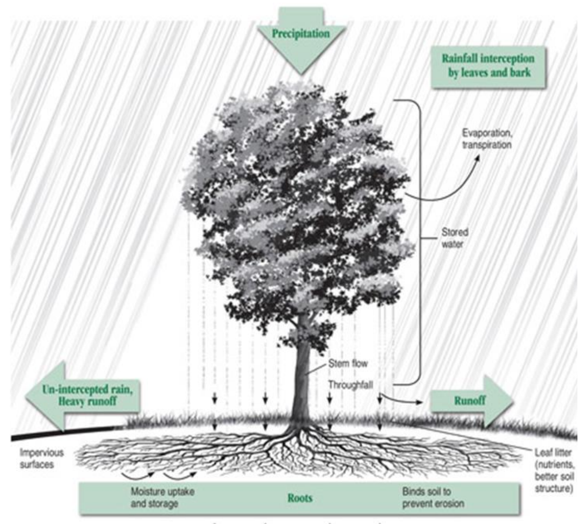

Figure 1. The role of trees in hydrology (ADF, n.d.).

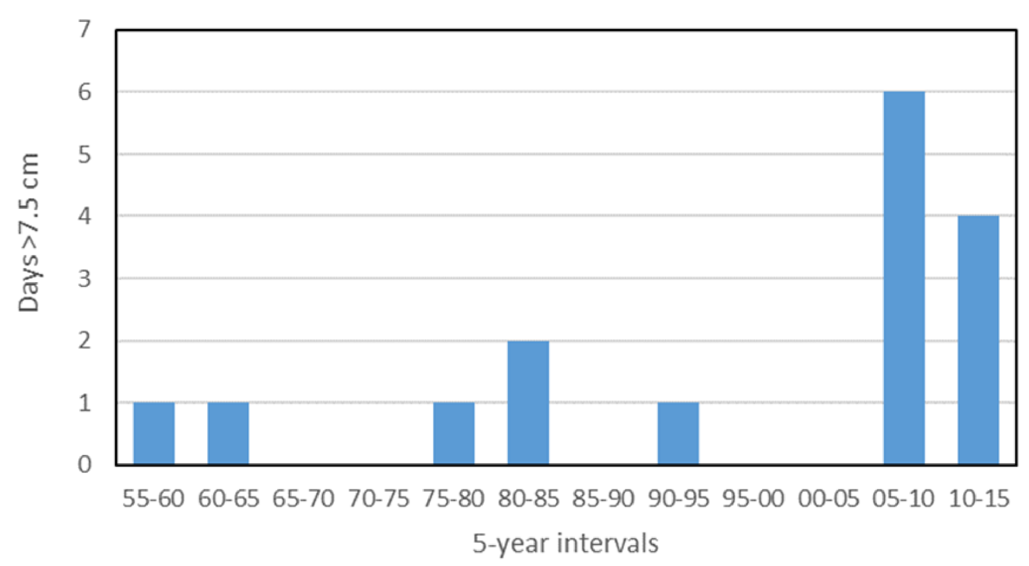

Figure 2. Increase in the number of days with >7.5 cm of rainfall in 24 hours from 1955-2015 in southeast, Missouri.

BIG BARREN CREEK

Big Barren Creek (191 km^2) is a tributary of the Current River in southeast Missouri (Figure 3). The watershed is located in the Salem Plateau physiographic subdivision of the Ozarks Highlands, which is underlain by flat, Paleozoic age sedimentary rock. The watershed is in a karst region where caves, sinkholes, and losing streams are common. Land cover within the watershed is about 92% forested, with around 78% being National Forest lands. Most of the remainder is pasture and hay, along with small areas of developed open space. Forest composition is 83% deciduous (oak, hickory) and 17% evergreen (shortleaf pine, red cedar) tree species.

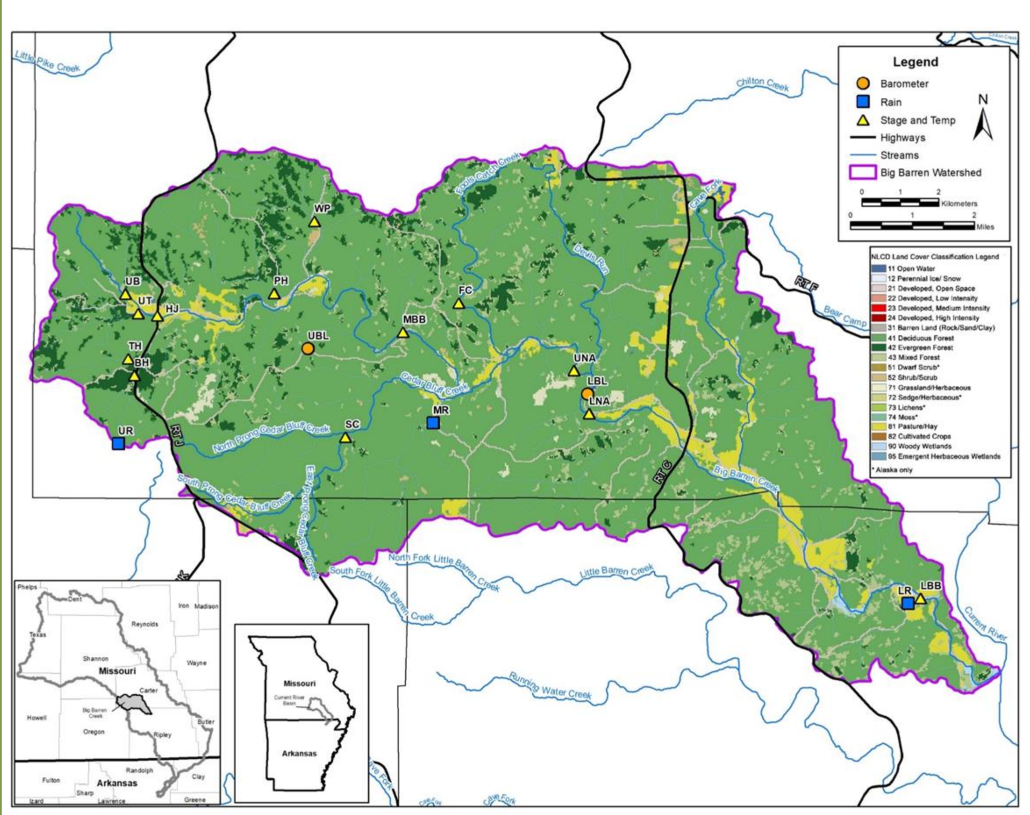

Figure 3. 2016 land use of Big Barren Creek watershed.

THE EFFECT OF HISTORICAL LOGGING

The Missouri Lumber and Mining Company operated the mill at Grandin, Missouri between 1887-1909 averaging 60 million board feet of lumber per year. During peak production, roughly 70 acres of trees were cut daily to feed the operation and logs were transported to the mill on tram railways. Shortleaf pine was once the dominant tree species in local forests that was targeted by commercial logging and today only 10% of the pre-settlement pine forest remains (Figure 4).

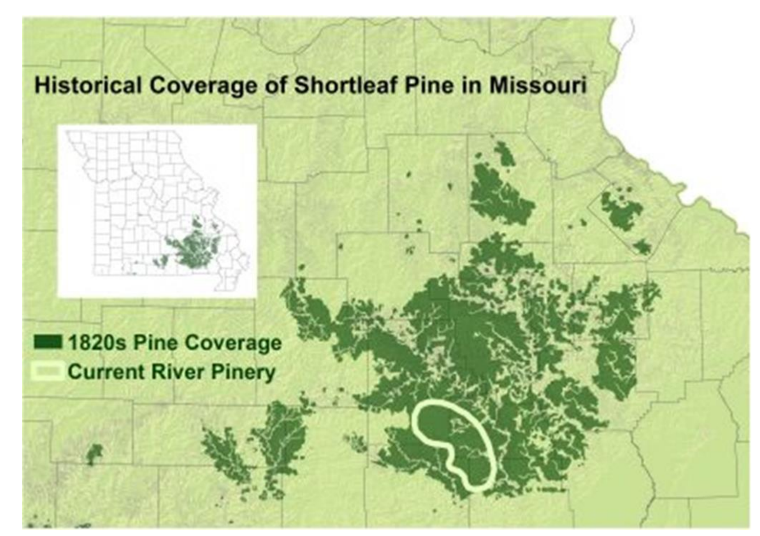

Figure 4. Map showing the native distribution of shortleaf pine in southeast Missouri in the 1820s (Vaughn, 2020).

BANKFULL FLOOD CHANGES

A hydrology model was developed to test how the increase in pines within the watershed could influence runoff during a bankfull event during leaf-off conditions (Figure 5). A series of storms from March 27th-30th, 2018 produced 12.5 cm of rainfall and a near-bankfull flood used in the simulation. Model was calibrated to field data with runoff and peak discharge was within 10% of the observed (Figure 9). Two pre-settlement scenarios were tested: 1) with 3x greater pine cover than today by sub-watershed; and 2) 100% pine cover. Scenario 1 – Modern runoff depth, peak discharge, and cross-sectional stream power increased 7-17% compared to pre-settlement #1 (Figure 6 and Table 1). Scenario 2 – Modern runoff depth, peak discharge, and cross-sectional stream power increased 25-37% compared to pre-settlement #2.

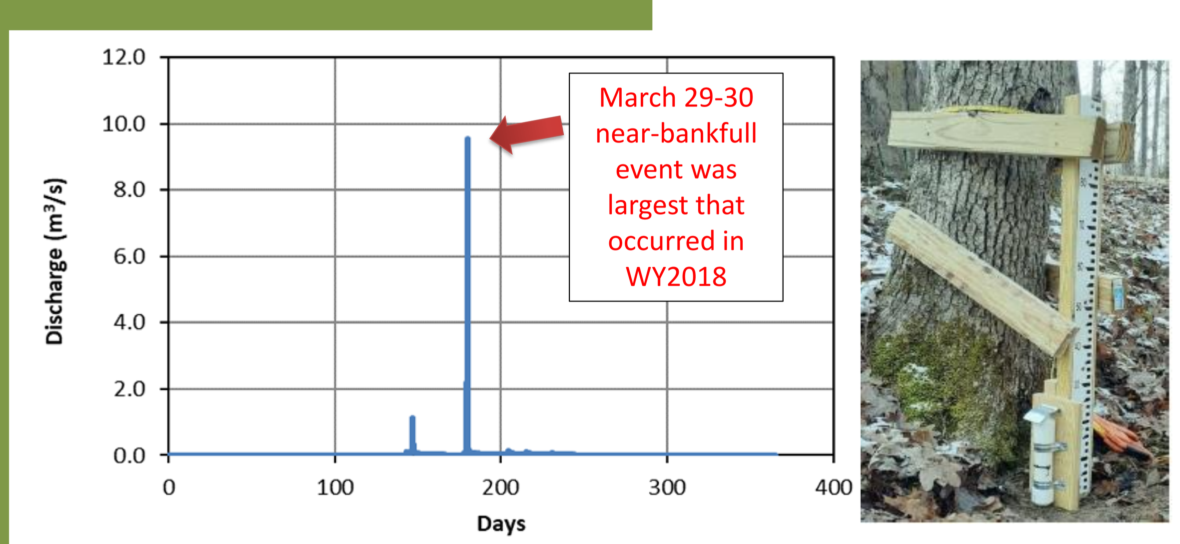

Figure 5. Annual hydrograph for WY2018 showing only two significant flood events over the year. Photo shows an example of gaging station installed in sub-basins within the watershed.

Scenario	Runoff Depth (mm)	Peak Q (m^3/s)	Cross-Sectional Stream Power (W/m)
Present	4.1	9.34	421.5
Pre-settlement #1 3x increase in pine	3.5	8.70	392.6
Pre-Settlement #2 100% Pine	3.0	7.46	329.9

Table 1. Comparison of present conditions compared to two pre-settlement scenarios.

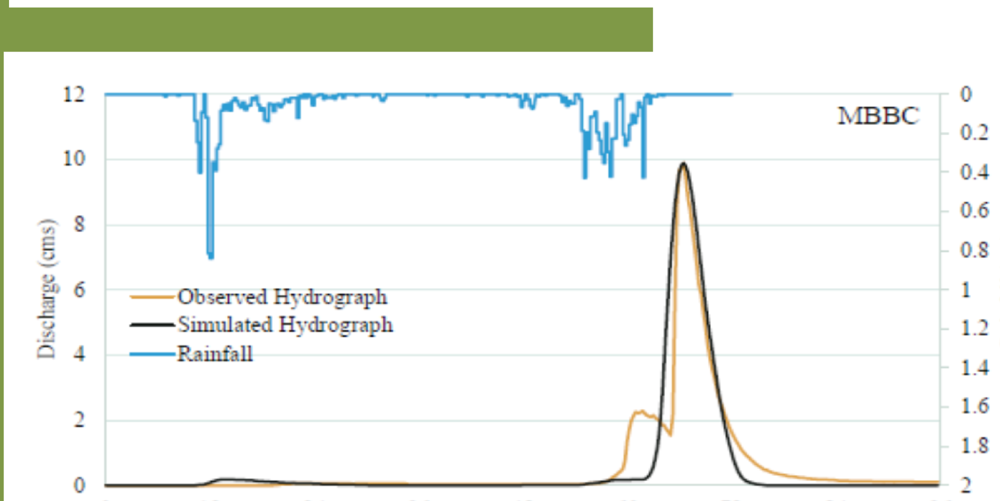

Figure 6. Simulated and observed hydrograph and rainfall.

CHANNEL CHANGES

Changes in channel width over the last 200 years was assessed by comparing measurements from 1821 General Land Office (GLO) survey notes to modern channel width using LiDAR and field-based measurements at 38 sites throughout the watershed (Figures 7 and 8). Overall, modern widths were on average 2.6 times larger than in 1821 (Figure 8). The largest increase was in 2nd order streams averaging 3.4-fold increase. Not all width changes occurred immediately after the timber boom period with nearly 50% of the GLO sites analyzed have increased in width since 2007 identified in modern aerial photographs.

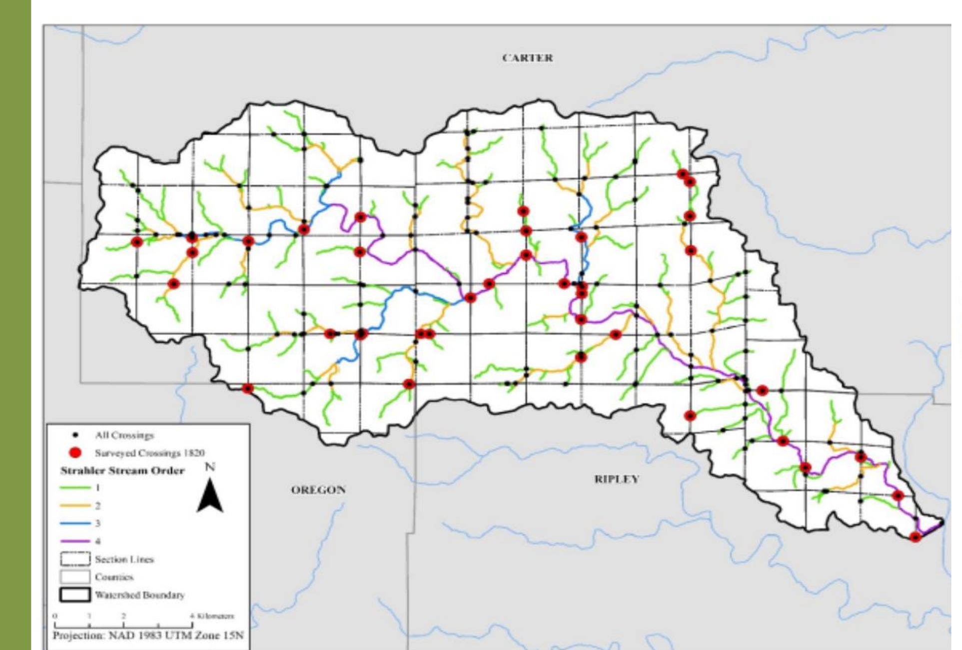

Figure 7. Locations of sites in the watershed where GLO surveyors recorded channel width in field notes in 1821.

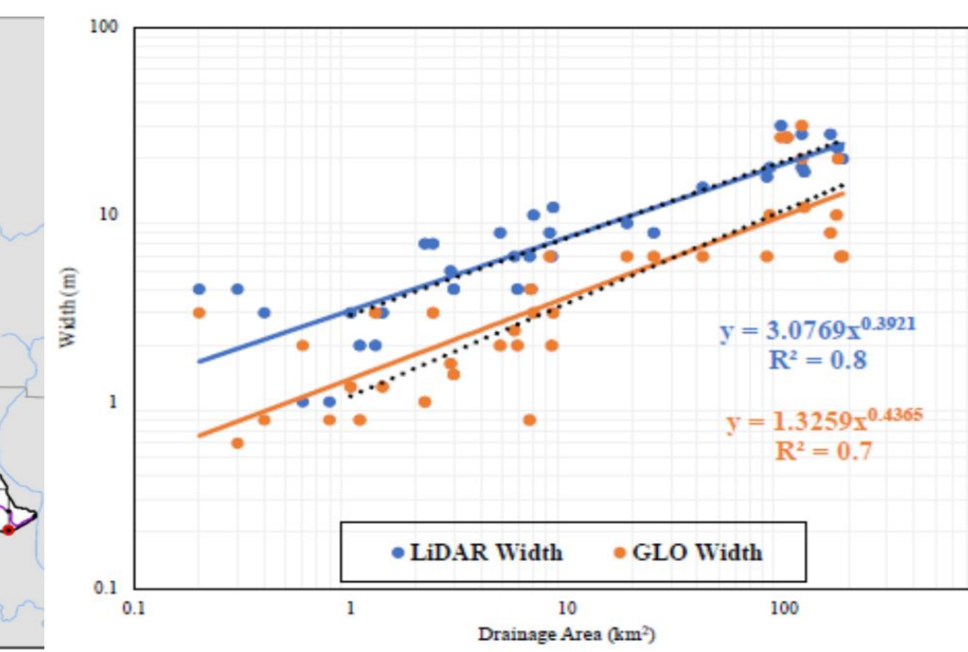

Figure 8. GLO recorded width from 1821 compared to modern LiDAR derived width.

The transition from a pine dominated forest to an oak dominated forest may be a key contributor to post-settlement stream disturbance where channels have transitioned from being shallow and multi-threaded to U-shaped and single-threaded aided by channelization. Annual average runoff depth (cm) from water year 2016-2020 decreases with increased percentage of evergreen forest (pine and cedar) in the watershed (Figure 9). Results of this study suggest that watersheds in the Ozarks with more shortleaf pines may be more resistant to increased flooding from high intensity rainfall events in the winter-early spring due to climate change (Figure 10).

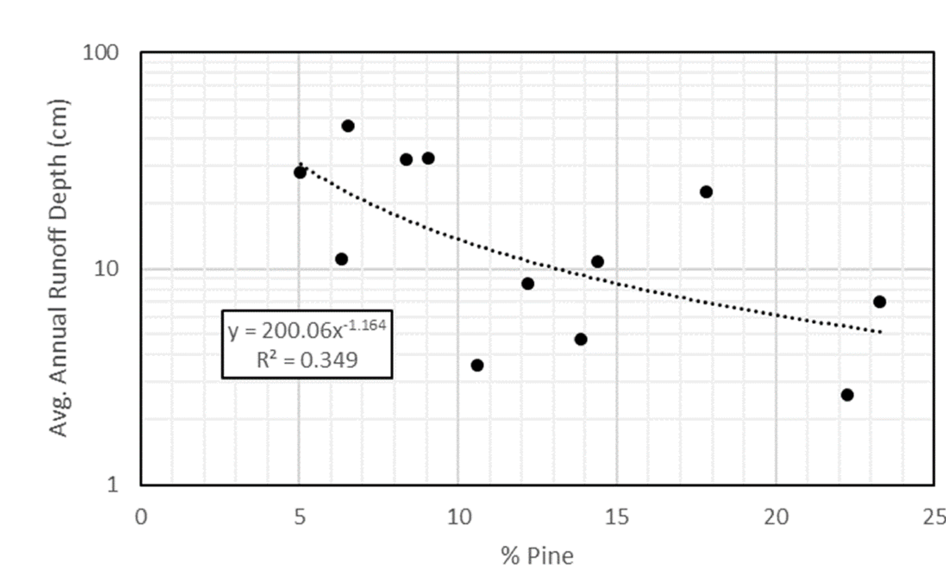

Figure 9. Average annual runoff depth vs. % pine within the watershed from water years 2016-2020 at Big Barren Creek.

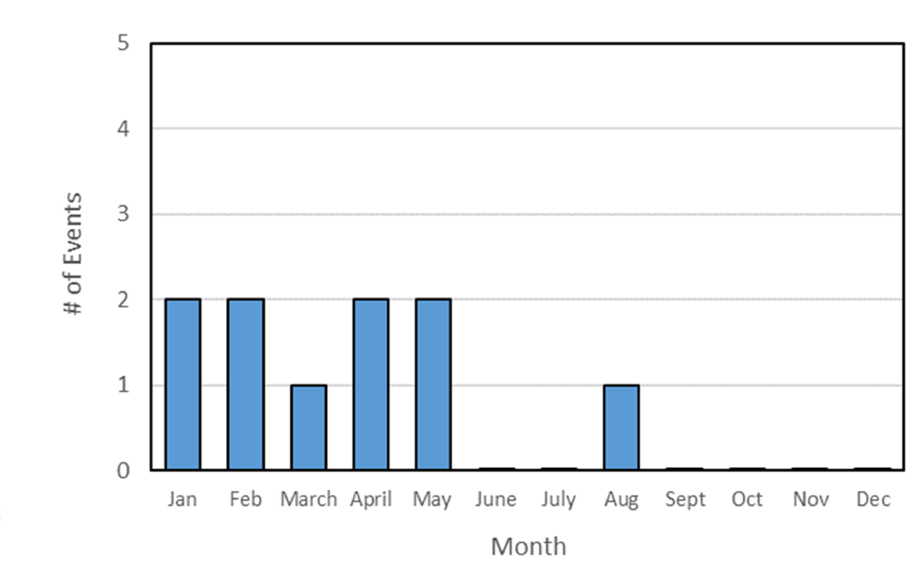

Figure 10. Number of significant flood events in Big Barren Creek from water year 2016-2021.

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Vaughn, D. H. (2020, May 19). The decline of shortleaf pine. Retrieved from Oak woodlands & Forests: https://oakfirescience.com/stop-2-history-the-decline-of-shortleaf-pine/