A Temporal Assessment of Channel Morphology Downstream from the Tuttle Creek Dam

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I. Introduction

Dams play a significant role in protecting the health and safety of downstream communities. However, dams also cause unintended changes to the natural environment. **This research will investigate the complex natural processes of the Big Blue River that are impacted by the upstream Tuttle Creek Dam and reservoir.** Dams work by capturing intense flooding events and releasing them slowly over a longer time period, reducing the intensity of flooding events (Graf, 2006) and thus, the flow regime. Dams cause sediment entrapment which occurs when sediment is prevented from flowing downstream. This leads to a higher rate of incision on the stream beds (Williams & Wolman, 1984).

II. Study Objectives

To assess channel morphology, three research objectives are examined in this research:

1. Assess the change in the flow regime following upstream dam installation using USGS recorded flow data.
2. Assess the downstream bed stability over time using USGS gage height information.
3. Compare observations to historical degradation line data collected by the USACE.

III. Study Area

The study area includes the Tuttle Creek Dam and reservoir located in eastern Kansas, along with an approximately 14.5-kilometer section of the Big Blue River immediately downstream from the dam. The Big Blue River provides up to 50% of the water for the Kansas River (Kansas Water Office, 2017). The Tuttle Creek reservoir watershed encompasses approximately 15,500 square kilometers of drainage area (Fig. 2). Approximately 81 cm of precipitation falls within the watershed primarily between April and September and the primary soil type within the watershed is silty clay loams (Kansas Water Office, 2017).

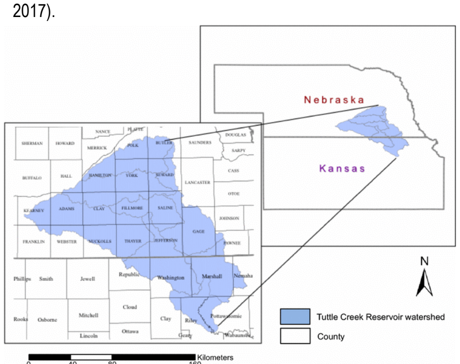

Figure 1. Drainage area of the Big Blue River. Figure retrieved from Rhodes et al. (2018)

IV. Methods

1. By using USGS recorded stream data, a temporal assessment was made to examine the changes the Tuttle Creek Dam has caused.
2. By using USGS gage height, discharge data, and Juracek (2011) methodology, a downstream bed stability graph was created to examine channel bed stability from 1953 – 2022.
3. Using distance and elevation from USACE monumentation multiple points in 9 cross-sections. With this data, graphs were developed, and two areas were calculated per cross-section. A map of each cross-section was made using Google Earth Pro

V. Results & Discussion

Objective 1. Tuttle Creek Dam did alter several hydrologic parameters for the Big Blue River, as shown in Table 1. Median hydrography rise and fall rate were diminished. Flood event discharge was also greatly reduced. Figure 1 is a comparison of the flow duration curve for the pre and post time period also showing flood events being reduced.

Flow Parameter	Pre-Dam (1951 -1959)	Post-Dam (1960 - 2022)
Median Daily Discharge (cms)	19.1	25.5
1% Exceedance Probability (cms) 99% Exceedance Probability (cms)	3032 250.2	1332 179.9
Median High Pulse Count (#/yr) Median High Pulse Duration (days/yr)	7 5.5	**8*** **11***
Median Hydrograph Rise Rate (cms/day) Median Hydrograph Fall Rate (cms/day)	**1.42*** **-1.84***	**1.13*** **-0.57***
Median Date of Annual Peak Flow	**6-Jul***	20-Jun
Median Annual Peak Discharge	104	**107***
1.05-yr Return Interval (cms) 2-yr Return Interval (cms) 25-yr Return Interval (cms)	250.2 724.6 2144	179.9 440.6 1030

Table 1. Comparison of hydrologic parameters for the pre and post dam time periods for the Big Blue River near Manhattan Kansas. **Bold*** indicates statistically significant results with a confidence level at or exceeding 95%.

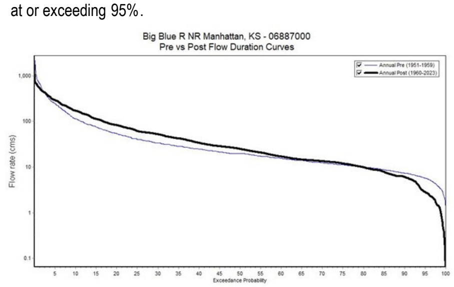

Figure 2. Comparison of pre-and post-flow duration curves on the Big Blue River downstream from the Tuttle Creek Dam.

Objective 2. Results of the downstream channel bed stability graph saw that the Big Blue channel bed experienced an increase in degradation 5 years after the dam installation in 1962 but appears to have stabilized after the Flood of 1993, as depicted in Figure 3. During the 27-year span (1967-1994) the bed dropped 1.6 meters. The 1993 flood experienced the highest discharge of 18,288 cms (cubic meters per second) since dam installation.

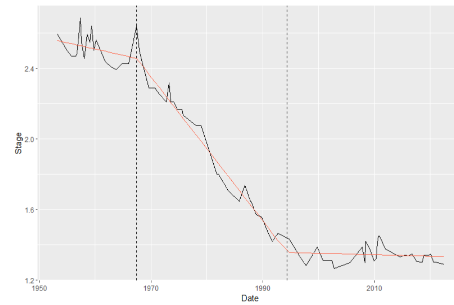

Figure 3. Results from the segmented linear regression analysis (red lines) showing breakpoints (dashed lines). The black line represents the reference stage data points found using USGS gage height data in meters and using 70.79 cubic meters per second for discharge (U.S. Department of Interior, n.d.).

Objective 3. As channel degradation occurred, cross-sectional area increased in each range. Thus the Simon and Hupp (198) channel evolution model was the best fit for the Big Blue River. This is because channelization was occurring, and both channel beds and banks experience degradation concurrently.

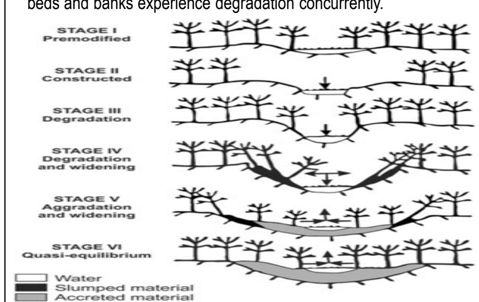

Figure 4. A depiction of the Simon and Hupp Channel Evolution model. Figure retrieved from Cluer & Thorne (2014).

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	Earliest Recorded Year	Earliest Cross-Sectional Area (m^2)	Latest Recorded Year	Latest Cross-Sectional Area (m^2)	Difference in Area (m^2)
Range B	1961	610.88	2021	980.45	369.57
Range C	1961	575.65	2021	845.32	269.67
Range D	1961	653.08	2015	789.26	136.18
Range E	1961	1079.14	2021	1784.15	705.01
Range F	1961	650.45	2021	867.055	216.605
Range G	1961	707.486	2021	722.99	15.504
Range H	1961	817.45	1995	891.04	73.59
Range I	1961	1202.95	1995	1248.02	45.07

Table 2. A summary of the earliest cross-sectional area and the latest cross-sectional area calculated for each range. Range A was eliminated due to inconsistent results.

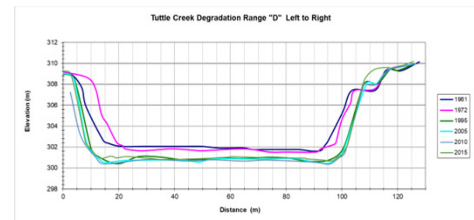

Figure 5. Depiction of the cross-sectional area of Range D in Tuttle Creek. The newer the measurement the larger the area.

VI. Summary

This research has investigated the complex natural processes of the Big Blue River that are impacted by the upstream Tuttle Creek Dam and reservoir. A summary of the results are:

- A change in the downstream flow regime has been observed within the study area for several hydrologic parameters.
- Bed degradation started with the implementation of Tuttle Creek Dam in 1962. In 1967, decline accelerated until 1994 when the bed appears to have stabilized due to the intensity of the 1993 Flood.
- As channel degradation occurred, the cross-sectional area consistently increased in each range.
- The Simon and Hupp (1987) channel evolution model was found to have best corresponded to this river.

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