Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Impacts of Stream Bed Adjustments on Local Bridge Morphology at Highway 281

Research Objectives

1. To establish a measurement method for rapidly collecting detailed topographic, bathymetric, and flow data at bridge crossings.
2. To utilize the new method to collect multiple complete data sets at a bridge crossing with dynamic streambed conditions (The Highway 281 bridges downstream of the Spencer Dam site).
3. To develop a hydraulic modeling approach for predicting short- and long-term morphologic changes at the bridge crossing and to compare predicted results with observed data.
4. To refine the modeling and data collection methods for application at any bridge crossing with a dynamic streambed.

Research Benefits

The primary outputs of this project will be two-fold: A detailed approach for collecting relevant channel and flow data at sand bed river sites with rapidly changing stream morphology and a hydraulic model that is capable of simulating stream morphology over short and long-time scales. In order to relay the information that we organize and the models that we develop over the course of the project, we will provide two detailed summary guides at the end of the project: (1) a guide on the methods used to collect aerial and flow data at sand bed river sites with rapidly changing bed morphology, and (2) a guide on applying an appropriate hydraulic model to predict changes at such sites.

Principal Investigator

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NDOT Lead TAC Member

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Background

The goal of this project is to synthesize a hydrodynamic model with improved methods of representing sediment transport to better predict short-term and long-term channel migration for aggraded sand-bed rivers. Our team can rapidly and reliably collect detailed flow and topographic data and incorporating that data into the model will provide results that are more accurate and more quickly implemented than previous efforts. In addition, the model will be developed at a bridge crossing (Highway 281 over the Niobrara River) with a strongly aggraded streambed, a crossing that is of particular interest to NDOT because of the potential for abutment undermining, scour issues, and ice damage. The result of the project will be a documented strategy for rapidly collecting relevant field data associated with channel bed migration predictions, a detailed plan for incorporating that data into a hydraulic model with new modules for accurately simulating sediment transport and bedforms and demonstrated short-term accuracy of the model at a field site that is of actual interest to NDOT. In addition, recommendations will be provided for collecting future data sets to validate the longer-term performance of the modeling approach. Along the way, channel migration concerns identified by the research team at the study site will be relayed to NDOT for possible mitigation efforts.

Conclusion

Nebraska sand-bed rivers have long been used in the development of well-known empirical bedload equations. Some of these studies have shown how adjustments in available sediment led to changes in local stream morphology. The sand-bed rivers of Nebraska are highly susceptible to such changes due to their wide, shallow cross-sections and erodibility. The objective of our study was to develop a methodology to predict both short and long-term channel adjustments for an aggraded sand-bed river – particularly the Niobrara River. The field component of our study targeted the reaches of the Niobrara River in northern Nebraska near two bridges, the Highway 11 bridge and the Highway 281 bridge. These reaches are of particular interest because they are situated upstream and downstream of Spencer Dam, which failed in 2019, releasing large quantities of sand into the downstream reach. There are two areas of eroding deposits upstream of the old dam structure and one area downstream. All three eroding areas contribute to sediment loads that are causing the river to aggrade in the vicinity of the dam. Scripts were written to assess changes in the bed profile over the duration of the project. The results showed that from spring of 2024 to September of 2022, the bed and local water surface elevation at the bridge increased by approximately 0.45 meters. Data collected in August of 2023 showed that the bed still had the same slope as the 2020 DEM bed, but that the bed and water surface elevation continued to increase another 0.06 meters at the bridge. HEC-RAS was used to create a one-dimensional model of the Niobrara River at the Highway 281 bridge. Data collected in 2023 were incorporated in the model to assess model performance and to adjust the model to recreate the observed data. Standing waves were observed in aerial imagery and confirmed the results of the model that showed that the flow of the river is critical through the entire reach. The bathymetry changes in the river are complicated due to the self-formed riverbed with multi-channel flow and critical flow conditions. Overcoming these complexities was not possible in the current project and will be necessary to develop a two-dimensional model that is able to accurately predict short- and long-term morphological changes at the study site.

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NDOT Recommendations Based Off Research Project – 2026 – RRL3

This research provided valuable preliminary insights; however, the Nebraska Department of Transportation (NDOT) anticipated a hydraulic modeling approach capable of accurately predicting short- and long-term morphological changes at bridge crossings, which the research did not provide. The study's use of 1-D cross-sectional snapshots limited its ability to characterize sediment dynamics across the broader floodplain. A 2-D modeling approach, capable of illustrating sediment transport and morphological evolution over the entire floodplain, would be of greater use to the NDOT.

To advance this effort, NDOT is considering approaching the researchers for a Phase II project to develop a 2-D sediment-transportation hydraulic model to better understand the bed topography across the entire floodplain. Development of such a model will require additional bathymetry data, which the NDOT has the equipment to collect, and may also benefit from supplemental land survey information.

- *As provided by Kirk Harvey and Jason Dayton, Lead TAC Member*

Research Readiness Level (RRL) Assessment

RRL 3

Level 3: Development
Follow up upon completion of Phase II or 1 year.

Technology Transfer

Principal Investigator did not have any technology transfer for this research project.

This brief summarizes Project SPR-FY23(021)
"Impacts of Stream Bed Adjustments on Local Bridge Morphology at Highway 281"
Nebraska Department of Transportation Research Program