The Effects of Headcut and Knickpoint Propagation on Bridges in Iowa

Tech transfer summary

Innovative field methods coupled with computation hydrodynamic models will facilitate understanding of knickpoint propagation and help estimate the needed response time to control the knickpoint's advance.

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RESEARCH PROJECT TITLE
The Effects of Headcut and Knickpoint Propagation on Bridges in Iowa

SPONSORS
Iowa Highway Research Board
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IIHR's historic C. Maxwell Stanley Hydraulics Laboratory was dedicated as a National Historic Civil Engineering Landmark in 2005, placing it among the major structures of national importance to the engineering profession. The mission of the IIHR is to conduct research in water resources and environmental engineering.

OBJECTIVES

The main objective of the study was to develop predictive tools for knickpoint migration and help engineers monitor, maintain, and protect bridge waterways to mitigate potential scour at the bridge structures.

This was accomplished through a semi-automated, field-oriented evaluation of an advancing knickpoint in southwestern Iowa using various monitoring methods. In addition, the field data was implemented into a one-dimensional, hydrodynamic/ sediment transport model, known as 3ST1D, to predict further migration rates.

PROBLEM STATEMENT

Channel erosion in the Deep Loess Region of western Iowa has produced billions of dollars of damage to highway and county road infrastructure from bridge scour and farmlands next to the channels due to stream bank collapses. A common form of channel degradation in this area is a knickpoint, which is an upstream-advancing step in the stream bed. Knickpoints advance as large volumes of sediment slump from the step face. Knickpoints may account for more than 60% of the erosion in the streams. Currently, there is limited knowledge of migration rates for knickpoints with no existing protocol for their evaluation.

Figure 1. Measurements of the water surface were conducted at the knickpoint using a state-of-the-art laser suspended from a radio antenna truss.

Figure 2. The knickpoint in Mud Creek below the Elderberry Rd. Bridge was the study's focal point.

RESEARCH DESCRIPTION

Different methods were employed to evaluate both geotechnical and hydraulic parameters at the Mud Creek knickpoint to determine the upstream migration. Methods included:

1. Grain size analysis of the bed and bank material,
2. Stage and flow discharge measurements,
3. Bi-annual surveys of the reach from the bridge through the downstream scour hole of the knickpoint, and
4. Daily monitoring of water elevations at the knickpoint using a remotely-mounted state-of-the-art laser.

It was hypothesized that water level could be a surrogate measure of the channel bed to facilitate studies of knickpoint migration because the high energy environment around a knickpoint makes it difficult to enter the stream for bed surveys.

The Steep Stream Sediment Transport 1-D model (3ST1D) was used to model knickpoint erosion and predict future migration. 3ST1D is generally used to calculate flow and sediment transport in mountain streams but is applicable to unsteady flow conditions that occur at knickpoints.

Figure 3. Samples of the stream bed and channel banks were collected for geotechnical analysis.

KEY FINDINGS

- The channel bed survey showed that the majority of the knickpoint face did not advance but a finger-like projection advanced upstream at a rate of 5.6 m/yr.
- The laser was able to monitor the advancement of this projection making it a reliable surrogate for knickpoint studies.

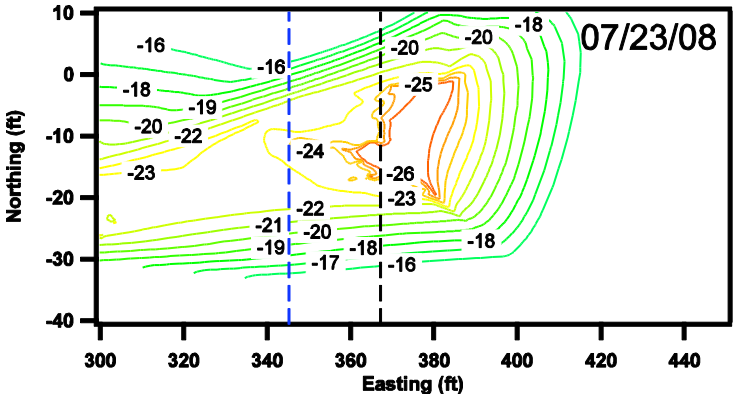

Figure 4. Channel bed survey for the knickpoint showing the finger like projection (between lines).

KEY FINDINGS (cont.)

- The laser also showed that the lowest water level in the downstream scour hole moved upstream2 ft. during a single runoff event.
- 3ST1D confirmed previous studies, which suggest that the development of unvented conditions below the knickpoint nappe enhance scour at low flows, which makes large scale collapse more probable.

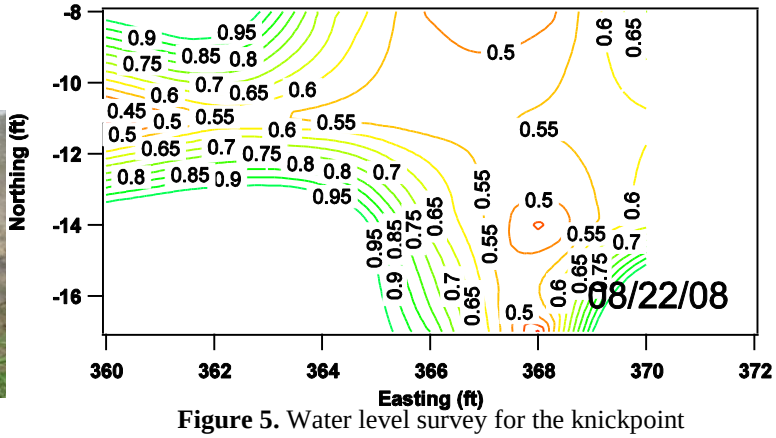

Figure 5. Water level survey for the knickpoint showing the finger like projection seen in the bed survey (circled area).