Michigan Department of Transportation
RESEARCH
Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Electronic Water-Level Sensors for Monitoring Scour-Critical Structures

START DATE: April 2021

REPORT DATE: June 2024

RESEARCH REPORT NUMBER: SPR-1740

PROJECT COST: $449,200

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Water-level sensors help prioritize inspections of scour-critical bridges

Monitoring bridge foundations for impacts from high water levels during or after storms is an essential public safety function of bridge inspectors at the Michigan Department of Transportation (MDOT). A cost-effective, reliable and easy-to-implement water-level sensor system could substantially improve the efficiency of bridge inspections by allowing staff to monitor water levels and prioritize responses, such as on-site inspections and potential closures, in real time. Data-driven decision-making will enhance overall bridge management practices and improve public safety during high-water events.

PROBLEM

Bridge scour – the erosion of sediment around a bridge's foundations – poses a structural risk to bridges, particularly during rainfall-induced high water levels and erosive flows. Bridge inspectors typically rely on storm forecasts; existing knowledge of Michigan's bridge inventory; and MDOT's High Flow Event Monitoring site (High Flow), an ArcGIS-based system that monitors water levels for bridges with nearby stream gages, to prioritize responses to the state's scour-critical bridges during high-water events.

Currently, the U.S. Geological Survey (USGS) manages about 8,000 stream gages nationwide. USGS stream gages are reliable and resilient; however, most are not located near Michigan's scour-critical bridges. Adding gages can be more complex, and they can be costly to maintain.

MDOT wanted to ensure the highest-risk bridges are being monitored and any

Real-time water-level sensors improve the bridge inspection process, allowing inspectors to focus on bridges experiencing critical high-water events.

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> *"These sensors provide significant support for monitoring scour and maintaining the safety of the traveling public. The ability to track water levels remotely is invaluable to bridge inspectors."*
>
> **Andrew Zwolinski**
> Project Manager

scour issues are addressed. Agency bridge engineers were interested in exploring a simple and cost-effective method to monitor bridges for high water levels in real time to assist in prioritizing response to high-water events, reduce unnecessary site visits and optimize inspection resource allocation.

RESEARCH

An evaluation of water-level monitoring systems included a review of sensing technologies such as ultrasonic sensors, radar and LiDAR (light detection and ranging); data logging technologies and their abilities to store data efficiently; wireless communication methods to transmit data from sensors to a central database; and power consumption considerations. Trade-offs between initial costs, maintenance requirements and data service fees were compared.

A review of other state transportation agency practices using real-time data in bridge scour inspection further informed the choice of monitoring technologies, including the Illinois BridgeWatch system, which issues storm event warnings and alerts; Ohio's intensive inspections and monitoring protocols; and Wisconsin's use of underwater profiling of scour-critical bridges.

In collaboration with MDOT engineers, researchers selected an open-source technology for real-time water-level monitoring to create a cost-effective water-level sensing package that was reliable and easy to deploy. The system was built to operate effectively in Michigan's harsh weather and included satellite data transmission and a tamperproof design to protect the sensors. Researchers also created a database to receive, store and manage the sensor data.

To deploy the sensor systems, MDOT bridge specialists helped identify more than 30 scour-critical bridges that were generally remote and had structural characteristics conducive to mounting the water-level sensing systems and solar power recharging. The systems monitored and transmitted real-time water levels at regular intervals for more than 19 months. Researchers continuously monitored system performance and analyzed the collected data.

RESULTS

The hydrologic sensor network and data system – custom, low-power, embedded computer sensor nodes – operated efficiently and reliably. Users had two methods to access the data and incorporate it into bridge inspector workflows. First, the research team integrated the sensor data with MDOT's High Flow system. Additionally, team members created separate web-based dashboards, housed at the University of Michigan's Digital Water Lab, which displayed water-level data from the scour bridge-monitoring systems for each district and enabled researchers to track user feedback and refine visualization. MDOT staff used both data visualization systems throughout the project.

The availability of real-time data received positive feedback from bridge engineers and inspectors, who reported enhanced situational awareness and decision-making capabilities. The real-time water-level sensing system could improve the efficiency of bridge inspections to monitor scour by reducing unnecessary site visits. A five-minute training video describes the real-time water-level monitoring system and provides historical data and forecasts for supporting bridge inspections.

IMPLEMENTATION

Based on the study's success, researchers recommended scaling up for deployment across the state. Expanding MDOT's existing High Flow system and integrating new water-level sensing data, or creating a stand-alone system to communicate the water-level data, would require the agency to coordinate with state information technology specialists to ensure appropriate Internet security requirements and other protocols are built into the collection, transmission and visualization of the data.

Research Administration

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The final report is available online at

MDOTjboss.state.mi.us/TSSD/tssdResearchAdminDetails.htm?keyword=SPR-1740.

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Research Spotlight produced by CTC & Associates LLC, March 2025.