Fixed Scour Monitoring Implementation in Minnesota

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University of Minnesota
Driven to Discover
Project Overview

“Scour Monitoring Technology Implementation”

- Install fixed scour monitoring equipment on two Minnesota bridges and maintain for three years.
- Focused on successful implementation rather than data collection.
- Use multiple types of sensors
- Continuation of “Bridge Scour Monitoring Technologies: Development of Evaluation and Selection Protocols for Application on River Bridges in Minnesota”
  - Focused on technology/sensor selection based on site specific river, bridge a and scour conditions
- Scour monitors installed on two bridges Oct 24-31, 2011
- Project completion March 2014
Scour and Fixed Monitoring

1. Local Pier Scour*

Fixed scour monitoring is permanent equipment installed onsite to measure scour.

- Benefits
  - Personnel not required on site, safety
  - Continuous monitoring
  - Automated warnings possible

- Challenges
  - Debris, ice require robust installations
  - Data validation

2. Local Abutment Scour*

3. General Scour (Contraction, Scour at Bends, Pressure Flow, Confluences)

Previous Fixed Scour Installations in Minnesota

- Magnetic sliding collars installed on three bridges
  - Bridge 74004 in 1993
    - Yearly manual readings until 1996, then no longer operational
  - Bridge 23015 and 9003 in 2003
    - Both heavily damaged by debris within 6 months
Current Project Installations

Bridge 07011 over Minnesota River in Mankato, MN
- Piers 4 and 5 are scour critical and are monitored

Bridge 5900 on TH over Mississippi River in Winona, MN
- Piers 19 and 20 are monitored
## Bridge 07011 – Pier 4

### Bridge 07011, Pier 4 (Deck Elevation, 813.3 feet)

<table>
<thead>
<tr>
<th>Item</th>
<th>Elevation (feet)</th>
<th>Distance from Downstream Pier Face</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote Station</td>
<td>~811</td>
<td>Close</td>
<td>(Mounted on deck barrier) Enclosure, datalogger, radio, antenna, 12 volt battery</td>
</tr>
<tr>
<td>Radar Stage Sensor</td>
<td>800.9</td>
<td>3.75 feet</td>
<td>Clamped to I-Beam Sub Structure 20 feet west of pier centerline</td>
</tr>
<tr>
<td>Sonar (Scour) Sensor</td>
<td>755.3</td>
<td>1.25 feet</td>
<td>Mounted on sonar mount, typically above water surface</td>
</tr>
<tr>
<td>Solar Panel</td>
<td>~800</td>
<td>N/A</td>
<td>Mounted on upstream pier face to increase solar charging</td>
</tr>
<tr>
<td>Sonar Mount</td>
<td>755.3</td>
<td>Close</td>
<td>Fixed, can likely access with boat</td>
</tr>
<tr>
<td>Conduit</td>
<td>N/A</td>
<td>Close</td>
<td>Houses sonar cabling, on centerline of downstream pier face</td>
</tr>
</tbody>
</table>

![Image of Solar Panel and Sonar](image-url)
<table>
<thead>
<tr>
<th>Item</th>
<th>Elevation (feet)</th>
<th>Distance from Upstream Pier Face</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master Station</td>
<td>~808</td>
<td>Close</td>
<td>(Mounted on deck barrier) Enclosure, datalogger, radio, antenna, 12 volt battery, cellular modem, float-out receiver</td>
</tr>
<tr>
<td>Float-out Receiver Antenna</td>
<td>~800.4</td>
<td>3.6 feet</td>
<td>Clamped to I-Beam Sub Structure 6 feet west of pier centerline</td>
</tr>
<tr>
<td>Float-out 1</td>
<td>756.4</td>
<td>2.5 feet</td>
<td>Buried 2.5 feet downstream and 9 feet west of pier face, float-out to stay west of pier if unburied by scour</td>
</tr>
<tr>
<td>Float-out 2</td>
<td>753.7</td>
<td>2.5 feet</td>
<td>Buried 2.5 feet downstream and 9 feet west of pier face, float-out to stay west of pier if unburied by scour</td>
</tr>
<tr>
<td>Tethered Buried Switch (TBS) 1</td>
<td>753.7</td>
<td>0</td>
<td>Buried 4.7 feet west of pier face</td>
</tr>
<tr>
<td>TBS 2</td>
<td>751.7</td>
<td>0</td>
<td>Buried 4.7 feet west of pier face</td>
</tr>
<tr>
<td>Solar Panel</td>
<td>~808</td>
<td>Close</td>
<td>Mounted on deck barrier next to datalogger</td>
</tr>
<tr>
<td>Conduit</td>
<td>N/A</td>
<td>Close</td>
<td>Houses TBS cables on centerline of downstream pier face</td>
</tr>
</tbody>
</table>
## Bridge 5900 – Pier 19

<table>
<thead>
<tr>
<th>Item</th>
<th>Elevation (feet)</th>
<th>Distance from Upstream Pier Face</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote Station</td>
<td>~704</td>
<td>Close</td>
<td>Enclosure, datalogger, radio, antenna, 12 volt battery</td>
</tr>
<tr>
<td>Pressure Stage Sensor</td>
<td>640.75</td>
<td>9 inches</td>
<td>Mounted inside sonar mount</td>
</tr>
<tr>
<td>Sonar (Scour) Sensor</td>
<td>640</td>
<td>6 feet</td>
<td>Mounted on sonar mount</td>
</tr>
<tr>
<td>Solar Panel</td>
<td>~769</td>
<td>N/A</td>
<td>Mounted on top of bridge truss 36 feet east of pier centerline</td>
</tr>
<tr>
<td>Sonar Mount</td>
<td>640</td>
<td>Close</td>
<td>Hinged, can be rotated out of water with grab hook and eye bolt on upstream point</td>
</tr>
<tr>
<td>Conduit</td>
<td>N/A</td>
<td>Close</td>
<td>Houses sonar and stage sensor cabling, on centerline of upstream pier face</td>
</tr>
</tbody>
</table>
# Bridge 5900 – Pier 20

## Bridge 5900, Pier 20 (Deck Elevation, 710 feet)

<table>
<thead>
<tr>
<th>Item</th>
<th>Elevation (feet)</th>
<th>Distance from Upstream Pier Face</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master Station</td>
<td>~699</td>
<td>Close</td>
<td>Enclosure, datalogger, radio, antenna, 12 volt battery, cellular modem</td>
</tr>
<tr>
<td>Two-axis Tiltmeter</td>
<td>~701</td>
<td>11.25 feet</td>
<td>Mounted under deck at 1/4 pier width</td>
</tr>
<tr>
<td>Sonar (Scour) Sensor</td>
<td>640</td>
<td>2.75 feet</td>
<td>Mounted in sonar mount</td>
</tr>
<tr>
<td>Solar Panel</td>
<td>~735</td>
<td>N/A</td>
<td>Mounted on top of bridge truss 36 feet west of pier centerline</td>
</tr>
<tr>
<td>Sonar Mount</td>
<td>640</td>
<td>Close</td>
<td>Hinged, can be rotated out of water with grab hook and eye bolt on upstream point</td>
</tr>
<tr>
<td>Conduit</td>
<td>N/A</td>
<td>Close</td>
<td>Houses sonar cabling, on centerline of upstream pier face</td>
</tr>
</tbody>
</table>

## Diagram

- Two-axis Tiltmeter (On top of Pier)
- Master Station
- Solar Panel
- Sonar Mount
Data Flow

Remote Station → Master Station → SAFL Database → Weekly Voltage/Temperature Updates → Access via IP Addresses

Access via vdv.safl.umn.edu → VDV Web Interface → Alerts

Blue are machine to machine connections
Red are machine to person connection
Web Interface Bridge 5900

Date Adjustments

Function Buttons

Site Selection

Data
Validation

- 3-D Acoustic Survey performed on 9-11-2012
  - Collins Engineers Inc.
    Underwater Bridge Inspection
  - Both inspection and fixed scour monitor indicate 1.5 of scour below pile cap

Acoustic Image 2. Undermined seal with exposed timber piles at the upstream nose of Pier 19, Looking South.

Bed 1.5 feet below bottom of pile cap
Data Review - Oct 2011 to June 2012

- Both Bridge 07011 and 5900 stage measurements agreed well with nearby gages.
- Ice/debris cover reflections from sonar pings led to false readings on Bridge 5900
- Live bed scour recorded at Bridge 5900
- Bridge 07011 sonar activated twice
- Tilt sensors operated within specification but caused concern for structural engineers
- Inadequate battery capacity on Bridge 07011 due to high amp demand of float-out receiver
  - Replaced 15 A-hr with 35 A-hr
- No scour indicated by wireless or tethered float-outs
Bridge 5900 – Pier 19 Sonar

Pier 19 Scour History

- **1. No sonar return**
- **2. Reflection from surface ice/debris with poor averaging**
- **3. Reflection from surface ice/debris with poor averaging**
- **4. No sonar return with poor averaging**

**Graph Key:**
- Bed Elevation
- Water Stage
- Bottom of Footing
- Top of Footing

**Dates:**
- 11/3/2011 0:00
- 12/3/2011 0:00
- 2/1/2012 0:00
- 4/1/2012 0:00
- 5/1/2012 0:00
- 7/1/2012 0:00
Lessons Learned

- Power budget is critical, especially in northern latitudes. Straightforward, but critical.
- Discontinuity in scour progression observed just below bottom of pile cap
  - Pile cap somewhat protects against further scour
- Tilt sensors should be more accurate and/or data needs to be better explained to users
- Debris is a major concern, but can be mitigated through good installation plans
- Programming requires better trapping/removal or false readings
- Final project report will provide a well documented case study for future installations
Thanks to

ETI Instruments Systems

MnDOT Hydraulics Office

MnDOT District 6 and 7 Bridge Offices

MnDOT District 6 and 7 Electrical/Signal Technicians

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