

SMART Gate Update

2012 Lock Maintenance Workshop
Paducah, Kentucky

28 February 2012

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Information Technology Laboratory
ERDC



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US Army Corps of Engineers
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Greenup L&D Miter Gate – Instrumented Nov 2003



Data logger located in gate operators room

Instrumentation:

- 22 - strain gages on the gate
- 2 - pressure cells (water level)
- 1- gate position sensor

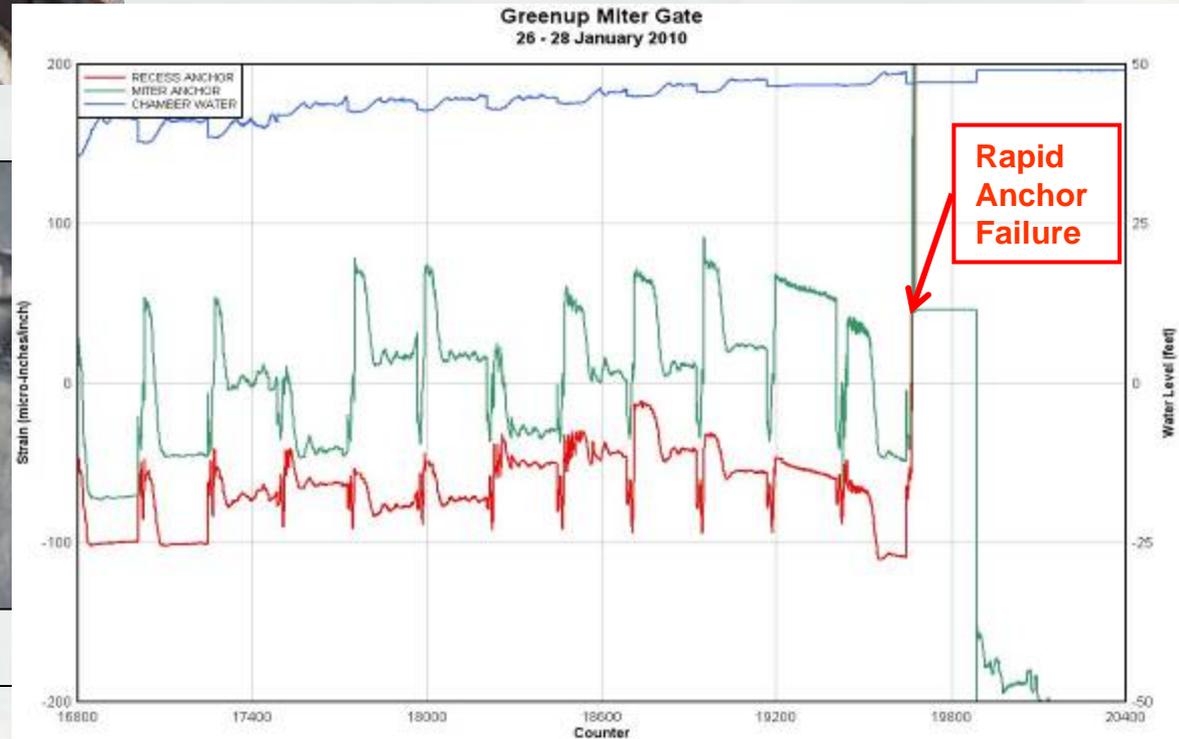


Greenup Lock

Anchor Failure – January 27, 2010



The gate leaf in foreground has dropped 6-inches and is resting on the sill.



November 2007 –Emergency Repairs and Instrument Installation

The purpose for the instrumentation:

- Monitor for deteriorating conditions
- Provide insight into the cause of damage
- Validate the FEM



The Dalles Nav Lock Instrumentation 2007 - 2009



Total of 123 sensors on the gates

- 97 Full-bridge strain gages
- 10 Bi-axial tilt-meters
- 4 Tri-axial Accelerometers
- 10 Temperature sensors
- 2 Water Level sensors



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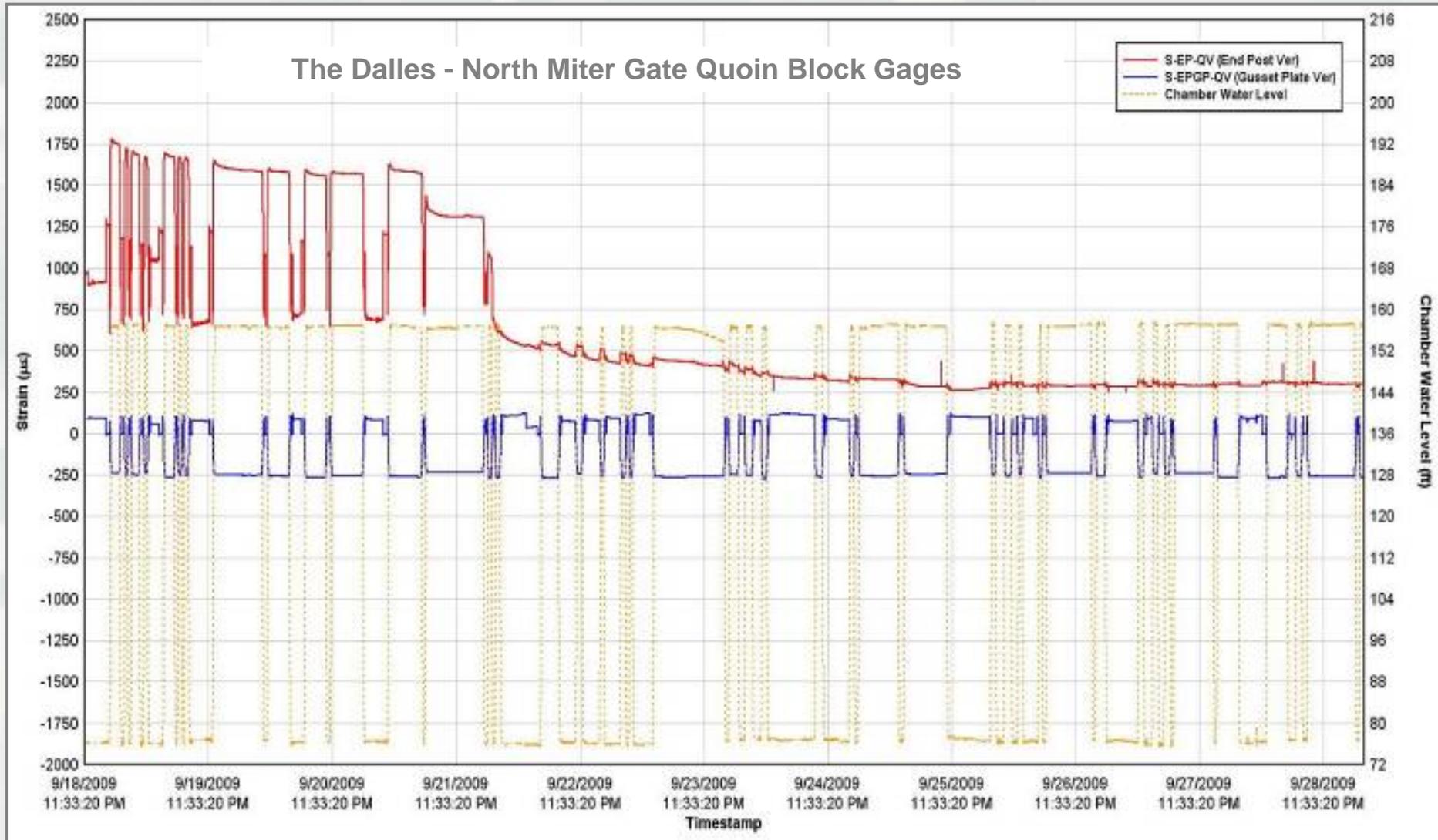
October 2009 – Emergency Closure and Repairs



- On 29 Sept 2009 The Dalles nav lock was closed for emergency gate repairs.
- **This decision was based in part by anomalous strain gage data.**
- Inspection showed substantial damage to the lower girders and diagonals.
- Emergency repairs began on roughly 4 Oct.
- The lock re-opened for normal operation on 12 Oct.



Strain Data from Sept 2009 – The Dalles



Lessons - Learned

- Gate instrumentation is viable for the long term.
- System needs to be affordable.
- Installation needs to be fast.
- User access must be “easy.”
- Data storage must be “permanent.”
- Data analysis needs to be part of the service.
- System needs to communicate with users.
- Must have project “buy-in.”
- Equipment must be maintained



“SMART Gate” – Structural Monitoring and Analysis in Real Time of (Lock) Gates

OBJECTIVE: To provide the district and project personnel with an effective Structural Health Monitoring tool for lock gates that will provide advance notice of deteriorating conditions before they hamper operations or safety.



New Gate at Marmet L&D

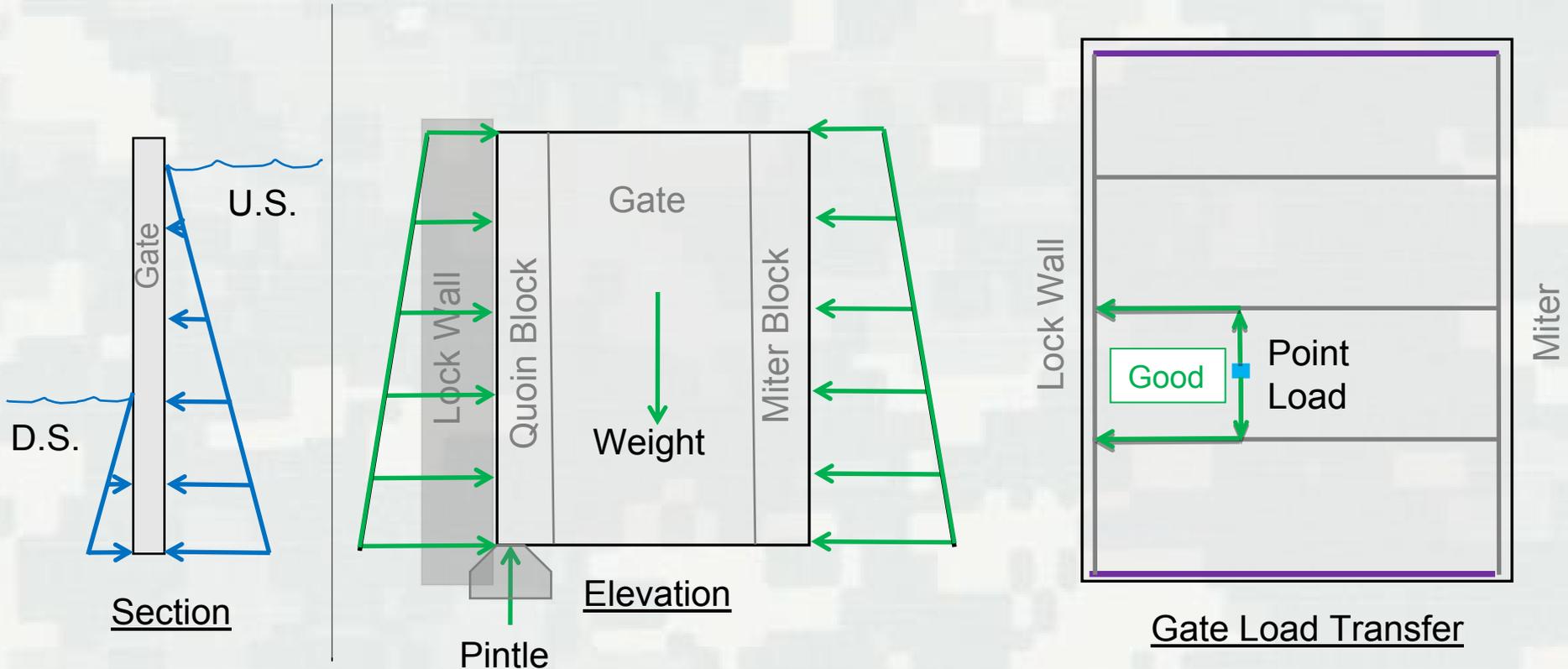


Greenup miter gate – 2003



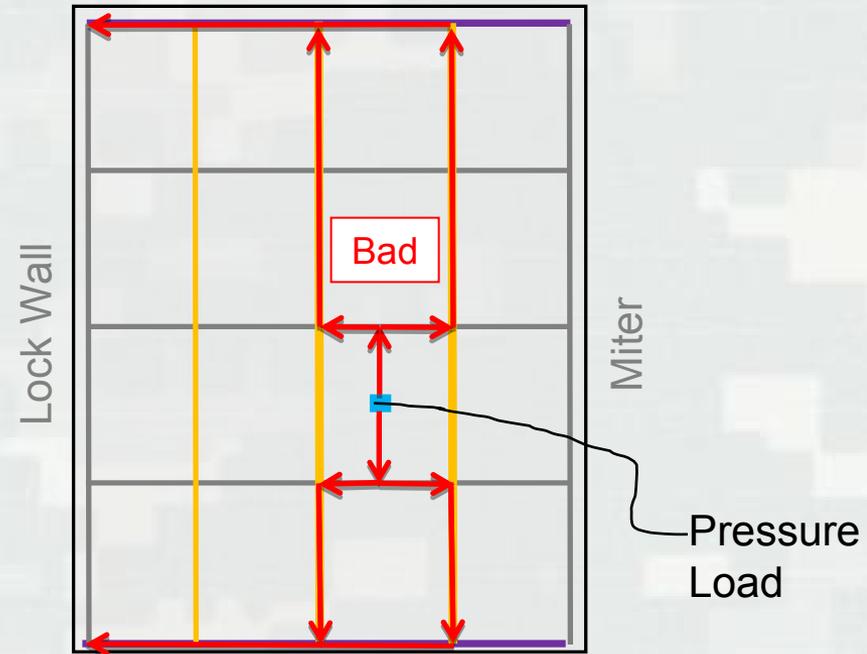
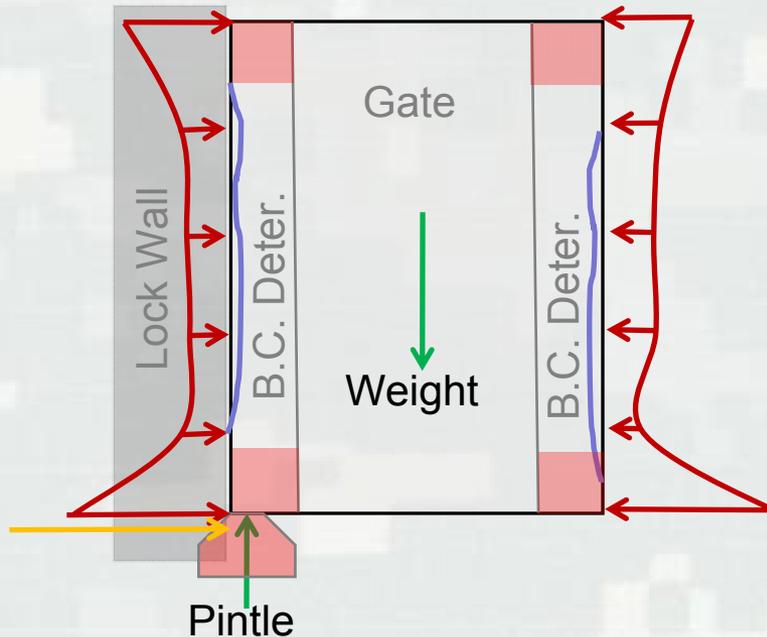
Fundamentals: Analysis of Basic Boundary Conditions

Ideal Performance



Deterioration of Boundary Conditions: High Potential for Damage

Closed Gate – Boundary Deterioration



- Change in **Boundary Reaction** Shape
- **Horizontal Load** on Pintle
- High Stresses at Localized Regions

- Load Increase in **Vertical Diaphragms**
- Load Increase in **Top and Bottom Girders**



Typical Gate Deterioration

Greenup L&D Nov 2003



1st SMART Gate Instrumentation Deployment at The Dalles Nav Lock – March 2011



The new gage suite is designed to detect changes in boundary conditions before excessive asymmetric load can damage the structure.

Total of 90 instruments:

- 24 strain gages on thrust diaphragm
- 40 strain gages on girders
- 12 strain gages on diagonals
- 6 tilt-meters
- 8 temperature sensors

- Contractor-installed instruments
- ERDC-installed monitoring system



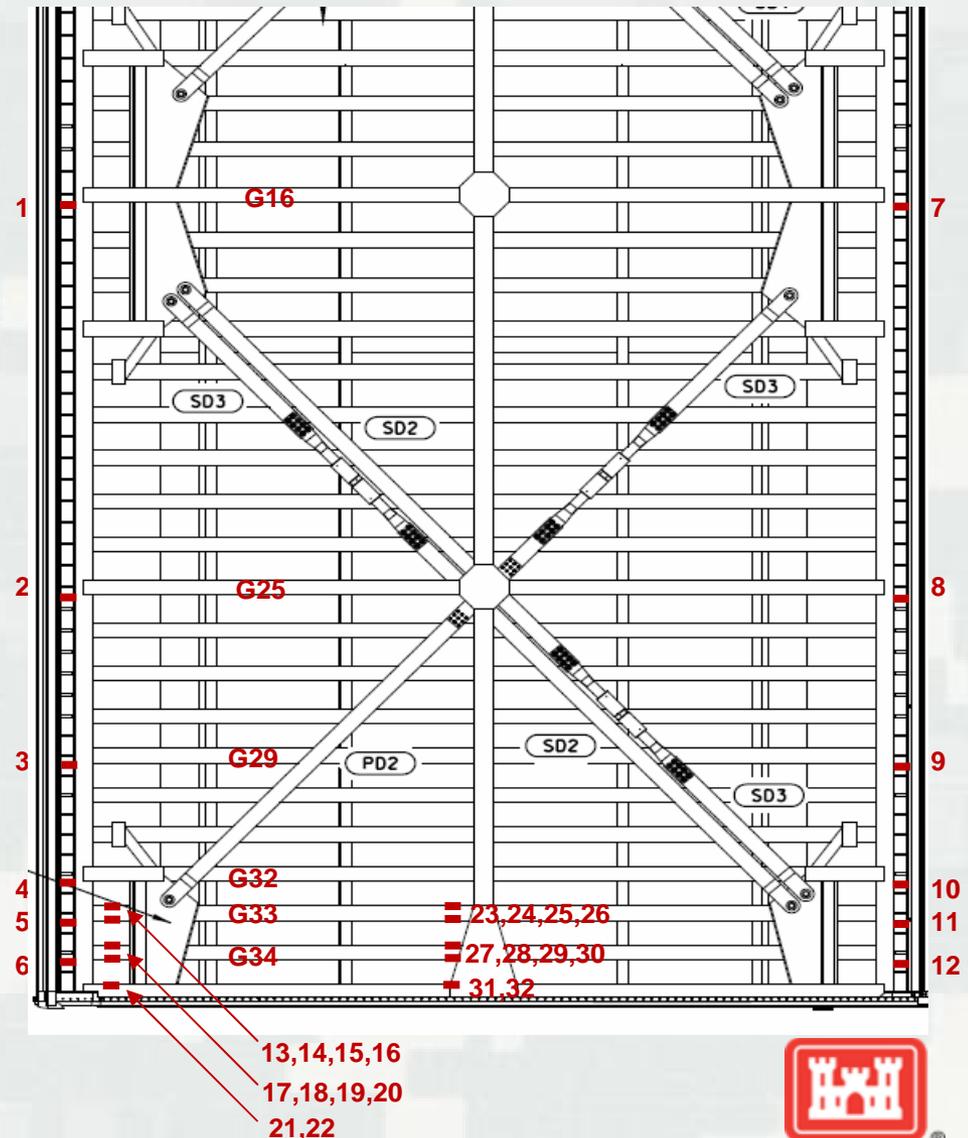
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New Gage Locations – The Dalles

The new gage suite is designed to detect changes in boundary conditions before excessive asymmetric load can damage the structure

Total of 45 Instruments on each Gate

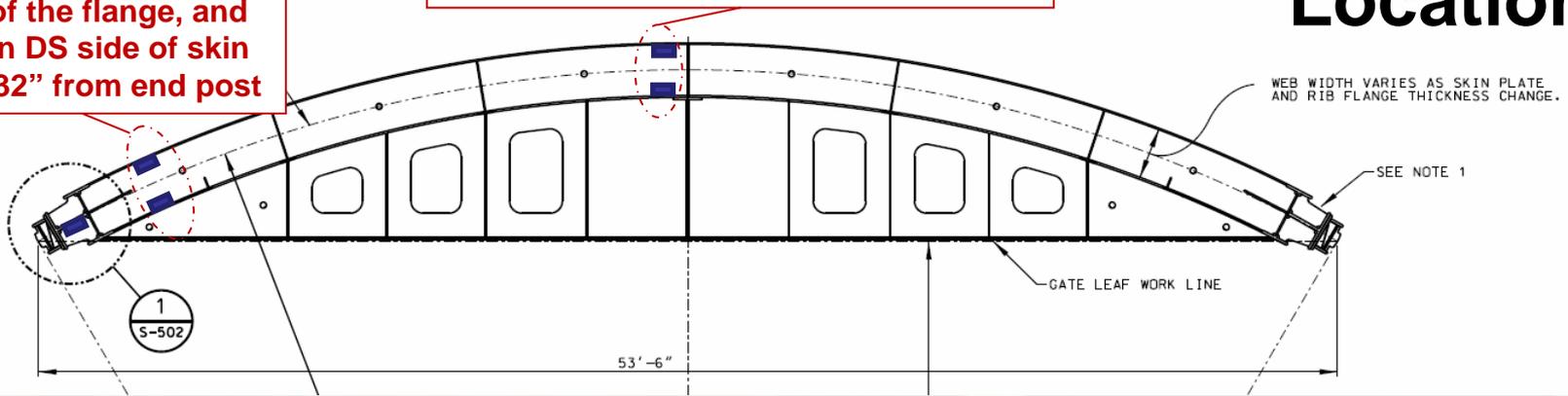
- 6 Strain gages on thrust web quoin side
- 6 Strain gages on thrust web miter side
- 8 Strain gages on girder 33
- 8 Strain gages on girder 34
- 4 Strain gages on girder 35
- 6 Strain gages on diagonals
- 3 Tilt meters (1 top, 2 bottom)
- 4 RTD (temperature gages)



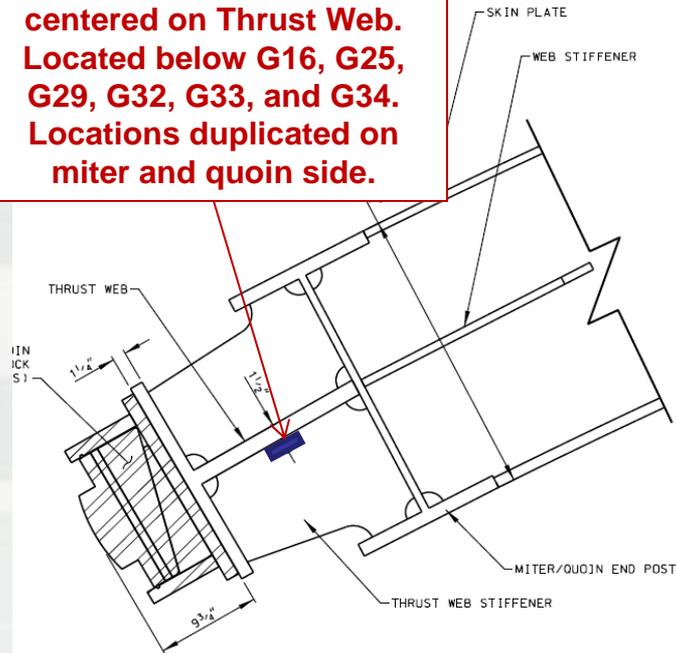
Strain Gage Locations

Set of 4 horizontal strain located X" above and below girder. 2 on US side of the flange, and two on DS side of skin plate, 32" from end post

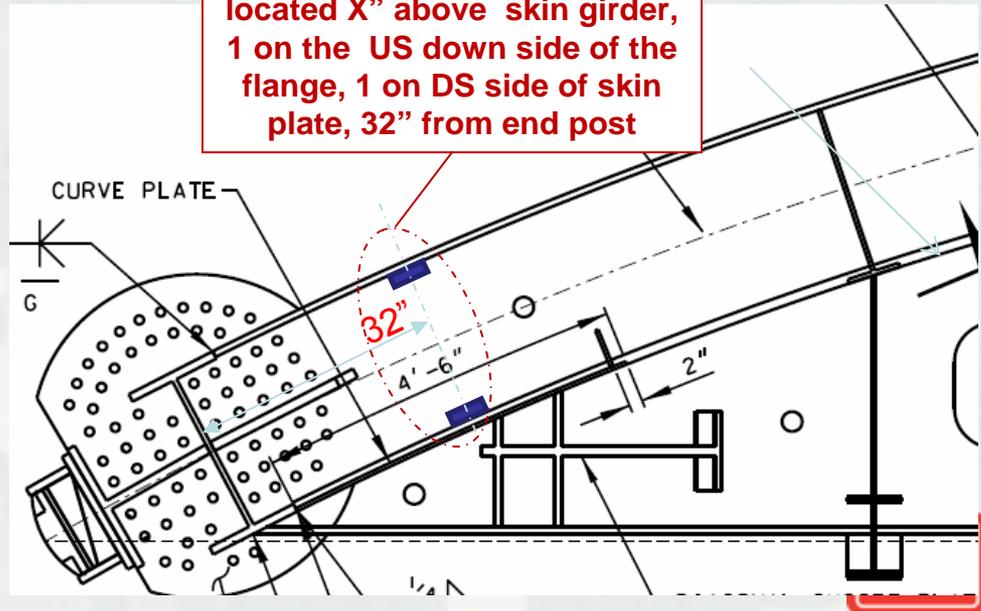
Set of 4 horizontal strain located X" above and below girder. 2 on US side of the girder flange, and two on DS side of skin plate, 12" from gate center



Horizontal strain gage centered on Thrust Web. Located below G16, G25, G29, G32, G33, and G34. Locations duplicated on miter and quoin side.

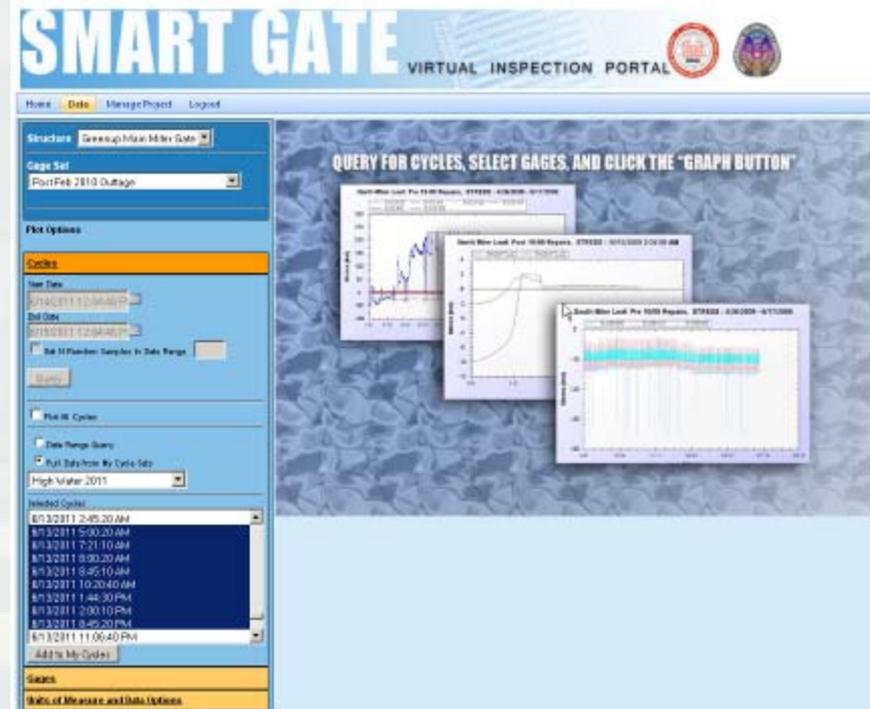


Set of 2 horizontal strain located X" above skin girder, 1 on the US down side of the flange, 1 on DS side of skin plate, 32" from end post



SMART Gate System Attributes

- Provides robust, centralized data repository
- Provides Web Application front-end to present/query data in useful ways
- Design based on portable architecture
 - Architecture Reuse
 - Rapid redeployment
- Uses trend analysis to track anomalous conditions.
- Capable of sending Email alerts and generating reports





Home **Data** Manage Project Logout

Structure

Greenup Main Miter Gate

Gage Set

Post Feb 2010 Outtage

Gage Types

- Logger Battery
- Strain Gage
- Temperature
- Water Pressure

Evaluation Period

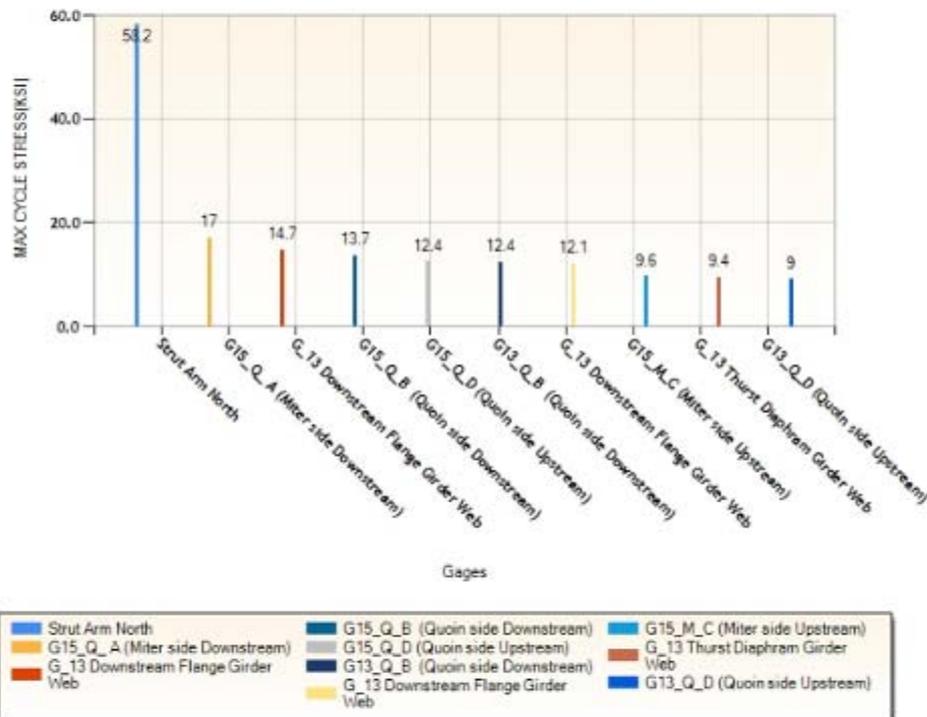
- Entire History
- This Year
- This Month
- This Week
- Last 20 Cycles

Rank Type

- Min-Max Drift
- Initial State Drift
- Cycle Stress

Submit Query

Top 10 Cycle Stresses on Post Feb 2010 Outtage 6/14/2011 - 6/15/2011



Tip: You can drill down on chart series to view details



Home **Data** Manage Project Logout

Structure **The Dalles South Miter Leaf**

Gage Set **New South Gate Gages May 2011**

Plot Options

Cycles

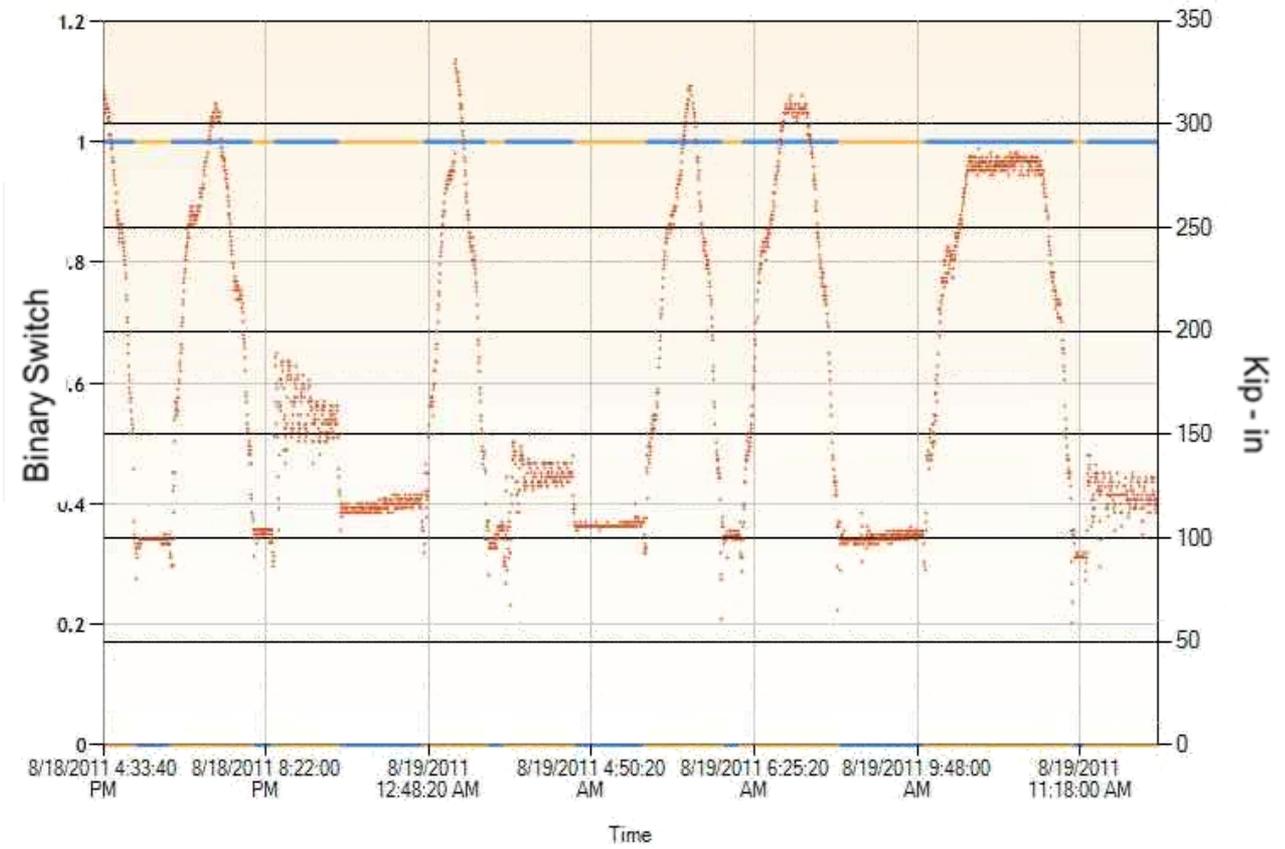
Gages

- New South Gate Gages May 2011
 - Virtual Channels
 - Girder 16 Strain
 - Girder 25 Strain
 - Girder 29 Strain
 - Girder 32 Strain
 - Girder 33 Strain

Units of Measure and Data Options

Graph Request CSV File

Structural Forces - New South Gate Gages – May 2011



■ Gate In Miter ● Gate In Recess ● Girder 33 Miter Side Flexural Moment (Mx)

Tip: In multi-cycle plots, you can click on plot data points to zoom in on the point's cycle.

SMART GATE

VIRTUAL INSPECTION PORTAL



Home Data **Manage Project** Logout

Manage Structures, Gagesets, Gages **Manage Gageset Gage Groups**

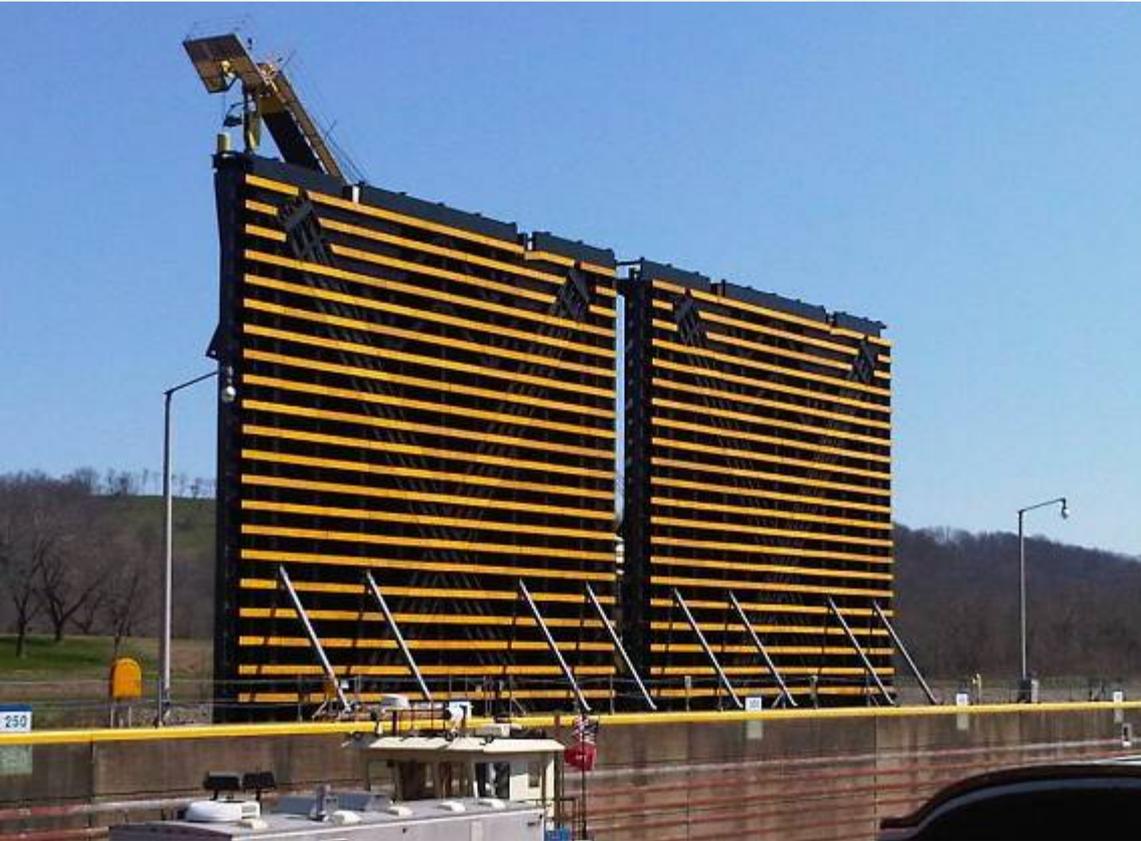
SHOWNAME	DESCRIPTION																																																												
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Post Feb 2010 Outtage																																																													
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▶ The Dalles North Gate	The Dalles NAVLOCK North Miter Gate																																																												

Current Project: Capt. Anthony Meldahl L&D Instrument Placement, Huntington District October – December 2011



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Capt. Anthony Meldahl L&D Instrument Placement October – December 2011

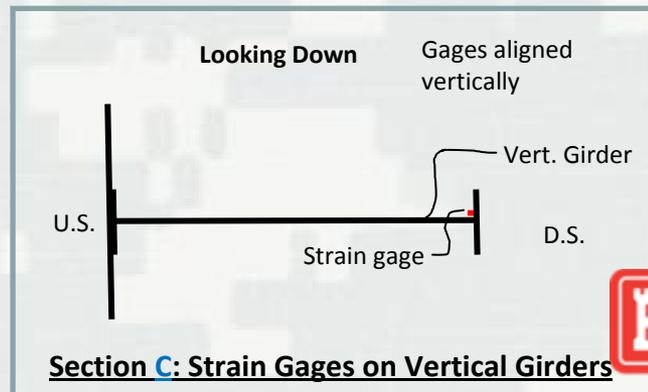
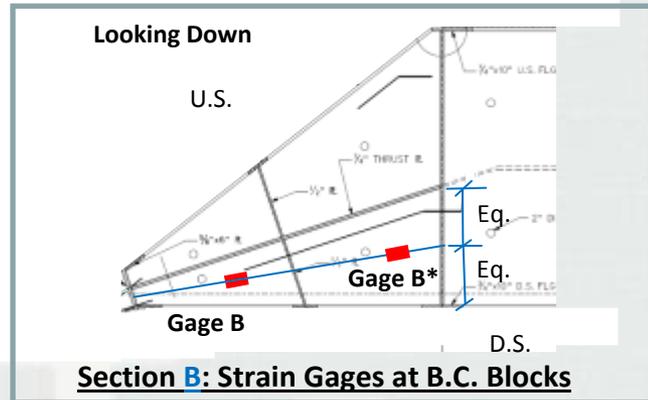
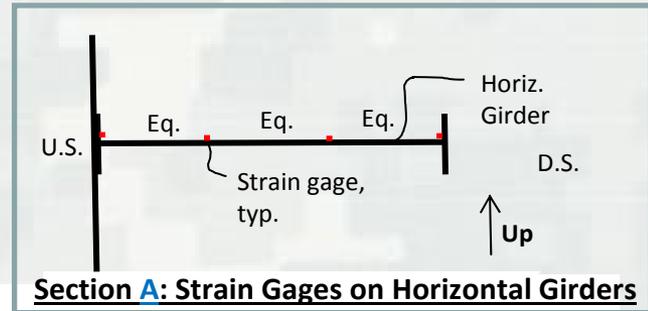
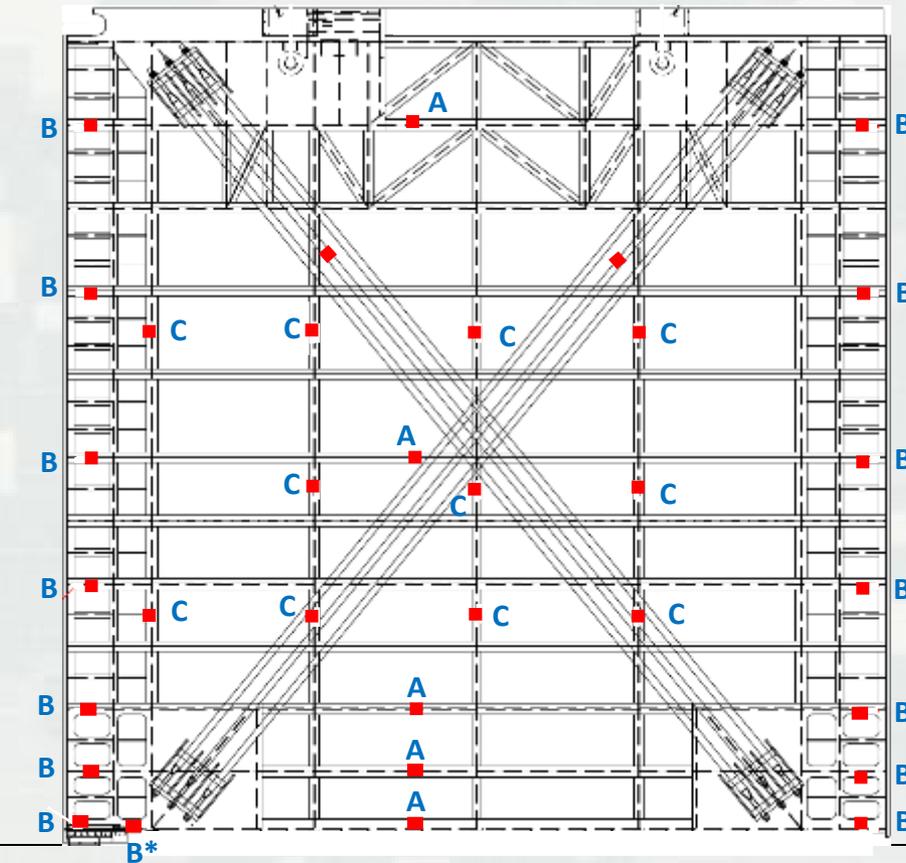


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Capt. Anthony Meldahl L&D Instrument Suite

132 Total Channels both gates

- 96 Strain gages on gates
- 12 Strain gages on anchors
- 12 Load cells
- 4 Tilt-meters
- 2 Position sensors
- 4 Water level
- 6 Temp sensors





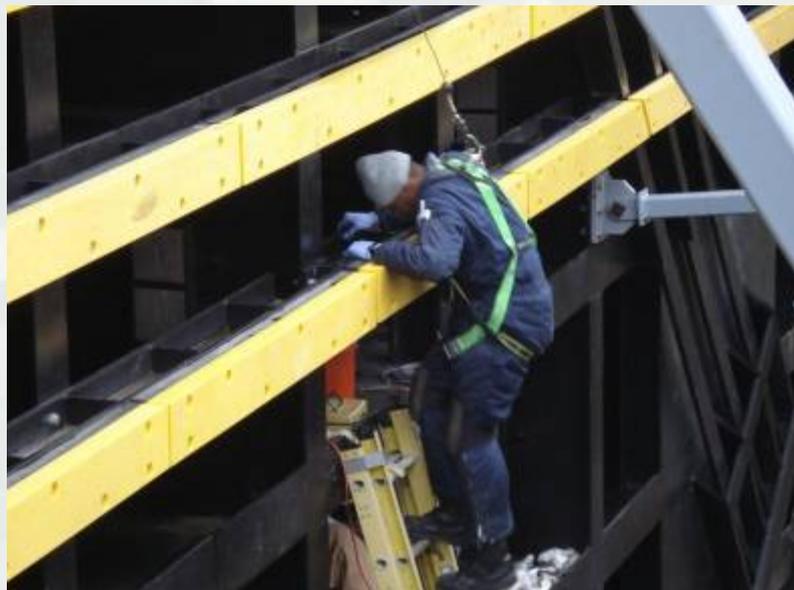
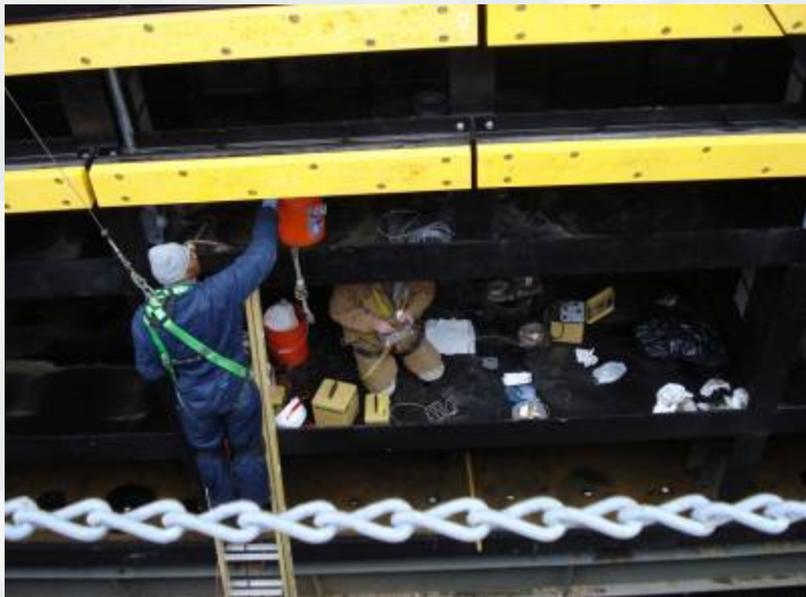
Meldahl Miter Gate Instrumentation Effort – Dec 2011

ERDC Technician
preparing surface and
installing strain sensor

ERDC Electrician and
Electronics Technician
routing instrument
wires through
protective conduit.



Capt. Anthony Meldahl L&D Installation Effort Nov - Dec 2011



SMART Gate Projects FY12 / FY13

- Bonneville L &D (old gate) March 2012
- Captain Anthony Meldahl L&D (US gate) April 2012
- Greenup L&D (gate 1) June 2012
- Big Cliff Dam (Tainter Gate) July 2012
- Captain Anthony Meldahl L&D (DS Gate) Fall 2012
- Chain of Rocks Lock (LD27) Nov 2012
- Cannelton L&D (Louisville District) 2013?
- Hannibal L &D (Pittsburgh District) 2013?



2013 Proposed SMART Gate R&D Project – Chain of Rocks Locks and Canal (L&D 27), St Louis District



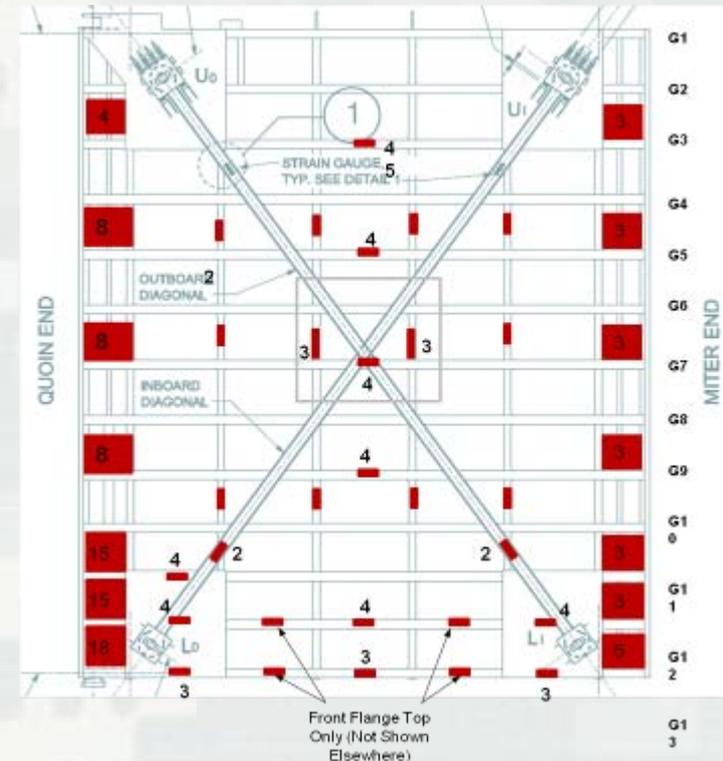
This project is intended to provide:

- 1.The intensive structural data needed to optimize SMART Gate sensor placement**
- 2.Fundamental understanding of structural loads in a typical gate**
- 3.A test bed for enhanced SHM development.**



LD 27 Instrumentation Plan

- 348 Strain gages on gate leafs
- 24 Strain gages on gate anchors
- Clevis pin load cells at critical locations
 - ▶ Gate diagonals
 - ▶ Gate anchors
 - ▶ Strut
- 6 Bi-axial Tilt-meters on gate girders
- 12 Temp sensors (strain gage compensation)



Acknowledgements

ERDC Project Delivery Team:

- Chris Lunderman, Research Physicist
- Chris Bogen, PhD, Computer Scientist
- Harold Carr, Senior Electronics Technician
- Guillermo Riveros, Structural Engineer
- Matthew Smith, Structural Engineer
- Bruce Barker, Supv. Physicist

Sponsors and Proponents:

- Huntington District – Doug Kish, John Jaeger, and John Clarkson
- Portland District – Travis Adams, Lance Helwig, Mark Sawka, Pat Duyck, and Brian Mason
- St Lewis District – Rob Kelsey,
- Navigation Systems R&D Program, Jeff Lillycrop and Eddie Wiggins, ERDC
- Navigation Safety Program, Tom Hood, HQ USACE



Questions?

