



US Army Corps
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Huntington District

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Marmet Lock & Dam

Automated Instrumentation Assessment

Summer / Fall 2004

2005 Tri-Service Infrastructure Conference
August 4, 2005

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Considerations

- ◆ Project Overview
- ◆ Automated Data Acquisition System Overview
- ◆ ADAS Challenges
- ◆ Deep Seated Sliding Occurs
- ◆ ADAS Failure
- ◆ Emergency Action Plan Response
- ◆ Remediation Attempts
- ◆ Current Status



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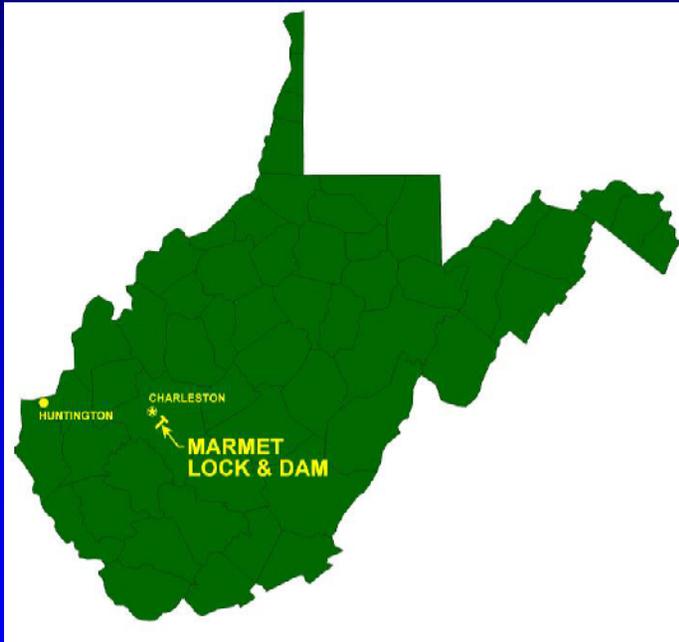
Project Overview

- ◆ Project Located On Kanawha River
(Just SE Of Charleston, WV)
- ◆ Built In 1934 – Twin Locks 56'x360'
- ◆ Average Lock Time Is Over 4 Hours Per Tow
- ◆ Contract Awarded May 2002
 - Kokosing / Frucon, LLC (KFC)
- ◆ Estimated 7-year Construction
- ◆ New Lock Is 110'x800'



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Project Location



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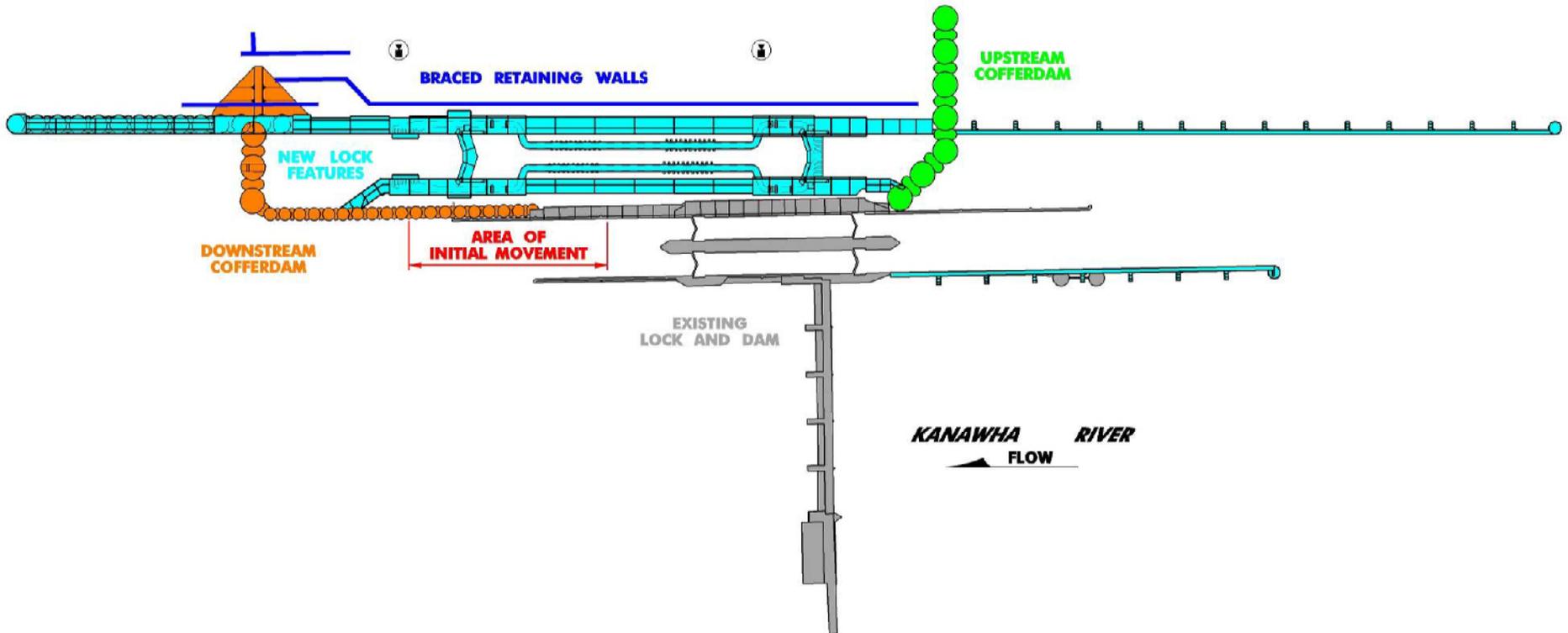


Marmet Lock & Dam Prior to New Lock Construction



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Marmet Lock - New Construction



Spoil Area

Downstream Cofferdam →

→ Anchored Retaining Wall

→ Existing Lock Wall

Existing Lock →

Dam

Upstream Cofferdam →



Cofferdam at Time of Initial Movement



Cofferdam at Time of Initial Movement



Cofferdam at Time of Initial Movement



08/19/2004

Cofferdam at Time of Initial Movement



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ADAS Overview

- ◆ Monitors Cofferdam Cells, Existing Lock Wall And Spoil Site
- ◆ Central Monitoring Station
- ◆ Geo-Net / Geo-View Website Computers
- ◆ 30 Remote Computers (MCU)
(Measurement And Control Unit)
- ◆ 350+ Sensors Include:
 - IPI (In-Place Inclonometers)
 - Vibrating Wire Piezometers
 - Load Cells (On Anchors)
 - Digital Tilt Meters
 - Pool Transducers



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ADAS Overview

Manually Read Instruments

- ◆ Portable Inclinerometers
- ◆ Settlement And Alignment Pins
- ◆ Joint Monitoring Pins
- ◆ Saw Cuts



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ADAS Overview



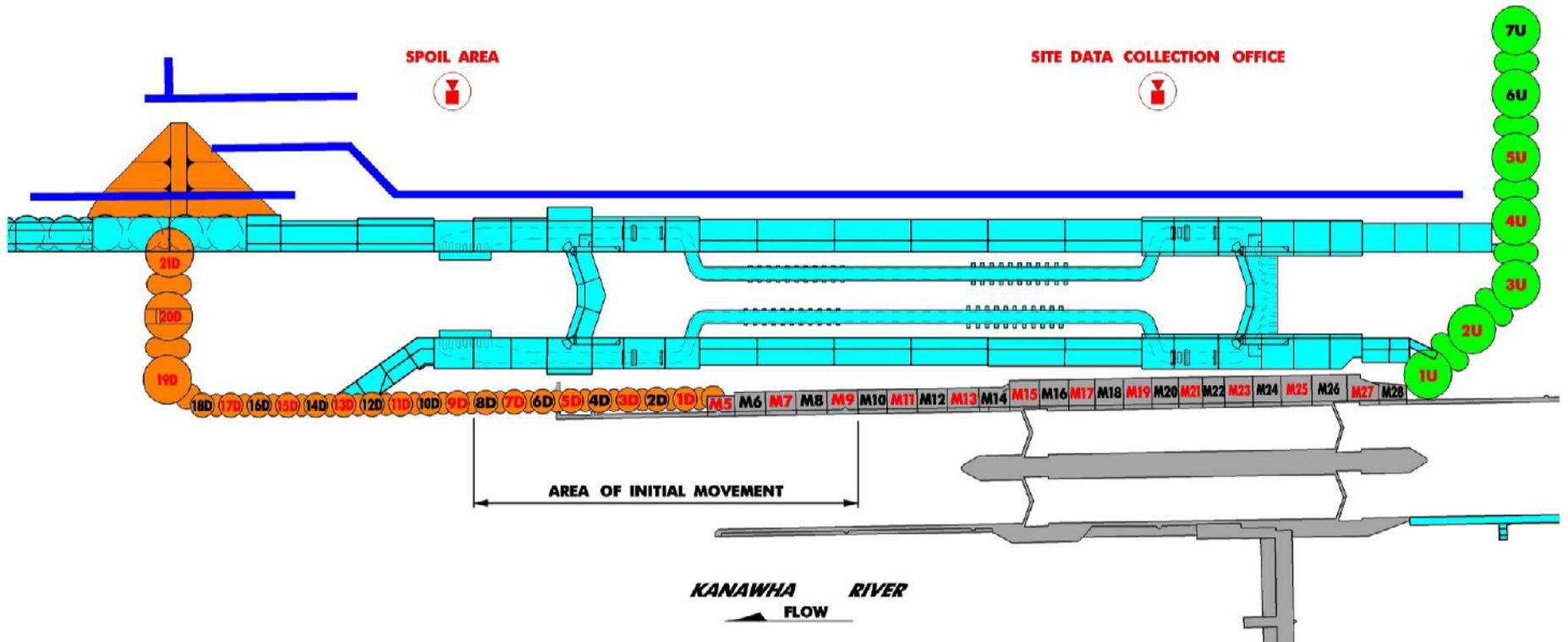
**30 MCUs (Remote Computers)
Installed on Site**



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ADAS Overview



MCU Locations (Shown in Red)



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ADAS Overview

Cofferdam Cell Installations



Upstream Cells

Downstream Cells



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ADAS Overview Lock Wall Installations





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ADAS Overview

Load Cells On Anchors





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ADAS Overview





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ADAS Challenges

◆ Grounding / Physical Location

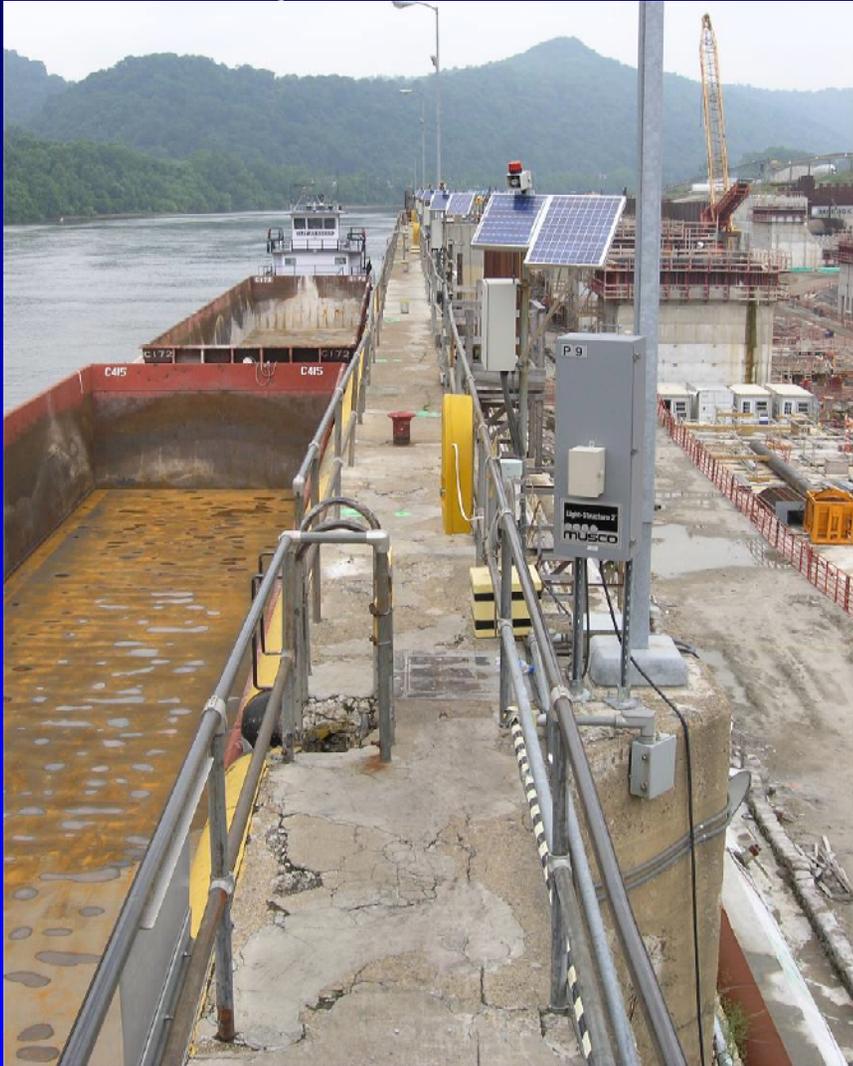
- MCUs Located On Cells And Existing Lock Wall
 - Kanawha River On West Side
 - Excavated Walls / Construction On East Side
 - No Good Location For Individual Grounds
 - Bare Copper Ground Wire Runs From Upstream Cell To Downstream Cell, Exposed Above Ground
 - Copper Ground Wire Fastened To Safety Fence
 - All Lock Wall MCUs Grounded To Same Copper Ground Wire



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ADAS Challenges Grounding / Physical Location





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ADAS Challenges Grounding / Physical Location





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ADAS Challenges

- ◆ **Communication Antenna Arrays**
 - Two Large Communication Arrays Are Located Within 2-miles Upstream And Downstream Of Marmet Lock
 - The Arrays Both Transmit And Receive Signals Over A Wide Range Of Frequencies
- ◆ **River Traffic Radio Transmissions**
 - Lock To Barge Communications
- ◆ **Hydroelectric Plant Control**
 - Remote Communication Control
- ◆ **All Data Transmission Is Performed Via Radio Between The MCUs And The Central Monitoring Station**



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ADAS Challenges

- ◆ Limited On-site Expertise
 - Hardware And Software Support Is Provided By Off-site Sub-contractors
- ◆ Limited Experience With MCU / Software
 - Initial Installer And Programmer Had Limited Experience With Geomatics Hardware / Software



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Deep Seated Sliding Occurs

◆ Construction Status At The Time Movement Occurs

- All Rock Anchors And Thrust Blocks Had Been Installed
- Drilling, Rock Blasting And Foundation Rock Excavation Had Begun In Downstream Area Of Cofferdam
- Reading, Plotting And Evaluation Of Instrumentation Data Was An Ongoing Task



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Deep Seated Sliding Occurs

◆ Initial Downstream Movement

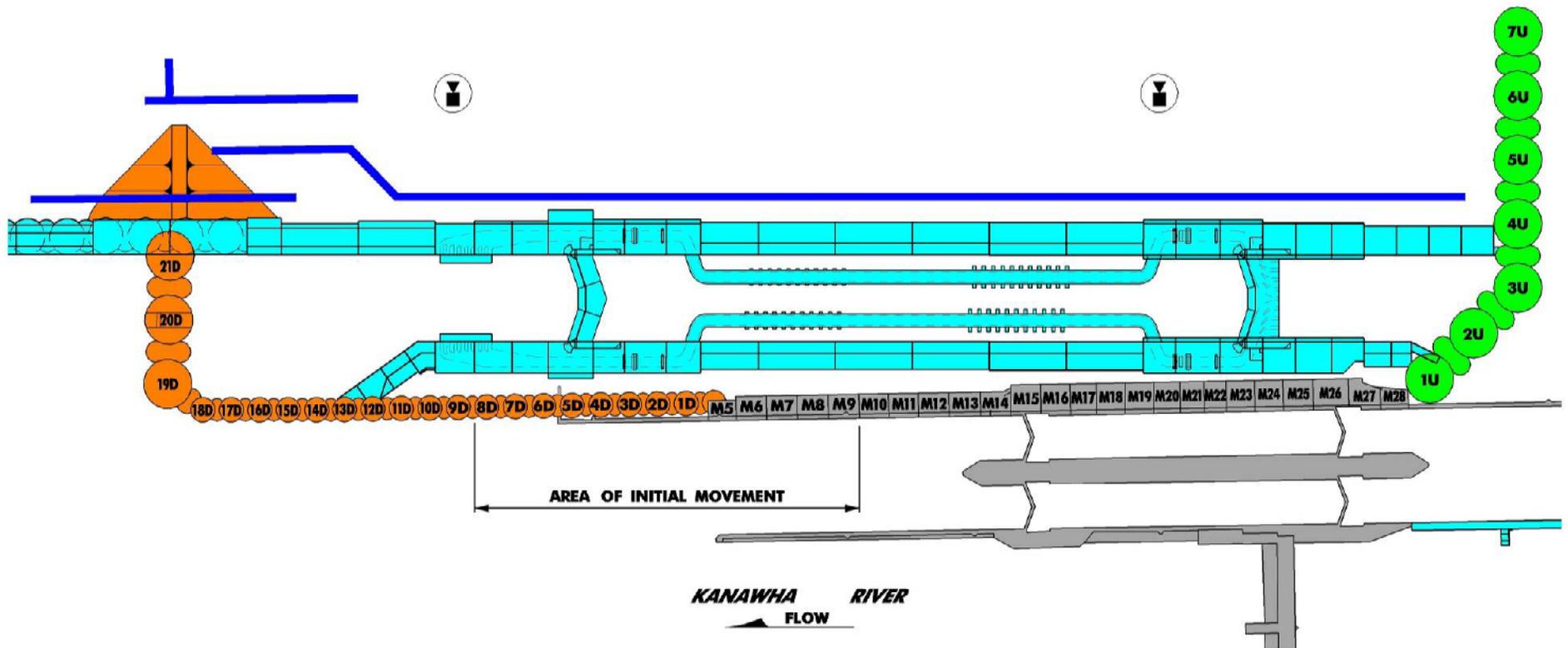
- August 2004 Movement Occurred Along Two Weak Planes
 - EI 540 +/- Where There Is A Series Of Thin Seams Of Carbonaceous Shale And Coal Within An Otherwise Generally Competent Sandstone Formation
 - EI 520 +/- Where There Is A Discontinuous Thin Seam Of Clayey Material Near The Bottom Of The Sandstone Unit And An Underlying Shale Formation. This Seam Is Slightly Lower Than Any Required Excavation



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Deep Seated Sliding Occurs



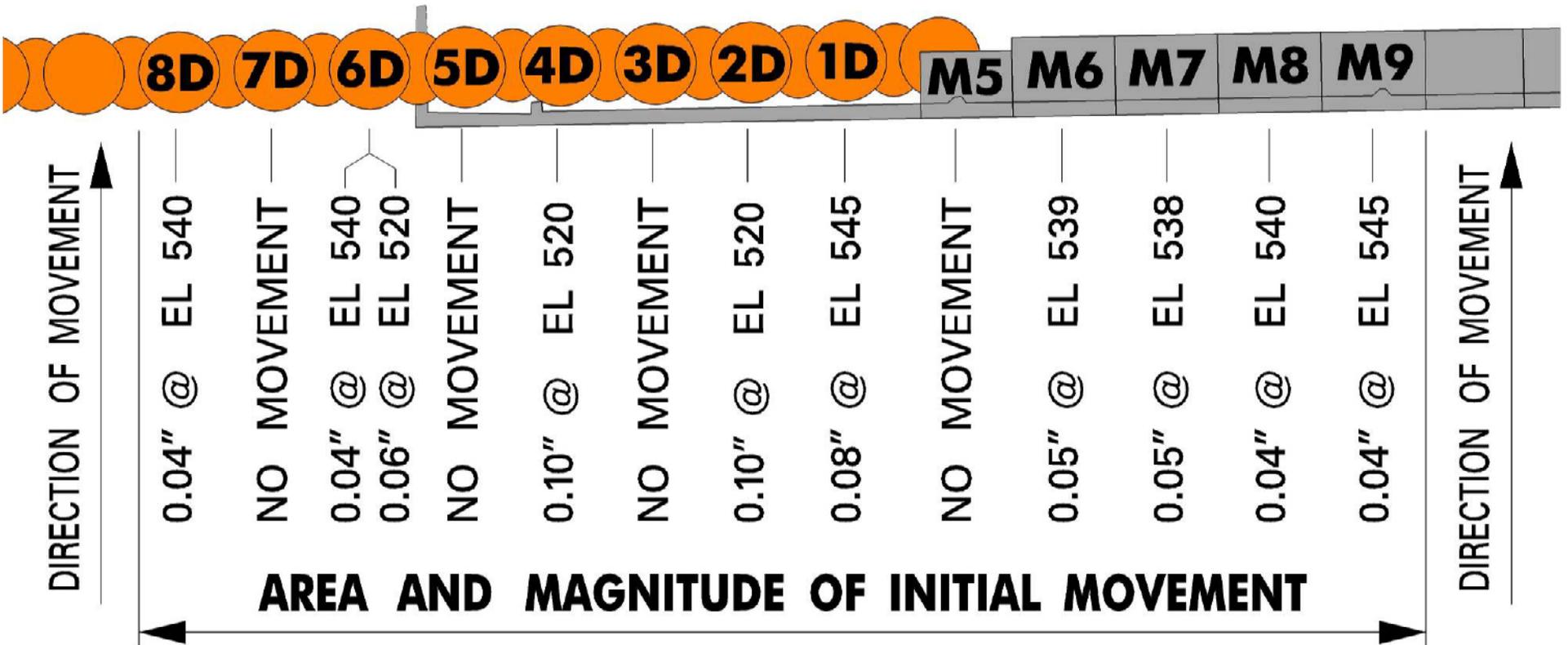
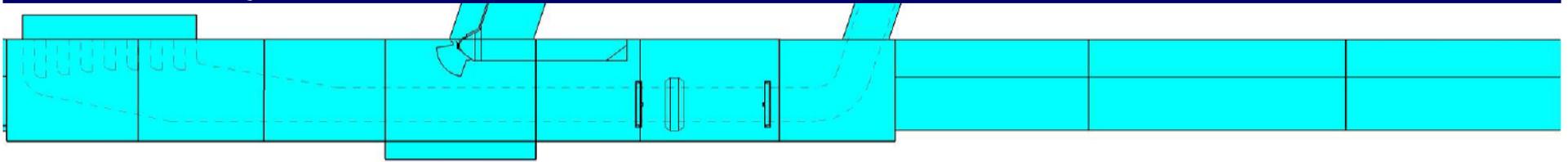
Cofferdam Area



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Deep Seated Sliding Occurs





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Deep Seated Sliding Occurs

◆ Initial Downstream Movement - Continued

- The Magnitude Of The Movement Was Consistent With That Expected For The Initial Transfer Of Load As Estimated From Direct Shear Tests In The Foundation Rock
- The Movement Was Generally Within Tolerable Limits; However The Consensus Of The PDT Was That The Trend Of Gradual And Steady Increases Warranted Concern And Additional Scrutiny



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Deep Seated Sliding Occurs

◆ Initial Downstream Movement - Continued

- The Movement Stabilized Within 6-8 Weeks After Rock Blasting And Foundation Rock Excavation
- The Initial Threshold Of 0.25" Of Total Movement Was Revisited By The PDT And Deemed Reasonable And Appropriate.

◆ Additional Upstream Movement

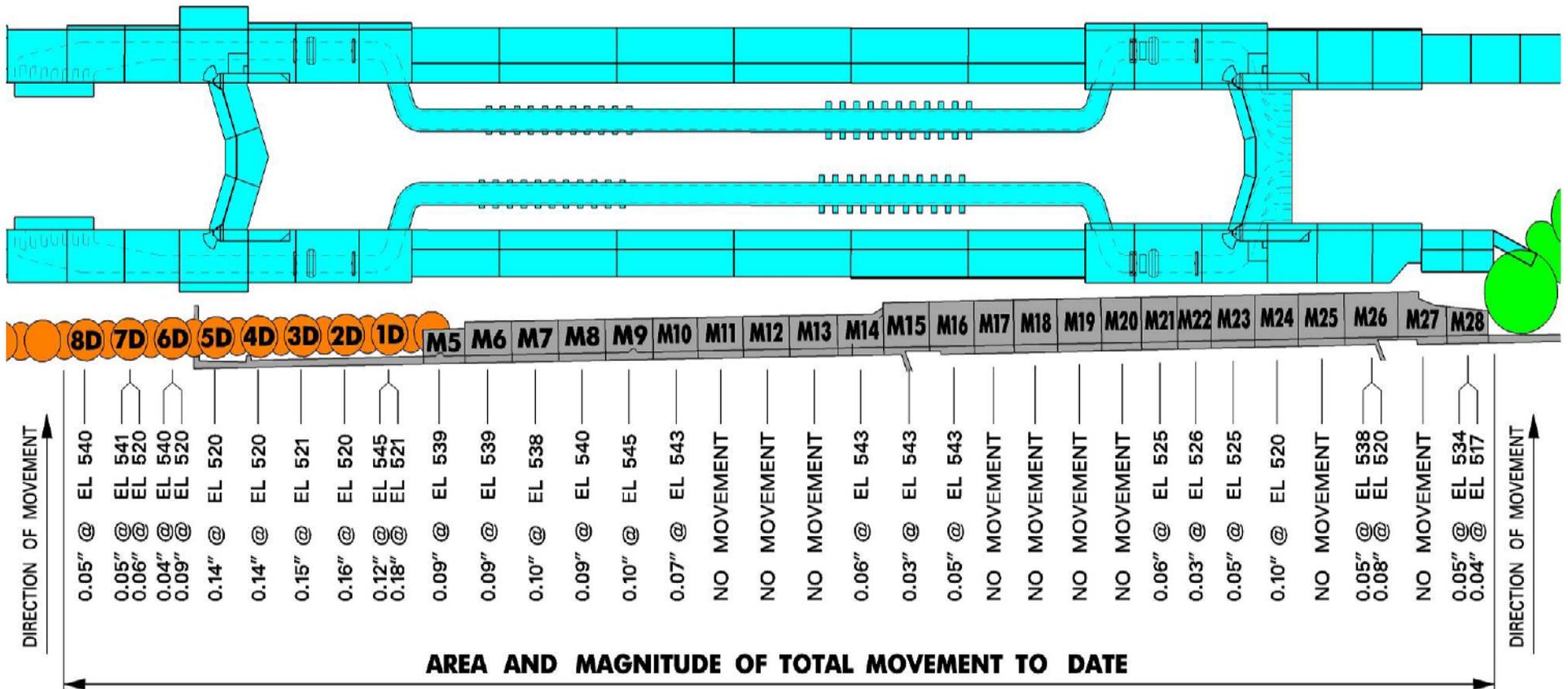
- Additional Upstream Movement Was Anticipated And Did Occur, But PDT Response Actions Minimized The Magnitude Of That Movement.



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Total Movement To Date





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ADAS Failure

- ◆ Reliability Of The ADAS Had Been Suspect For Some Time
 - Significant Disagreements Between IPI And Portable Inclinometer Readings
 - IPI Readings Had Provided Erratic Results
 - Excessive Number Of False Alarms
 - Monthly Instrumentation Reports Regularly Contained Graphs With Considerable Gaps In Recorded Data And Readings That Significantly Exceeded Established Threshold Limits



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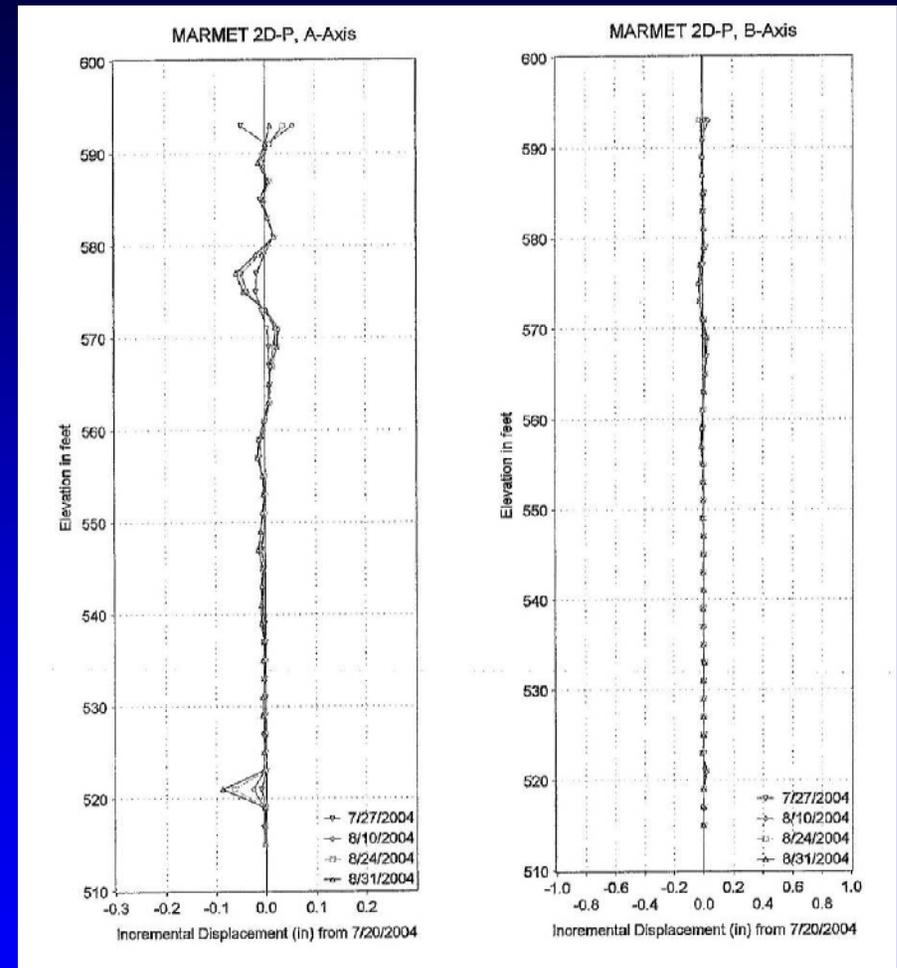
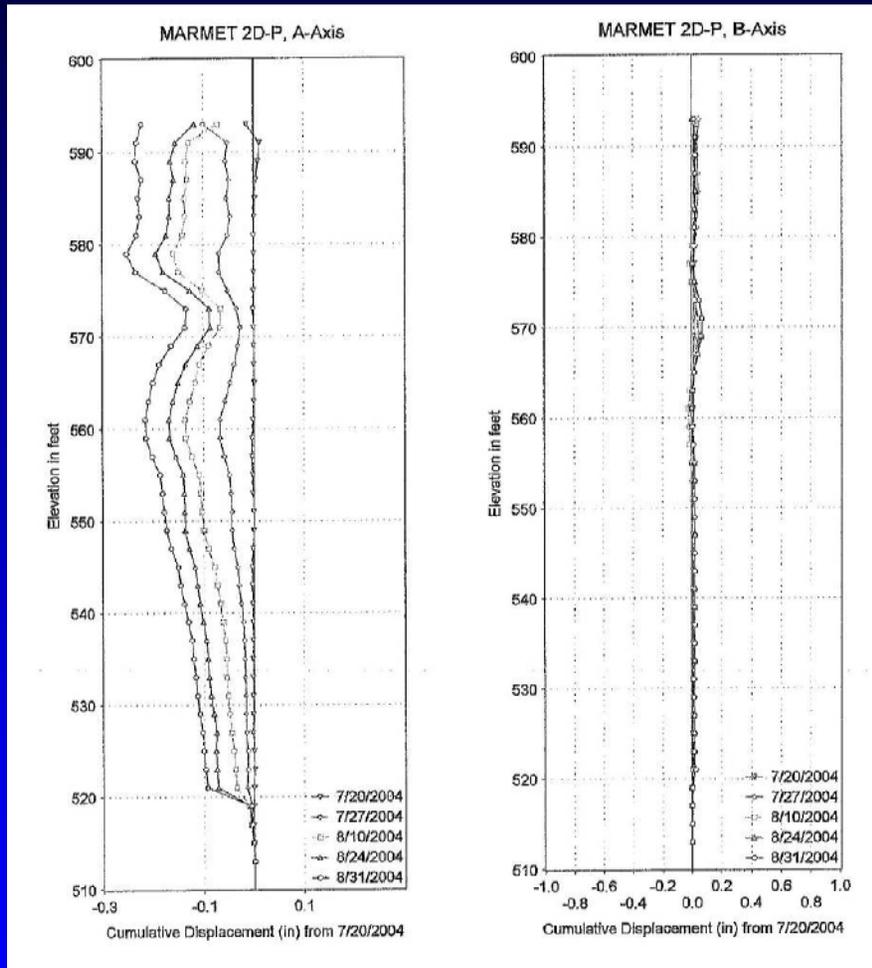
ADAS Failure

◆ August 31, 2004 Special Meeting

- Contractor Provides COE With Portable Inclinometer Graphs Indicating Movement In Foundation Below Several Monoliths And Cells
- Movement Elevations Correlated With Previously Identified Weak Seams And Occurred In Four Consecutive Weekly Readings
- Movement Was Recorded In Graphs For A Number Of Adjacent Cells And Monoliths
- Movement Was Oriented Landward And Occurred A Few Weeks After Blasting And Excavation Of Adjacent Foundation Rock Had Begun
- Rate Of Movement Was Consistent And Linear (0.01" To 0.02" Per Week)



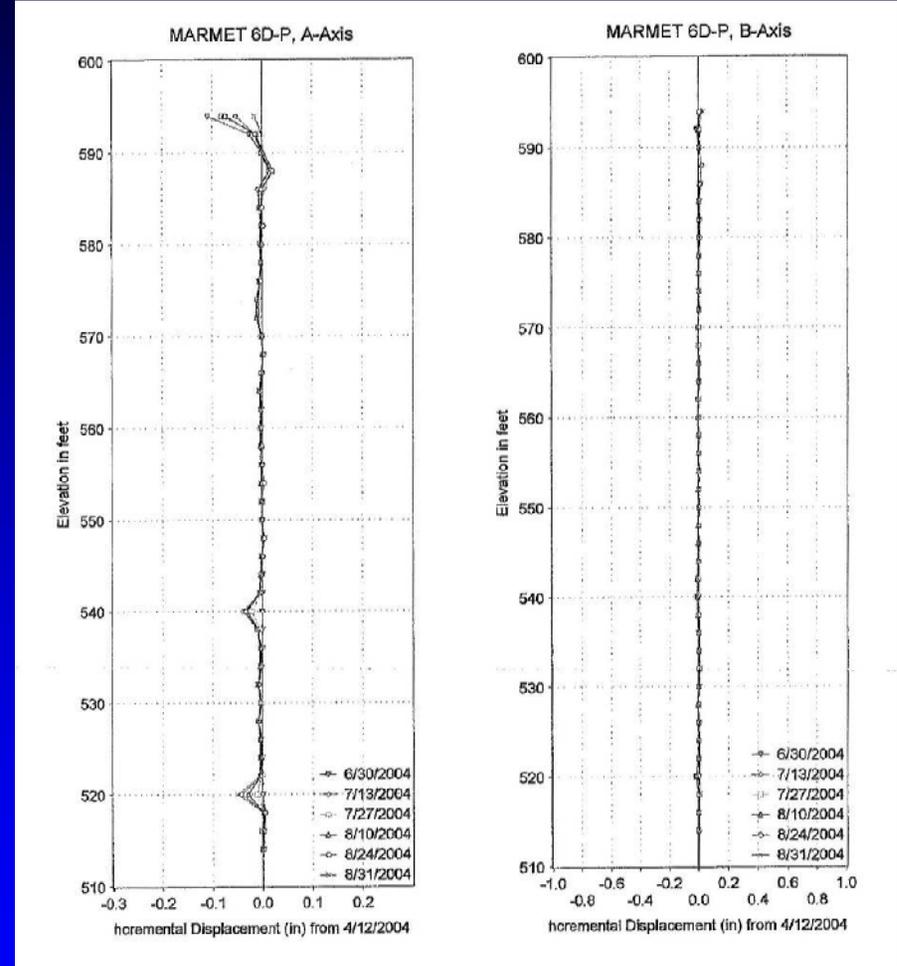
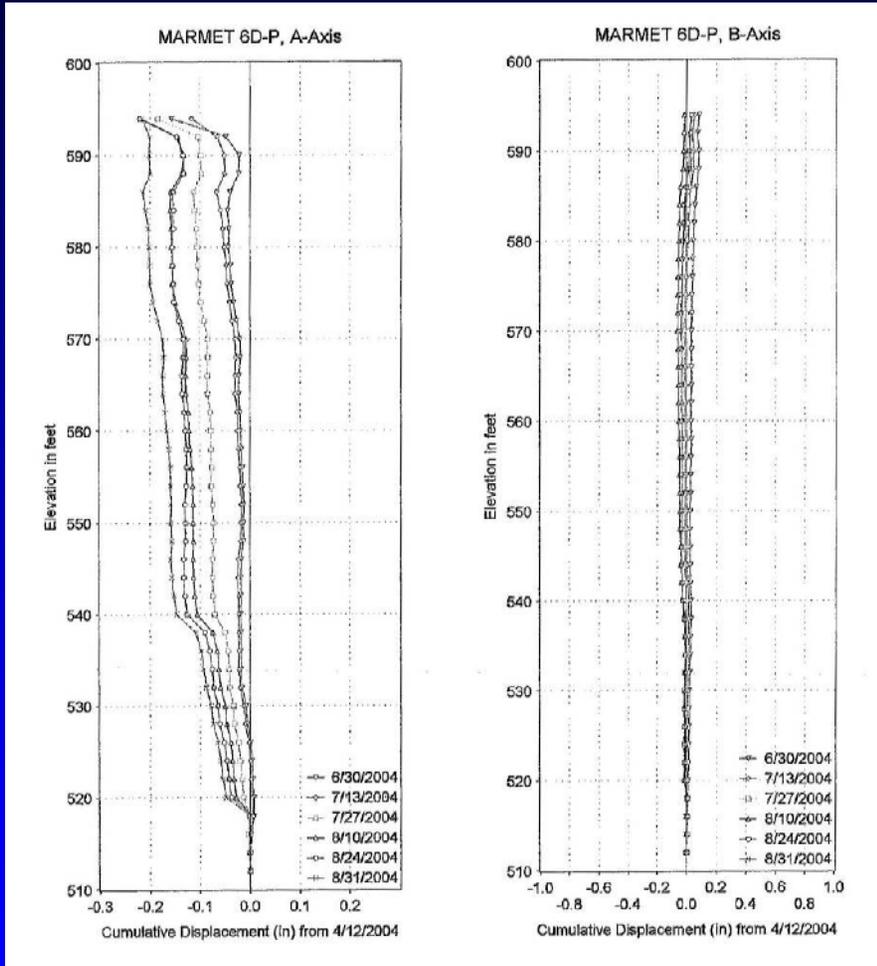
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Initial Movement – Cell 2D
August 2004



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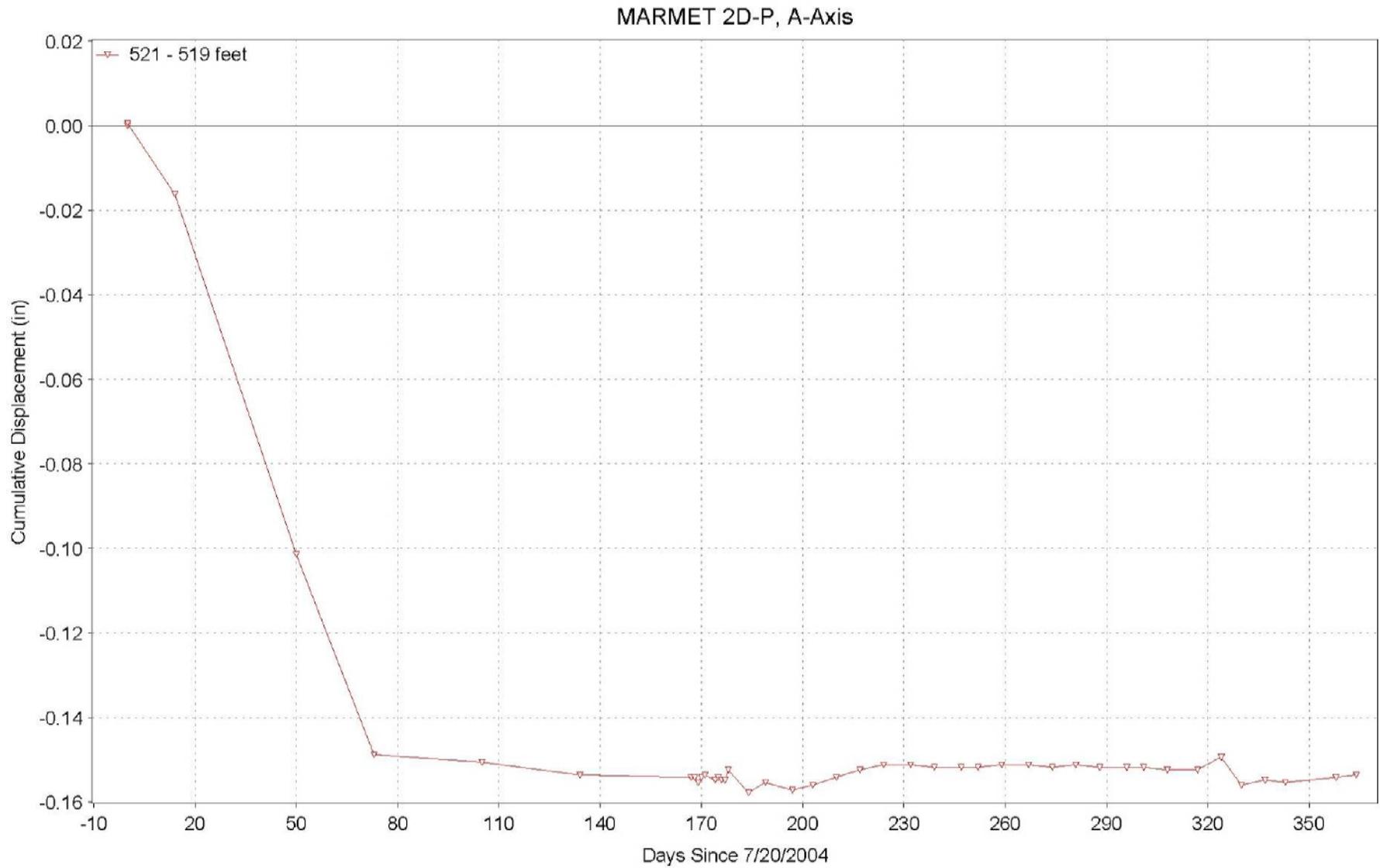


Initial Movement – Cell 6D

August 2004

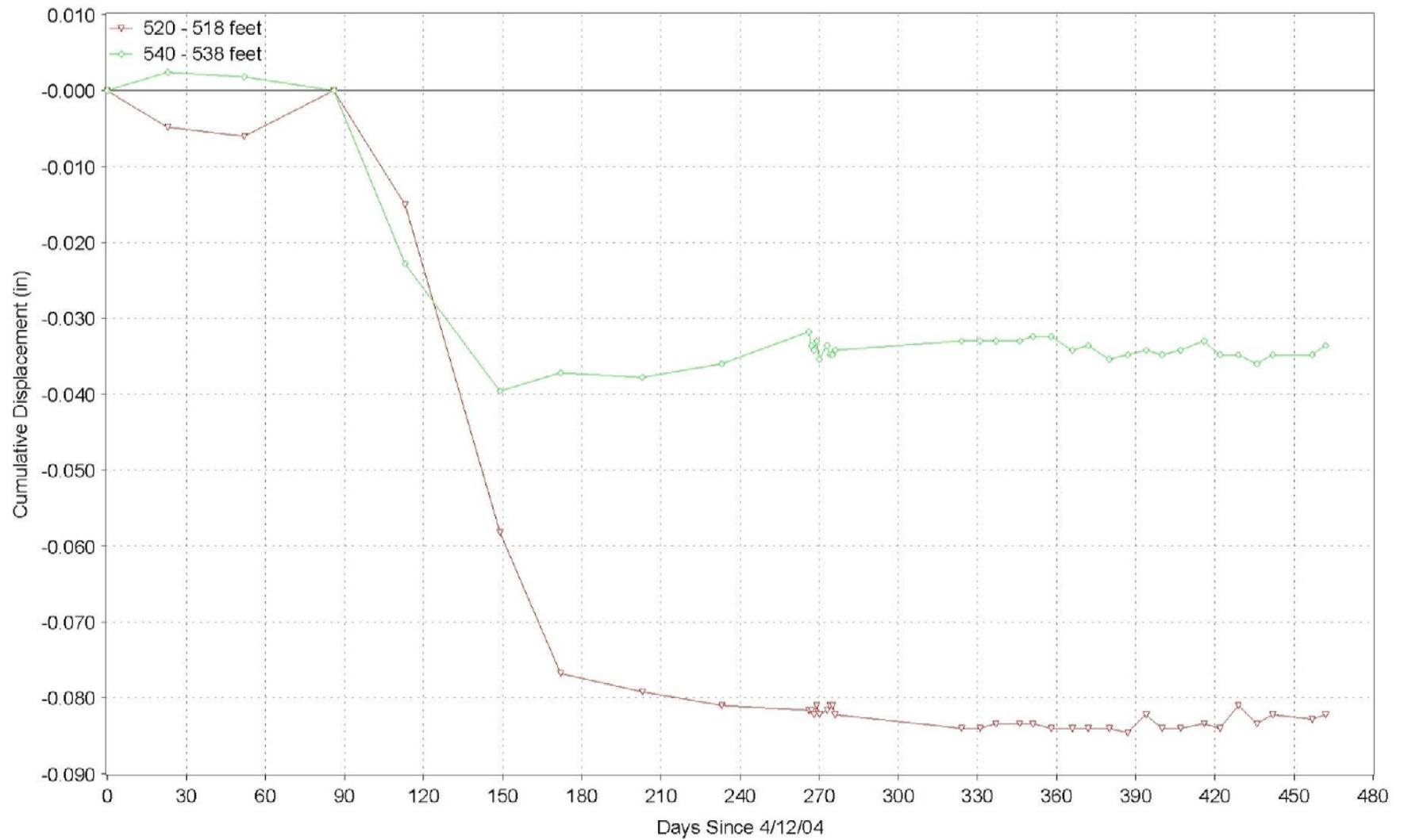


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MARMET 6D-P, A-Axis





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ADAS Failure

◆ Resulting Actions

- The Readings Recorded By The ADAS Did Not Correlate With The Movement Identified By The Portable Inclinator Surveys And Validated COE Concerns
- The Lack Of Confidence In The ADAS Resulted In An Increase In The Number And Frequency Of Portable Inclinator Readings And Resulting Evaluation Of That Data
- COE Directed The Contractor To Perform An Investigation Of The ADAS
- While Some Movement Was Expected, The PDT Developed An “Emergency Action Plan” To Provide Guidance If The Movement Exceeded Anticipated Levels



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E.A.P. Response

Engineering & Construction Division Response

Movements in Rock Foundation
Marmet Construction Project

17 September 2004
Updated 27 September 2004
Updated 30 September 2004

Developed from PDT and Management Meetings
September 2004

Outline

1. Purpose
2. Background Information
3. Site Observations
4. Conclusions
5. Recommendations



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E.A.P. Response

◆ Recommended Actions Of The PDT

- Increase Frequency Of Instrumentation Readings And Evaluation Of Data
- Reanalyze Additional Failure Planes Within The Rock Foundation
- Complete Second Stage Grouting Of Anchors
- Add Additional Upstream Anchors
- Add Additional Inclinometers Of Greater Depth And At Additional Locations
- Improve Reliability Of Instrumentation System



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E.A.P. Response

- ◆ Recommended Actions Of The PDT – Continued
 - Obtain Additional Technical Oversight (Engineering Geology Experts, RTS, Etc)
(Instrumentation Experts)
 - Evaluate Alarm Thresholds For Load Cells
 - Establish Displacement Thresholds And Stabilizing Actions



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Remediation Attempts

◆ Instrumentation Summit #1 (Sept 2004)

- Remote Computers
 - Contractor Recommended System Change From Geomation To Campbell
- In-Place Inclinometers
 - Thermal Drift



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Remediation Attempts

- ◆ Instrumentation Summit #2 (Nov 2004)
 - Remote Computers
 - Replace All Remaining Original Boards
 - Upgrade Charging System
 - Reprogram Recanvassing Frequency
 - Possible Signal Interference
 - In-Place Inclinometers
 - Thermal Drift
 - Install IPIs With Automatic Compensation
 - Develop Programming Compensation For IPIs Currently Installed Without Compensation Capability
 - Install Load Cells On All New Anchors



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Remediation Attempts

- ◆ Geomation 2380MCU Performance History Review / Research (March 2005)
 - CELRH Conducted Performance Evaluation of 2380MCU To Determine If Unit Has Been Utilized With Success In Similar Applications.
 - Review Included Published Reports And Papers, Discussions With System Integrators And Actual End Users.
 - Review Answered Reliability Issue In The Affirmative



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Remediation Attempts

◆ Instrumentation Summit #3 (April 2005)

- Reprogram Recanvassing Frequency
 - Increase Time Of Alarm Confirmation Readings
 - Alarms Now Triggered By Two Consecutive Readings That Exceed Threshold Limits As Opposed To One
- Install Older Version Of Firmware On Specific MCUs
- MCU Isolation Tests
 - From Radio (Airborne Transients)
 - From Cabled Instruments (Subsurface Transients)
- Tilt Meters
 - Excitation Voltage No Longer Provided By MCU



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Remediation Attempts

- ◆ Instrumentation Summit #3 (April 2005) – Cont.
 - In-Place Inclinometers
 - Recalibrate Thermal Compensation
 - Excitation Voltage No Longer Provided By MCU
 - Campbell System Test Installation
 - Website
 - Update To Include All System Modifications
 - Address Issue Of Lost Data Transmission



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Remediation Attempts

◆ TCX - APMD

- Technical Center of Expertise (TCX) for Automated Performance Monitoring of Dams (CEMVS) has been contracted to perform an independent evaluation of the Marmet ADAS through a contract with URS



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Current Status of ADAS

◆ Reliability Of Data Still Suspect

- Contractor has been able to reduce the number of false alarms but the reliability of data being produced is still suspect.

◆ TCX – APMD / URS

- On Site System Review Week Of 15 August



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BEARS

Questions ?