XVI ECSMGE 2015

13-17 September 2015 - Edinburgh

Effectiveness of Remedial Measures Applied to Mitigate Differential Movement at Railroad Track Transitions

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TC202 Workshop on Railroad Geotechnics, September 13, 2015

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Federal Railroad Administration High Speed Rail Broad Agency Announcement (BAA) Project

Mitigation of Differential Movement at Railway Transitions for US High Speed Passenger Rail and Joint Passenger/Freight Corridors

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Co-PI: Timothy D. Stark

Research Engineer: Deb Mishra

Visiting Research Scholar: James P. Hyslip

RAILTEC

AMTRAK®

UNION PACIFIC

BUILDING AMERICA®

NORFOLK SOUTHERN

Research Objective

Development of design and repair techniques to minimize and mitigate, respectively, **differential movement at railway transitions** to **ensure safe high speed operation**

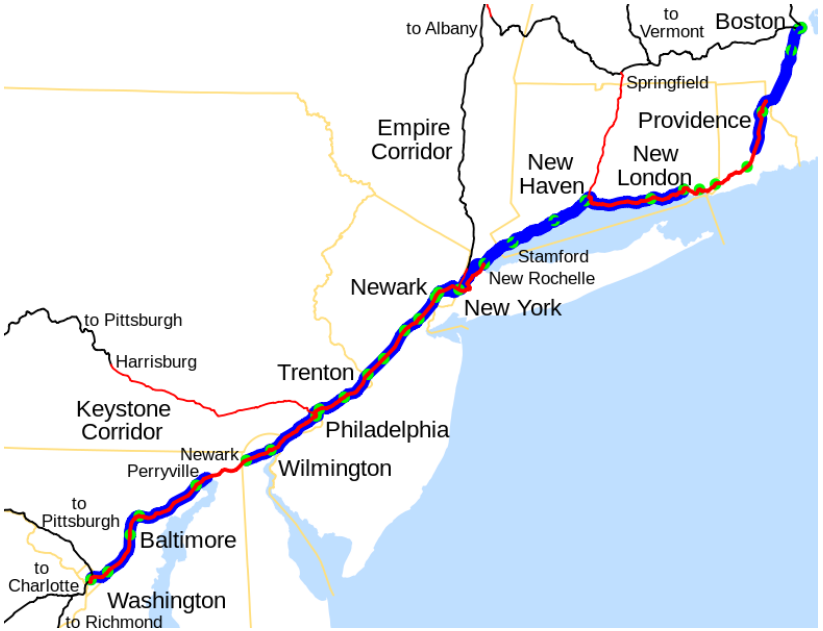
Project Duration: 51 Months (Oct. 2011 – Dec. 2015)

Scope

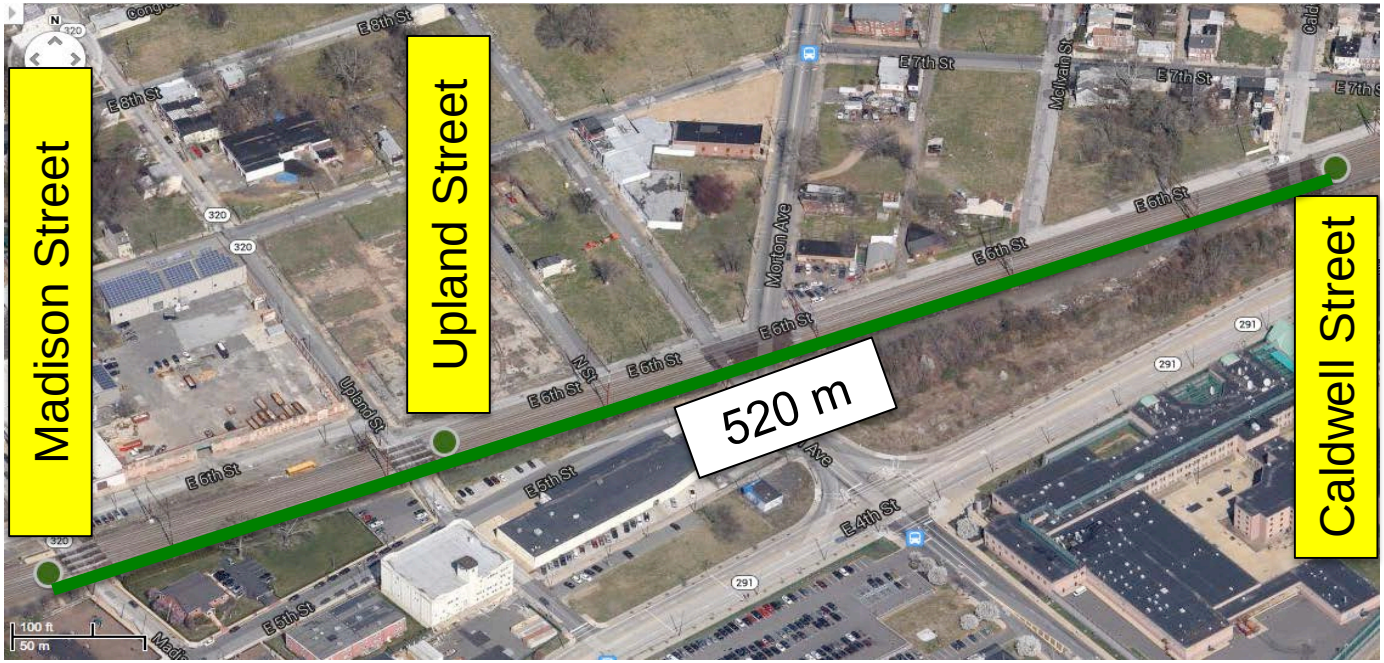
1. ***Monitor*** *Railway Transitions for Differential Movement*
2. *Identify* ***"Location"*** ***and Major Factors Causing*** *Differential Movement at Monitored Railroad Transitions*
3. *Numerical Modeling of Monitored Railway Transitions and of Preferred Design and Rehabilitation Techniques for Rail Transitions*

AMTRAK Northeast Corridor (NEC)

- ✓ The NEC is 457 miles long & has:
  - ✓ **17 tunnels**
  - ✓ **1,186 bridges**
- ✓ 2,220 passenger trains daily
- ✓ 70 freight trains daily (over 14 million car-miles of freight per year)
- ✓ 720,000 people ride along some part of the corridor each day.
- ✓ In 2011, 11 million passengers on Amtrak's Northeast Regional and Acela Express services



Three Bridge Approaches at Chester, PA Site

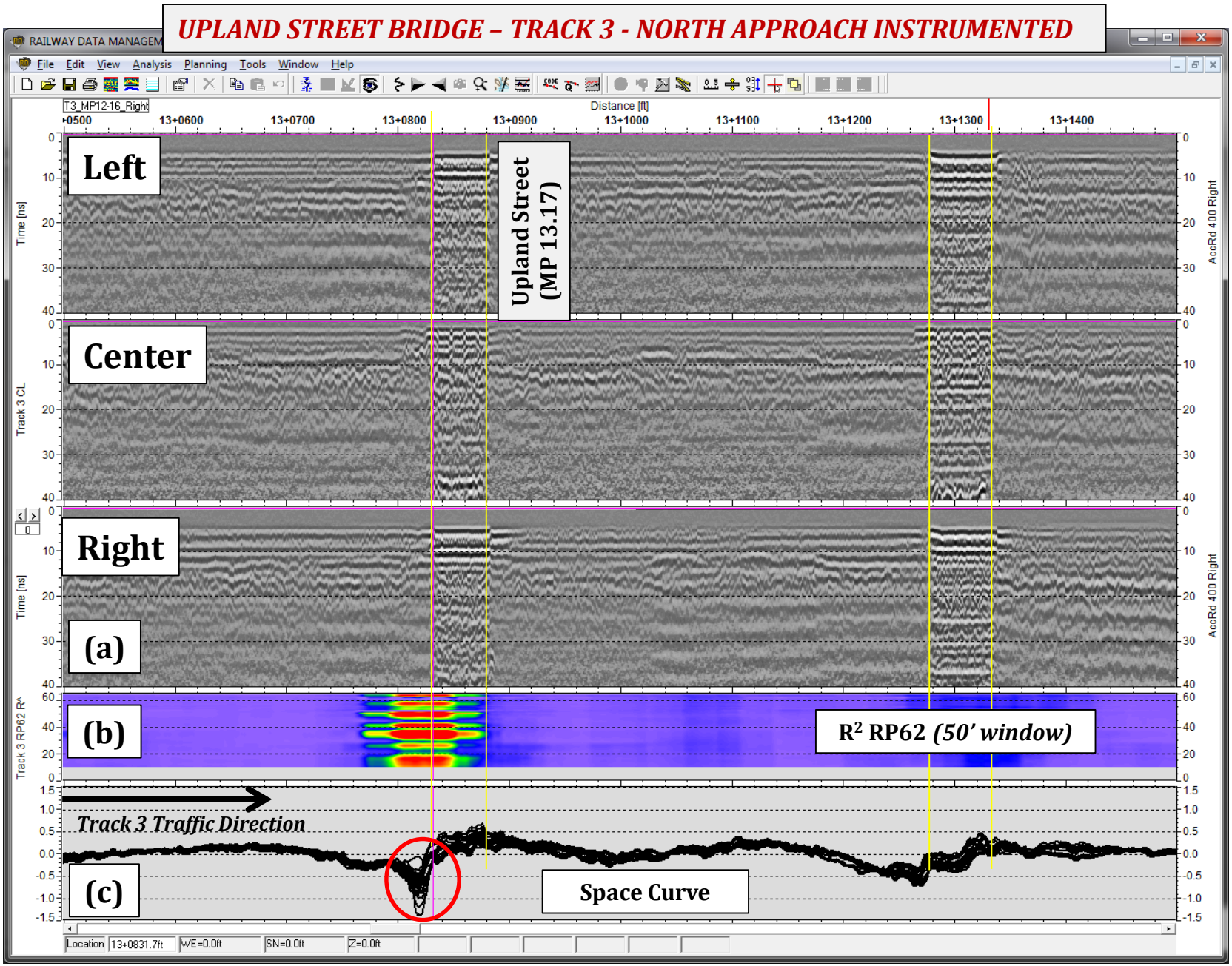


AMTRAK NEC

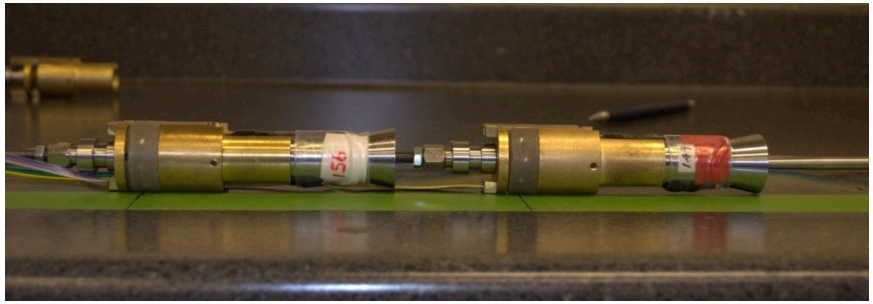
ACELA Passenger Trains 110 mph (177 km/h)

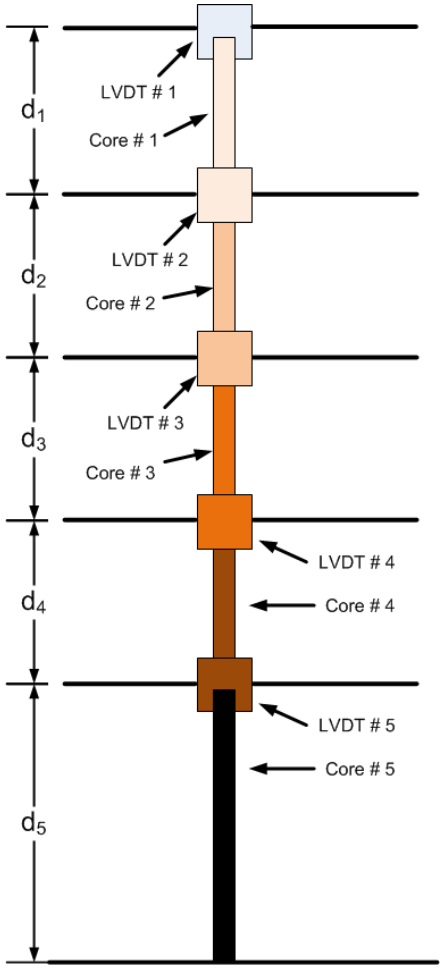
Recurring bridge approach settlement and geometry problems

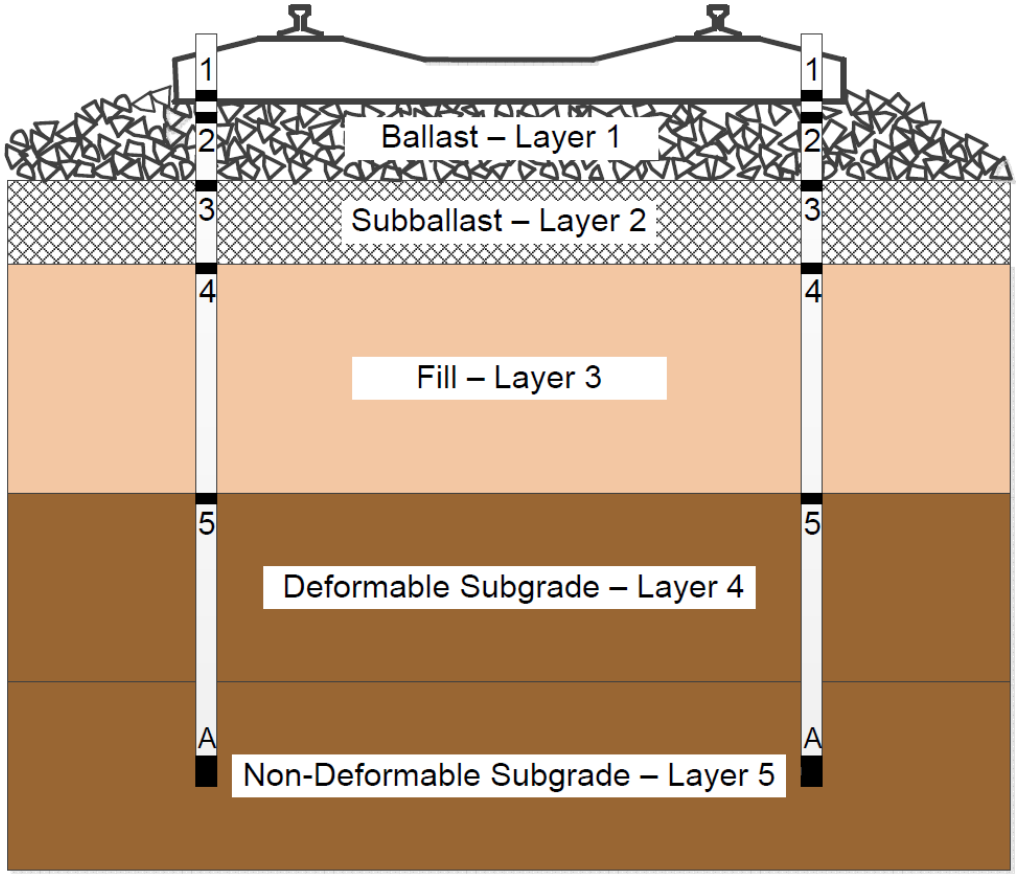
Chester Amtrak Station Bridge Approach (January 2012)


UPLAND STREET BRIDGE – TRACK 3 - NORTH APPROACH INSTRUMENTED
RAILWAY DATA MANAGEM
File Edit View Analysis Planning Tools Window Help
T3_MP12-16_Right
Distance [ft]
13+0500
13+0600
13+0700
13+0800
13+0900
13+1000
13+1100
13+1200
13+1300
13+1400
Left
Upland Street (MP 13.17)
Center
Right
(a)
(b)
(c)
Time [ns]
Track 3 CL
Track 3 RP62 R^
AccRd 400 Right
R² RP62 (50' window)
Track 3 Traffic Direction
Space Curve
Location 13+0831.7ft
WE=0.0ft
SN=0.0ft
Z=0.0ft

Installed **Multidepth Deflectometers (MDDs)** at 3 Bridge Approaches







The Independent Anchoring MDD System

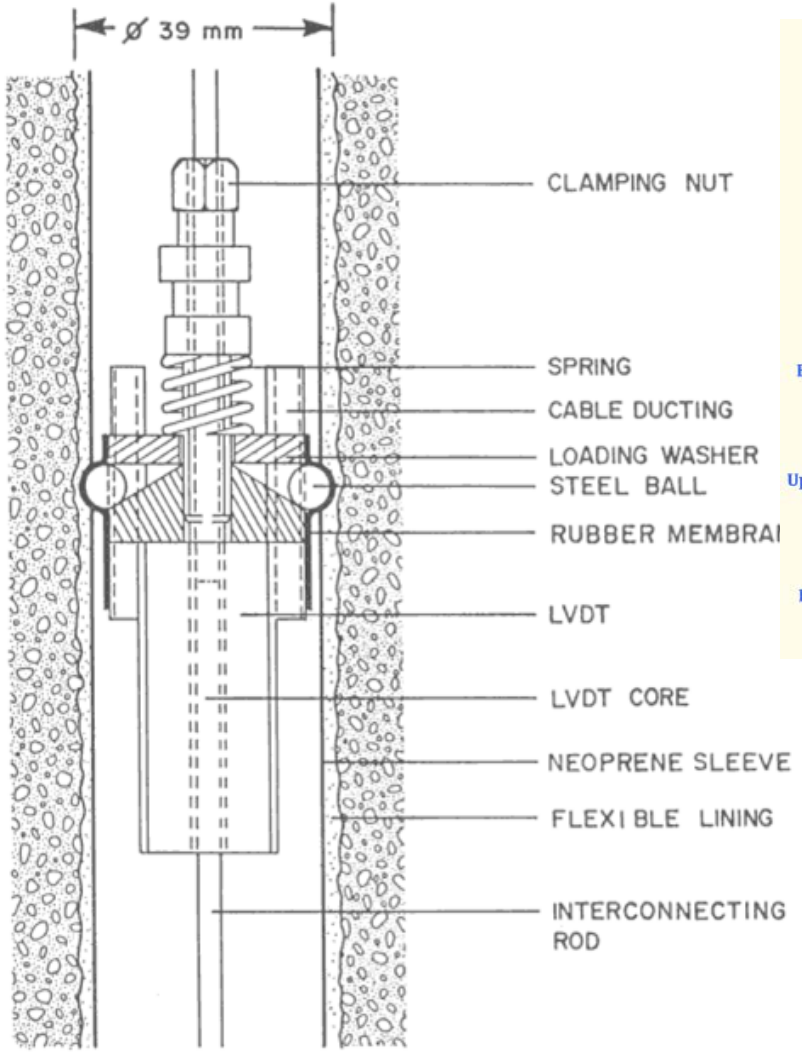
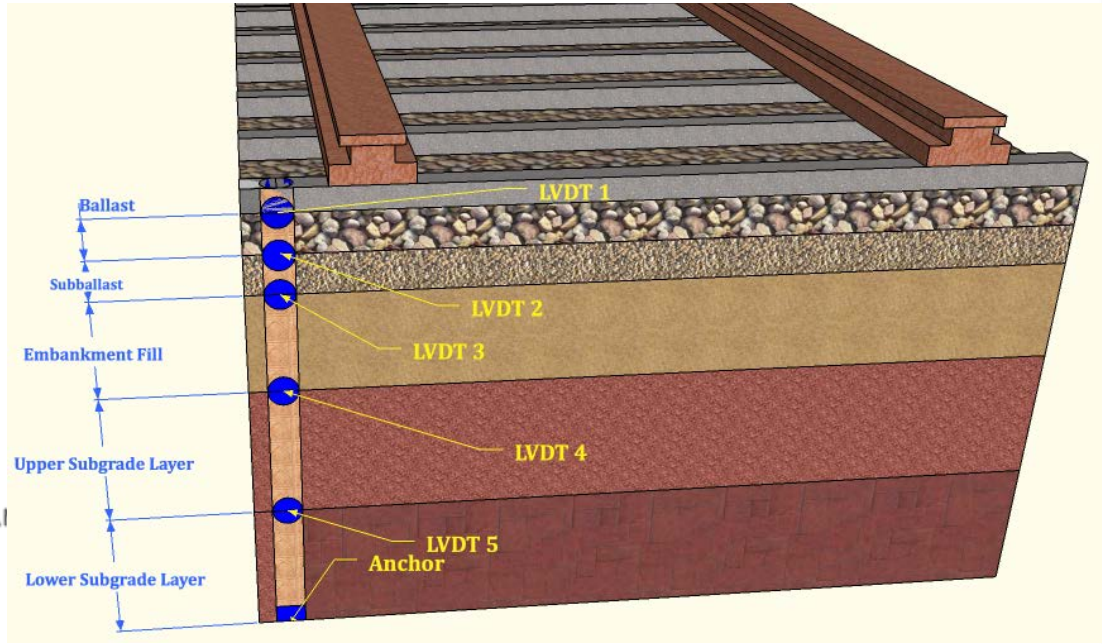


Figure Source: DeBeer, 1989

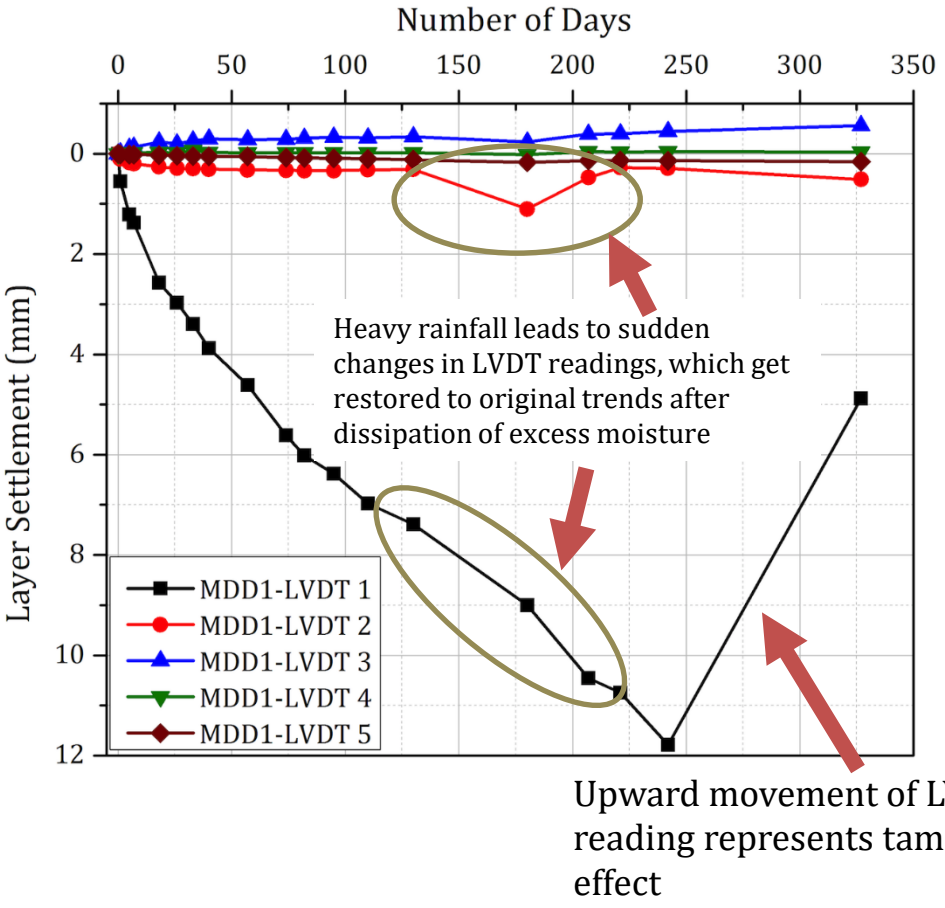
Multidepth Deflectometer Module

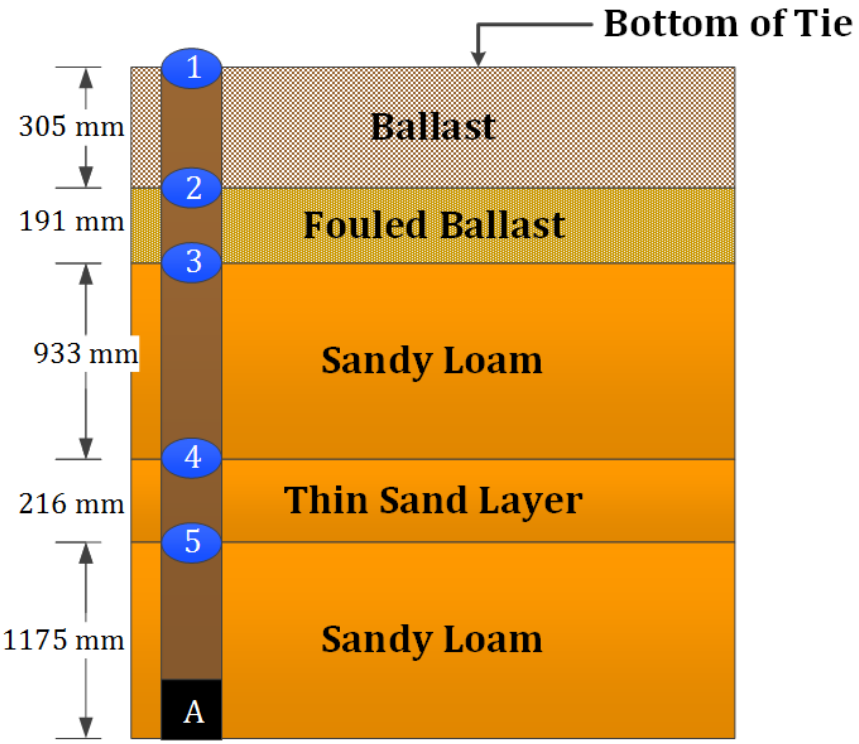


Assembled MDD Module

Layer Settlements – Upland St.

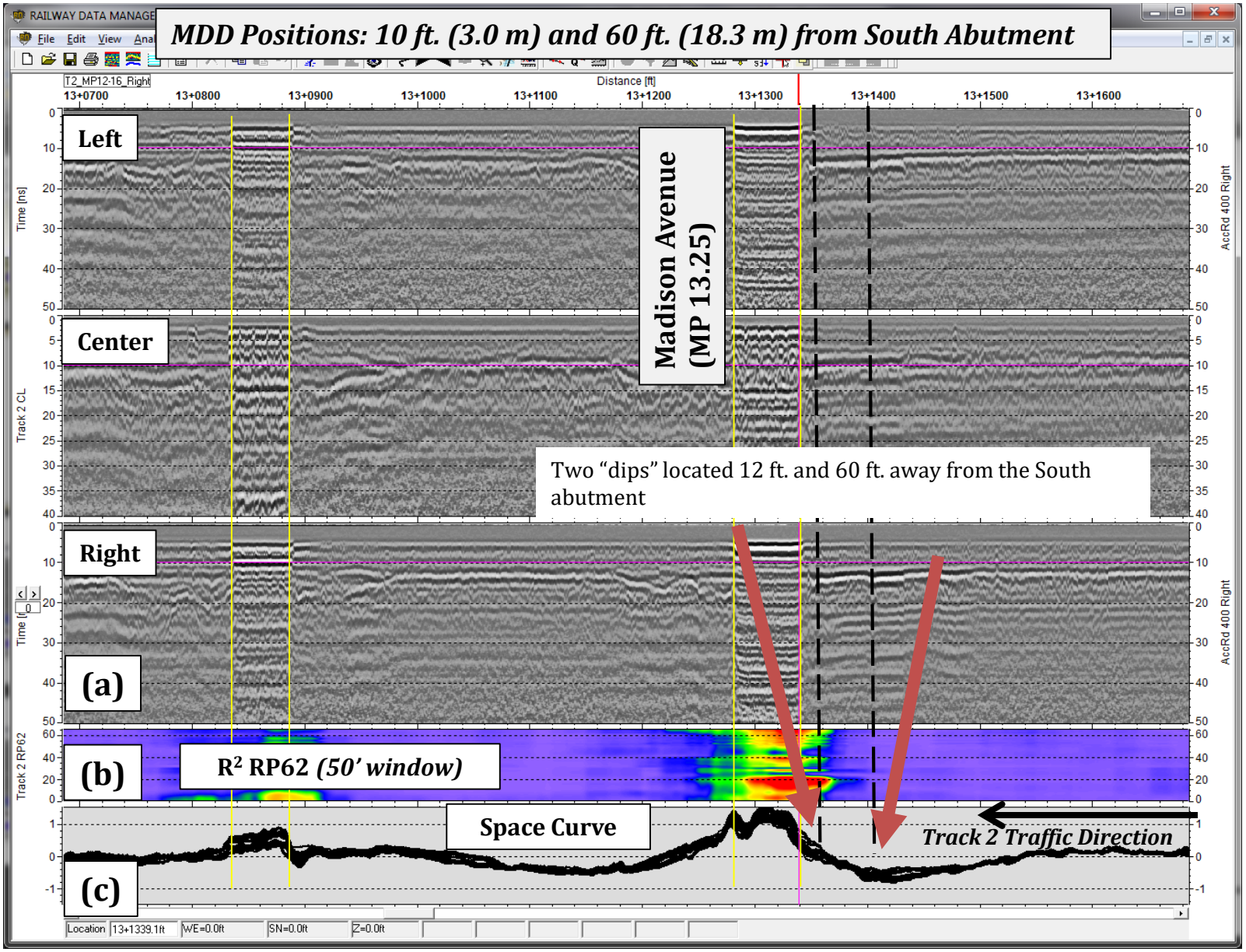
15 ft. from North Abutment





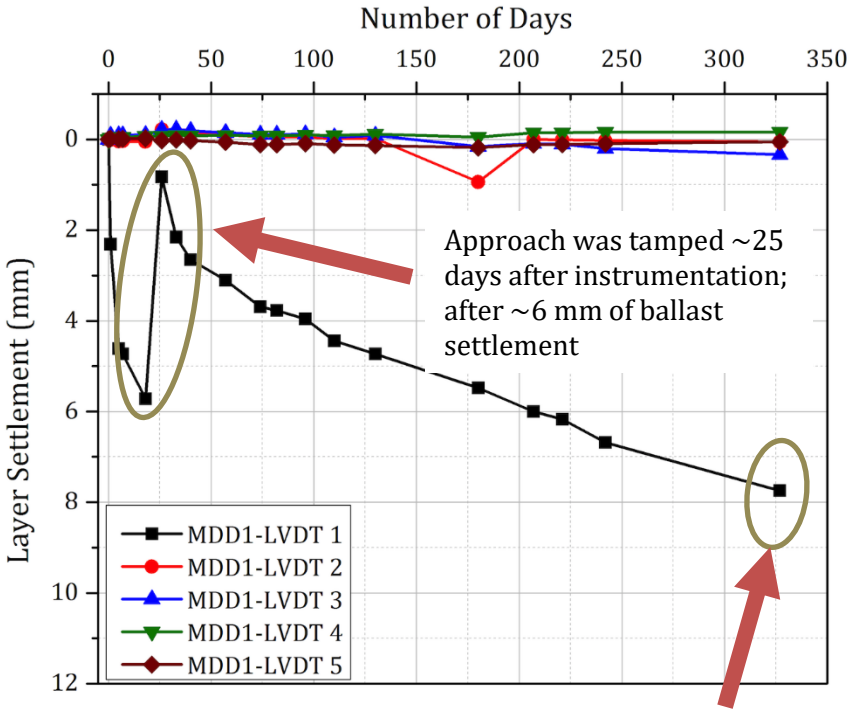
Up to 12 mm of ballast settlement recorded before track resurfacing

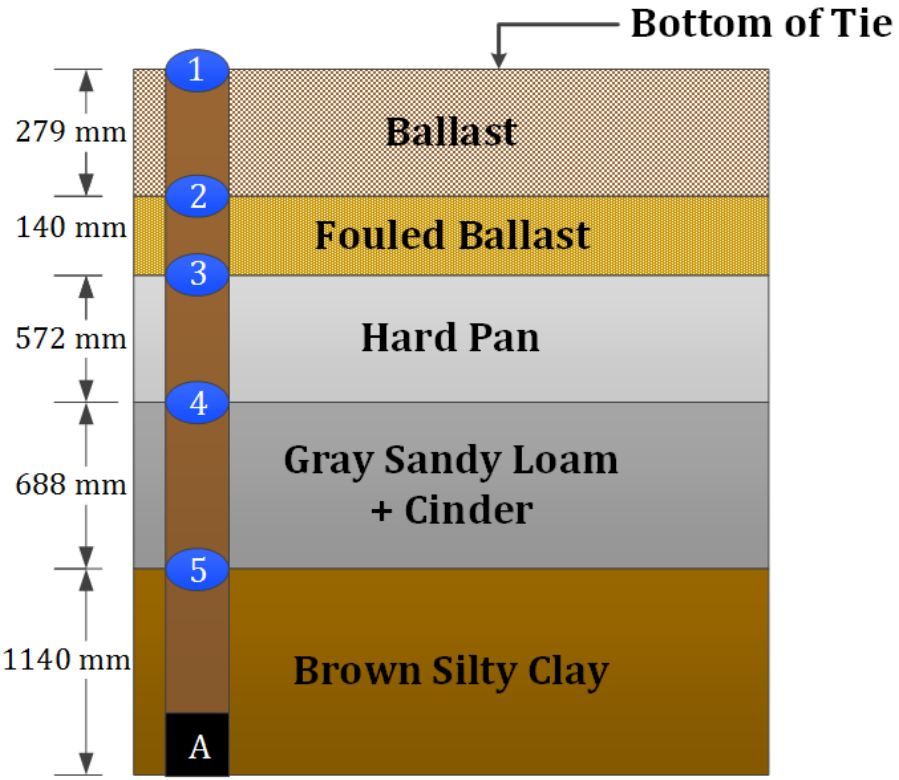
Madison Street Bridge-South Approach-Track 2



Layer Settlements – Madison St.

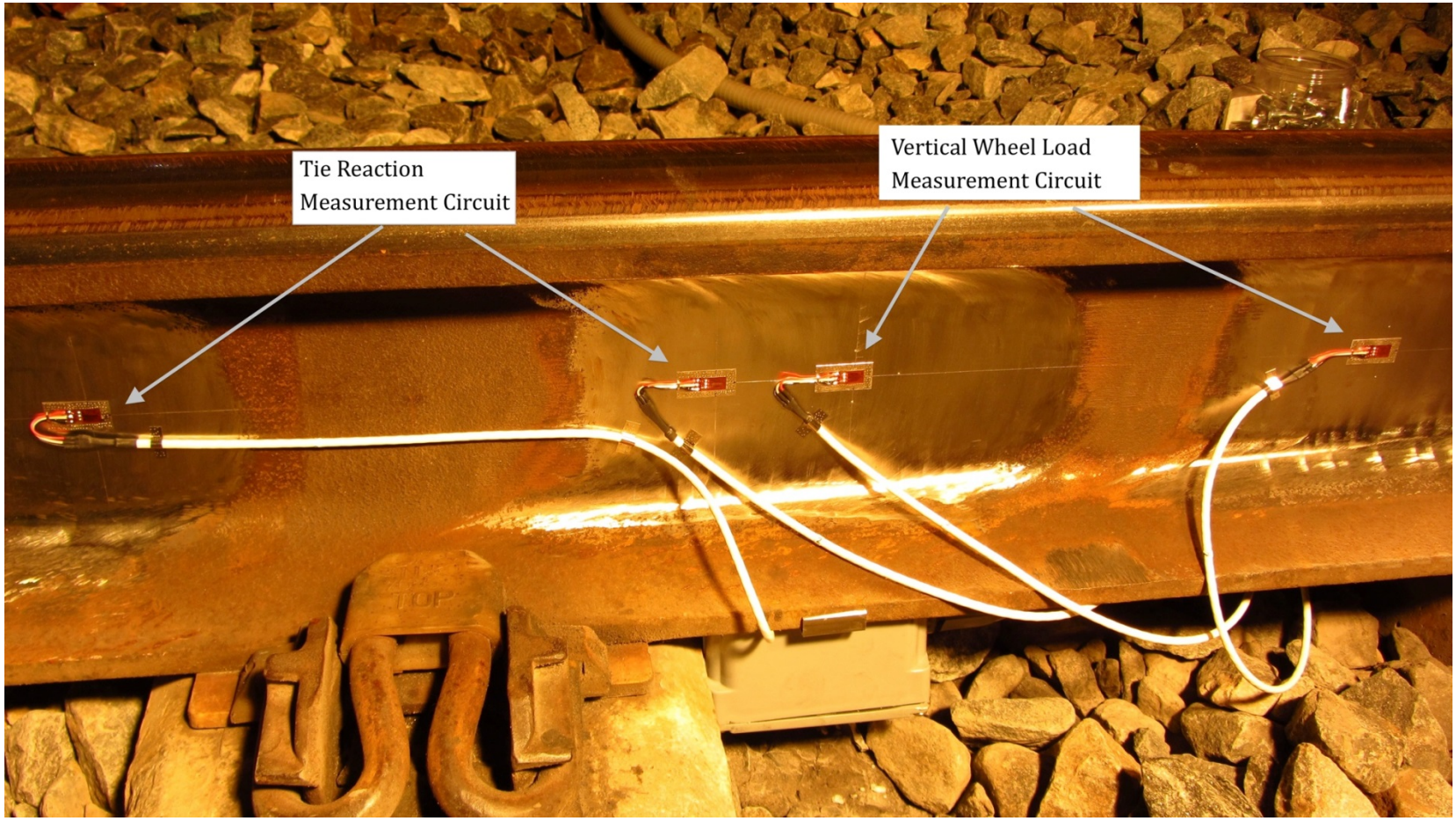
12 ft. from South Abutment



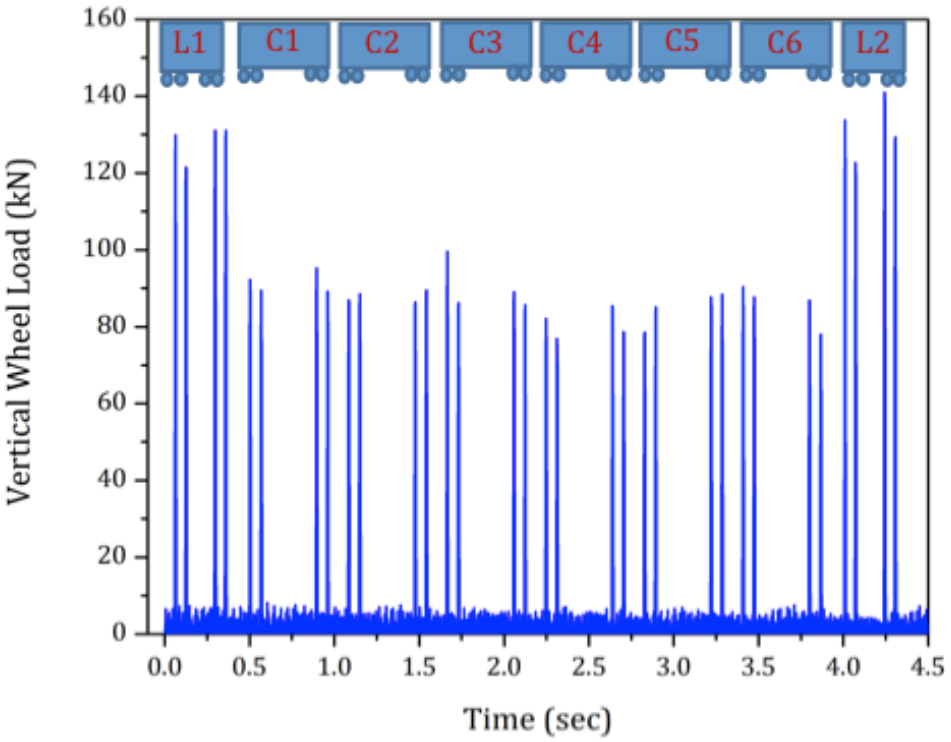


Last set of measurement indicated a total ballast settlement of ~ 8 mm. Due for tamping ?

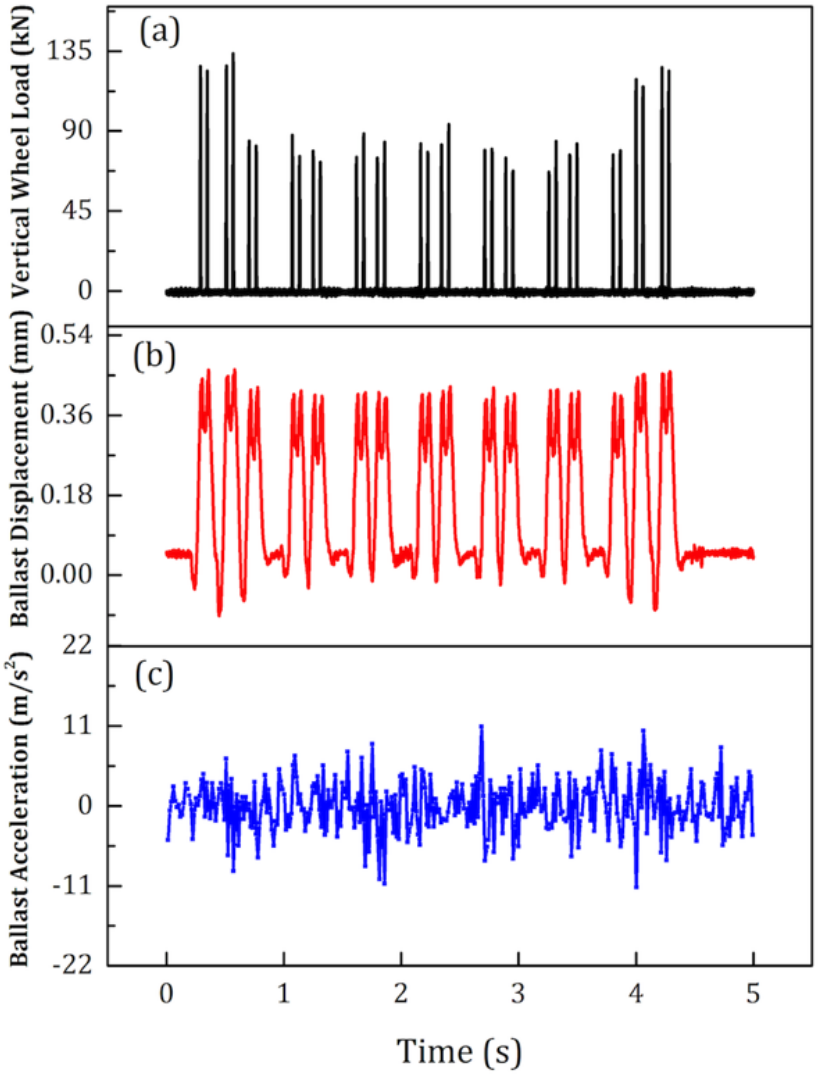
Strain Gauge Layout – Wheel Loads



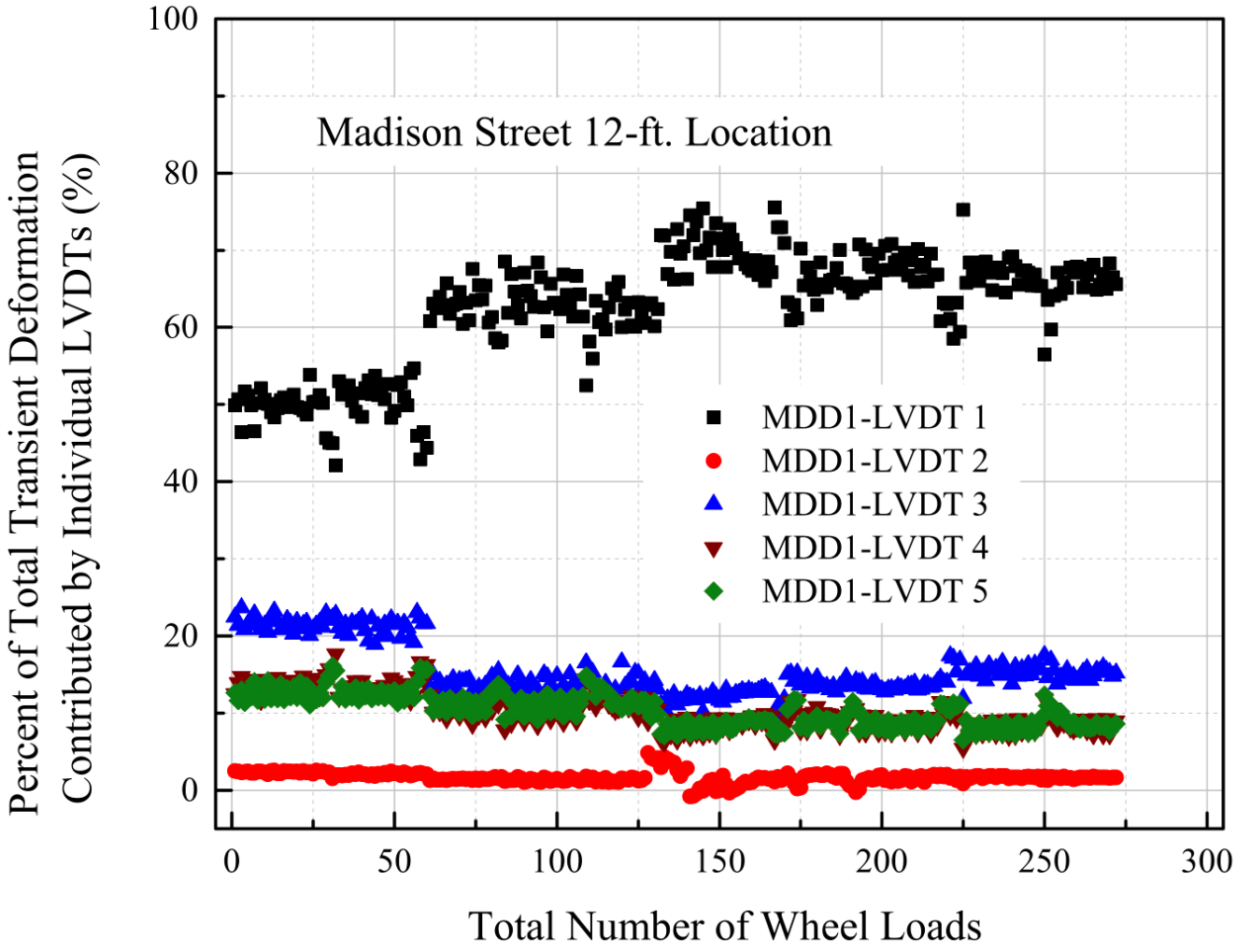
Measured (a) Wheel Loads; (b) Ballast Layer Displacements; and (c) Ballast Accelerations



Acela Express Wheel Loads

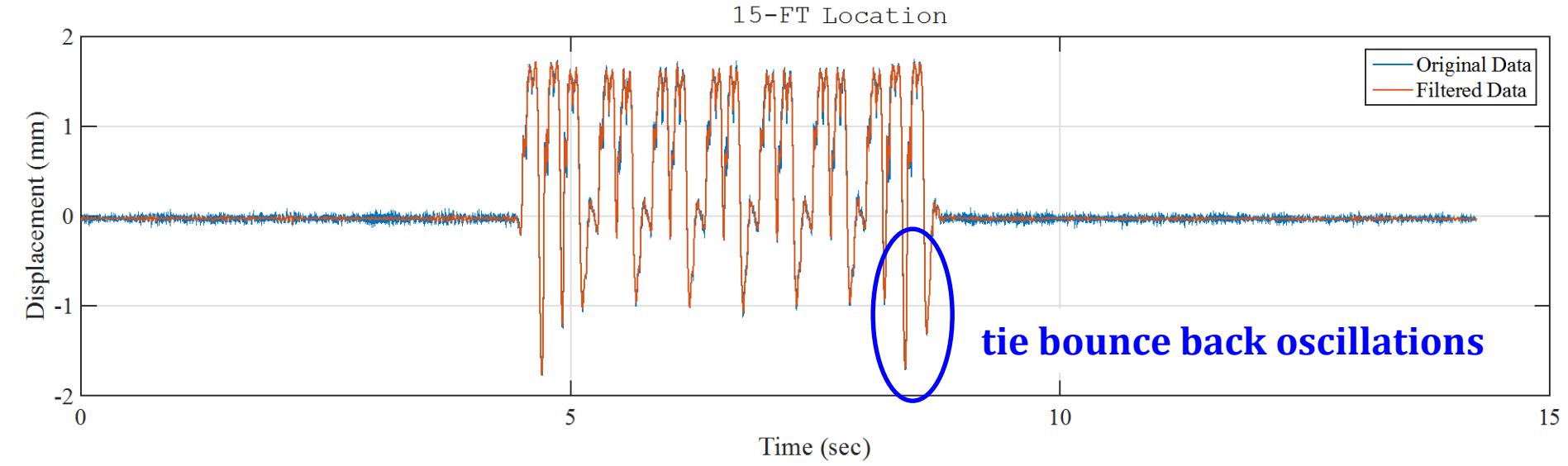


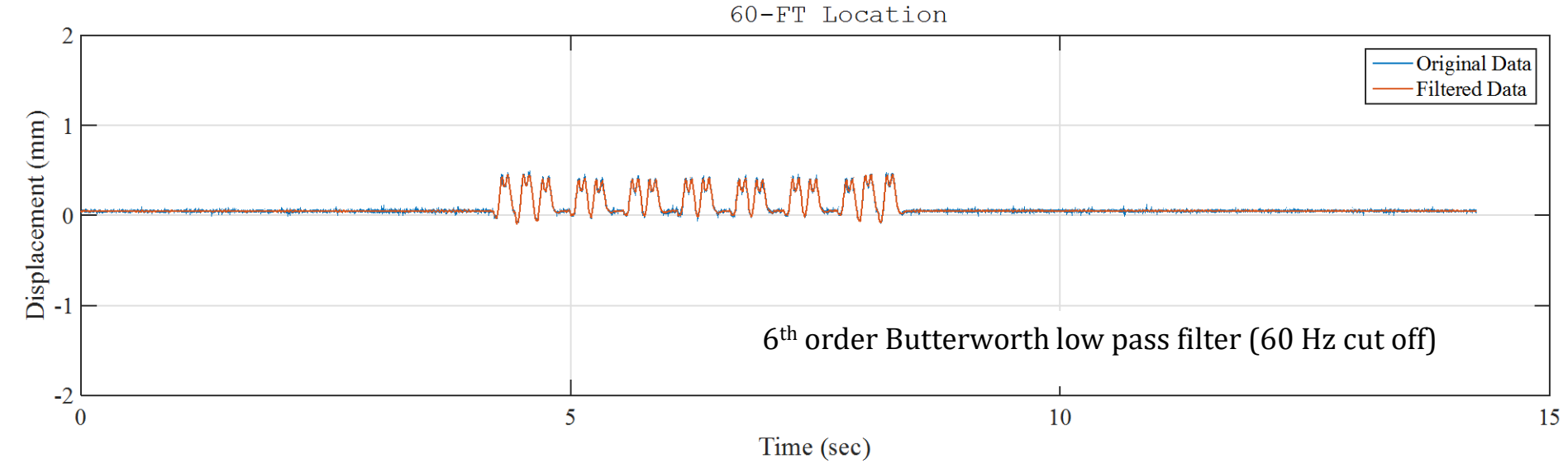
Summary Across All Months



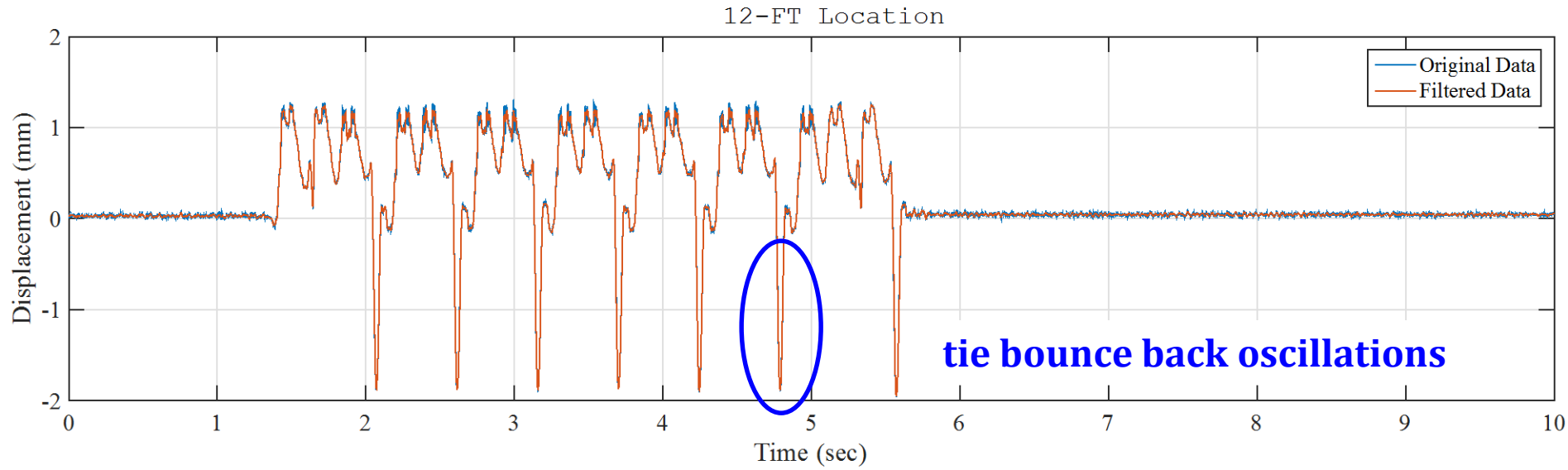
LVDT 1 accounts for 40-75% of the total transient deformations

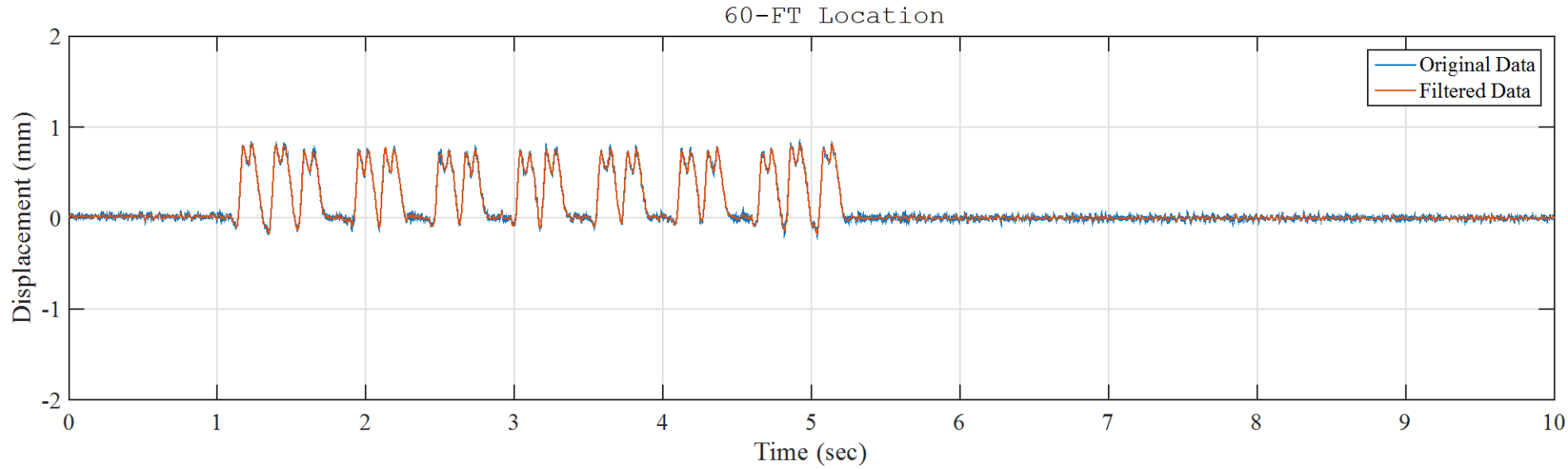
August 2012 – LVDT 1 Data
Upland St. Track 3 – ACELA Train



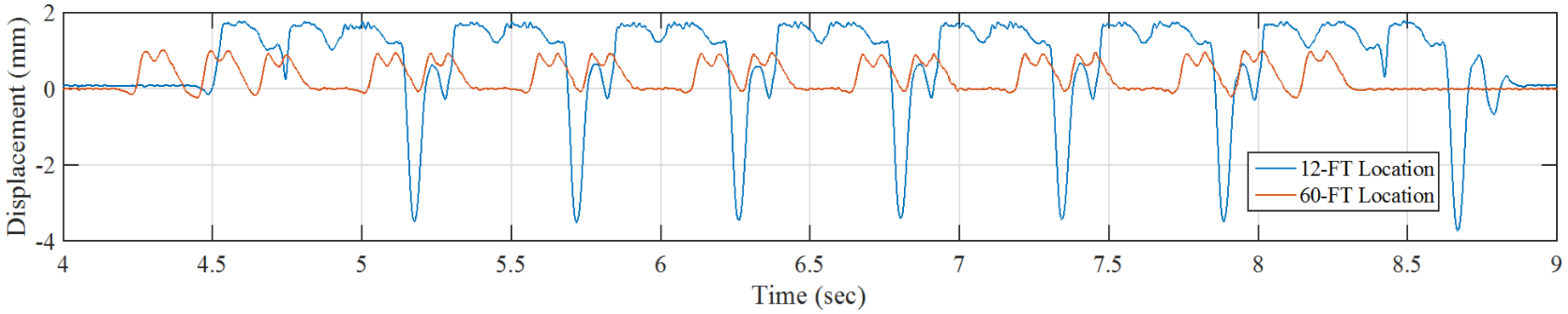


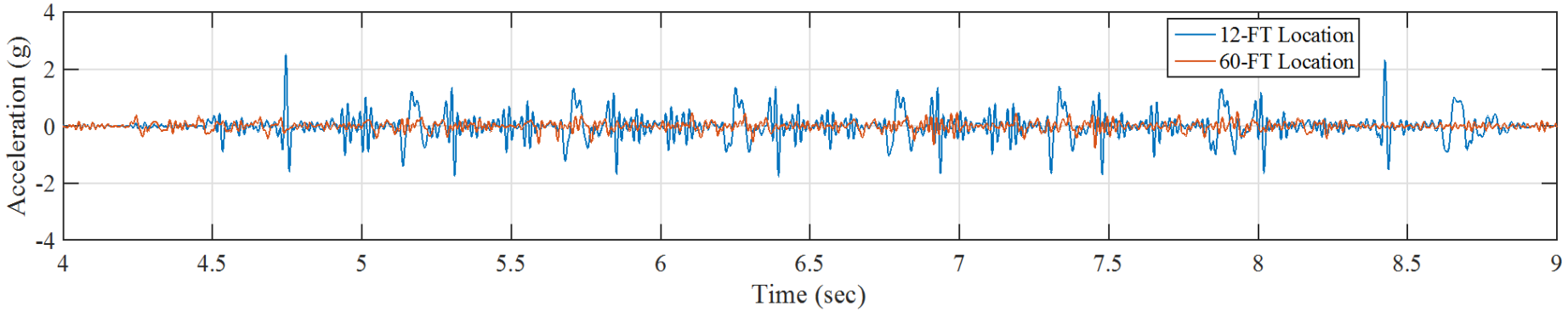
November 2012 – LVDT 1 Data
Madison St. Track 2 – ACELA Train

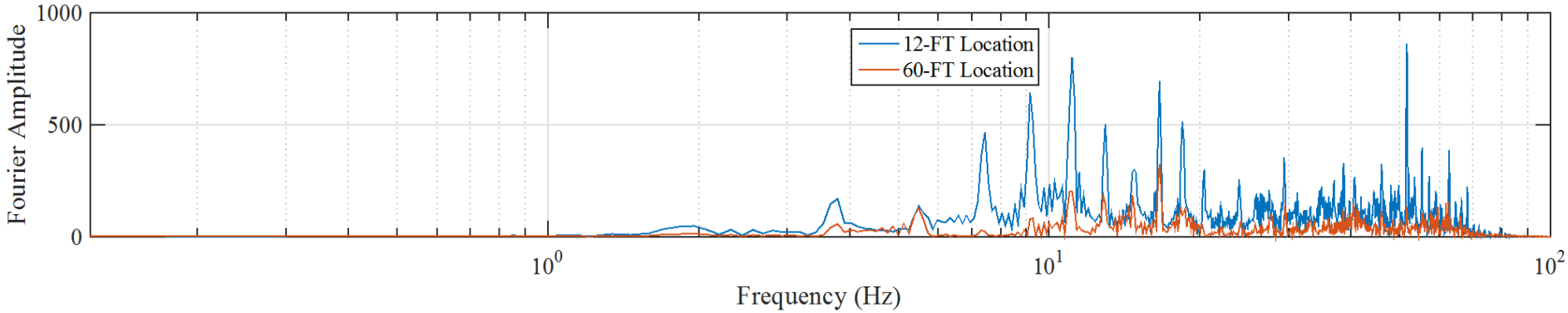




June 2013 – LVDT 1 Data
Madison St. Track 2 – ACELA Train







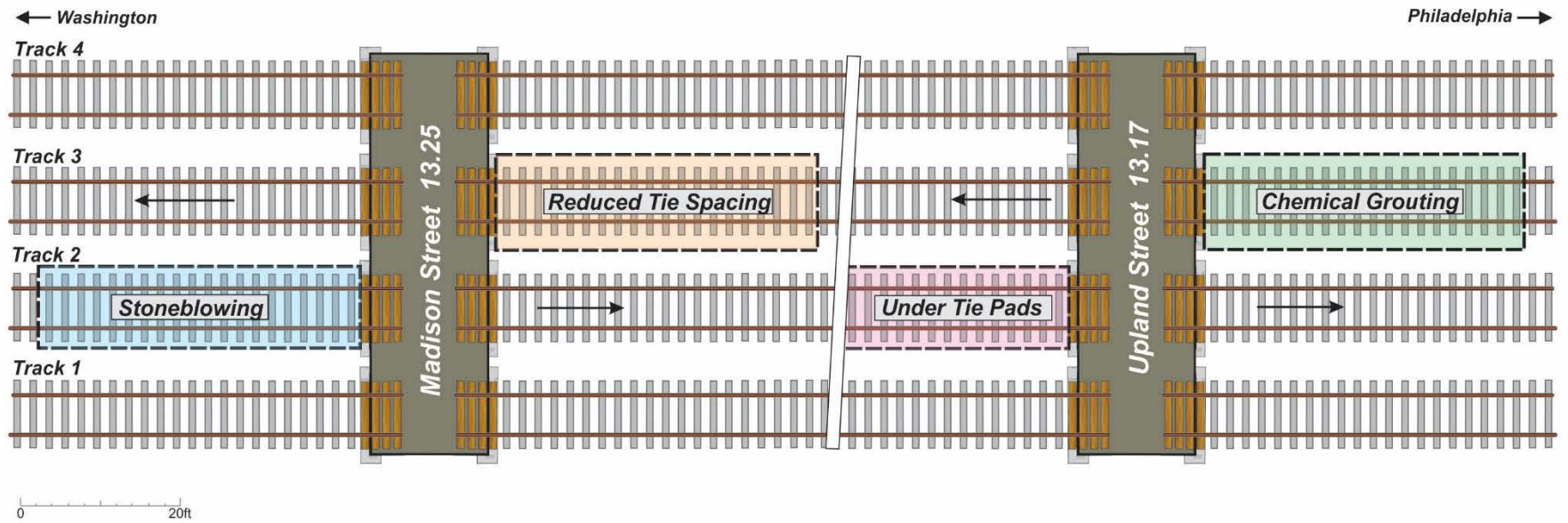
Summary of Observations from Field Instrumentation

- ✓ **MDD and strain gauge instrumentation technologies** were successfully employed to measure deformations of ballasted track substructure layers, wheel loads and tie reactions under high(er) speed passenger traffic at AMTRAK NEC in the US

- ✓ **Most of the deformations** at the instrumented bridge approaches at the AMTRAK NEC appear to be occurring in the **ballast layer**

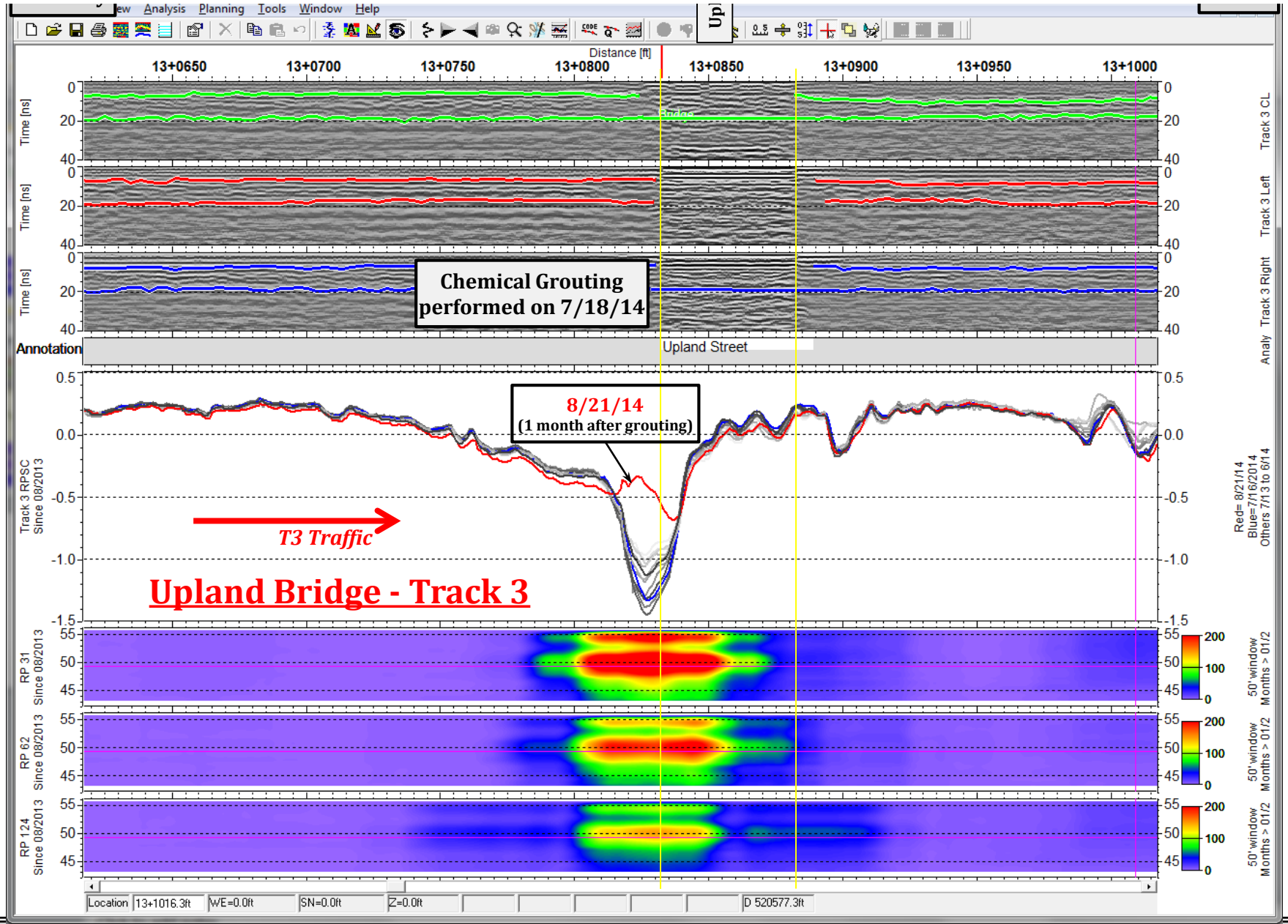
- ✓ **"Near-surface" remedial measures** are recommended to mitigate the differential movement problem by arresting excessive ballast reorientation and movement

Remedial Measures & Implementation Details

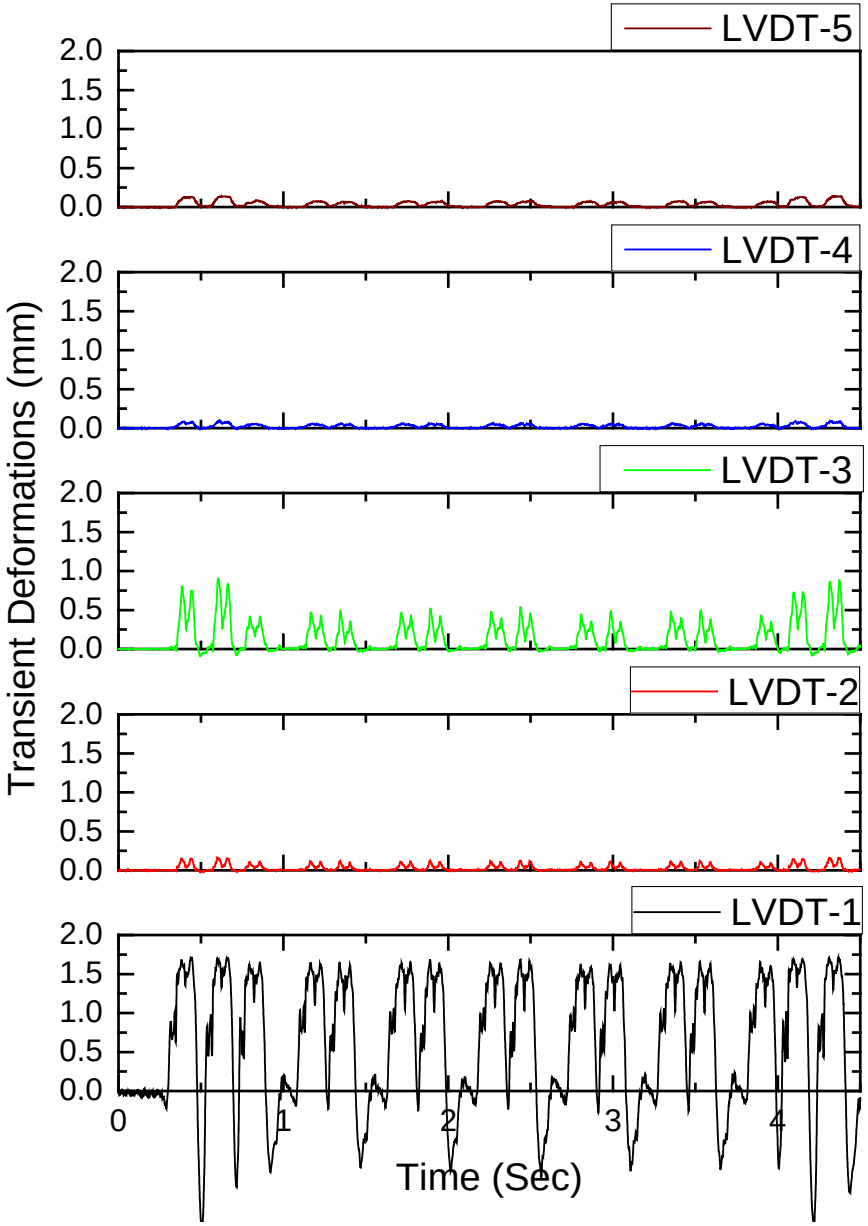


Bridge / Approach	Track	Remedial Measure	Approximate Length of Implementation
Upland / North	3	Chemical Grouting	40 ft.
Upland / South	2	Under-Tie Pads	60 ft.
Madison / North	3	Reduced Tie Spacing	60 ft.
Madison / South	2	Stone blowing	Based on Void Measurements

Chemical Grouting of Ballast: July 17, 2014

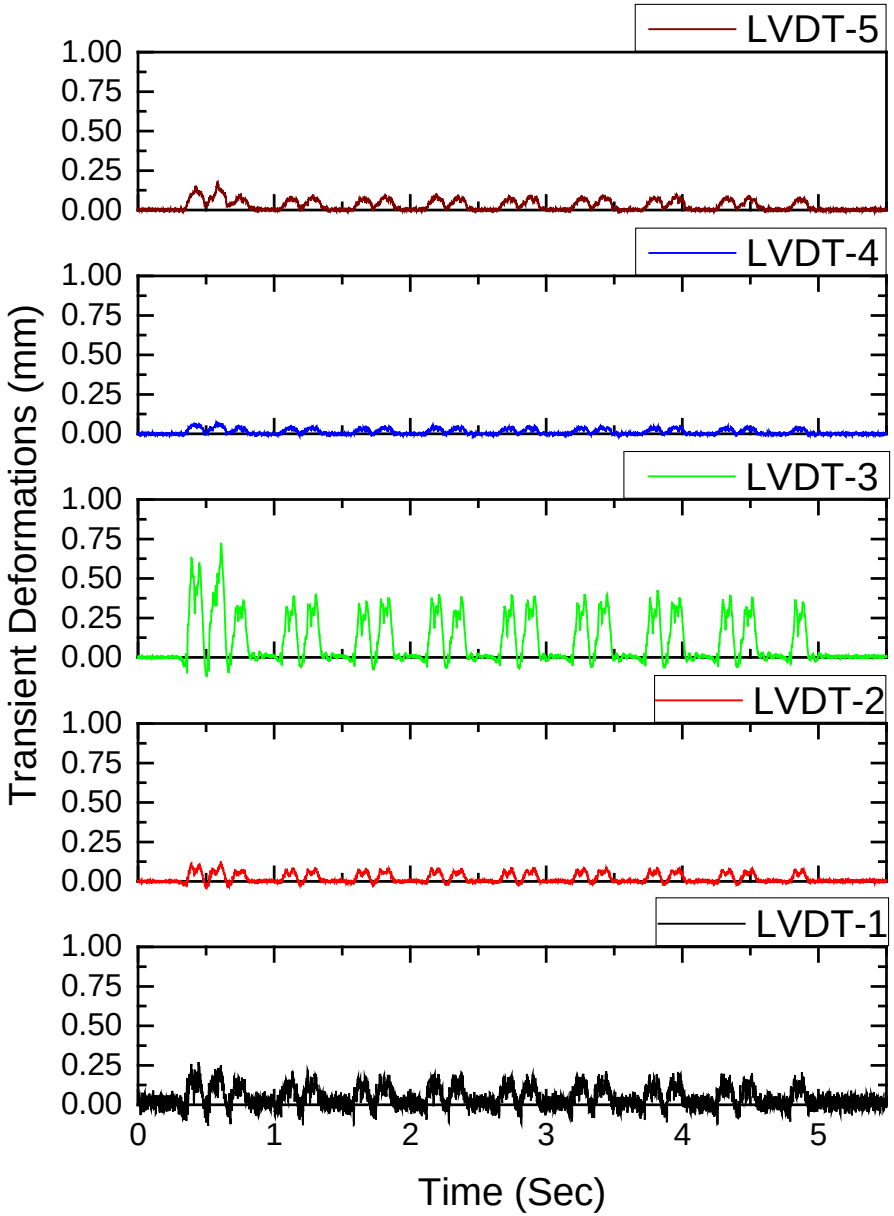


Upland 15 ft. (7 Aug 2012)



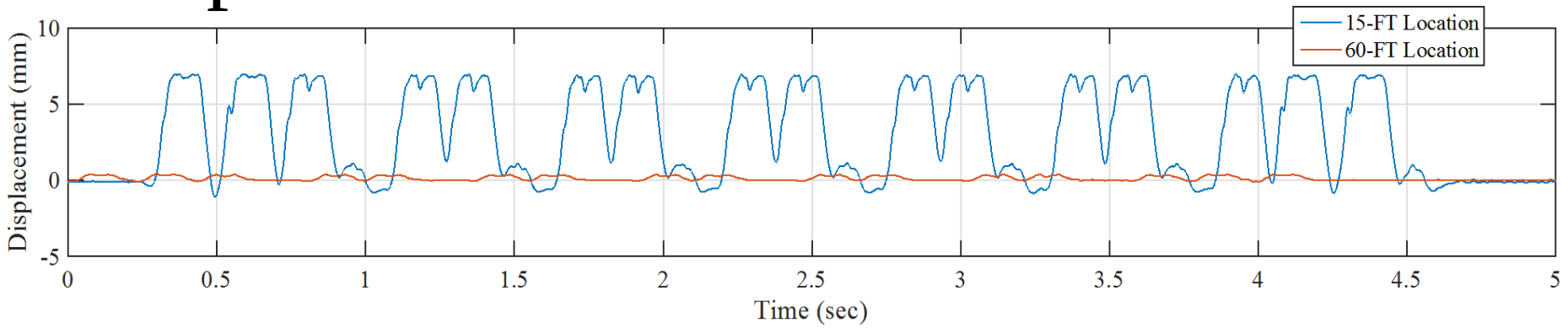
After Instrumentation in 2012

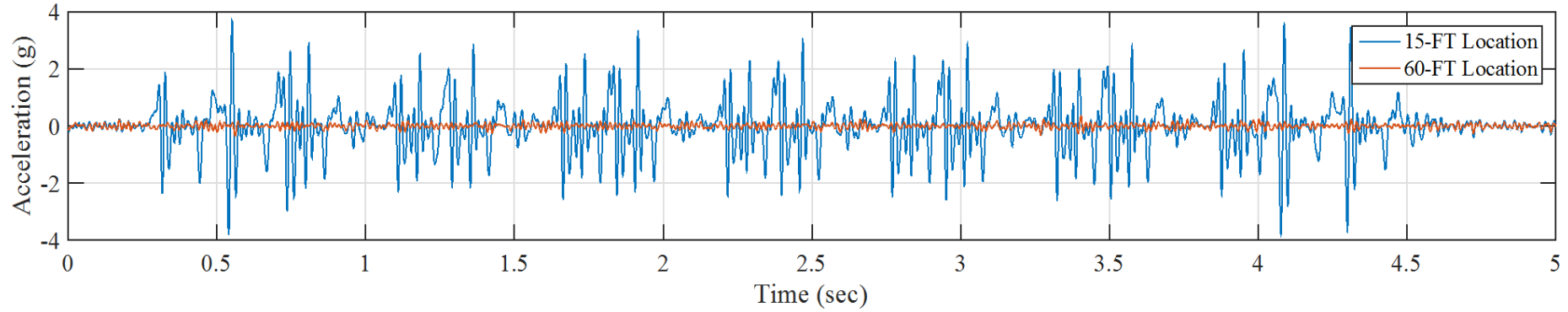
Upland 15 ft. (22 July 2014)

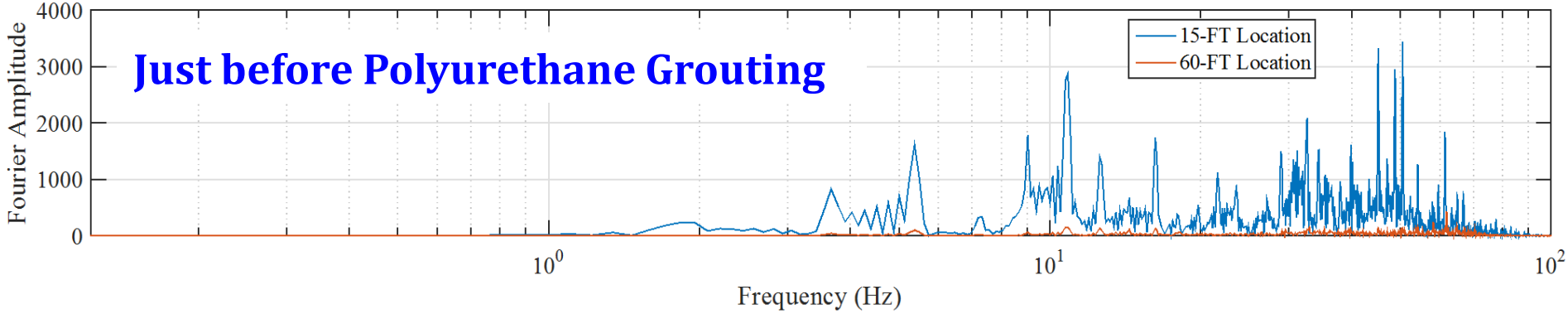


Post-Chemical Grouting

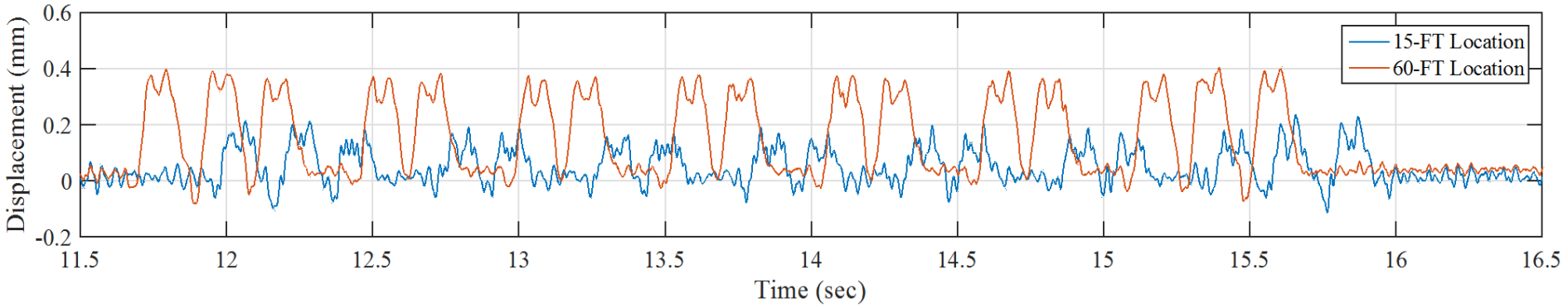
July 1, 2014 – LVDT 1 data
Upland St. Track 3 – ACELA Train

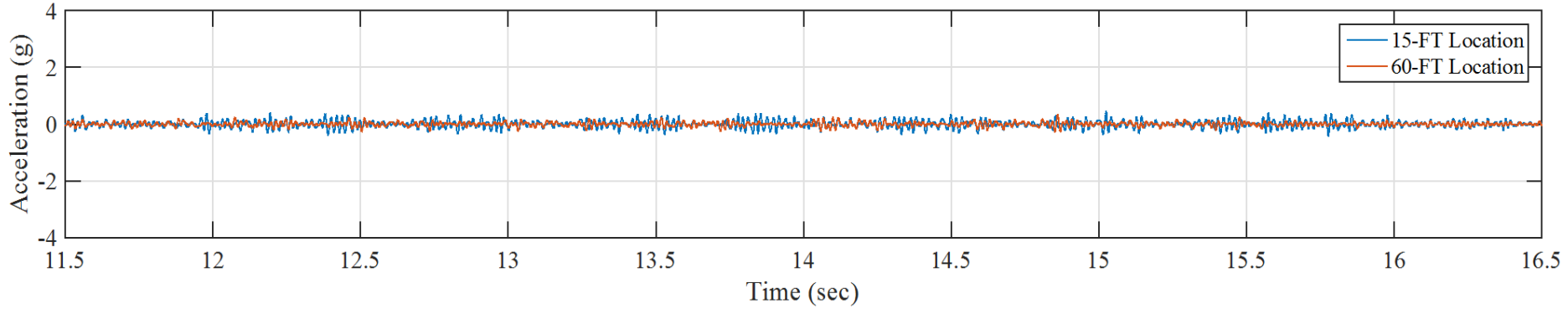


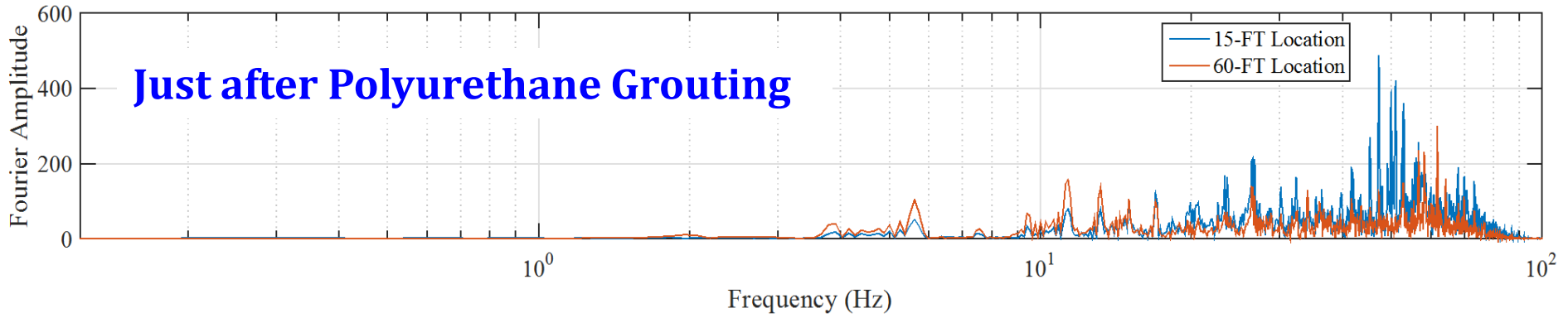




July 22, 2014 – LVDT 1 data
Upland St. Track 3 – ACELA Train







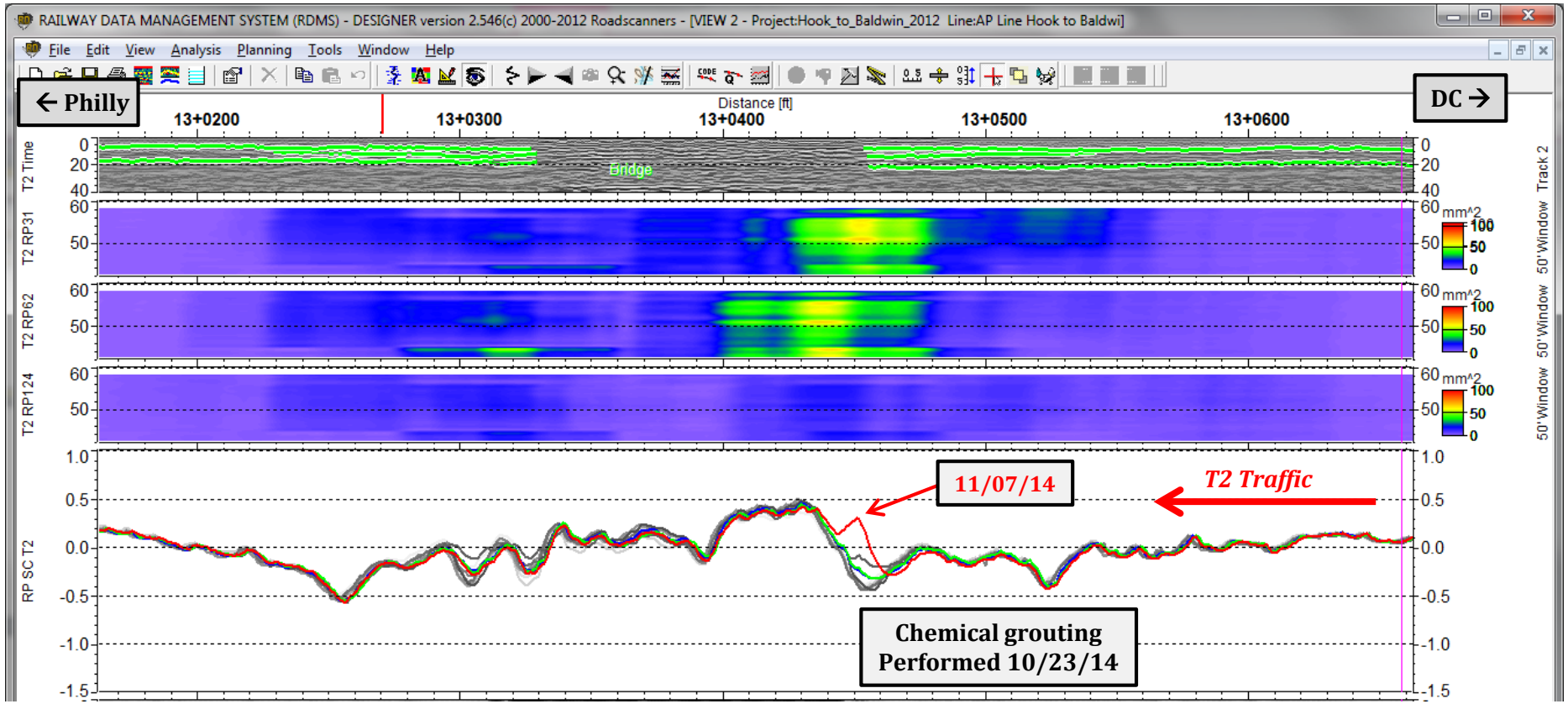
Chemical Grouting of Ballast: Oct. 23, 2014

Porter Street - Track 2- South Approach

- ✓ The procedure was improved considerably
- ✓ New ballast and increased amounts of void space in the matrix led to increased grout consumption

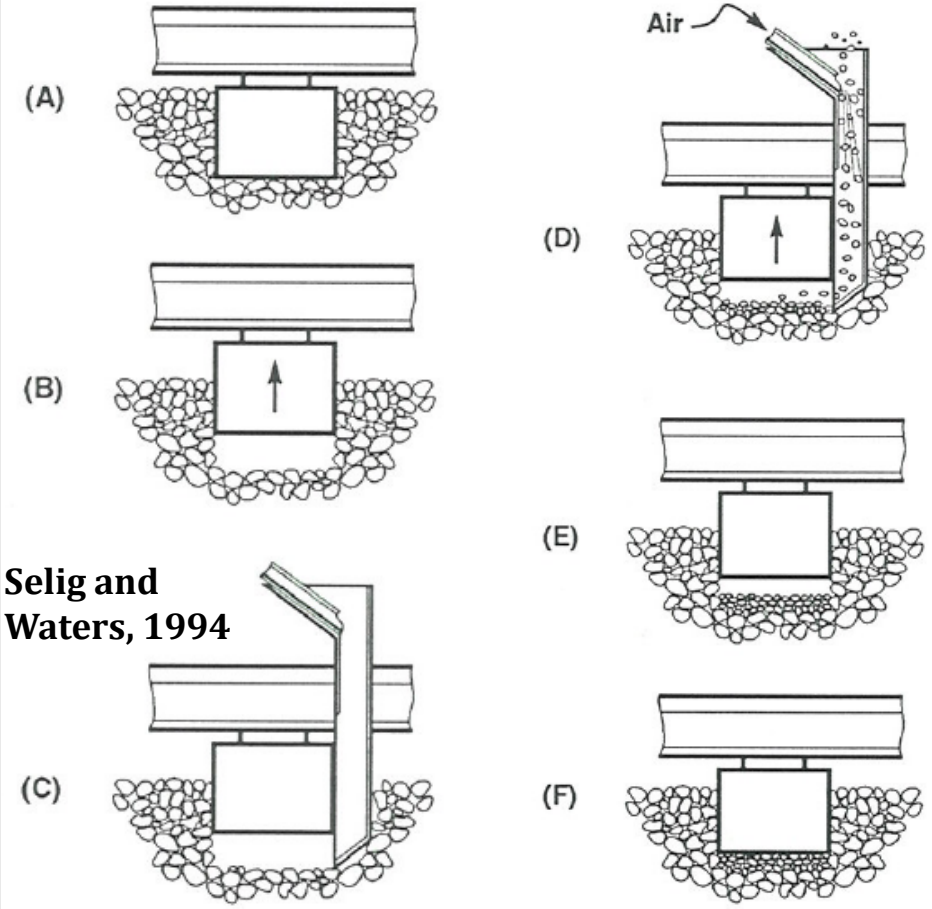
7-8 Ties were Successfully Polyurethane Grouted

Morton & Porter Streets- Track 2



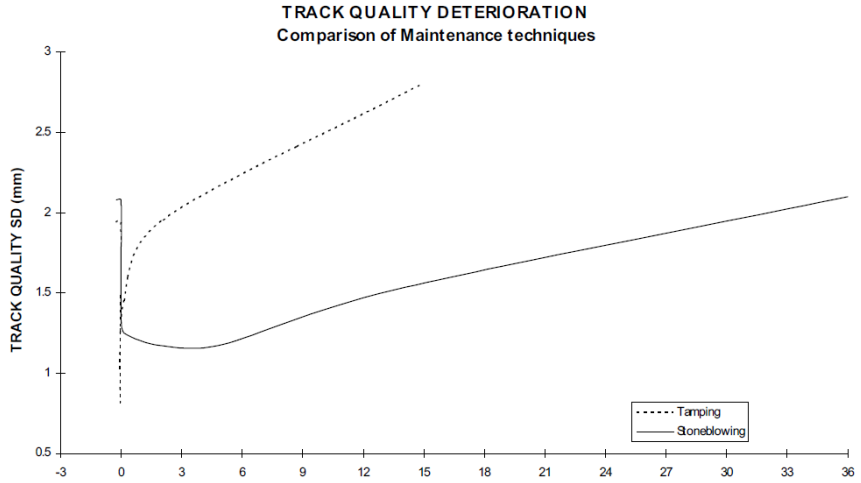
The profile of chemical grouting as of 11/07/2014

Stone Blowing



Selig and Waters, 1994

A	Initial condition
B	Ties raised
C	Stoneblowing tubes driven next to tie
D	Compressed air used to blow stones
E	Stoneblowing tubes withdrawn
F	Ties lowered to rest on freshly inserted stone



McMichael and McNaughton, 2003

Stone Blowing: October 27, 2014

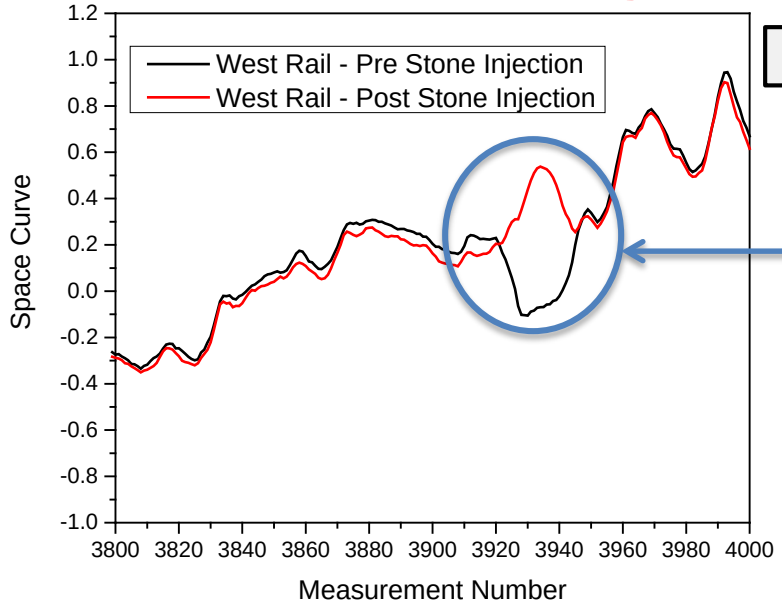
Madison St. Bridge - Track 2

Injection Chute with Air Connection Mounted on Top of the Injector Tube

Inject known quantity of ½-in. stone

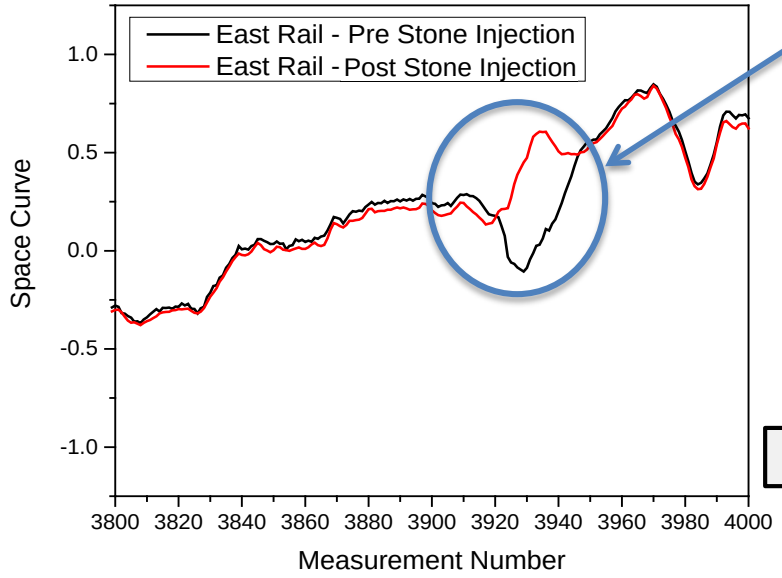
1 lb. stone for 1/32” lift

Track Geometry Data: Post Stone Blowing



West Rail

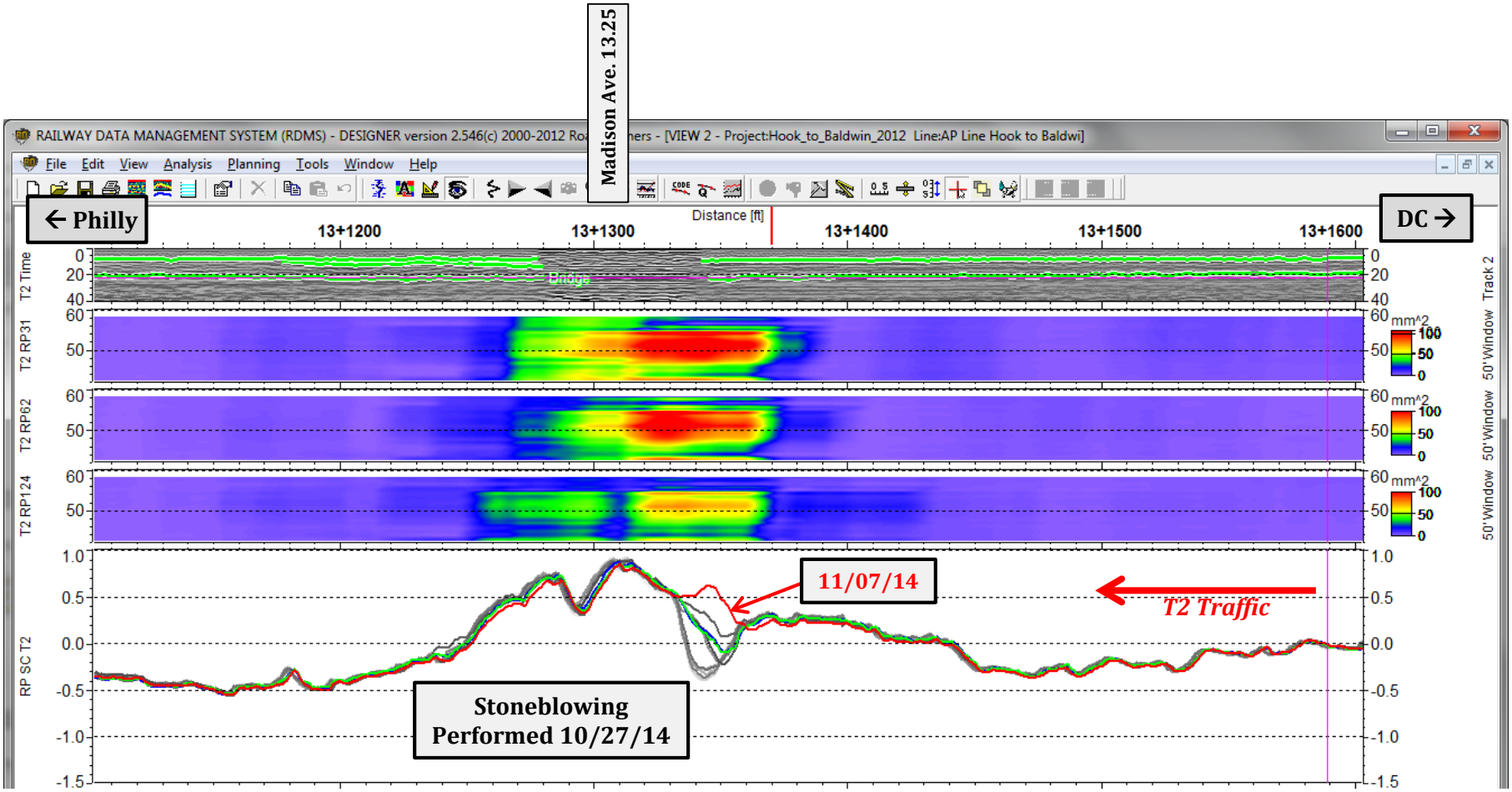
Track geometry data indicates the designed over lift has not dissipated as of 11/07/2014



East Rail

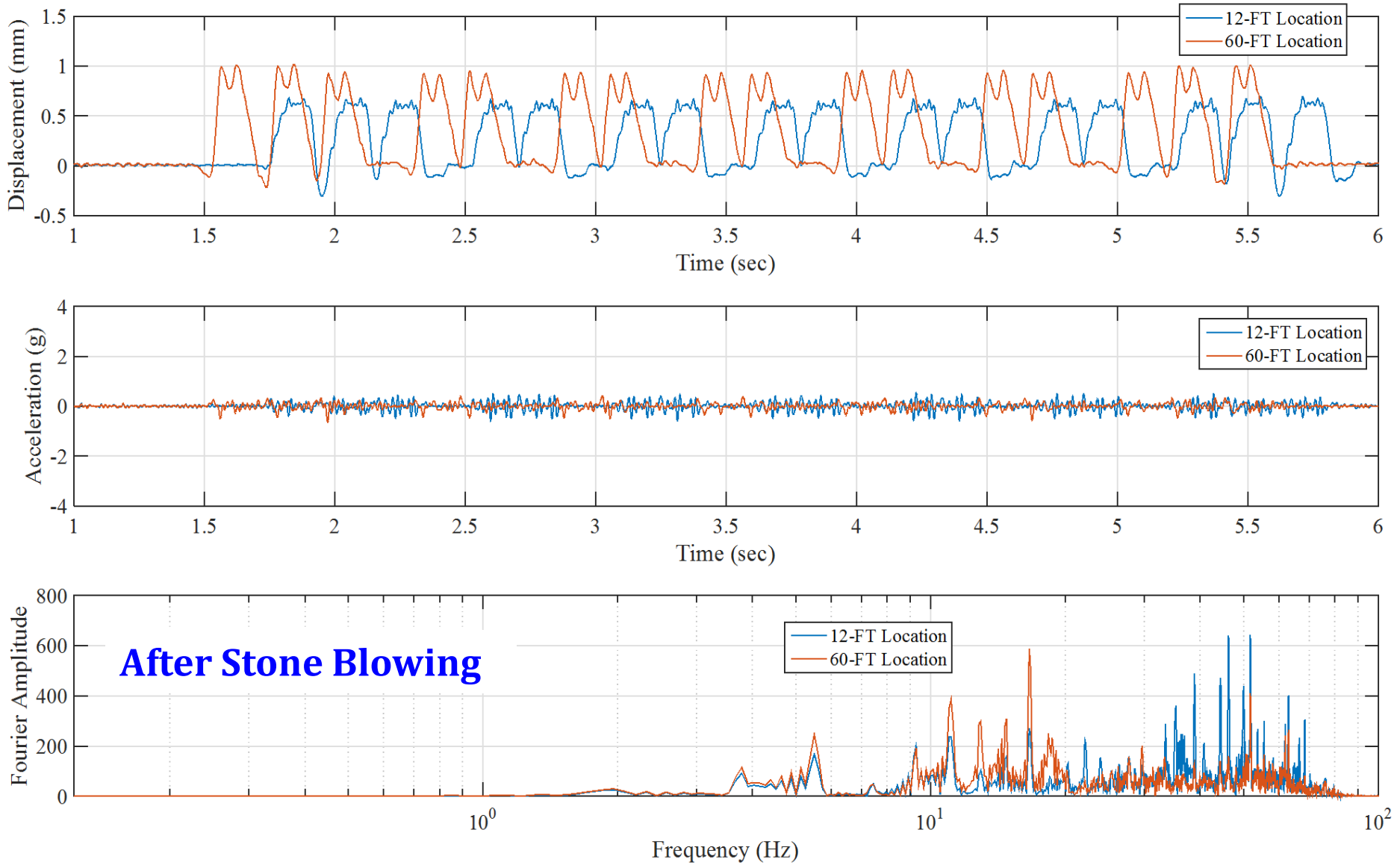
- Implementation: 27 October 2014
- Venue: Madison Street, Track 2 South Approach
- 12 ties successfully stone injected to provide better seating

Madison St. Bridge - Track 2

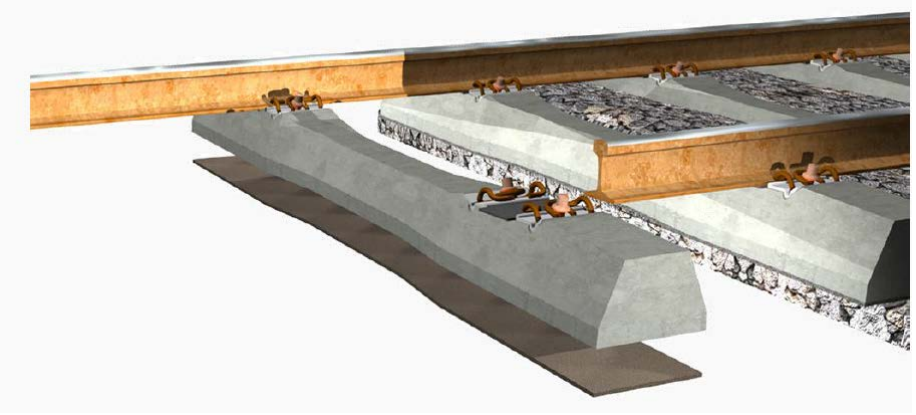


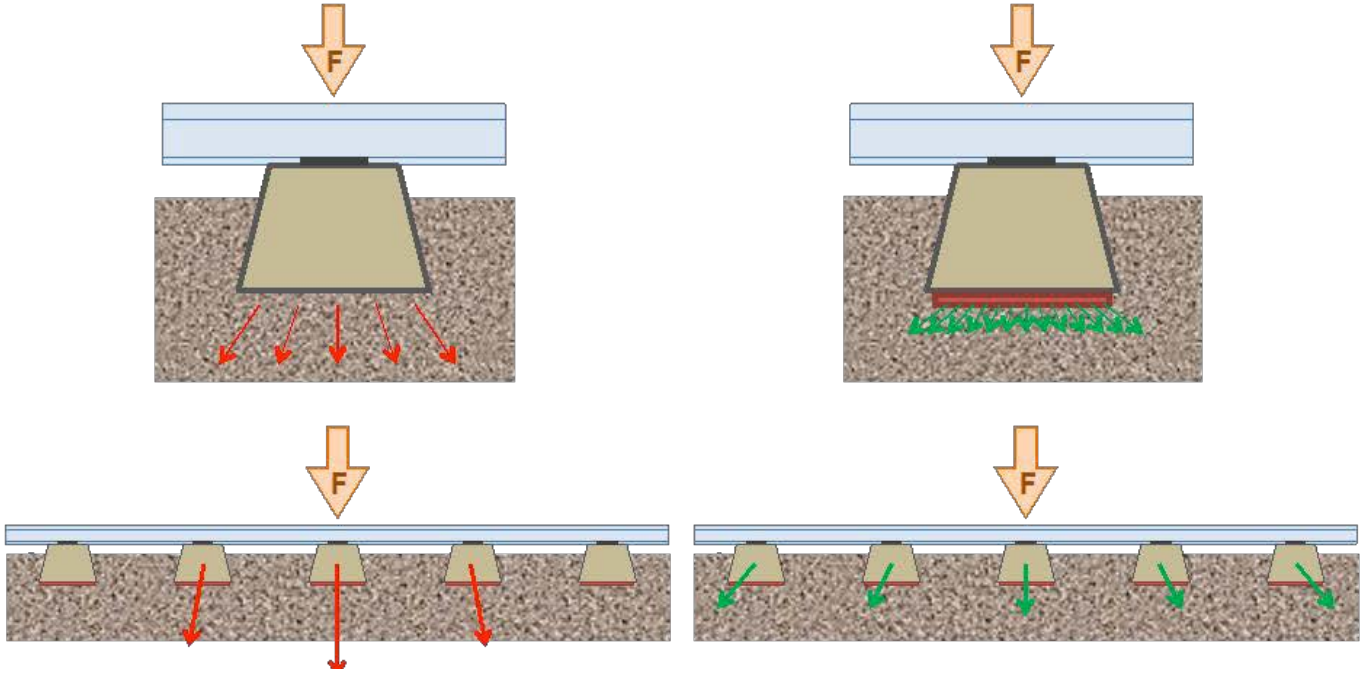
The profile of stone injection (12 ties) as of 11/07/2014

January 2015 – LVDT 1 Data
Madison St. Track 2 – ACELA Train



Installation of Under Tie Pads





Without Under-Tie Pads

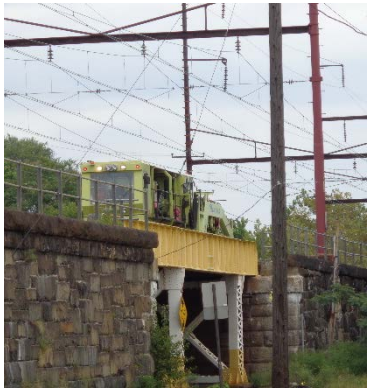
With Under-Tie Pads

Figure Source:
http://cdm-novitec.com/onewebmedia/Brochures/CDM-UTP%20Brochure%20-%20020713.pdf

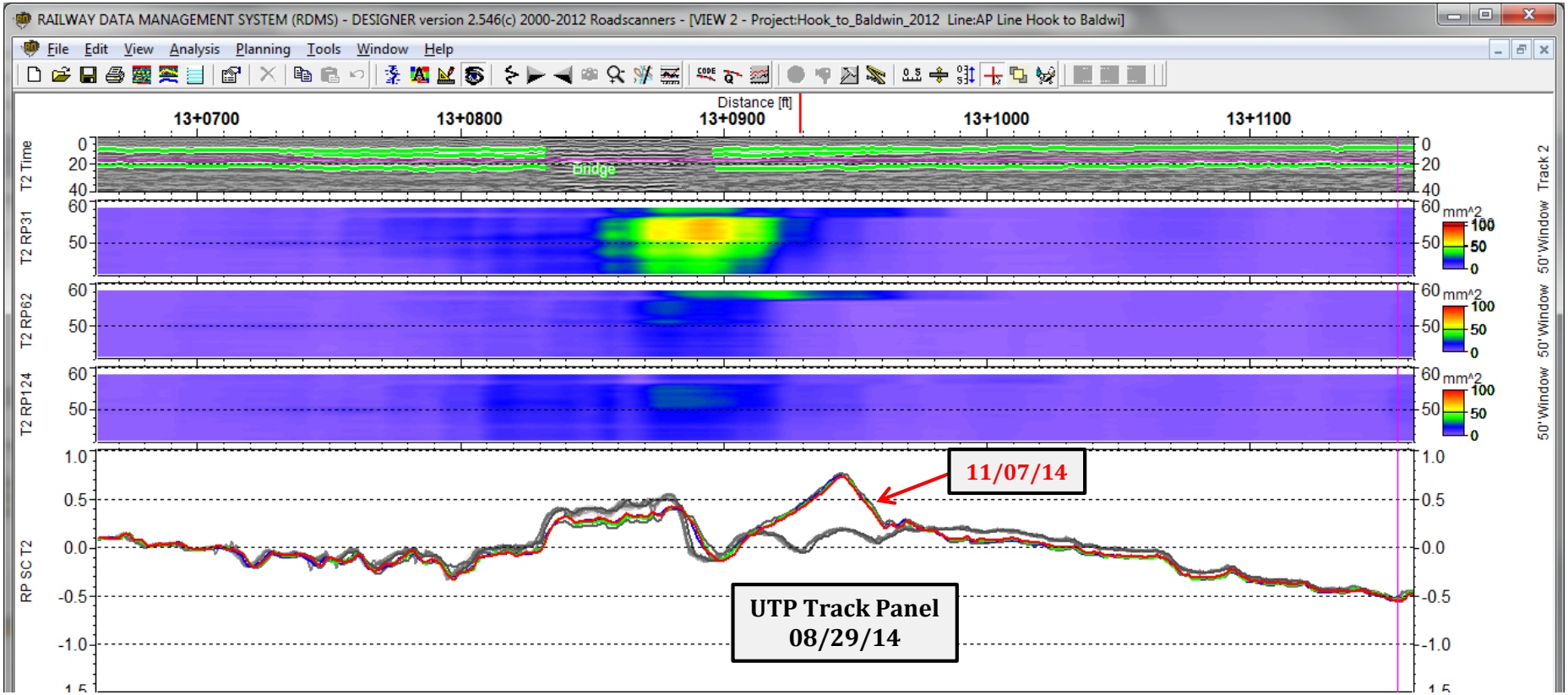
Under Tie Pad Track Panel Installation: Aug. 28-29, 2014

30 Tie Track Panel with Installed UTPs under New Ties

Track 2 – Upland St. Bridge



Track 2 – Upland St. Bridge



The profile of UTP track panel (30 ties) as of 11/07/2014

Latest Performance Data

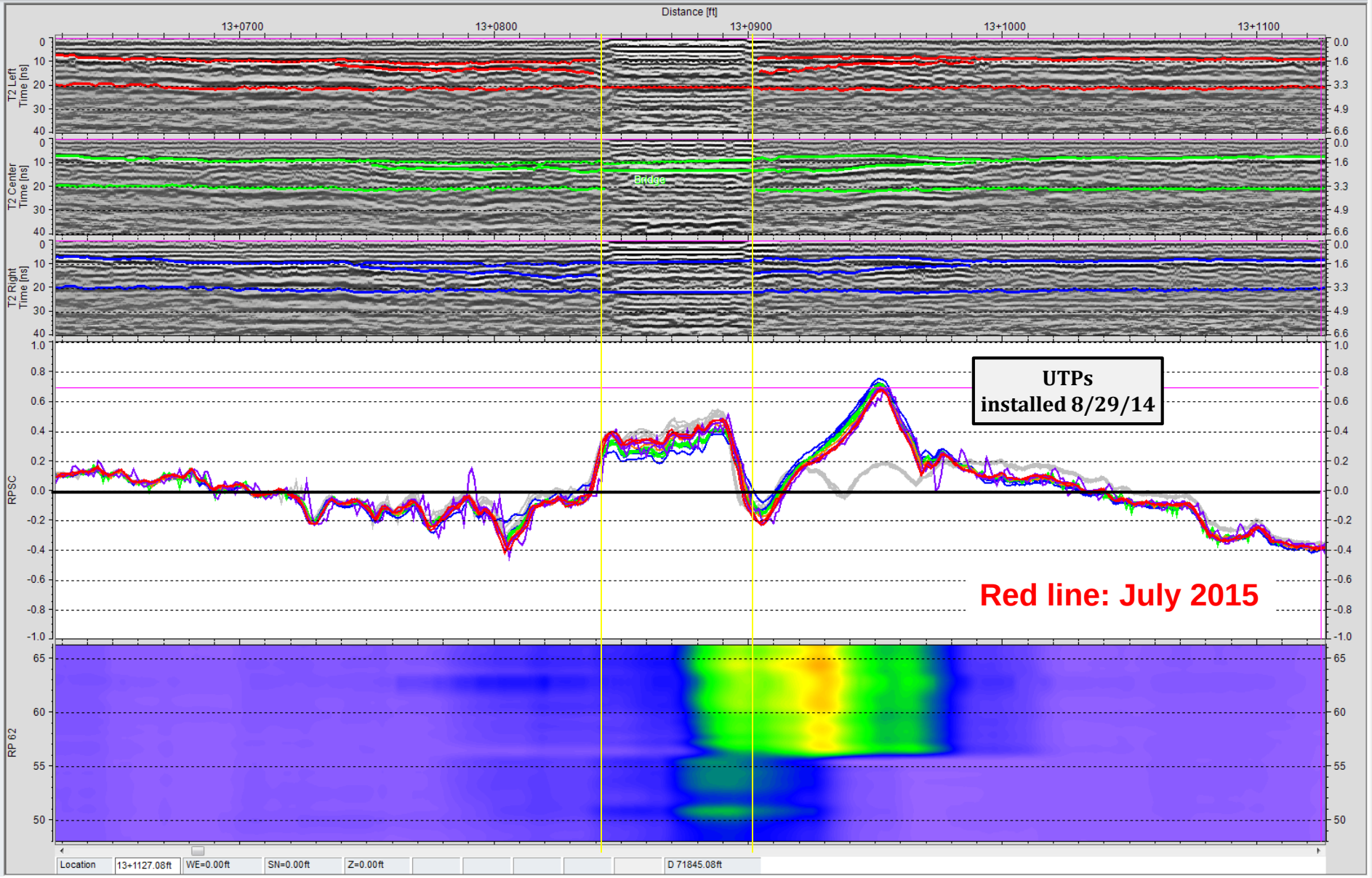
TC202 Workshop on Railroad Geotechnics, ECSMGE, Edinburgh – Sept. 13, 2015

← Philly

Upland St.- Track 2

T2 Traffic ←

DC →



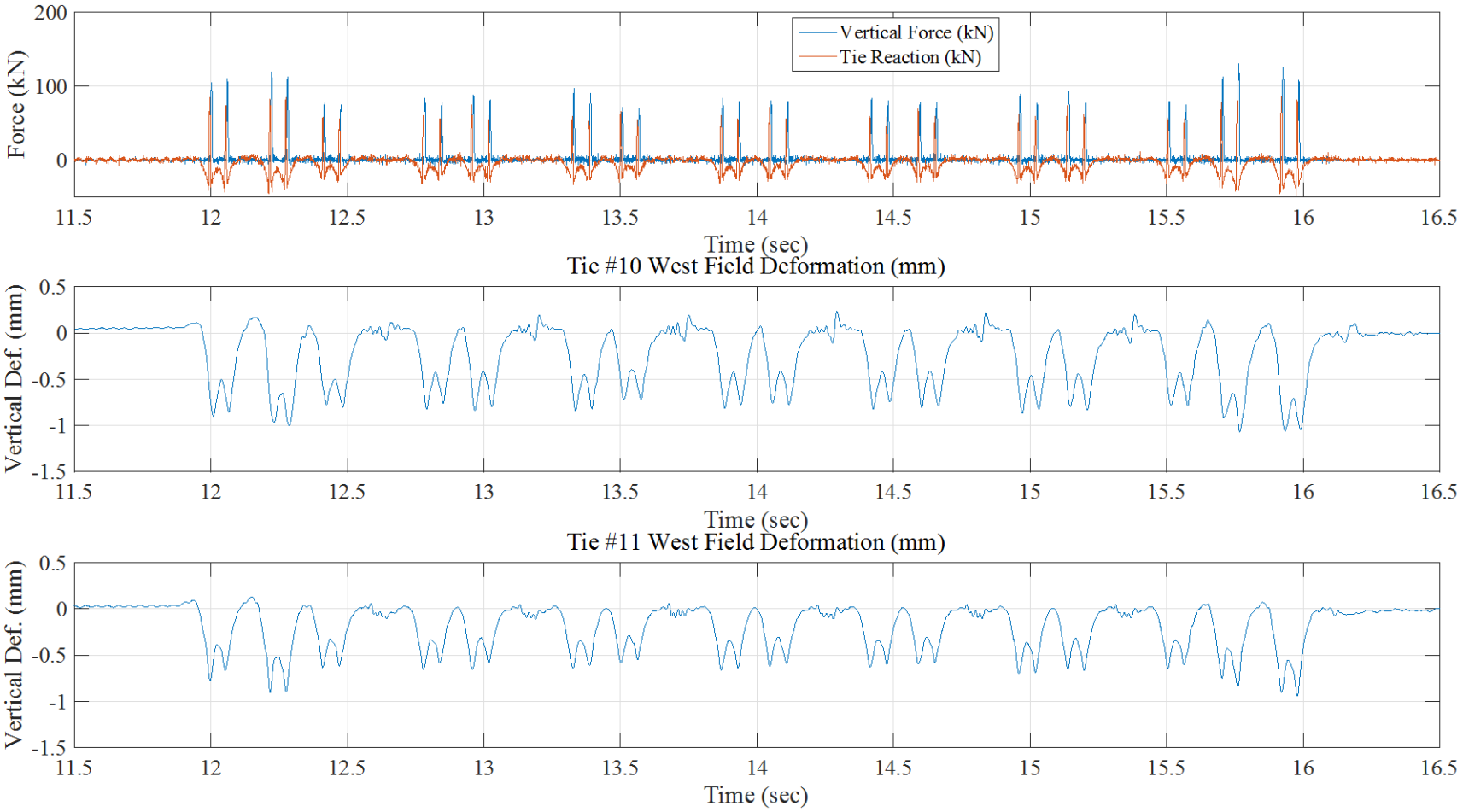
Under Tie Pad Track Panel Instrumentation

Strain Gauge Tie #10
Channel #10

Accelerometer Tie #10
West Field Site

Strain Gauge Tie #11
Channel #9

Under Tie Pad Track Panel Performance



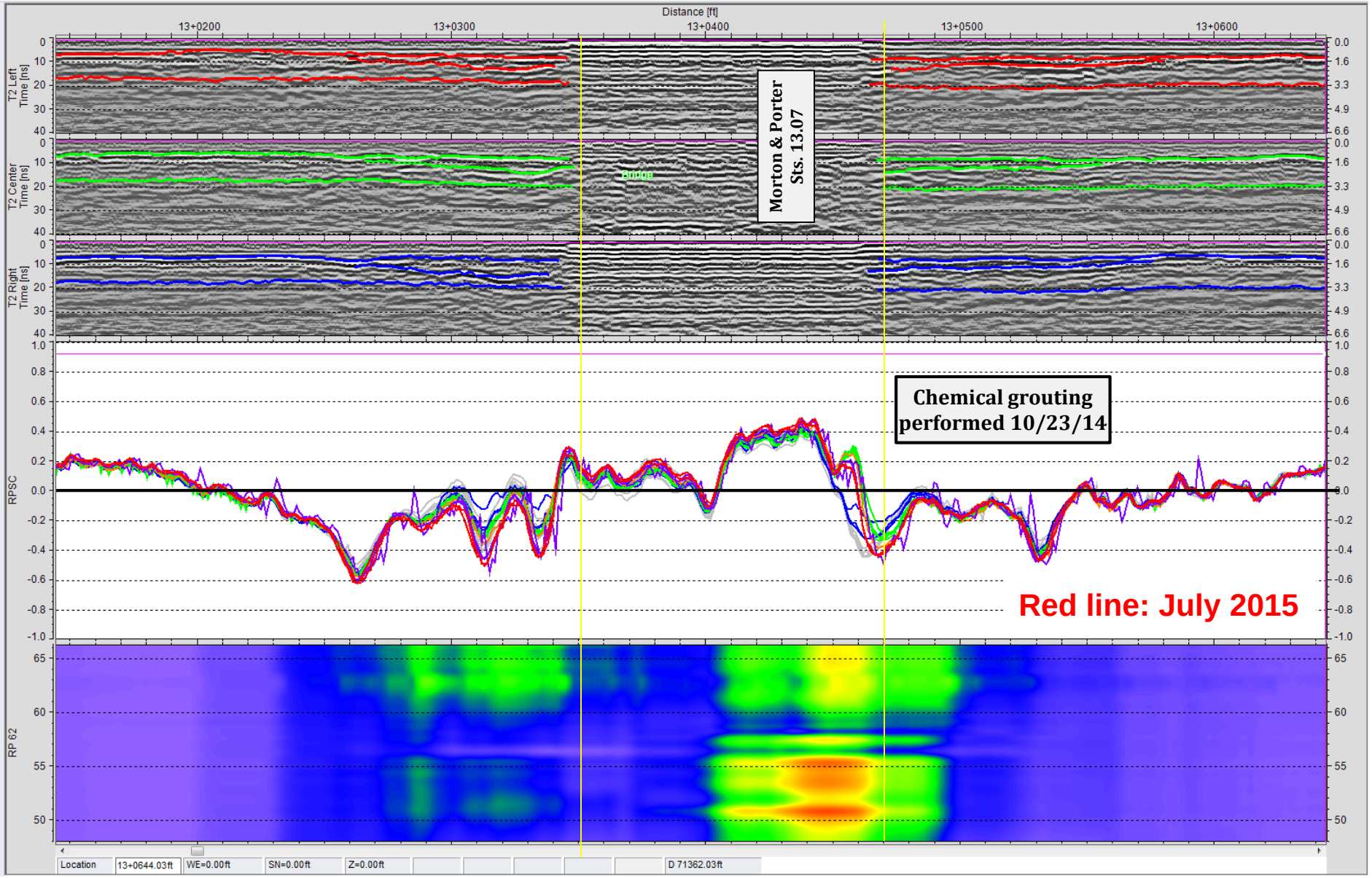
Deformations are less than or slightly over 1 mm. There is no excessive heaving or negative displacement.

← Philly

Morton & Porter Sts.- Track 2

T2 Traffic ←

DC →

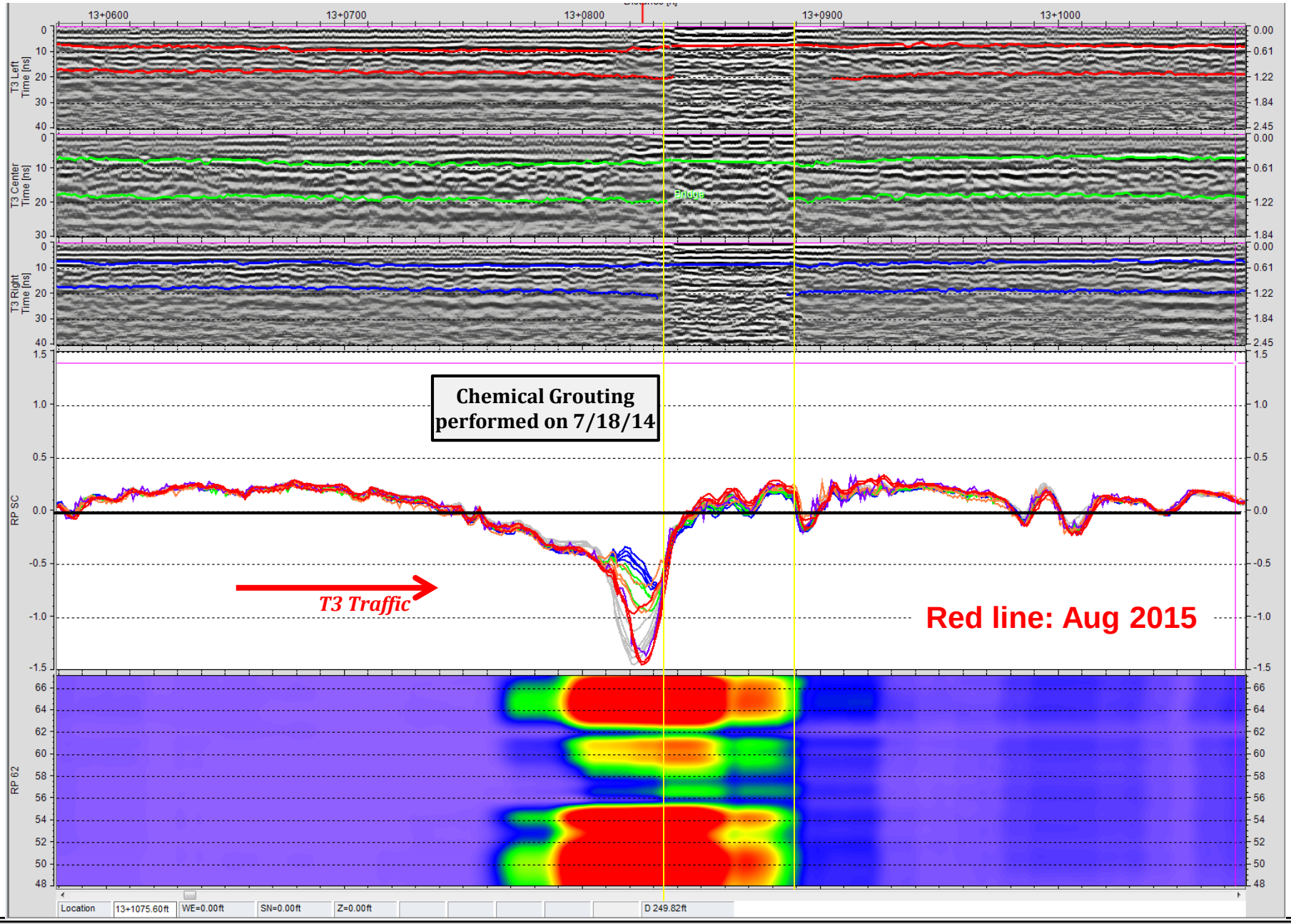


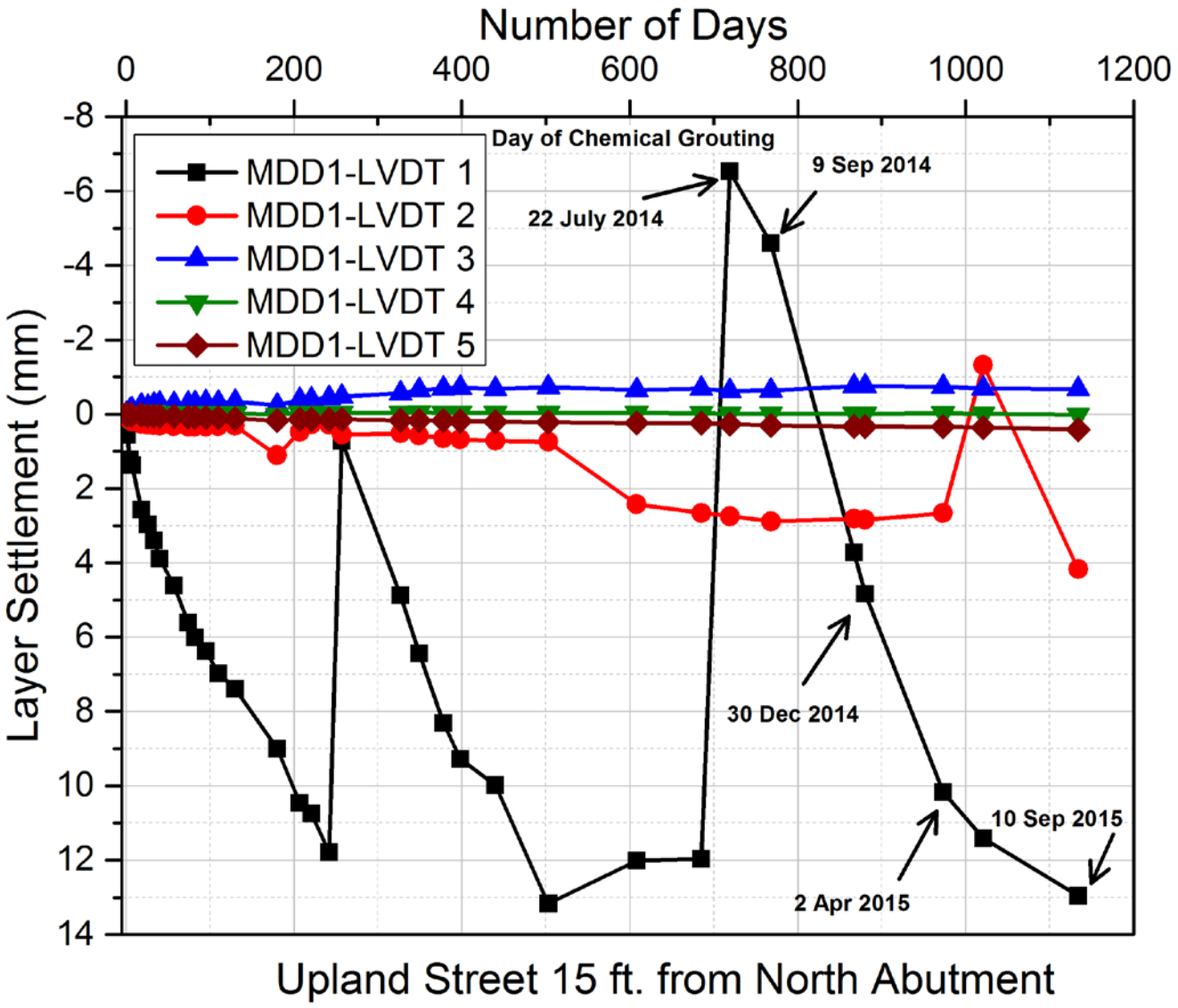
Upland Bridge - Track 3

← Philly

DC →

Upland St. 13.17




Number of Days
0
200
400
600
800
1000
1200
-8
-6
-4
-2
0
2
4
6
8
10
12
14
Layer Settlement (mm)
MDD1-LVDT 1
MDD1-LVDT 2
MDD1-LVDT 3
MDD1-LVDT 4
MDD1-LVDT 5
Day of Chemical Grouting
22 July 2014
9 Sep 2014
30 Dec 2014
2 Apr 2015
10 Sep 2015
Upland Street 15 ft. from North Abutment

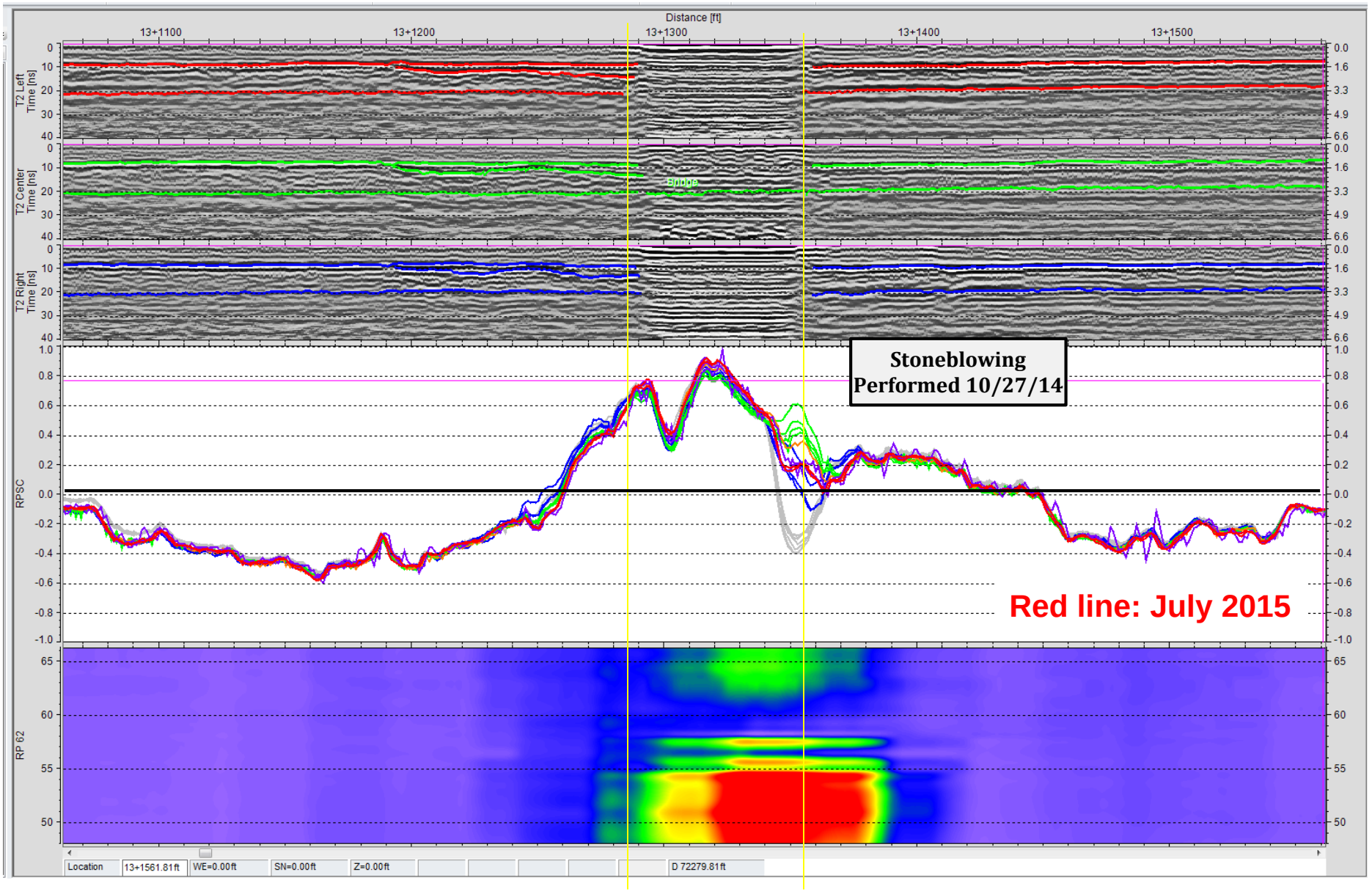
TC202 Workshop on Railroad Geotechnics, ECSMGE, Edinburgh – Sept. 13, 2015

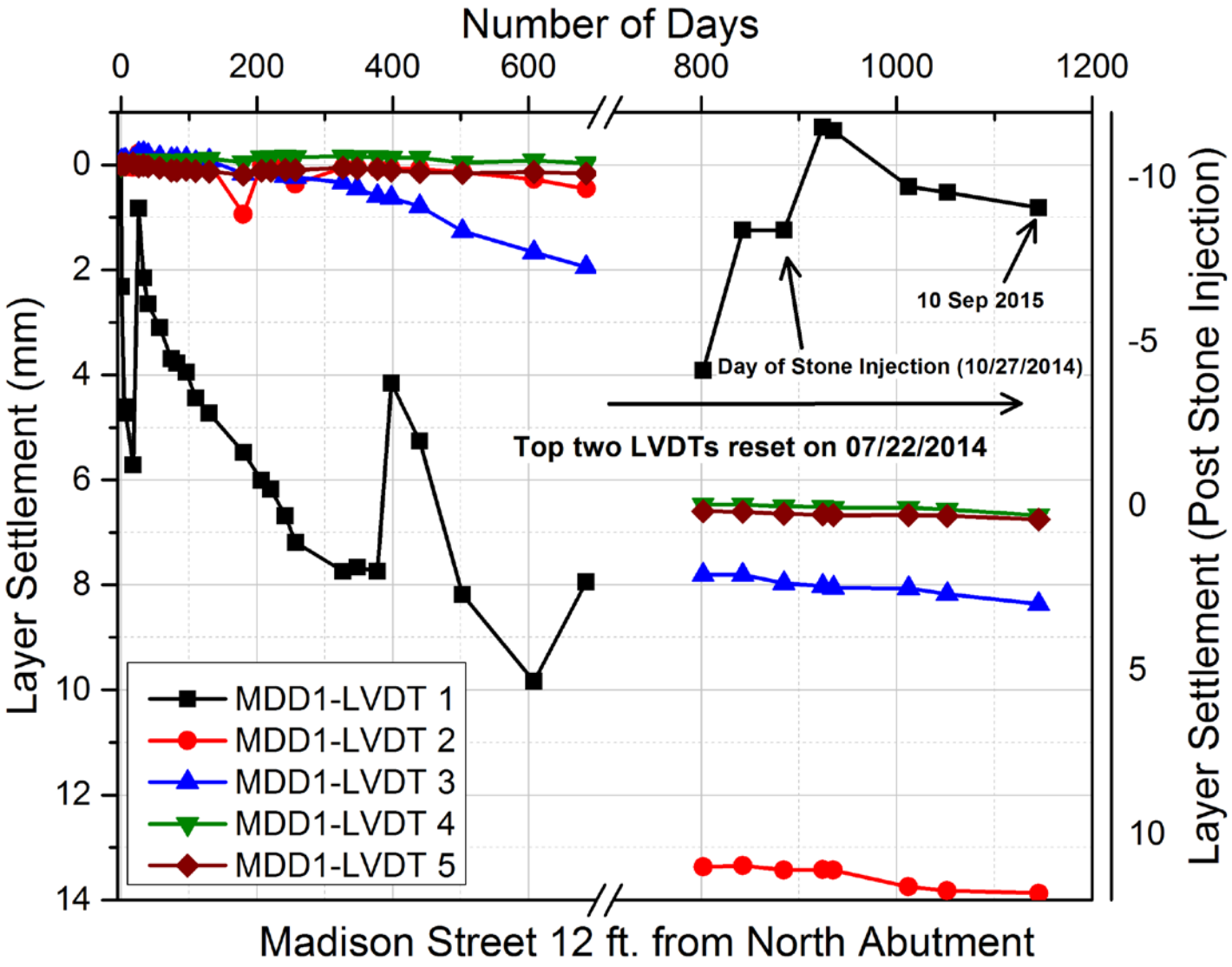
← Philly

Madison St. Bridge - Track 2

T2 Traffic ←

DC →




Number of Days
0
200
400
600
800
1000
1200
Layer Settlement (mm)
0
2
4
6
8
10
12
14
Layer Settlement (Post Stone Injection)
-10
-5
0
5
10
10 Sep 2015
Day of Stone Injection (10/27/2014)
Top two LVDTs reset on 07/22/2014
MDD1-LVDT 1
MDD1-LVDT 2
MDD1-LVDT 3
MDD1-LVDT 4
MDD1-LVDT 5
Madison Street 12 ft. from North Abutment

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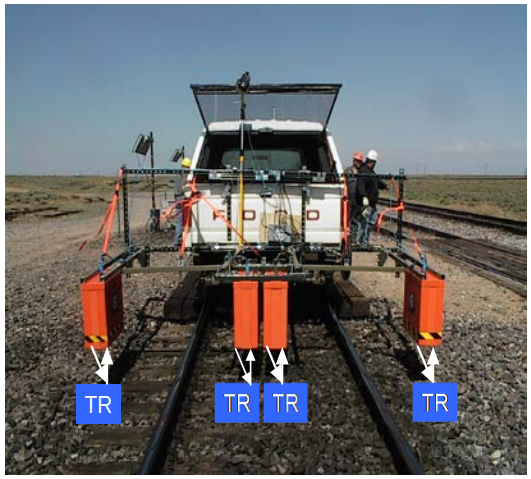
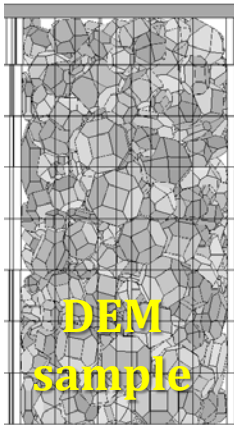
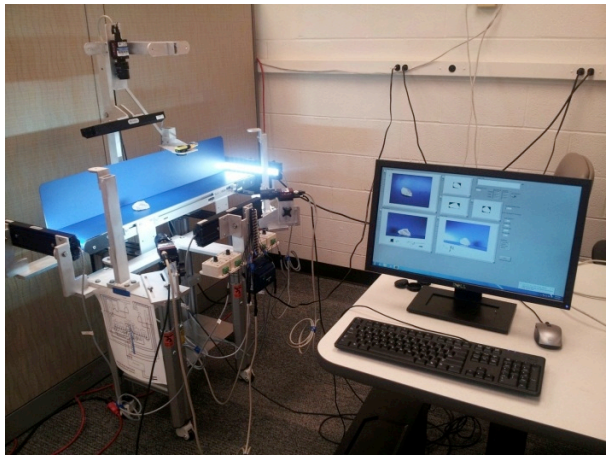
  - ✓Mike Tomas
  - ✓Steve Chrismer
  - ✓Mike Tirosino
  - ✓David Staplin

- ✓ Norfolk Southern
  - ✓Brad Kerchof

Thank you!
Questions?







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