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Fortezza da Basso • FLORENCE (Italy)

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CRITICAL ANALYSIS OF PIPE RAMMING BEHAVIOR AND FACTORS THAT IMPACT PREDICTIVE MODELS

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- Purpose of the Study
- Pipe Ramming Project
- Geotechnical Conditions
- Project Layout and Instrumentation
- Analysis of Results
- Conclusions

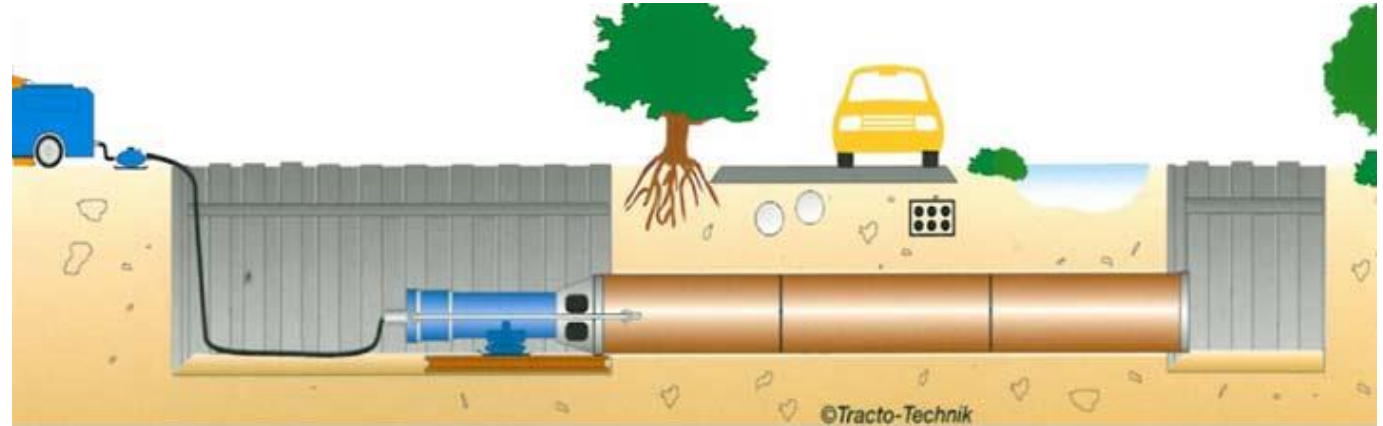
WHY PIPE RAMMING?



- Project was previously bid as a microtunneling project.
- 610mm (30-inch) and 915mm (36- inch) diameter microtunneling
- Microtunneling Machines Stuck on Cobbles and gravel
- Project terminated for convenience

PIPE RAMMING

- Pneumatic or Hydraulic Hammer
- Open-Ended Pipe
- Repeated Percussive Blows
- Soil Engulfed
- Non-Steerable



Typical Pipe Ramming Uses
Diagrams by courtesy of TTUK Ltd.

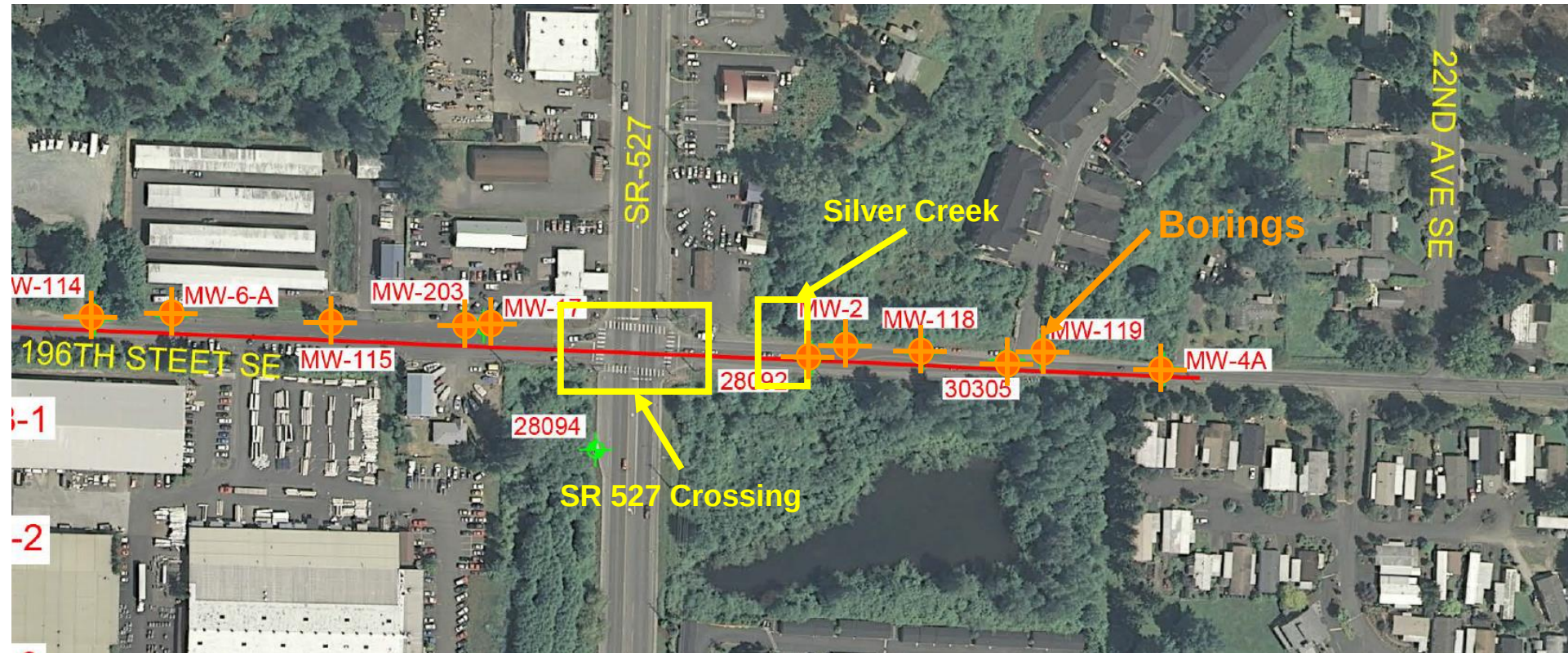
OLYMPUS MEADOWS TRUNK PIPE RAMMING

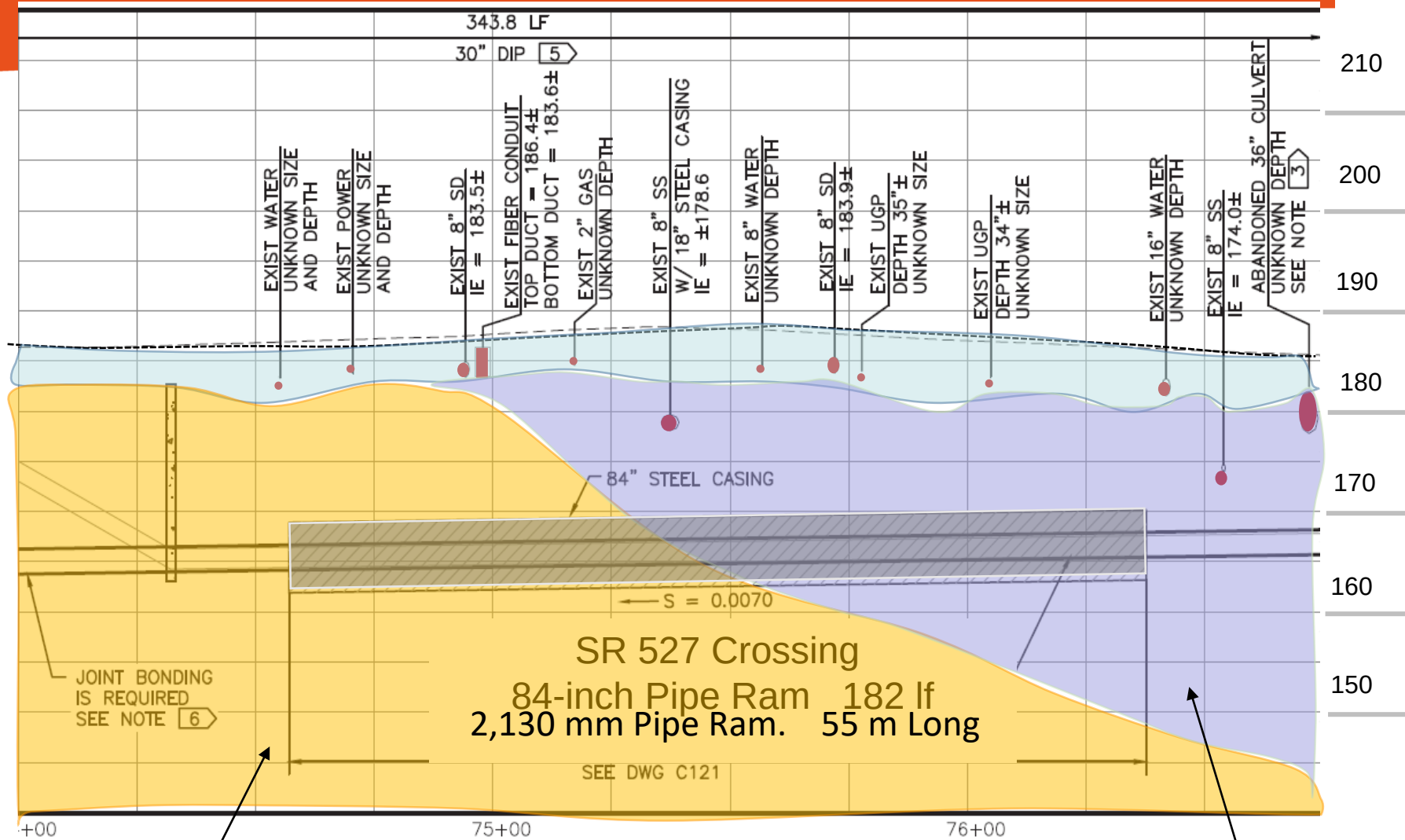
- Two 2,130mm (84-inch) Pipe Rams
- Crossings:
 - Highway 527
 - Silver Creek
- 760mm (30-inch) Gravity Sewer
- 610mm (24-inch) Water Line- (Force Main)



WHERE IN THE WORLD???

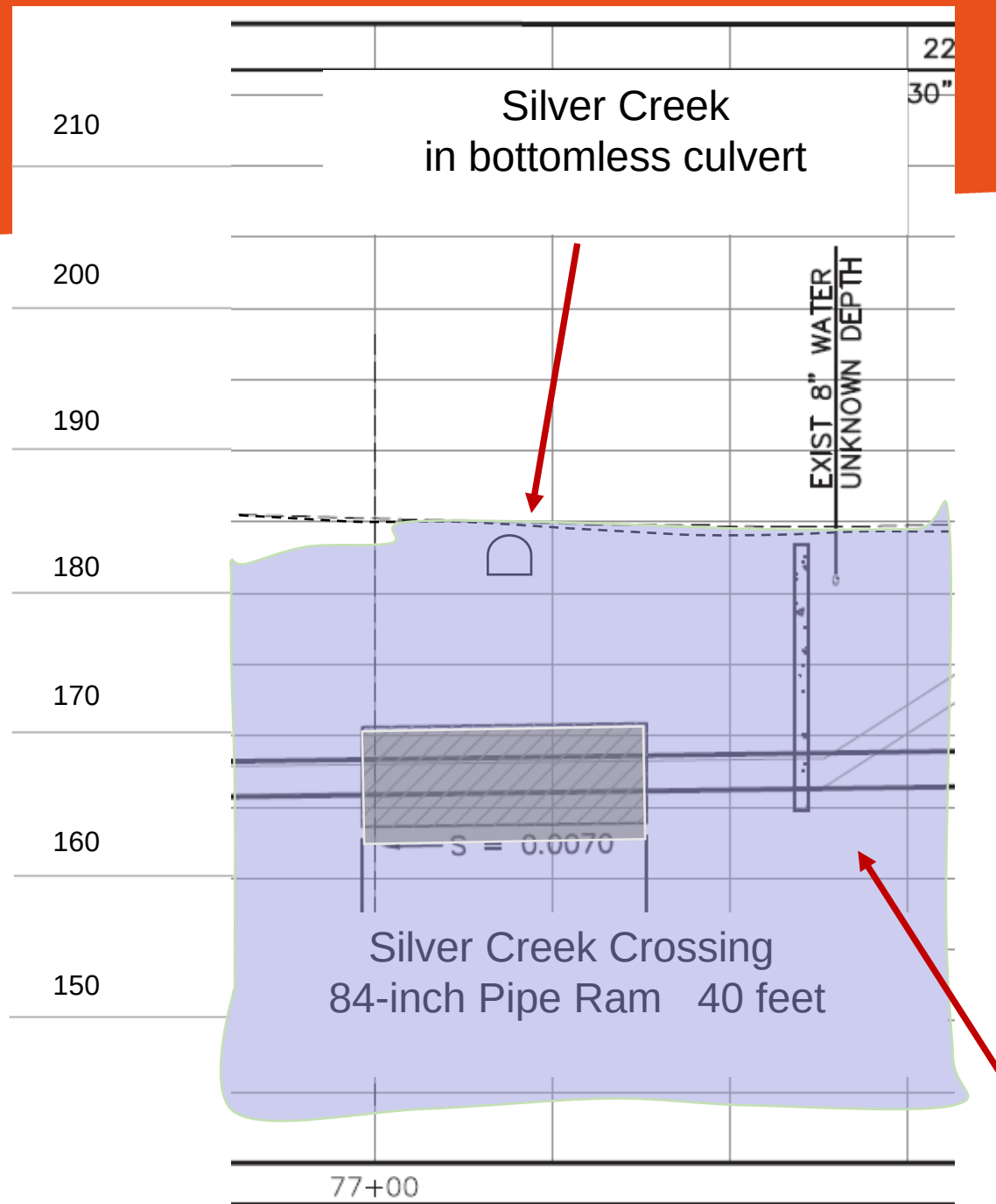






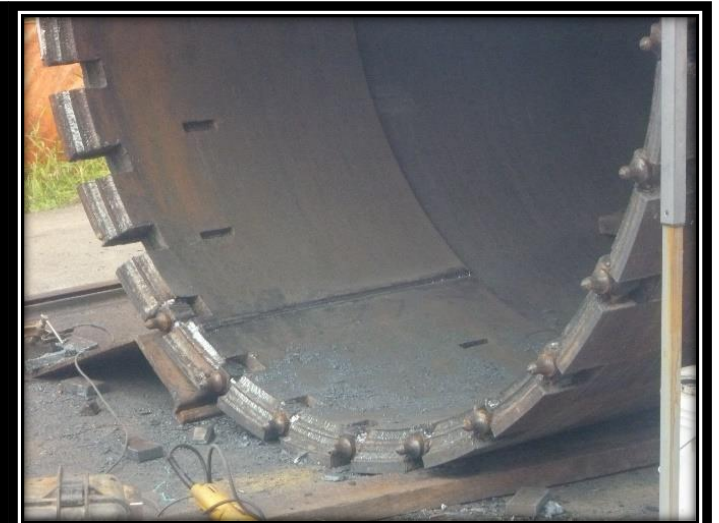
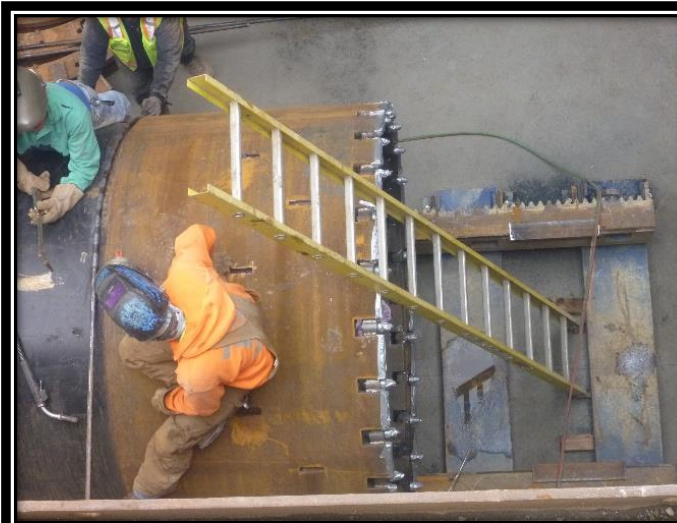
“Dense Glacial Deposits”

“Alluvium and Recessional Outwash Deposits”



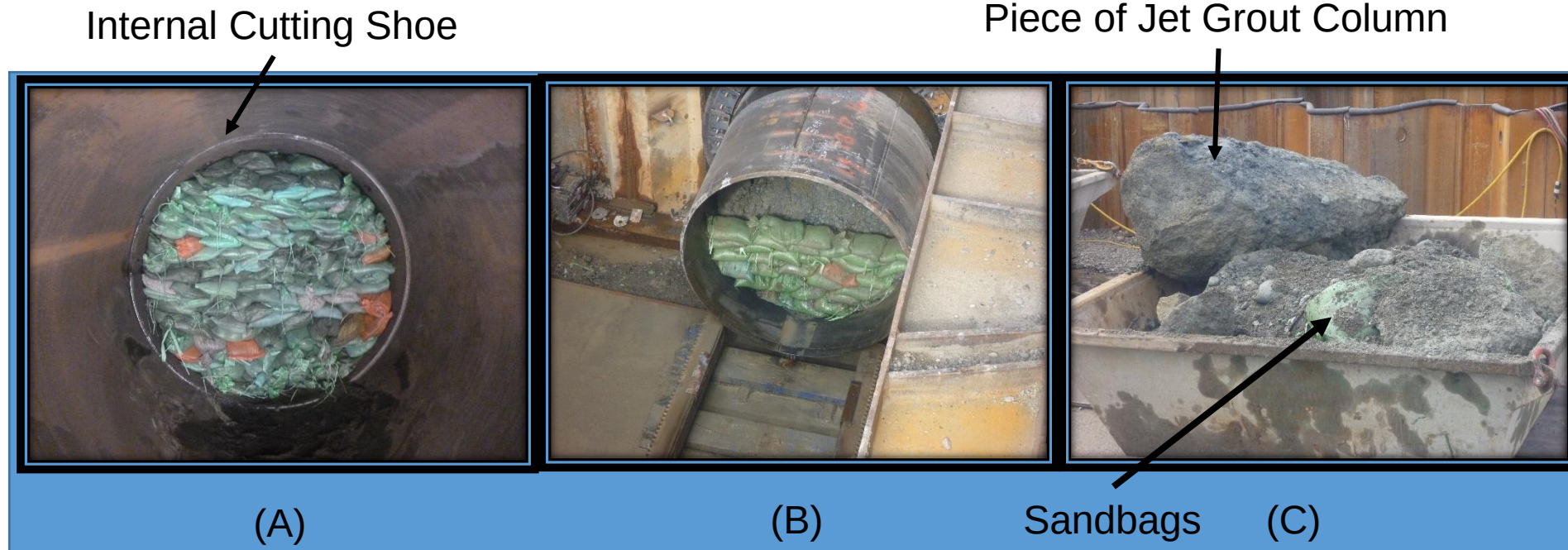
“Alluvium and Recessional Outwash Deposits”

- Cutting Shoe
 - D:t Ratio – Diameter to Shoe Thickness
 - Minimum 30
 - 2,130 mm (84-inch): 32mm (1.25-inch) thick steel pipe;
89mm (3.5-inch) shoe thickness
 - Kennametal Bullet Bits nested in Shoe



RAMMING BENEATH WATER TABLE

- Sandbags
- Alternating Sandbags and Gravel
- Use of Jet Grout Columns at Face



ENSURE HAMMER IS LEVEL (TO GRADE)

- Use of Sled
- Rails surveyed to design grade



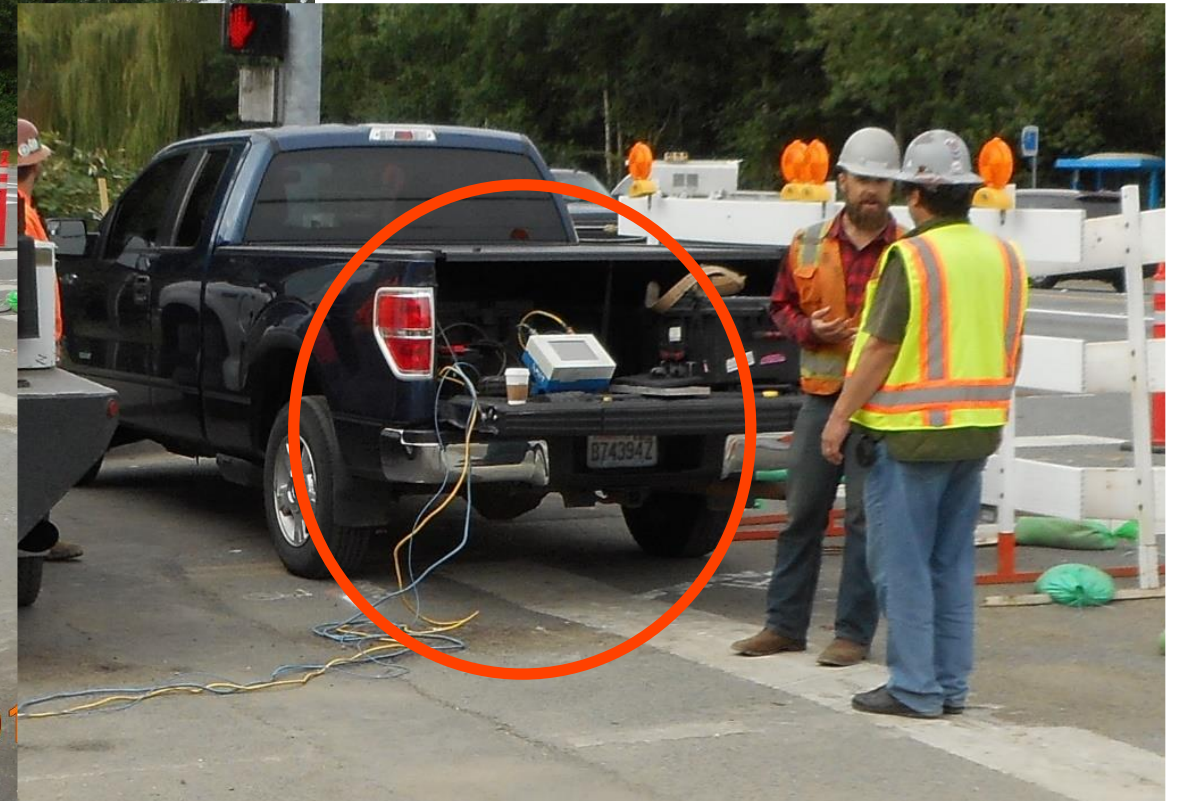
- Instrumentation of the Ram
- Strain Gages and Accelerometers
- Goal: Collect Valuable Information
 - Determine cause of high ramming forces
 - Provide real-time feedback on ram behavior
 - Understand Performance Parameters
 - Learn from one ram to the next



Ramming Direction

**Strain Gages
and
Accelerometers**

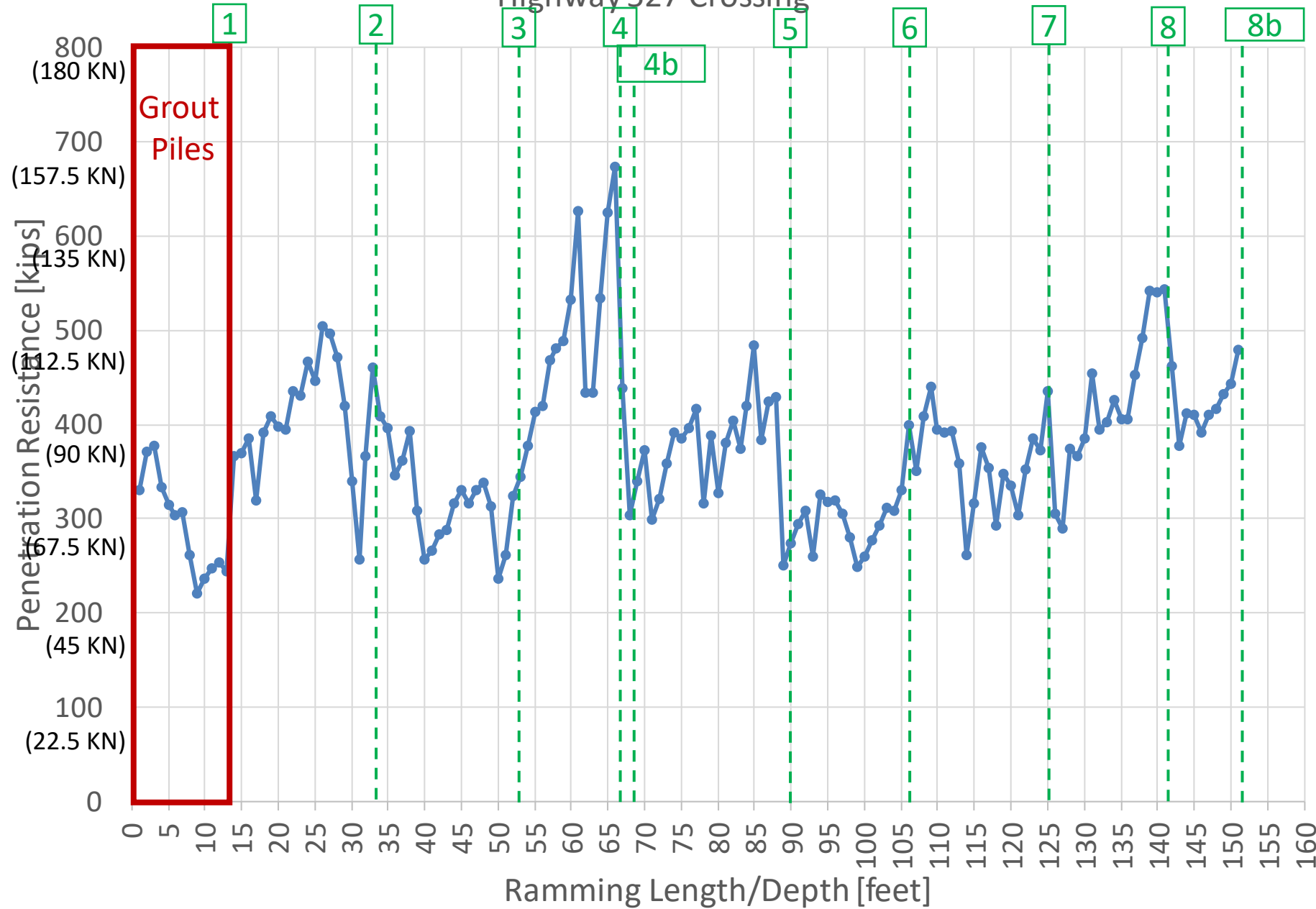
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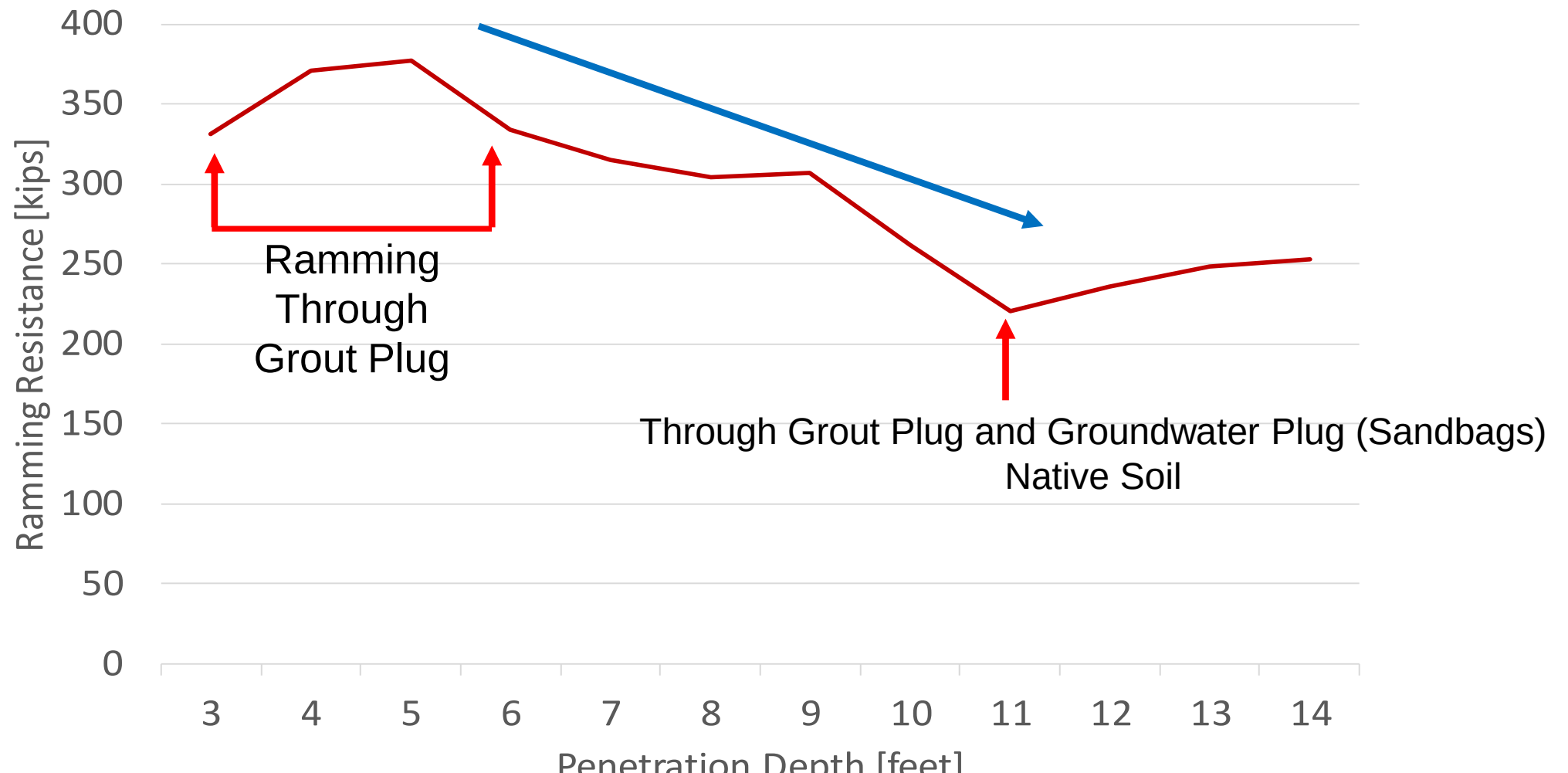
- Driving Resistance – kips
- Penetration Resistance – blows/ft
- Average Transfer Energy – kip-ft
- Average Transfer Efficiency %
 - Based on rating of the hammer
- Average Compressive Stress-- ksi
- Ramming Duration – per 20-foot pipe segment



Highway 527 Crossing

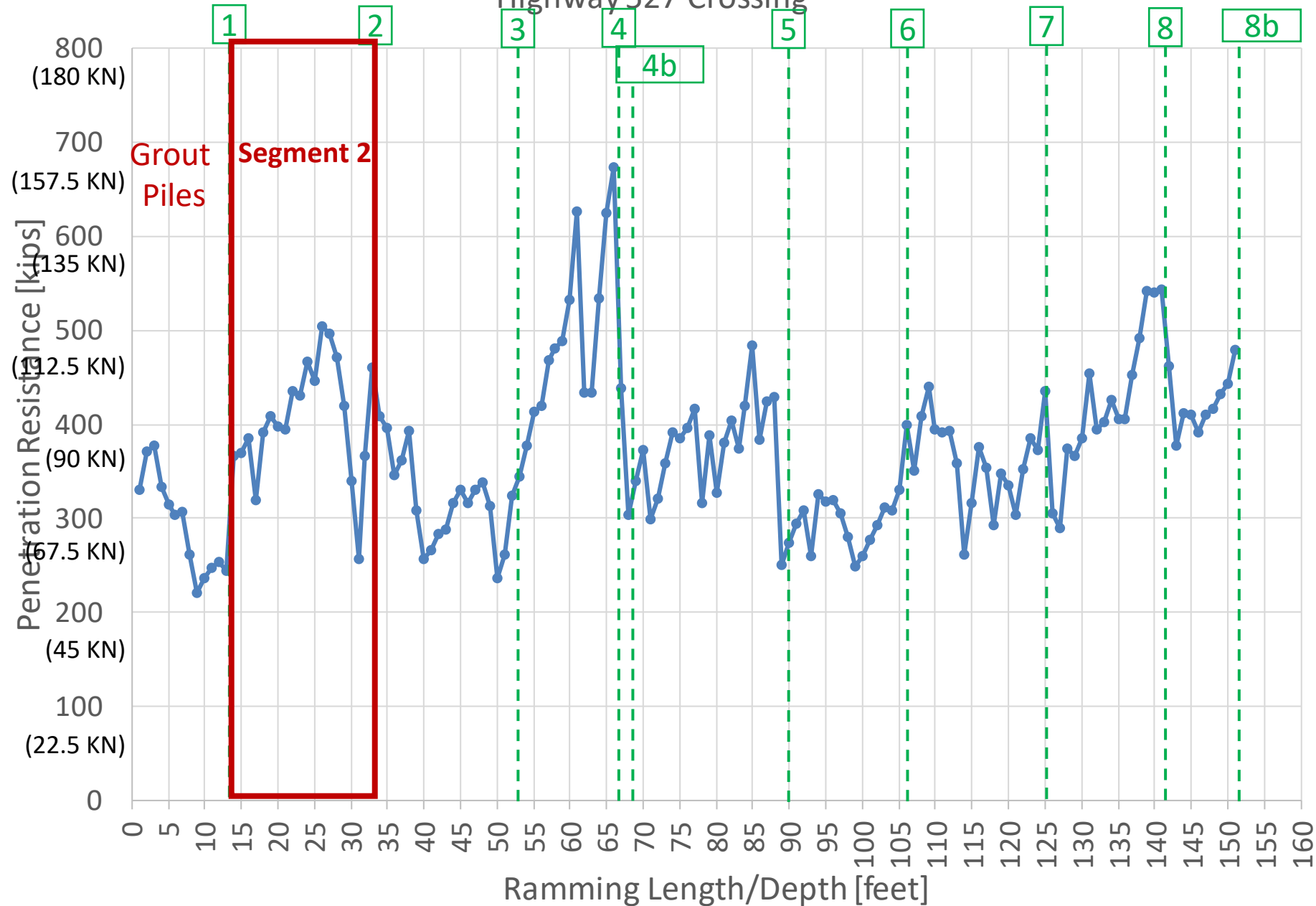


SR 527 Crossing Segment 1

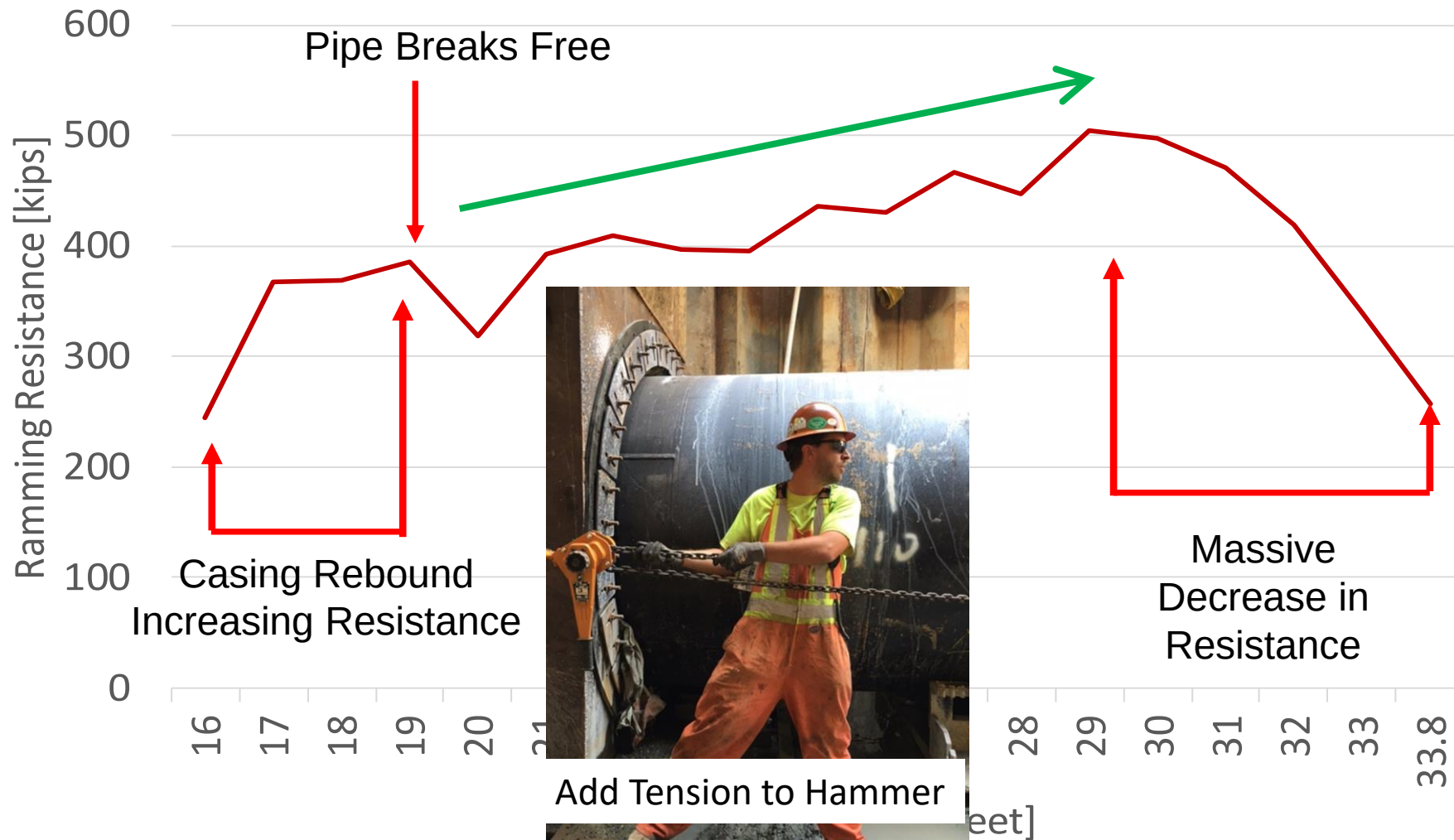




Highway 527 Crossing



SR 527 Crossing Segment 2





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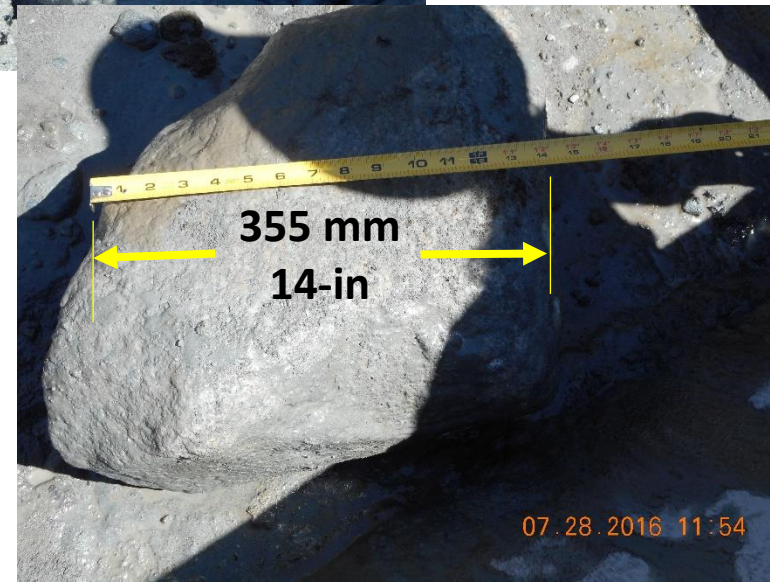
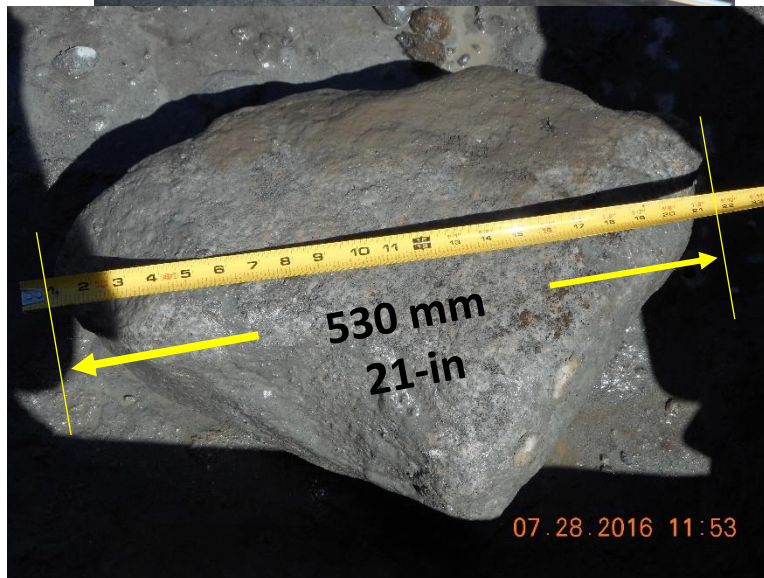
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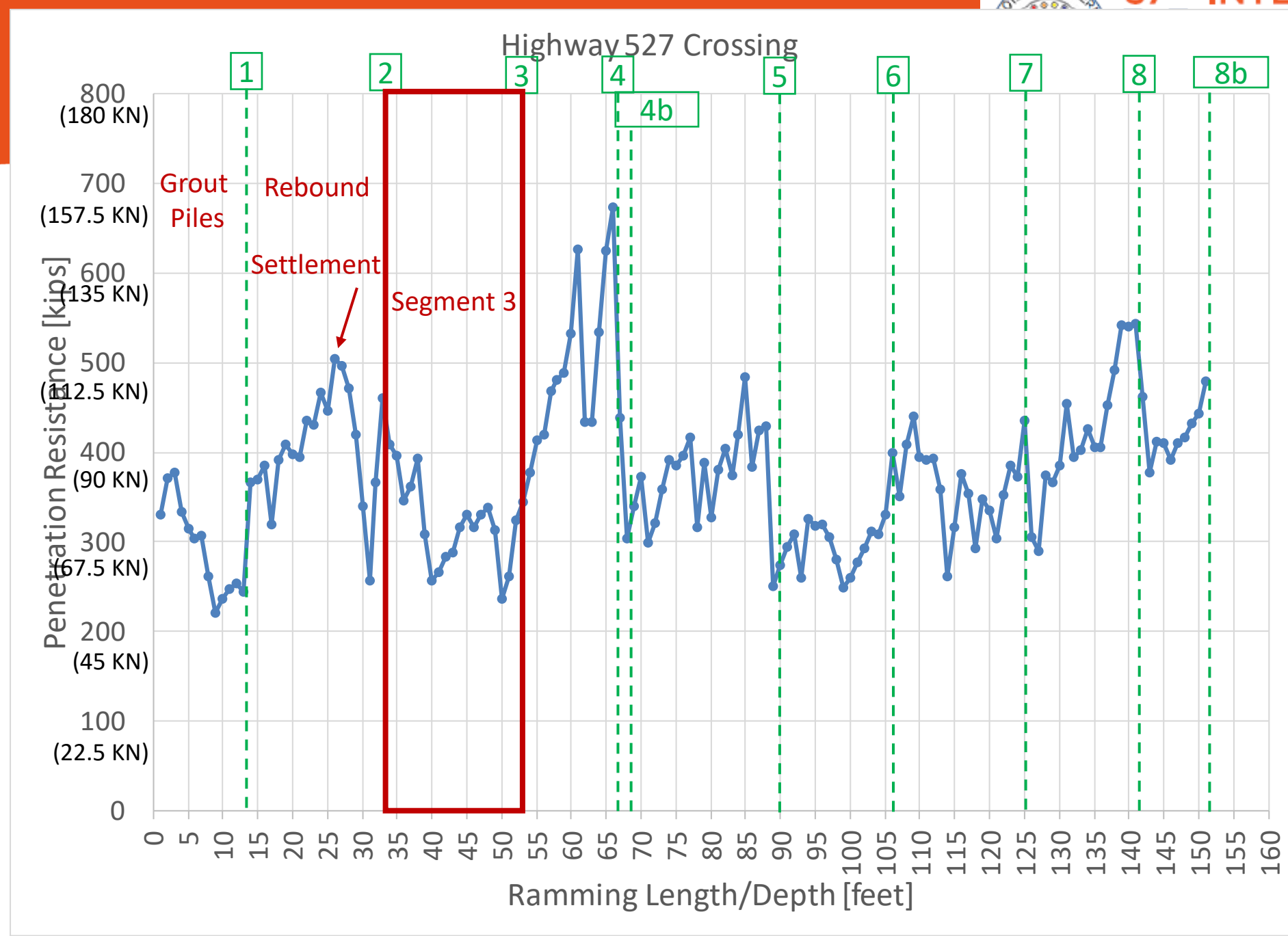


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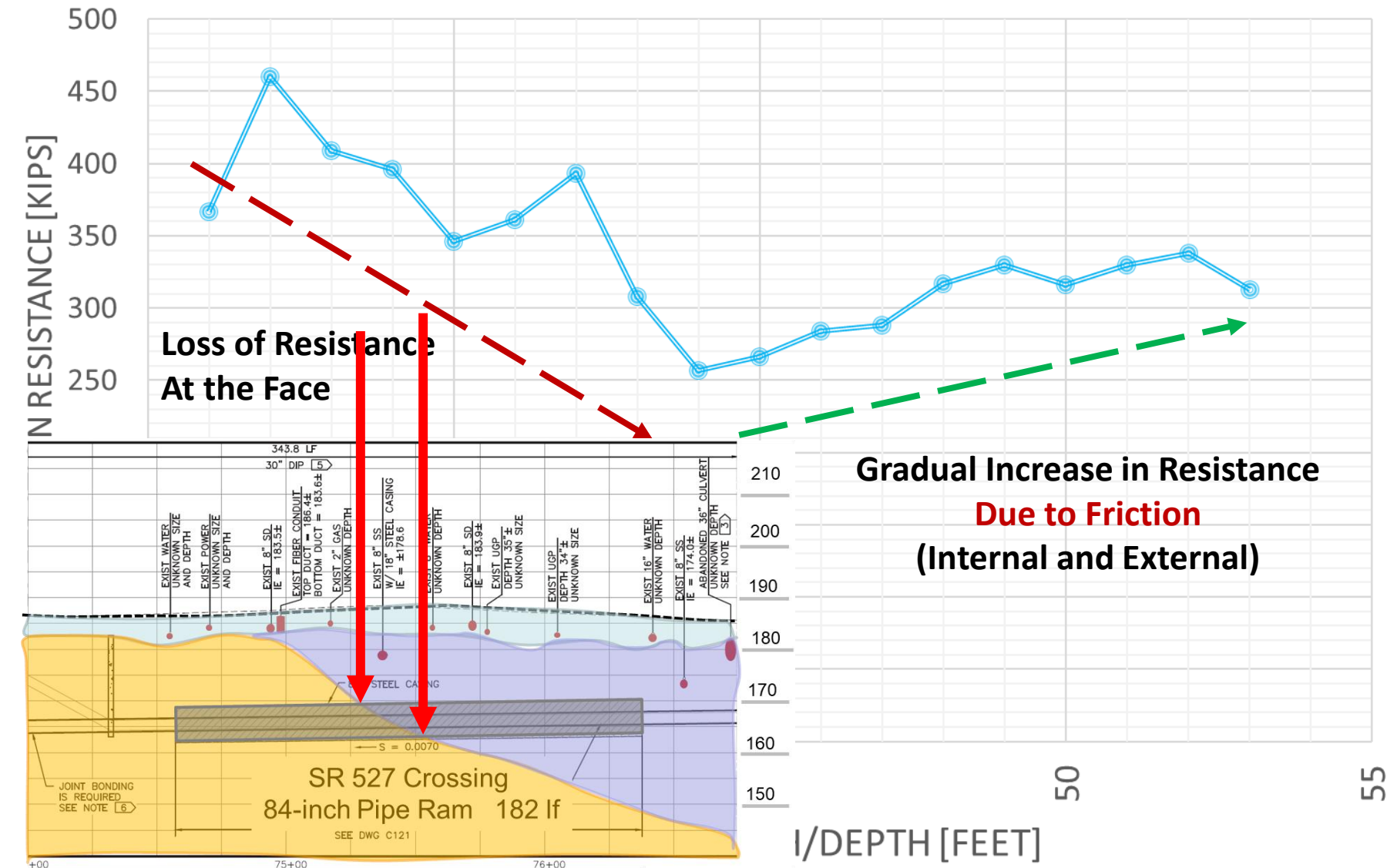
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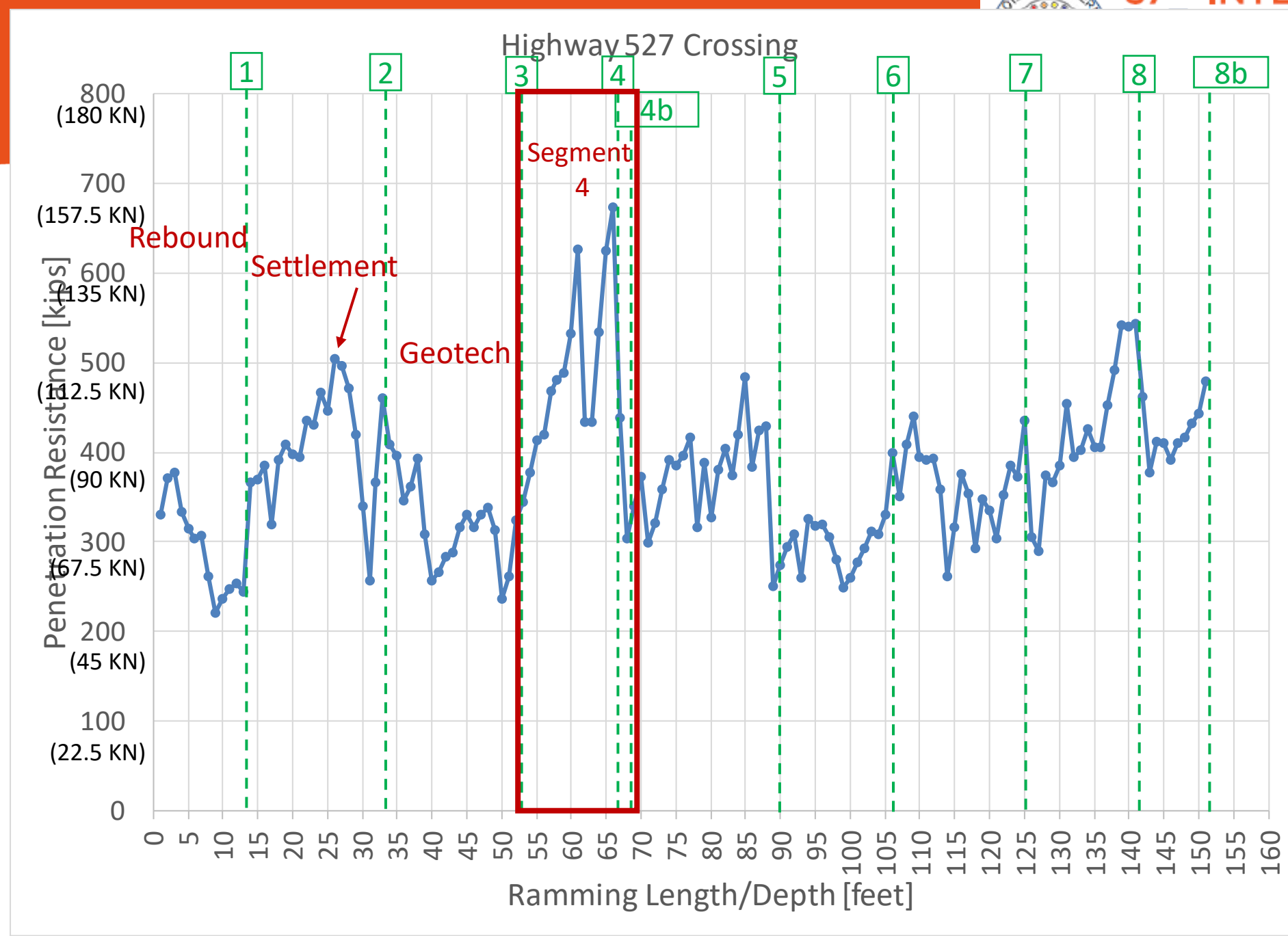
Highway 527 Crossing Segment 3



Alluvial and Recessional Deposits



Glacial Deposits



WHAT HAPPENED ON SEGMENT 4

- Forces Very High
- Ramming Very Slow
- Efficiency Very Low
- Hammer Very Hot





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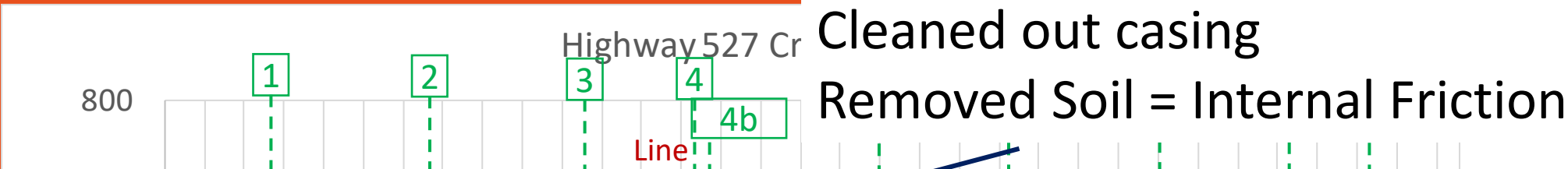
Significant Deviation

5 mm (14 inches) and trending

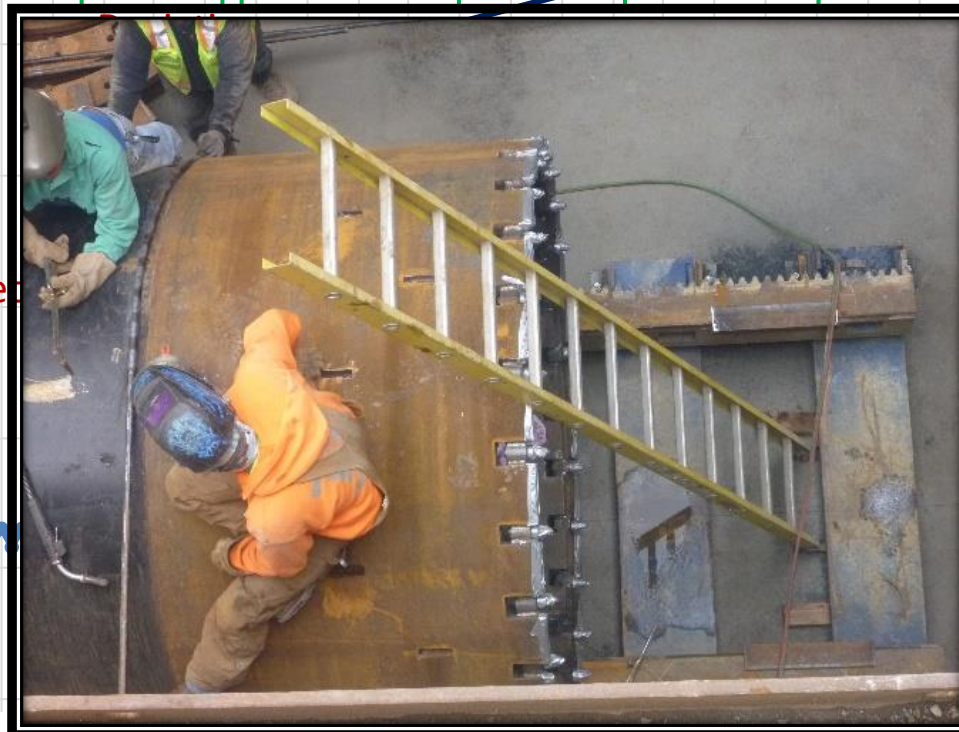
Maintained Grade

Grade?

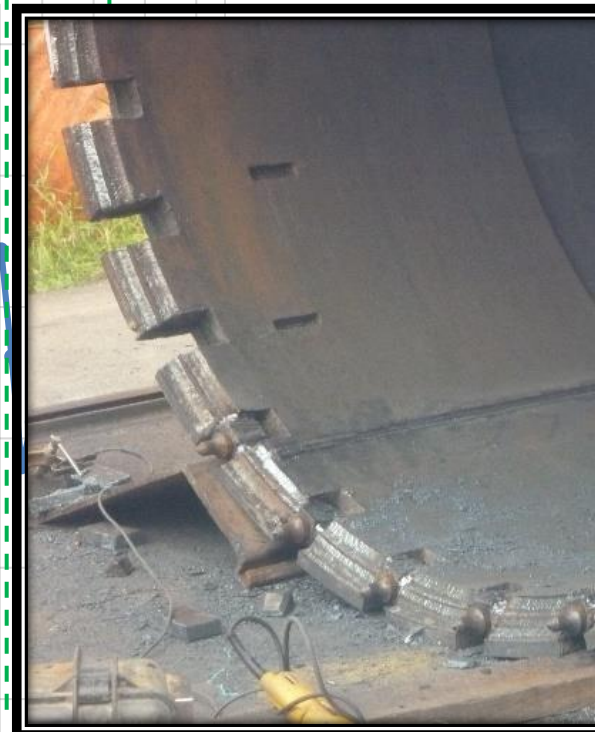
losing line?



A.



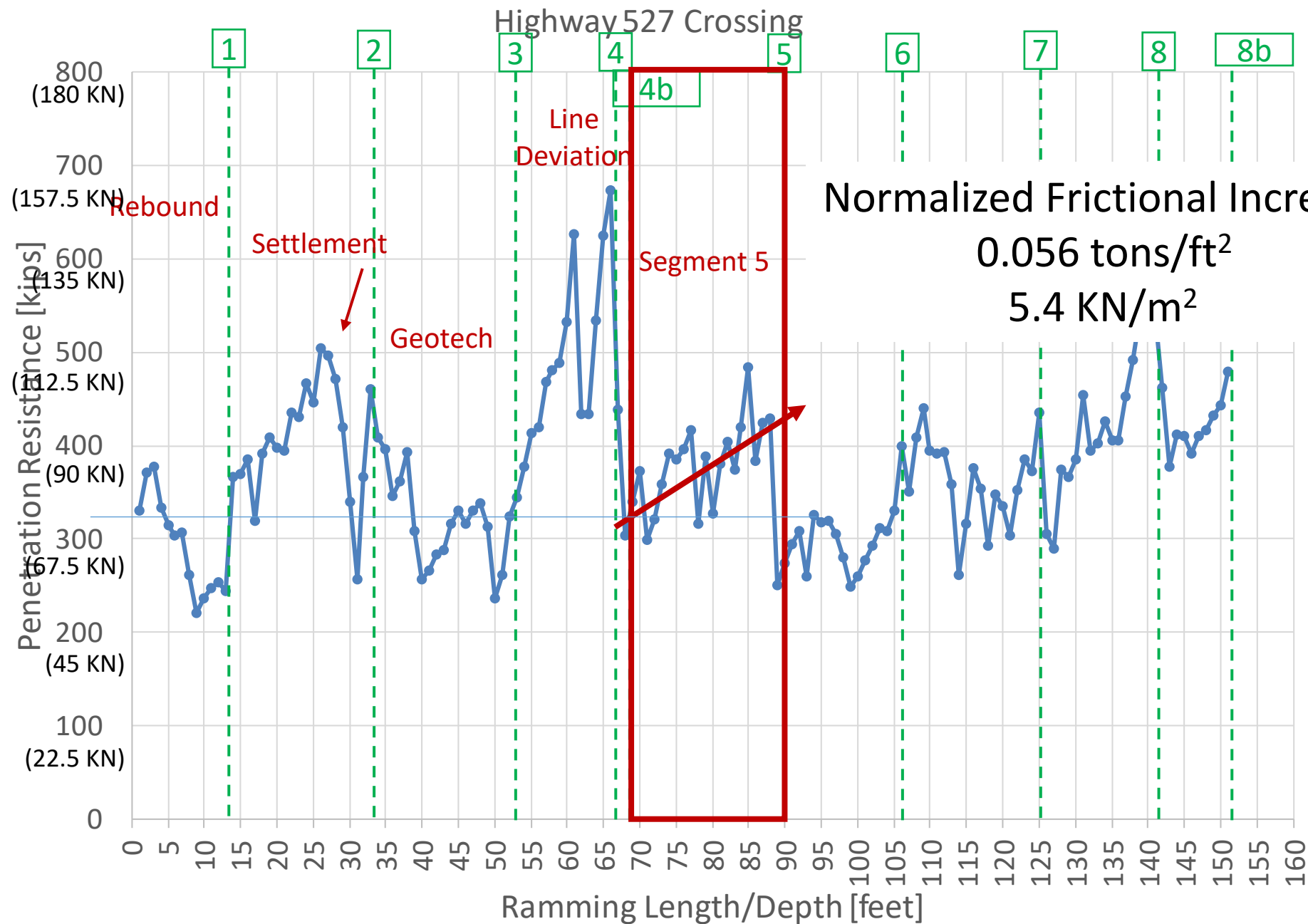
B.

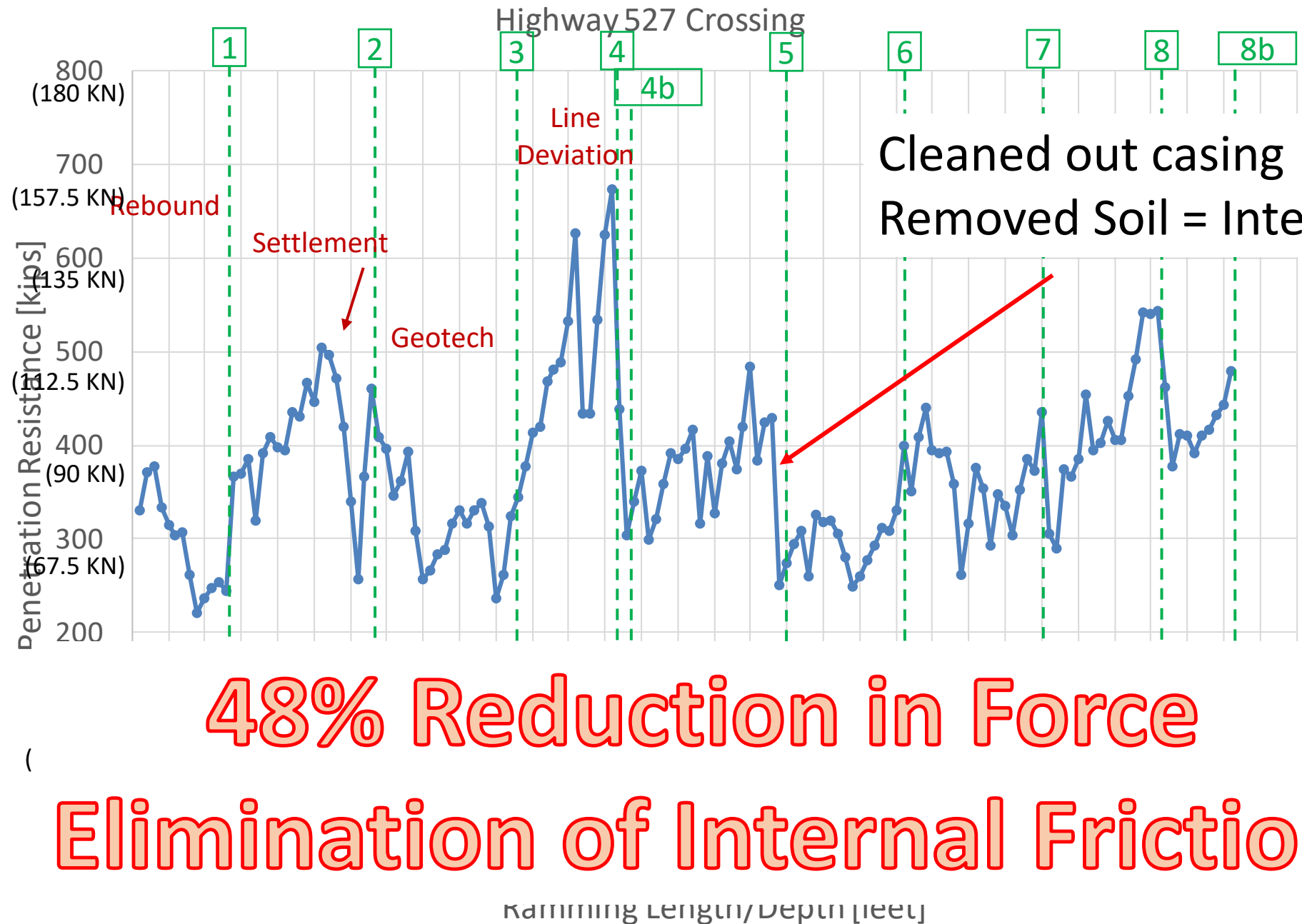


C.

56% Reduction in Force
Elimination of Internal Friction

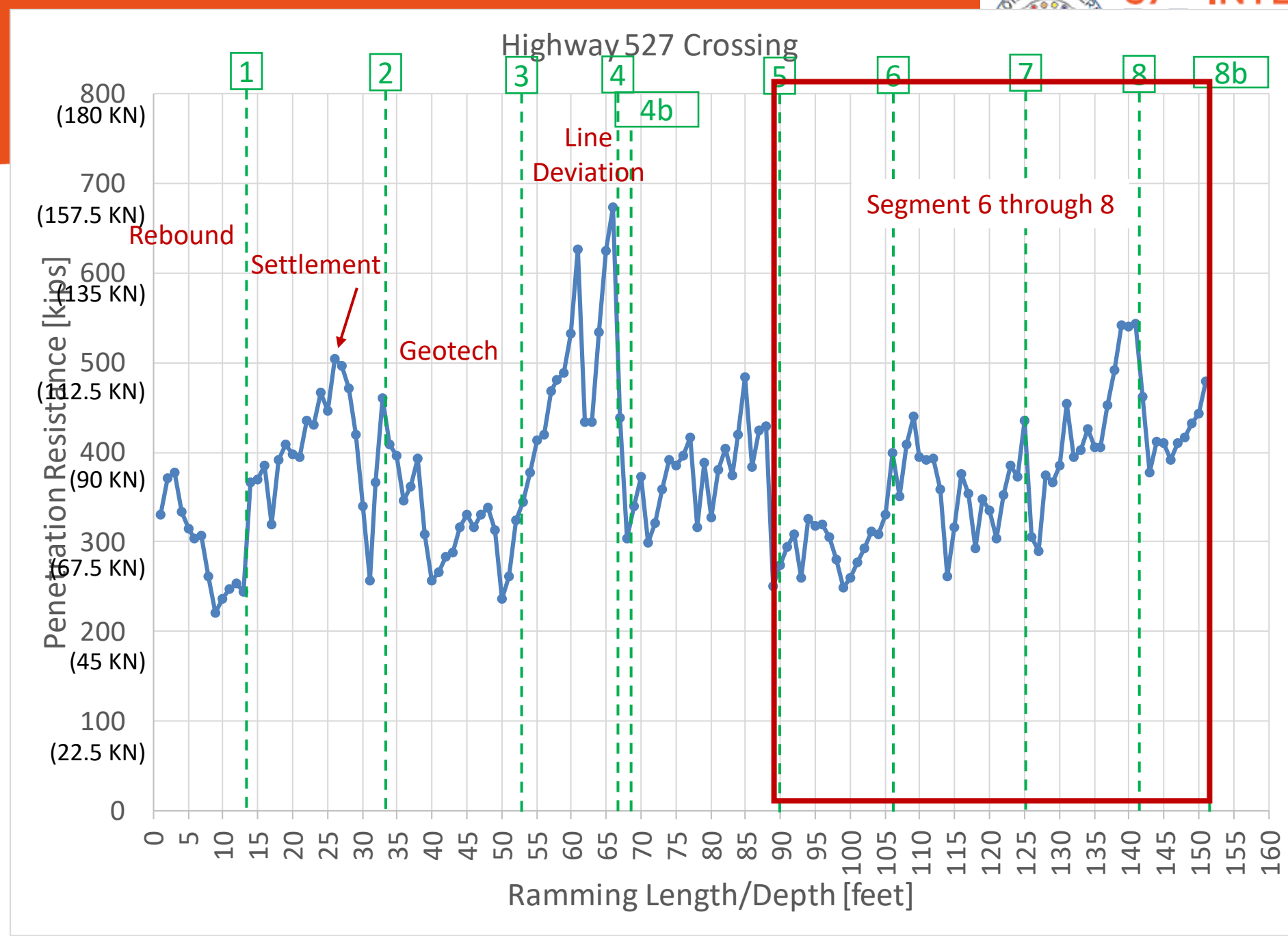
Ramming Length/Depth [feet]

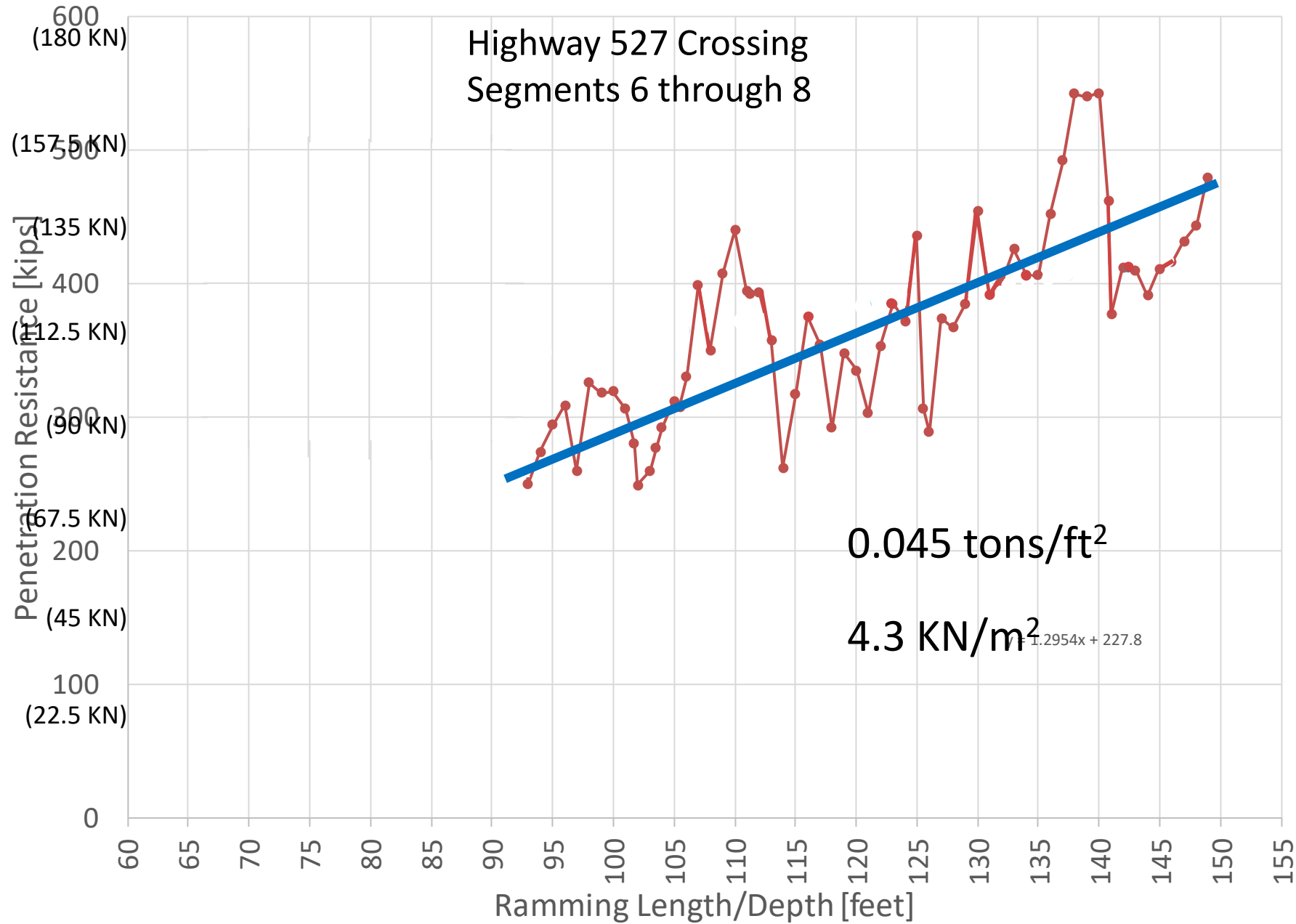




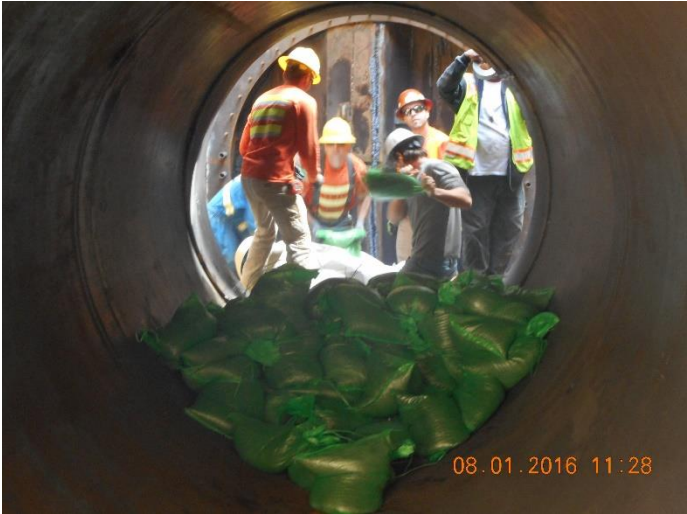
48% Reduction in Force

Elimination of Internal Friction





SILVER CREEK CROSSING

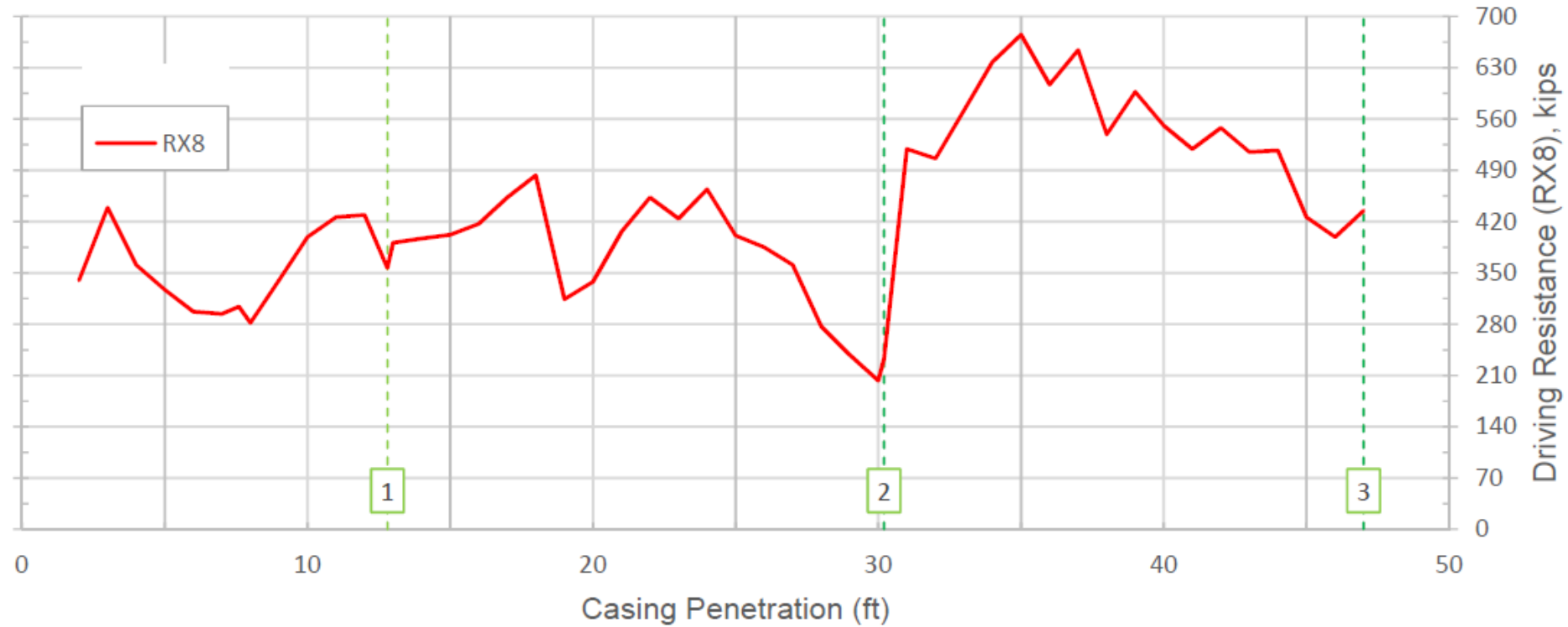


SILVER CREEK CROSSING

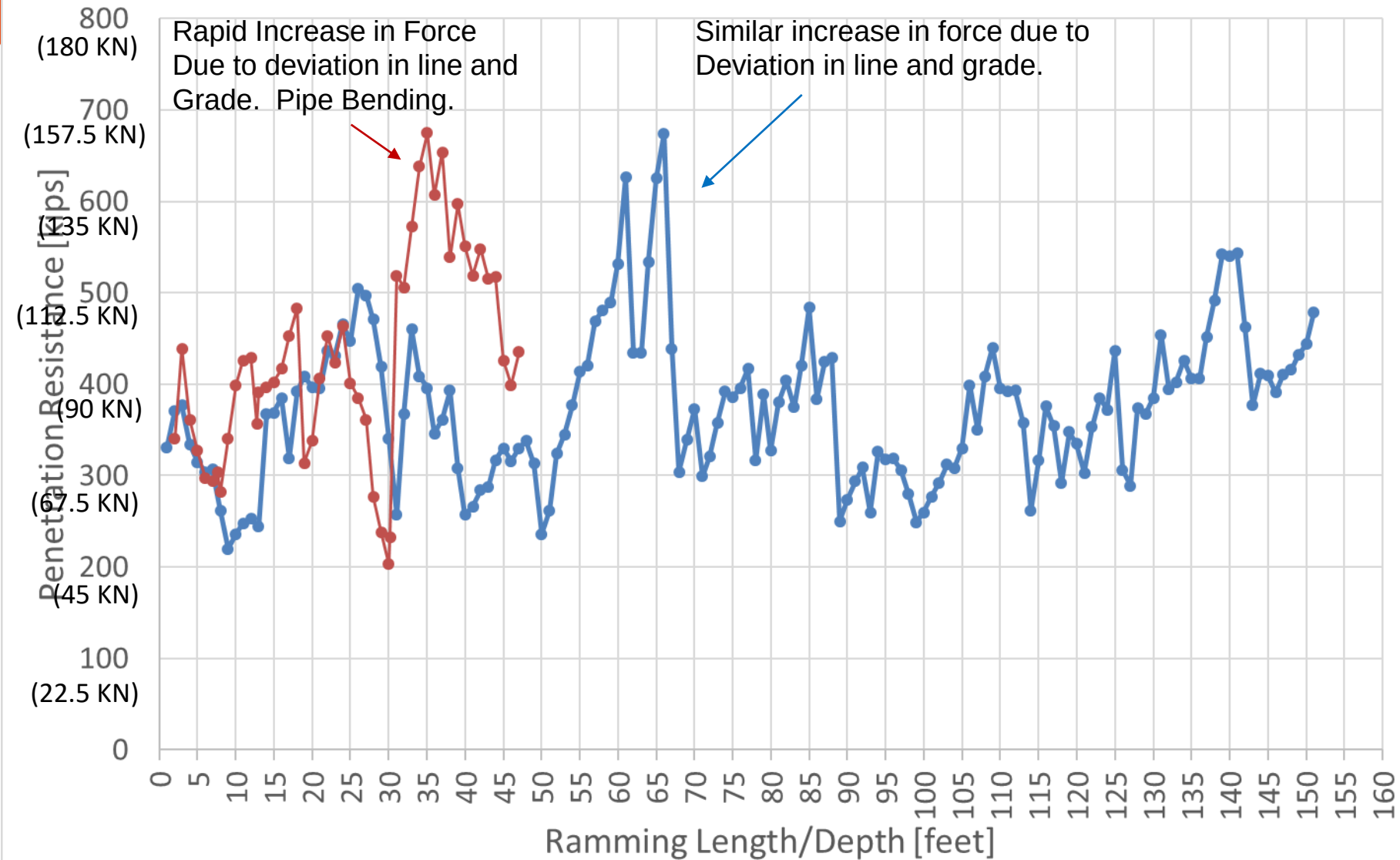
DRIVING RESISTANCE V. CASING PENETRATION



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SR 527 and Silver Creek Crossings Ramming Length v. Penetration Resistance



- Beginning to Understand Mechanisms Governing Pipe Ramming Behavior
- Interface Friction for Pipe
 - Very different for Ramming and Jacking
- Instrumentation reveals tremendous amount about ramming behavior
- More data analysis in process

MORE CONCLUSIONS...



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- Change in efficiency v. force at the shoe
 - Boulder v. Line/Grade Deviation
- Operator valued the information
 - Talk to instrumentation specialist during/after each pipe segment
- Instrumentation did NOT add to construction time but provided a lot of information for small cost
- Line and Grade Deviations???

THANK YOU

- Alderwood Water and Wastewater District
 - Seeing the Light
 - Trusting STC
 - Vision with Risk Management
- Kamloops Auger Boring
- ISTT

