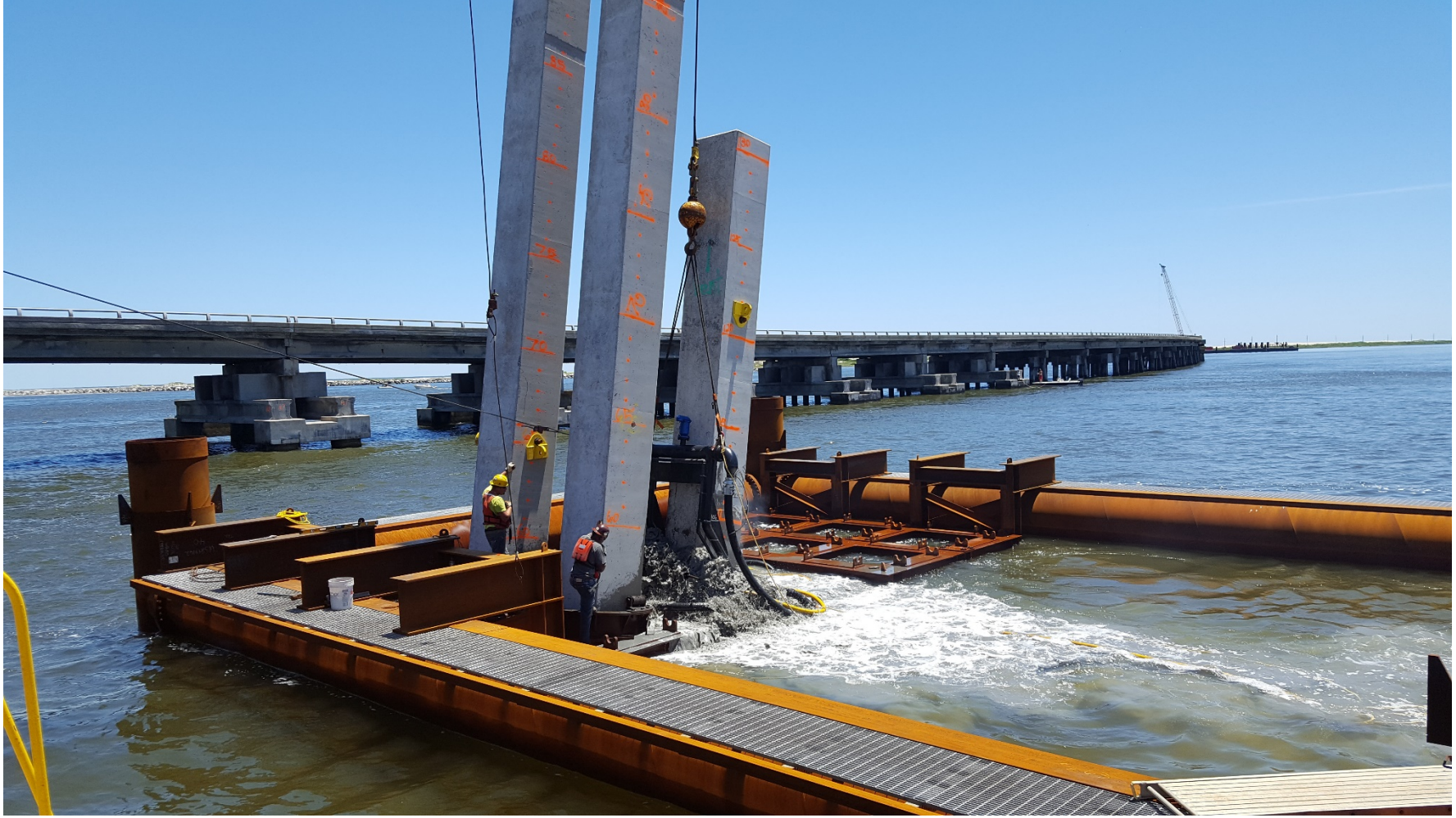


Comparison of Theoretical vs. PDA Measured Resistance for Jetted Piles

Mike Batten, PE
Beth Howey, LG, PE

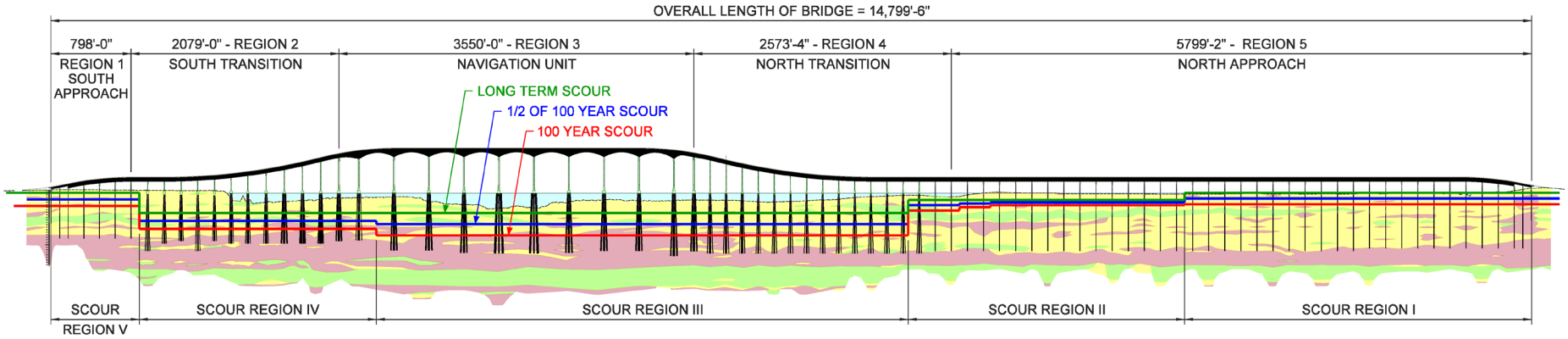
April 9, 2019

Outer Banks of North Carolina

Outer Banks of NC

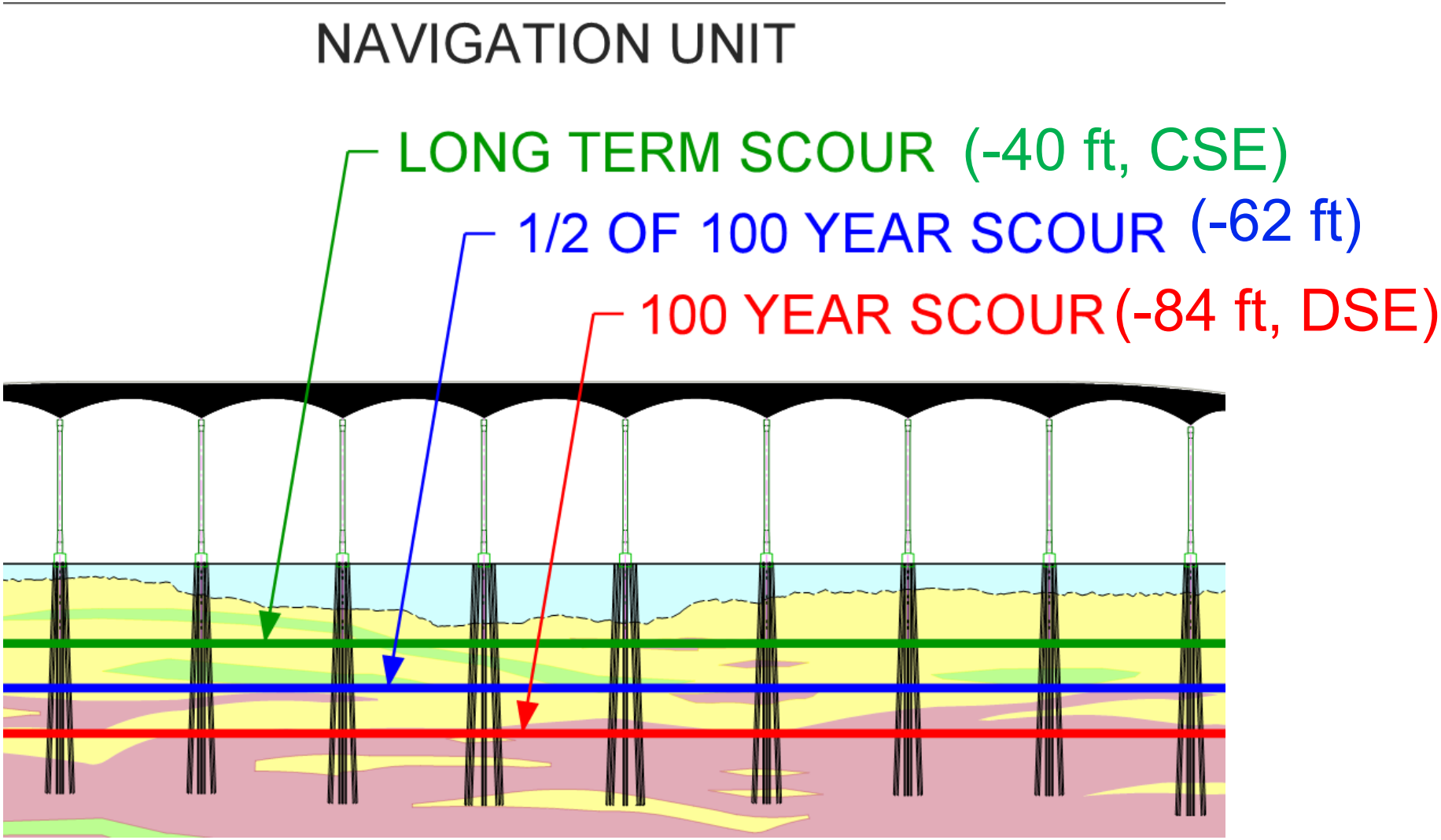
Existing Bonner Bridge Next to New Bridge

Existing Bonner Bridge Next to New Bridge



Profile of Bonner Bridge with Subsurface Information 82 Spans over 5 Regions

The profile along the bridge alignment shows silts and clays as green loose to medium dense sand as yellow, and dense to very dense sands as red.

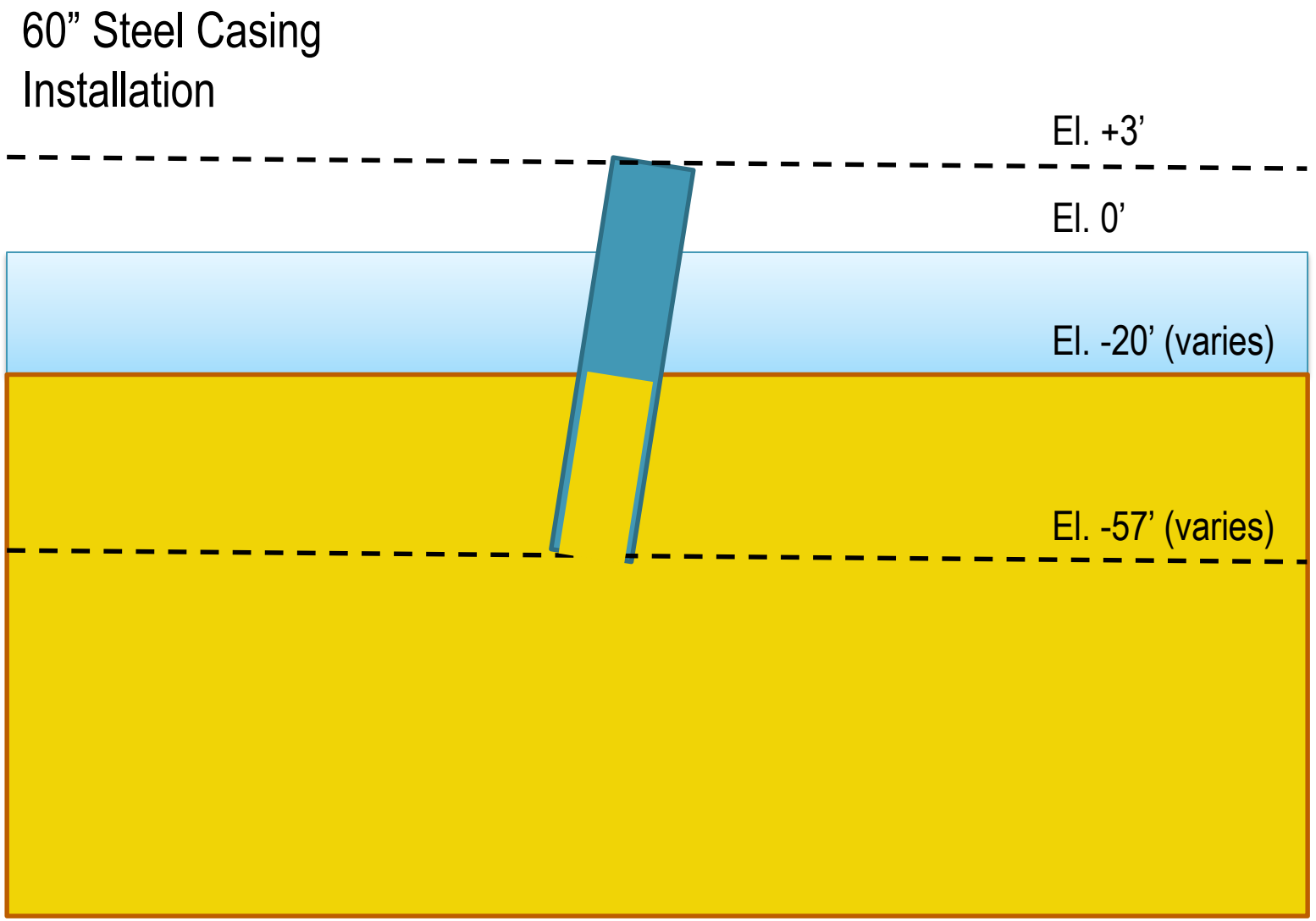


Subsurface Profile of Navigation Unit

36” Pre-stressed Concrete Piles

Jetting Utilized to Reach Minimum Tip Elevation

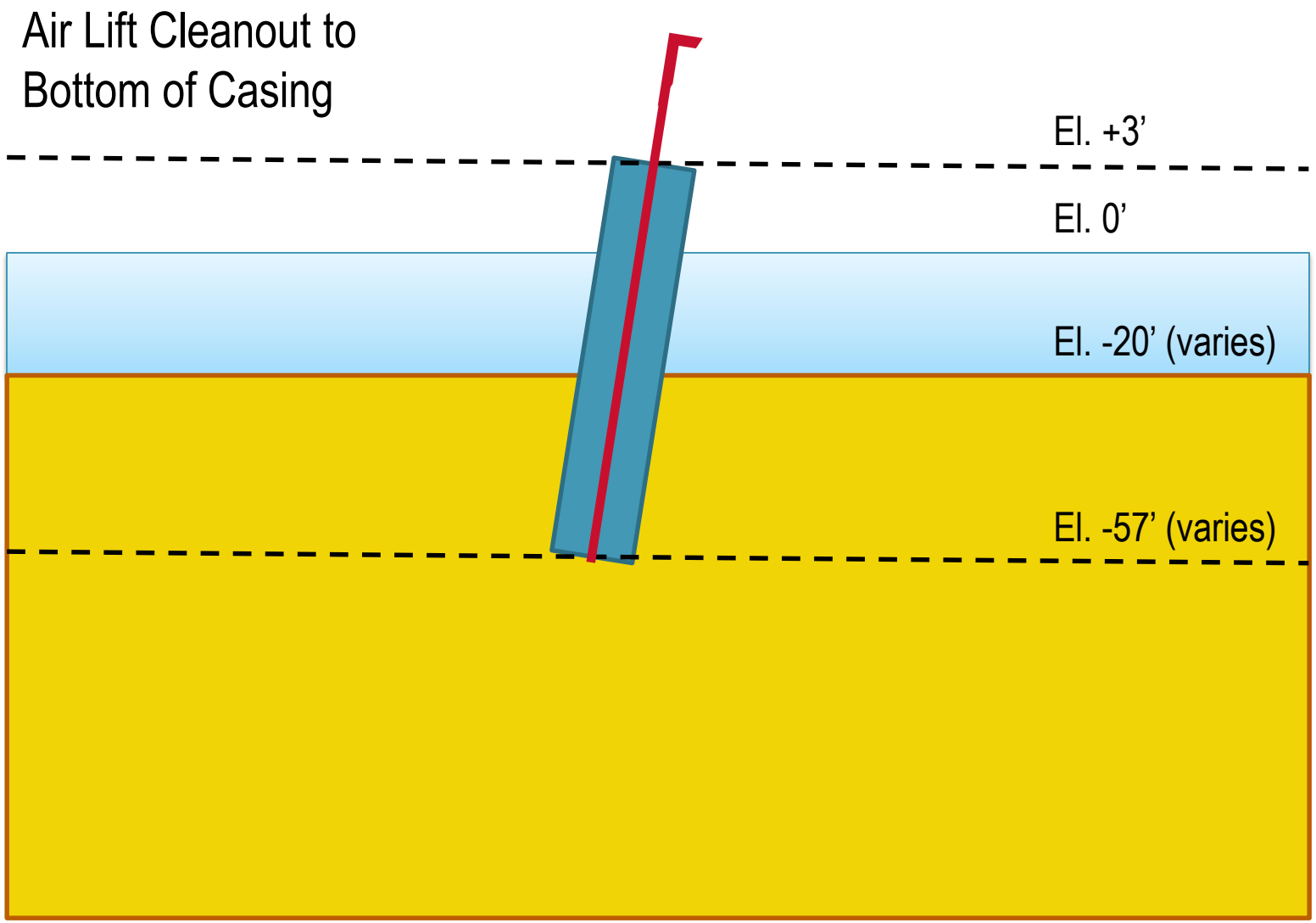
- Effects of jetting on axial resistance are not well documented
- Largely dependent on subsurface conditions and installation methods
- FHWA-NHI-16-009: “Poulos and Davis (1980) reported that the shaft resistance should be reduced by 50% of the originally calculated resistance in the jetted zone, if the pile is jetted and then driven to the final penetration.”
- Piles were jetted and then driven the last 10 to 20 feet



Pile Installation Procedure

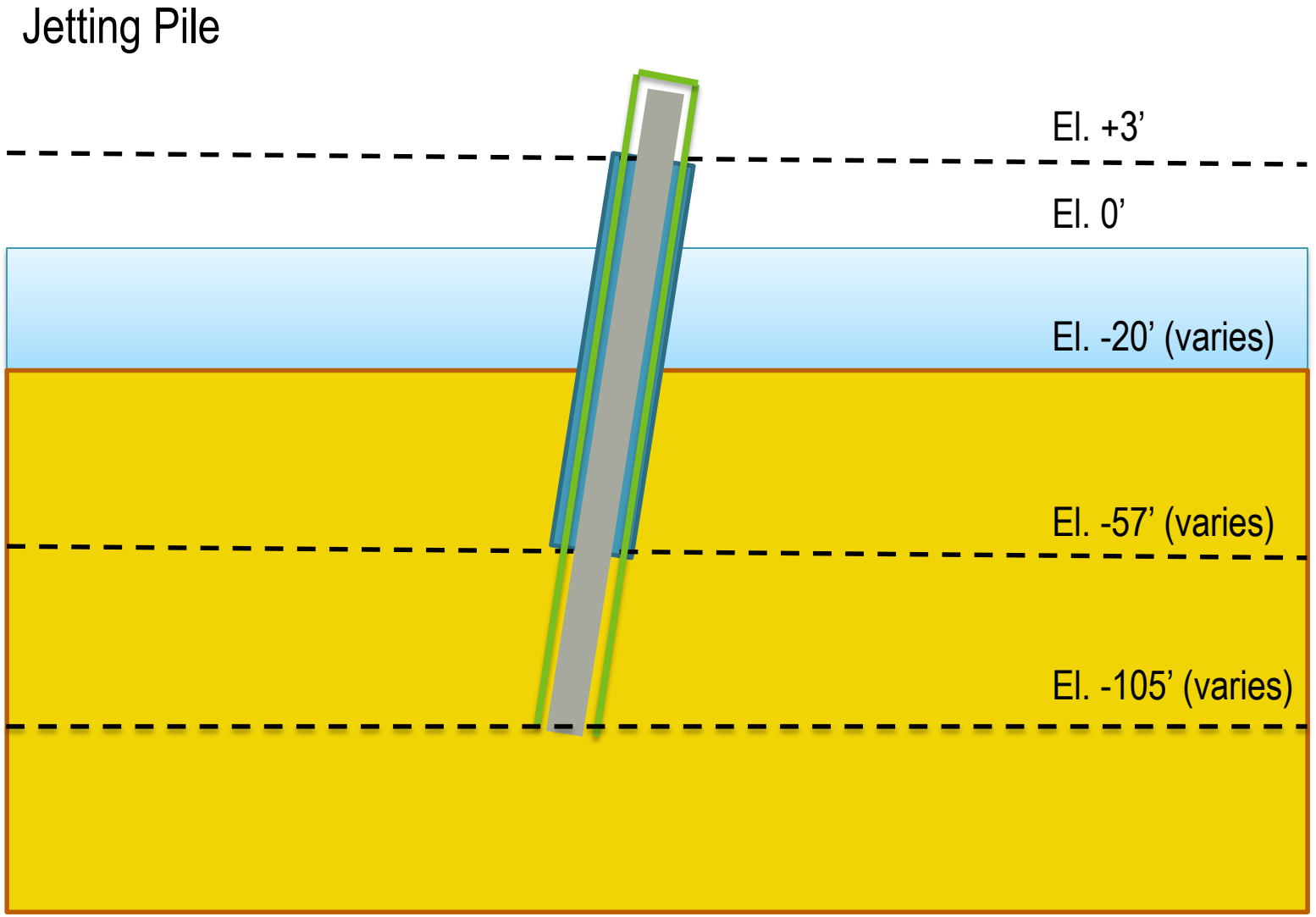
36” Pre-stressed Concrete Piles

Template with Casings Installed



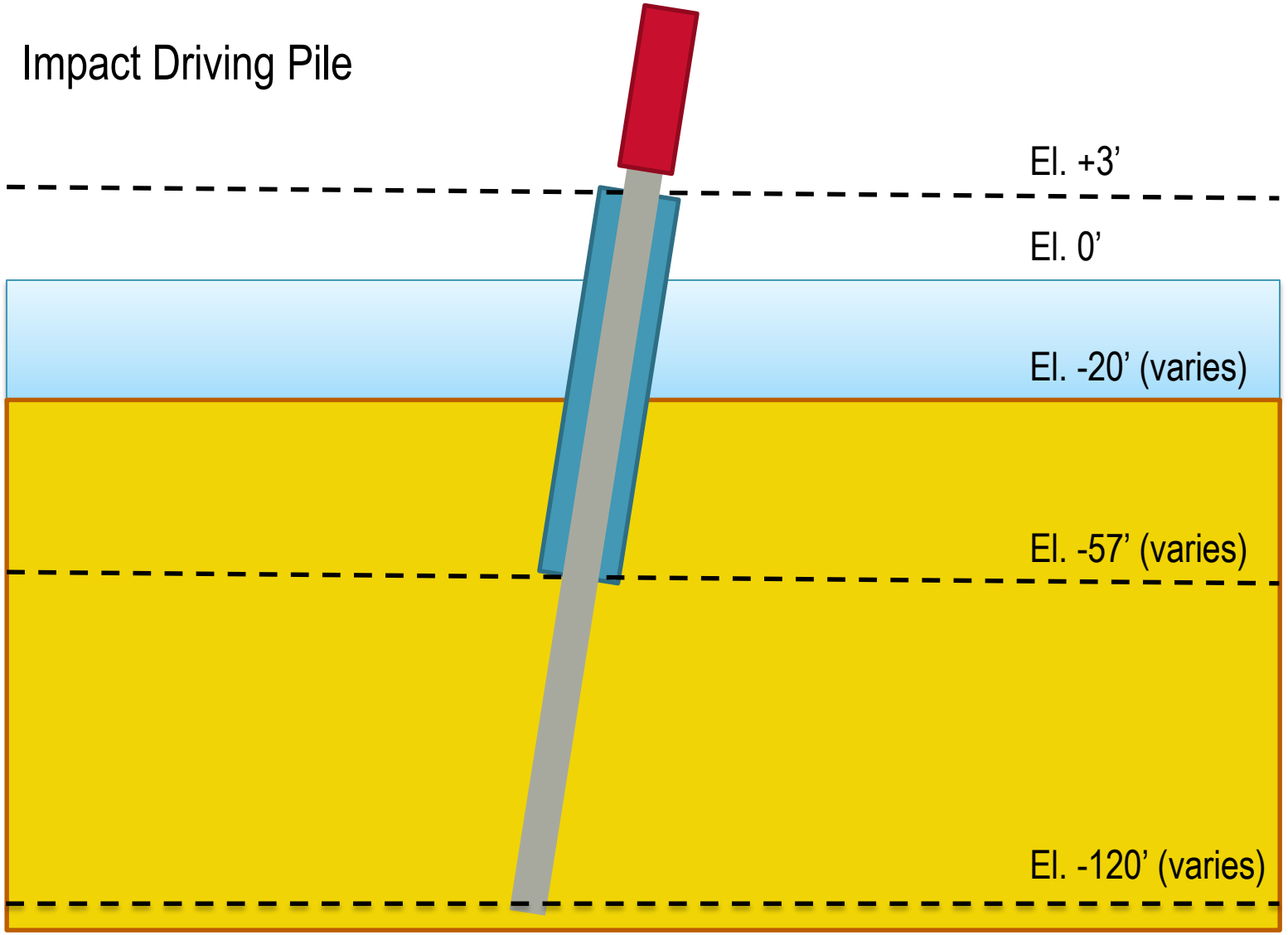
Pile Installation Procedure

36” Pre-stressed Concrete Piles



Pile Installation Procedure

36” Pre-stressed Concrete Piles



Pile Installation Procedure

36” Pre-stressed Concrete Piles

Ensoft's Program APILE was Utilized to Estimate Pile Resistance

- APILE 2015 Version was used
- FHWA Nordlund-Thurman and API RP2A Methods were used to estimate axial pile resistance – FHWA method used API limiting unit skin friction values
- With the API method, unit skin friction and unit end bearing values were both limited in the cohesionless soil in accordance with API guidelines

Unit Skin Friction Limits were applied

Soil	δ, degrees	Limiting f, kips/ft^2 (kPa)
Very loose to medium, sand to silt	15	1.0 (47.8)
Loose to dense, sand to silt	20	1.4 (67.0)
Medium to dense, sand to sand-silt	25	1.7 (83.1)
Dense to very dense, sand to sand-silt	30	2.0 (95.5)
Dense to very dense, gravel to sand	35	2.4 (114.8)

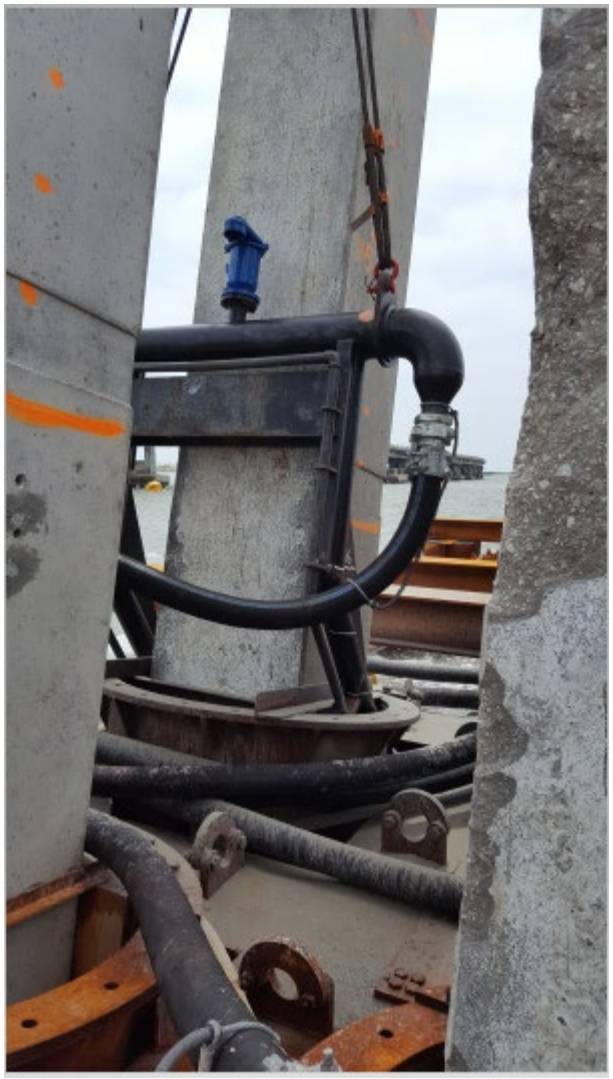
Unit End Bearing Limitations were Applied

Soil	N_q	Limiting q, kips/ft^2 (MPa)
Very loose to medium, sand to silt	8	40 (1.9)
Loose to dense, sand to silt	12	60 (2.9)
Medium to dense, sand to sand-silt	20	100 (4.8)
Dense to very dense, sand to sand-silt	40	200 (9.6)
Dense to very dense, gravel to sand	50	250 (12.0)

JET SYSTEM – utilized air and water

JET SYSTEM - top of jet string

JET SYSTEM – raising jet string



JET SYSTEM

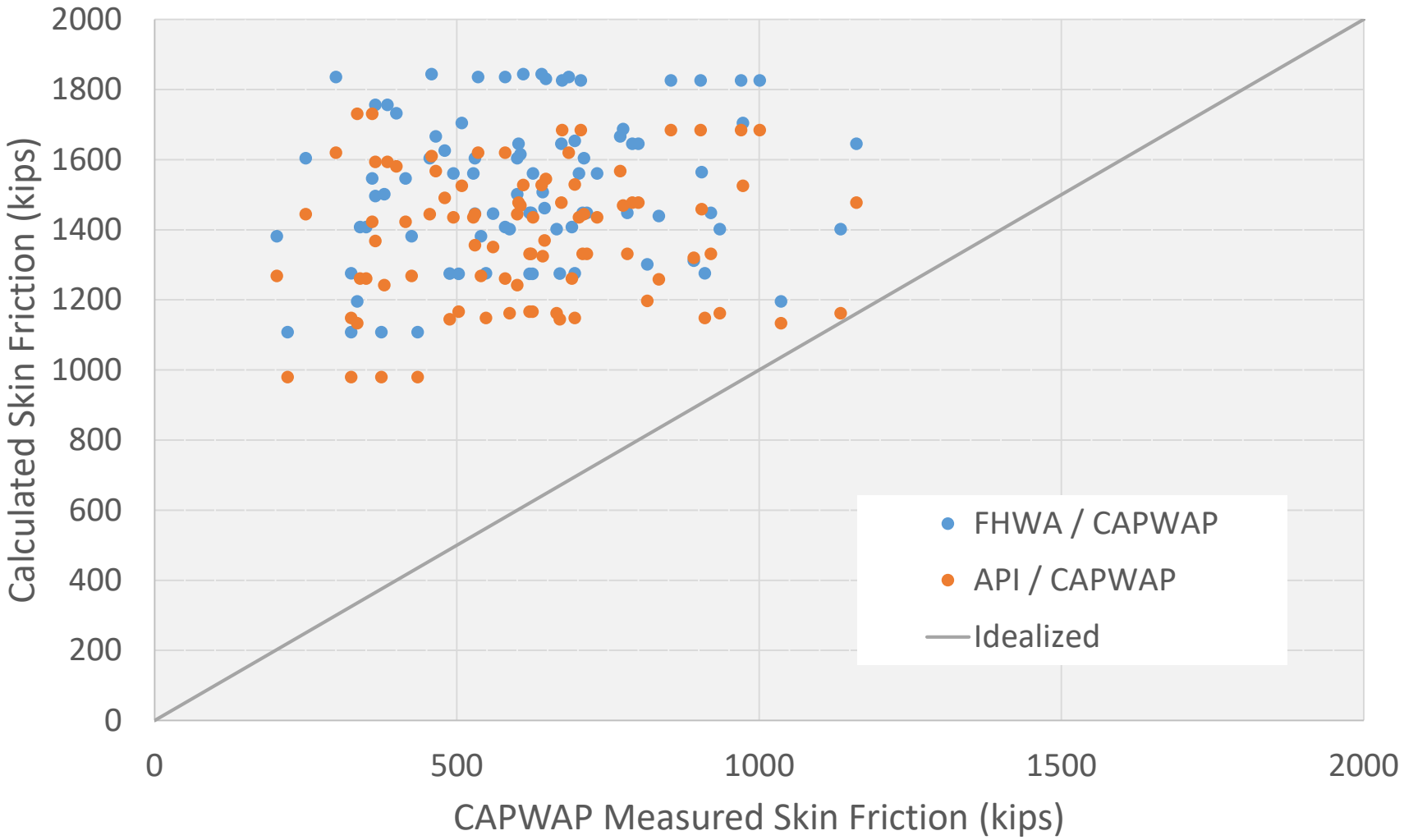
JETTING 36” SQUARE PILE

DRIVING 36” SQUARE PILE

Pile Dynamic Analyzer (PDA) Testing Performed

- 536 square P/S 36” concrete piles were installed
- 87 square piles were PDA tested at End of Initial Drive (EOID)
- 29 square piles were subjected to PDA testing at restrike – the majority of which were performed as part of re-jet/restrike study at Bent 22 or after jetting adjacent piles
- Square piles were generally evaluated at EOID – after set up, it was difficult to move the pile at restrike to mobilize and measure the full tip resistance

PDA Testing Results – Nominal Skin Friction

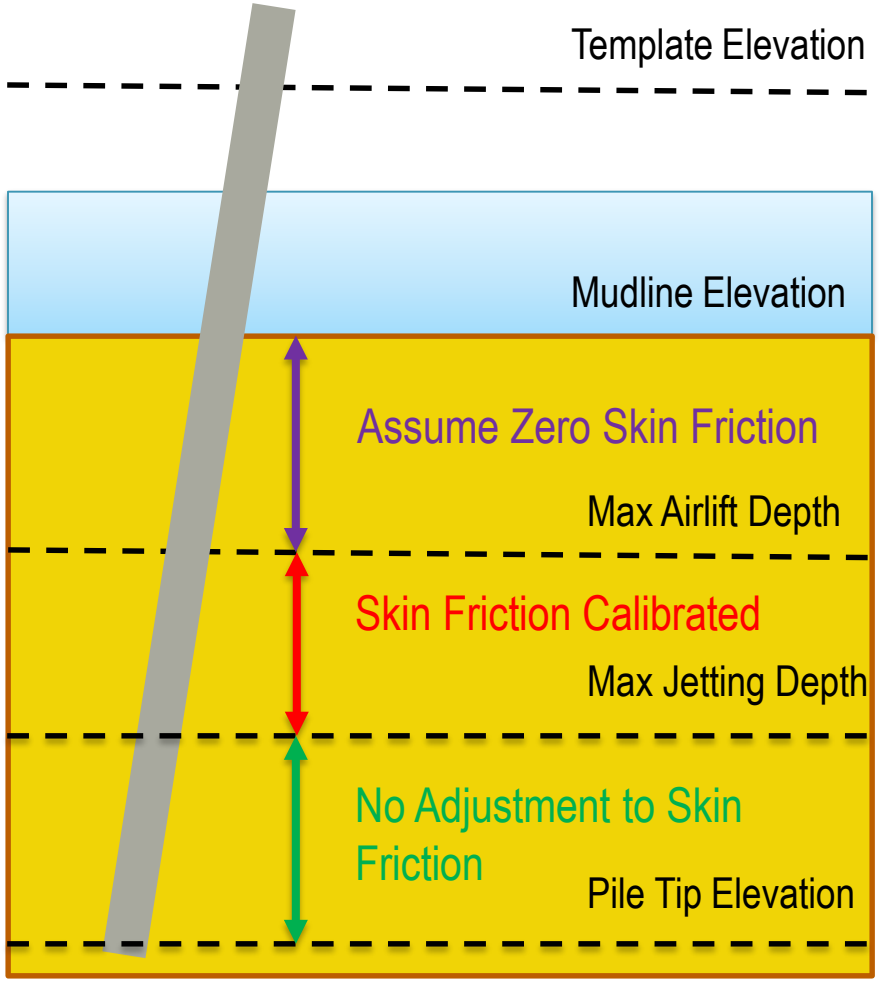


Skin Friction Comparison

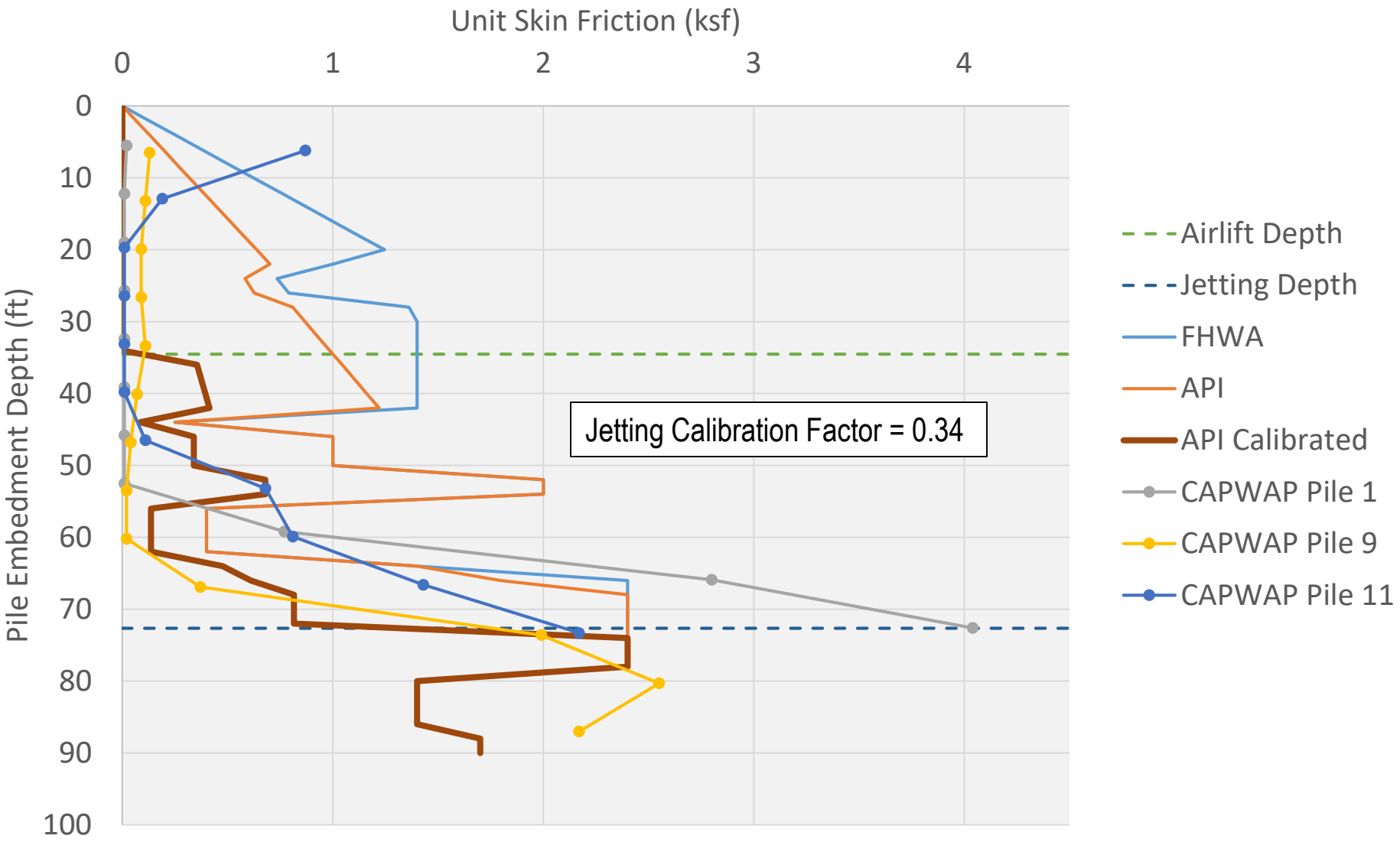
- Theoretical estimates of skin friction unconservative unless reduced substantially for jetting effects
- API method is more conservative than FHWA method but both methods significantly overpredicted skin friction
- One bent selected from South Transition, Navigation Unit, and North Transition to develop theoretical adjustment factor for unit skin friction to account for jetting effects

Skin Friction Calibration for Jetting Effects

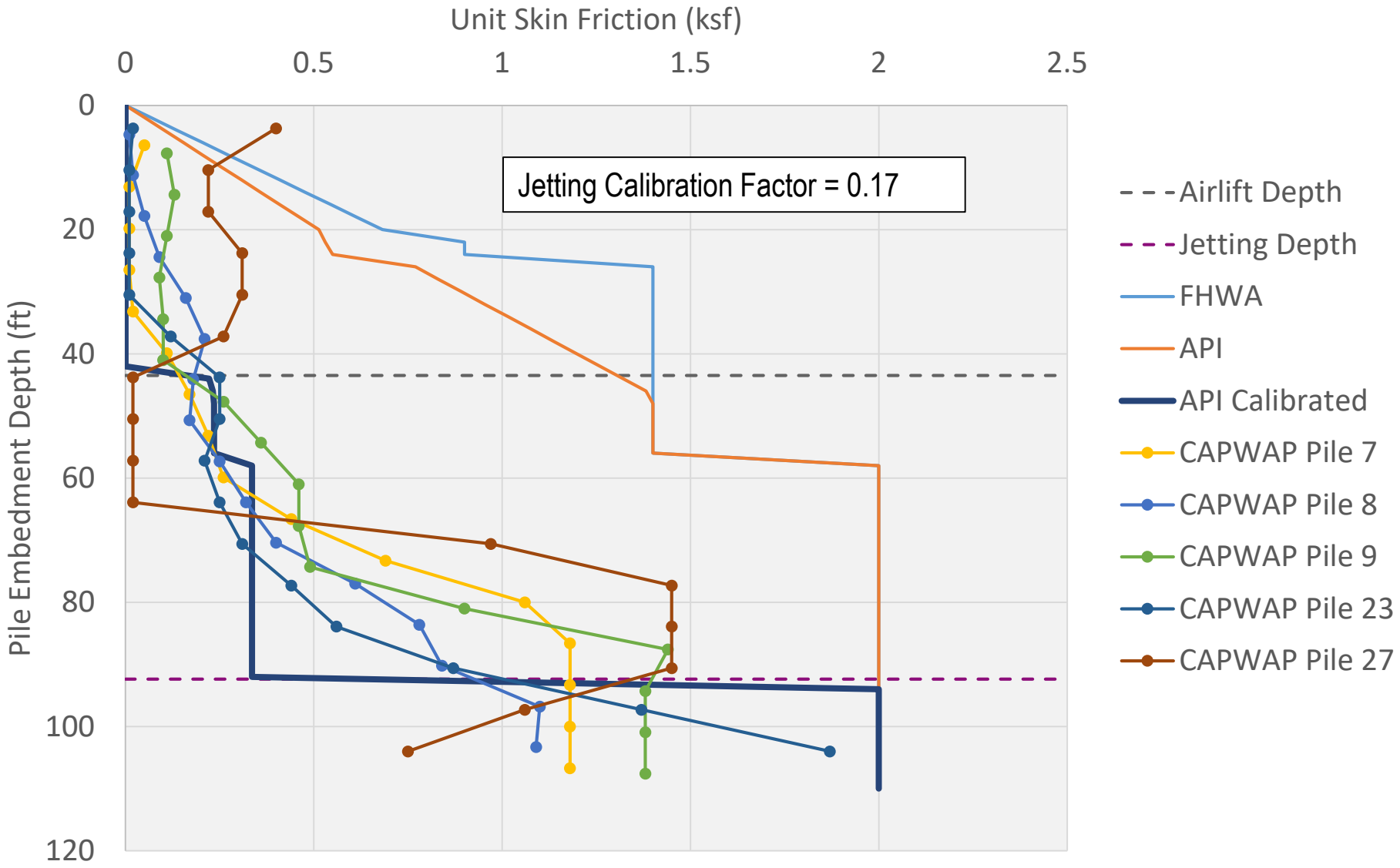
- API method calibrated using these parameters:
  - Assume zero unit skin friction from mudline to max airlift depth
  - Multiply unit skin friction by a **factor** from max airlift depth to max jetting depth
  - No adjustment applied to unit skin friction from max jetting depth to pile tip elevation



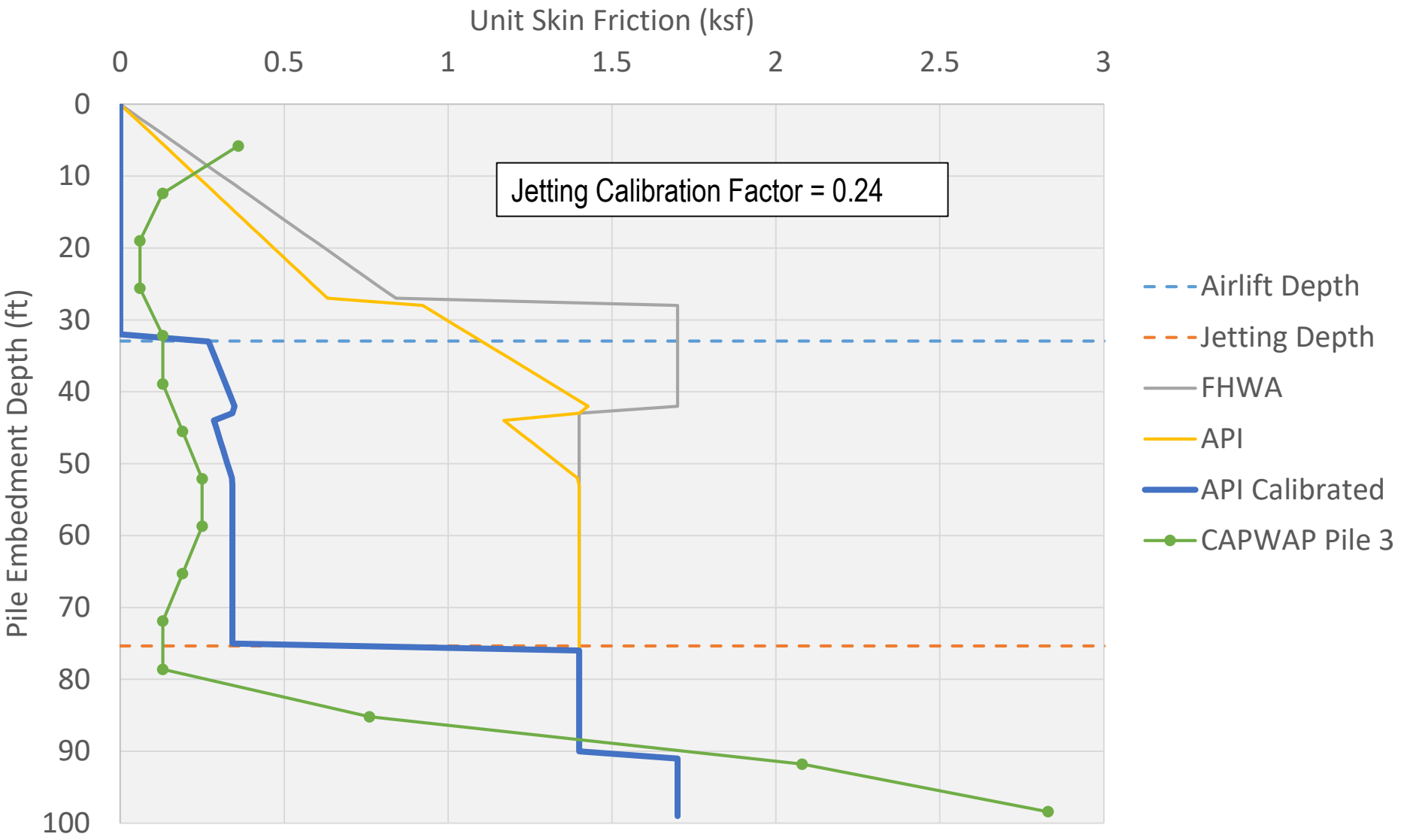
PDA Testing Results – Bent 14



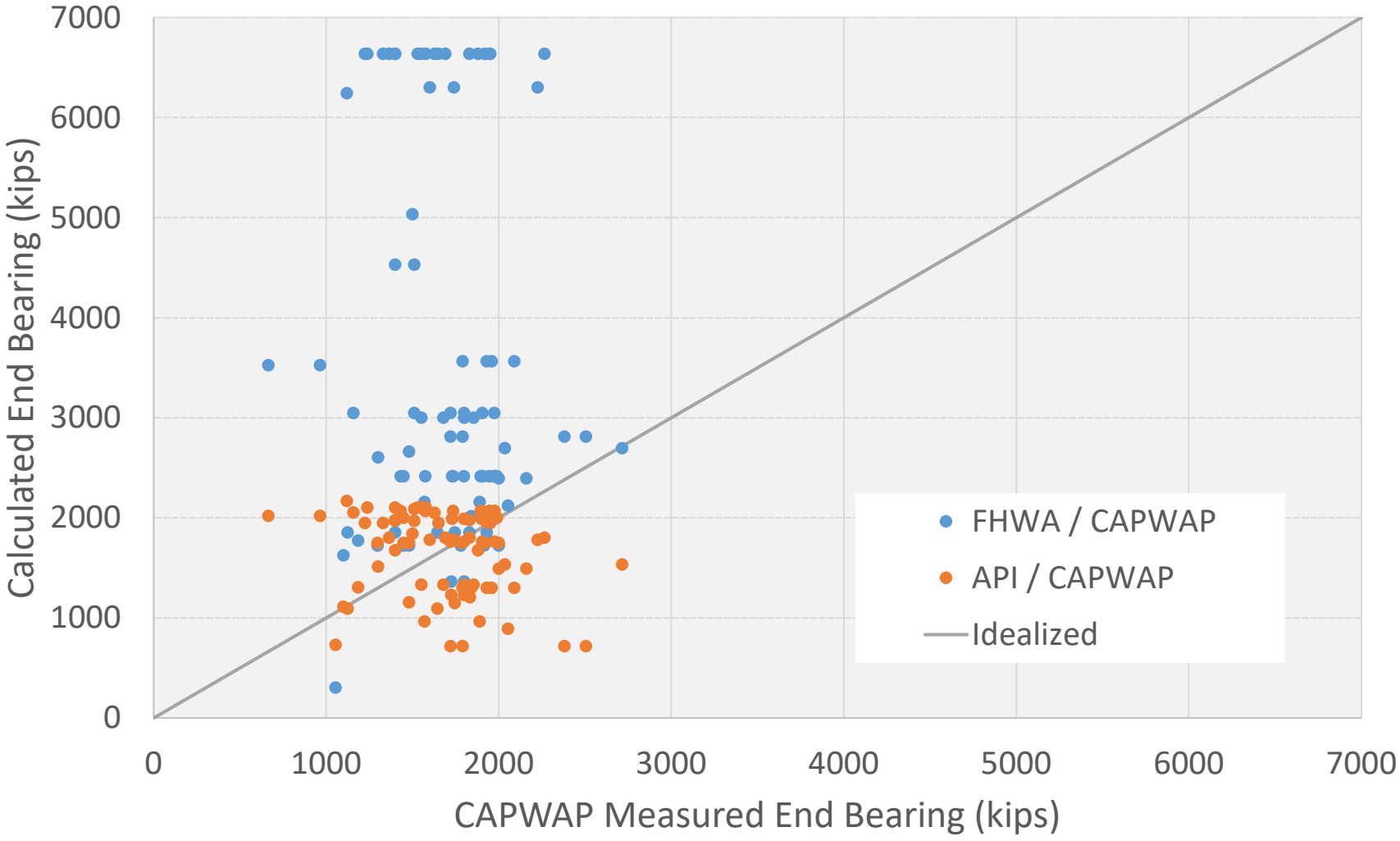
PDA Testing Results – Bent 23



PDA Testing Results – Bent 37



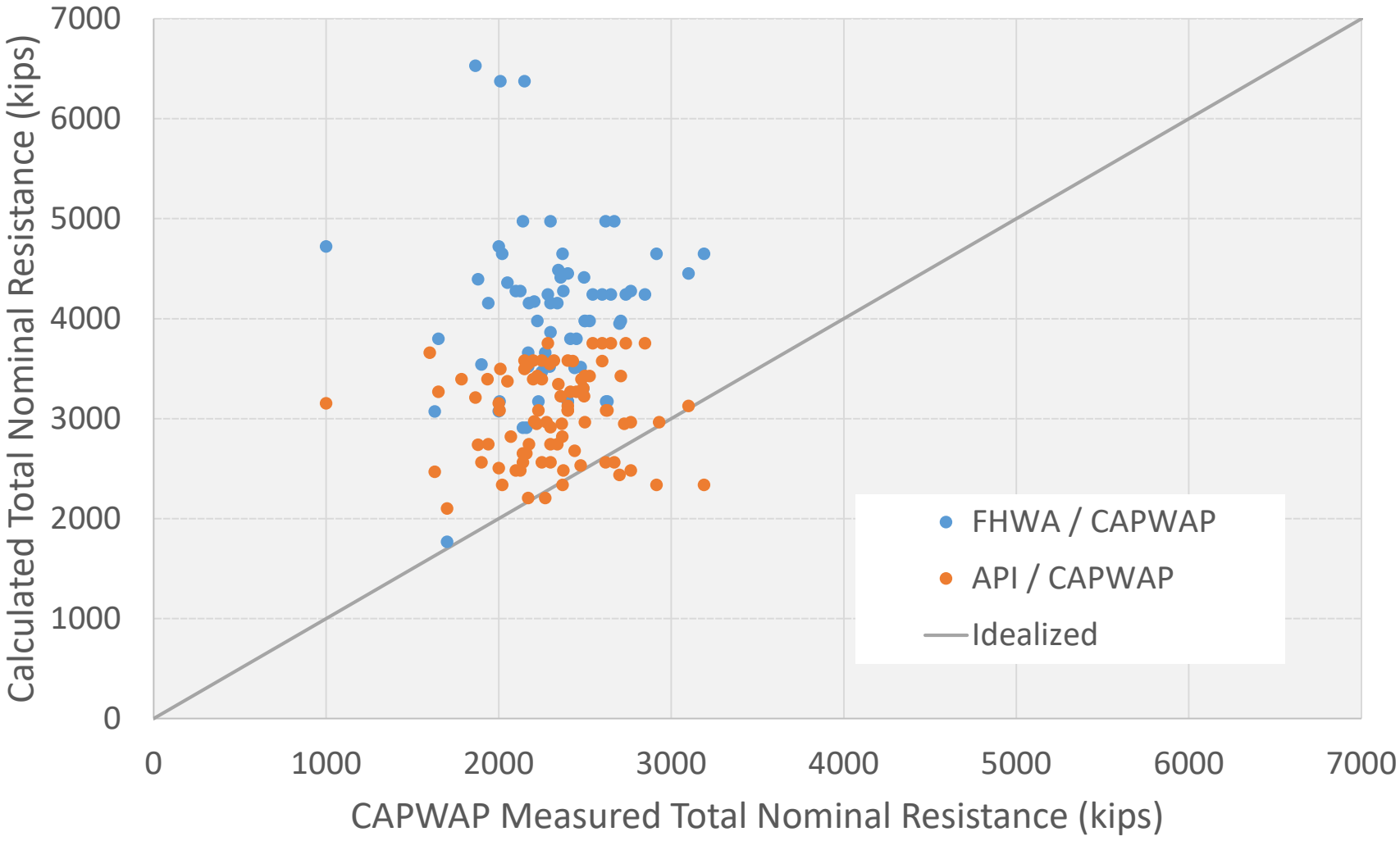
PDA Testing Results – Nominal End Bearing



End Bearing Comparison

- FHWA Nordlund-Thurman method is very unconservative for large diameter displacement piles
- API method is more realistic, but scatter is widely varying
- Additional research needed to evaluate jetting effects on end bearing resistance of large diameter piles

PDA Testing Results – Total Nominal Axial Resistance

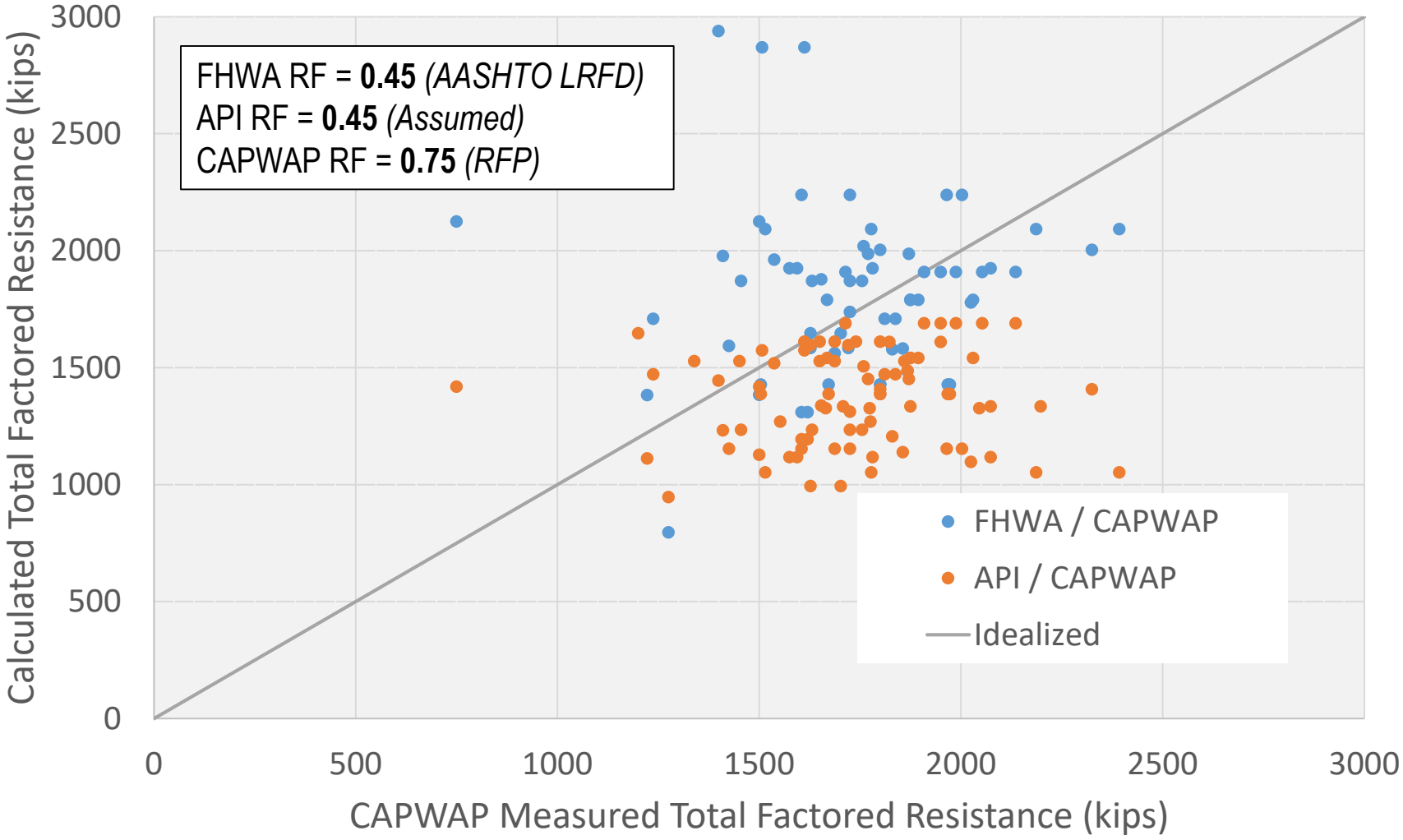


Nominal vs. Factored Axial Resistance

- During design phase, 0.45 resistance factor was used for FHWA Nordlund Method per AASHTO LRFD
  - Used to determine if pile length at minimum tip elevation was sufficient to provide required nominal axial resistance

- During production installation 0.75 resistance factor was used for CAPWAP results per RFP
  - Used to verify required nominal axial resistance in the field

PDA Testing Results – Total Factored Axial Resistance



Conclusions

- Tip elevations were controlled by lateral stability due to very deep scour so overestimated axial resistance was not an issue

- Accurately estimating axial resistance of large diameter displacement piles requires local experience – critical to assume upper bound unit end bearing resistance values for soil, API guidelines recommended

- Skin friction around jetted piles can vary widely based on jetting method, test time after jetting complete, pile driving distance – critical to reduce theoretical estimates significantly (by ~65% to 85% based on sample of tested values)


QUESTIONS?