Photo courtesy of James Construction Group

# LA-1 RELOCATED: TWO DECADES AND STILL GOING

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LADOTD
STGEC 2025-09-17

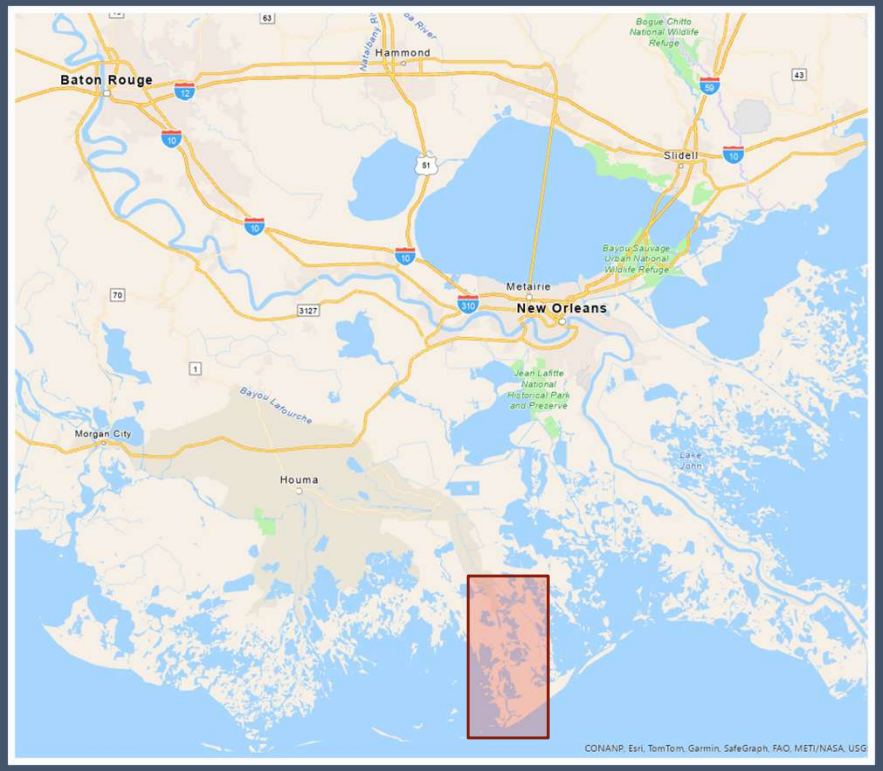
# PRESENTATION OUTLINE

- Project Background
  - Geotechnical Investigations
- Embankments & Fill
  - Embankment Settlement
  - Cracked Piles and Haul Road
- Pile Design
  - Test Pile Program
  - CPT Direct Design Methods
  - Other Design Challenges
- Pile Monitoring & Acceptance
  - Pile Setup & Dynamic Monitoring
  - Pile Splices

# PROJECT BACKGROUND

# PROJECT SUMMARY

- 19.3 miles of elevated highway between Golden Meadow & Port Fourchon
- Supports (per LA-1 Coalition):
  - 16% of nation's domestic crude oil production
  - 4% of nation's natural gas production
  - 20% of nation's seafood production
  - Hurricane evacuation for Grand Isle residents & offshore workers
- Susceptible to storm surge flooding




Project Location: Lafourche Parish, LA

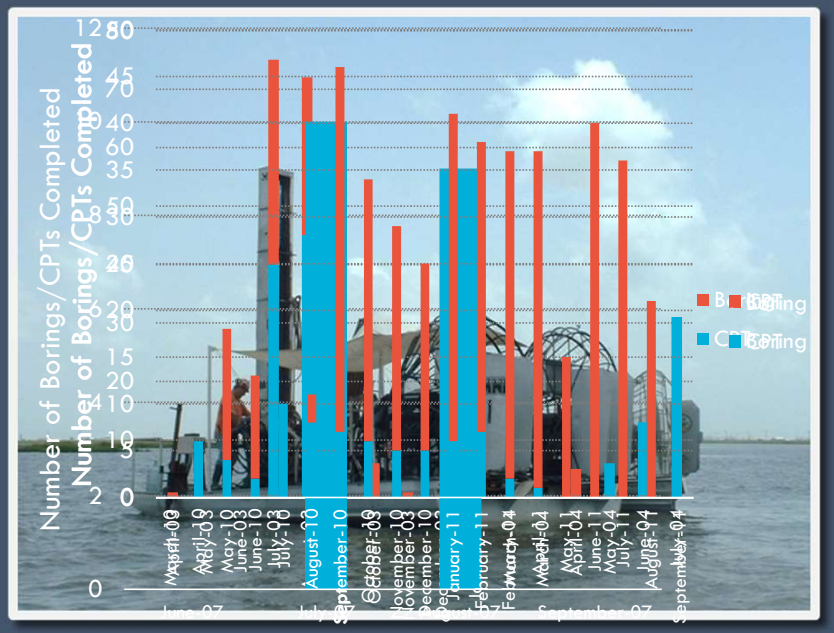
# CONSTRUCTION TIMELINE

- Phase 1: $338.5m (completed 2011)
  - Pre-construction (before 2006): $43.3m
  - Segment B (2006-2009): $141.4m
  - Segment C (2006-2009): $21.1m
  - Segment A (2007-2011): $132.7m
- Phase 2: $479.5m (60% complete)
  - Segment E (2018-2020): $13.4m
  - Segments A-D (2022-now): $466.1m

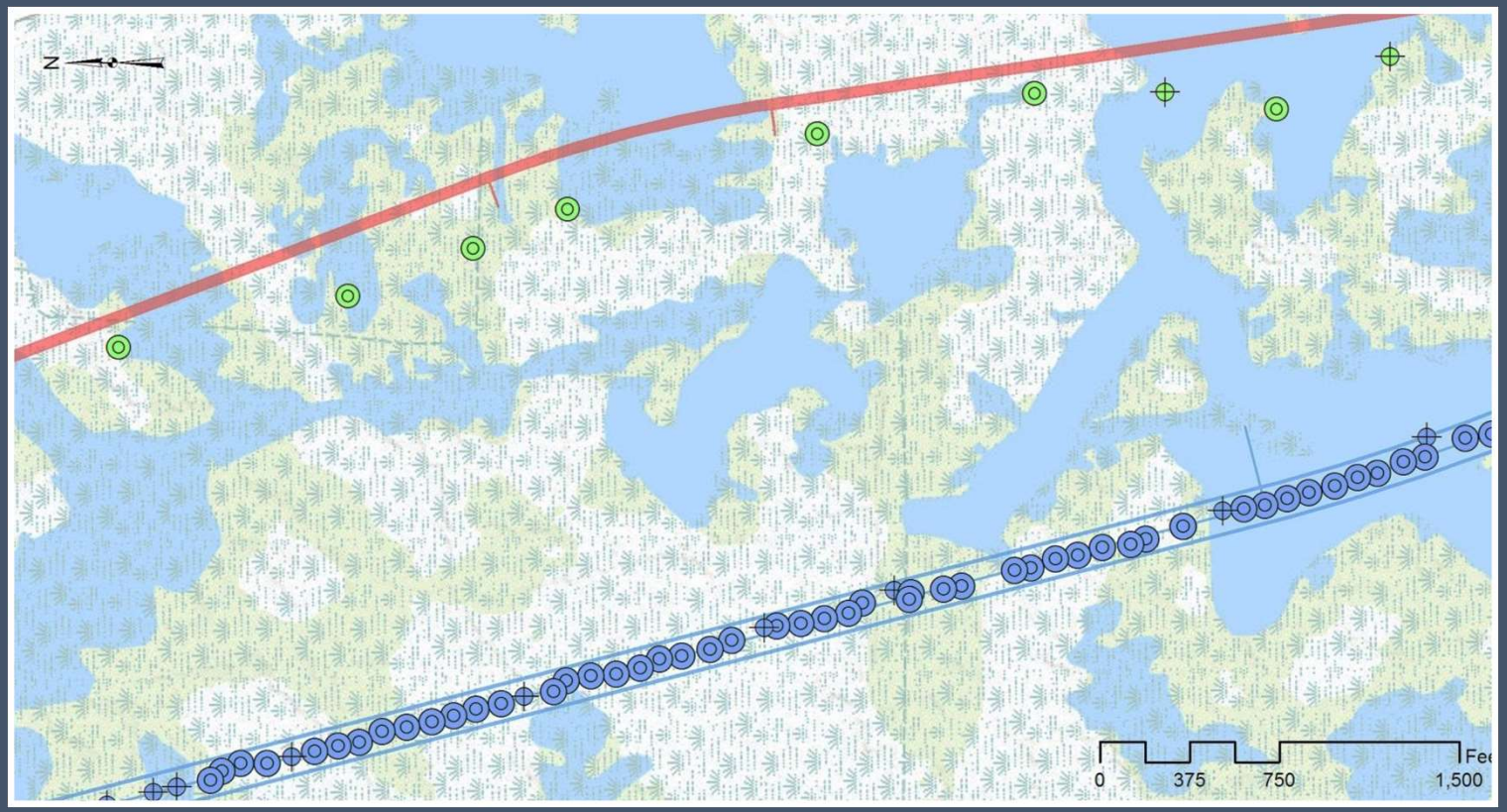

Project Alignment & Phasing

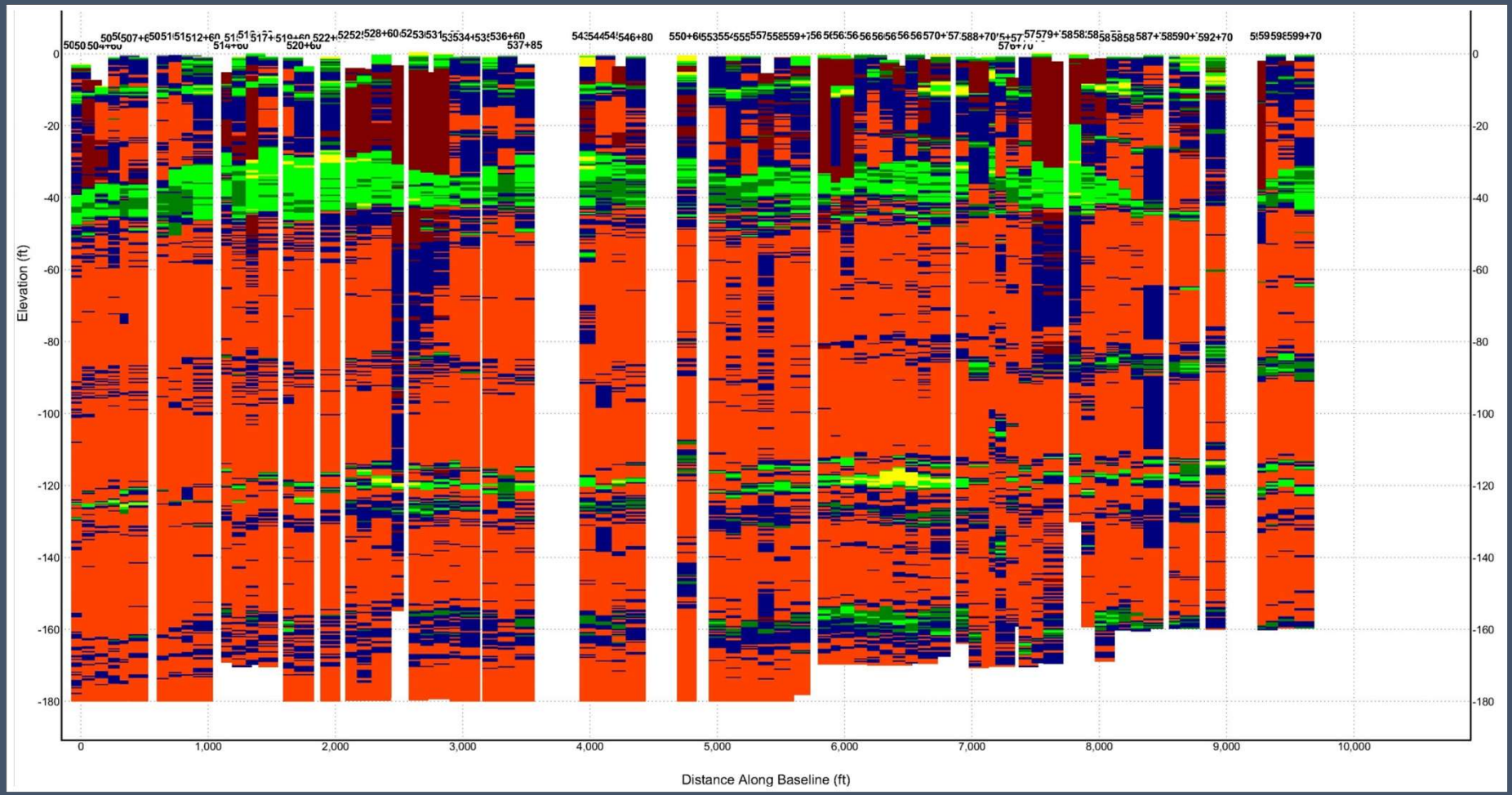
# GEOTECHNICAL INVESTIGATION

- 169 Borings / 562 CPTs made from truck rig, twin-engine airboats, & 4-engine airboats
- Phase 1B/1C
  - 100 soil borings, 155 CPTs
- Phase 1A
  - 19 CPTs
- Phase 2
  - 69 soil borings, 388 CPTs



# EXISTING DATA: SOIL BORINGS



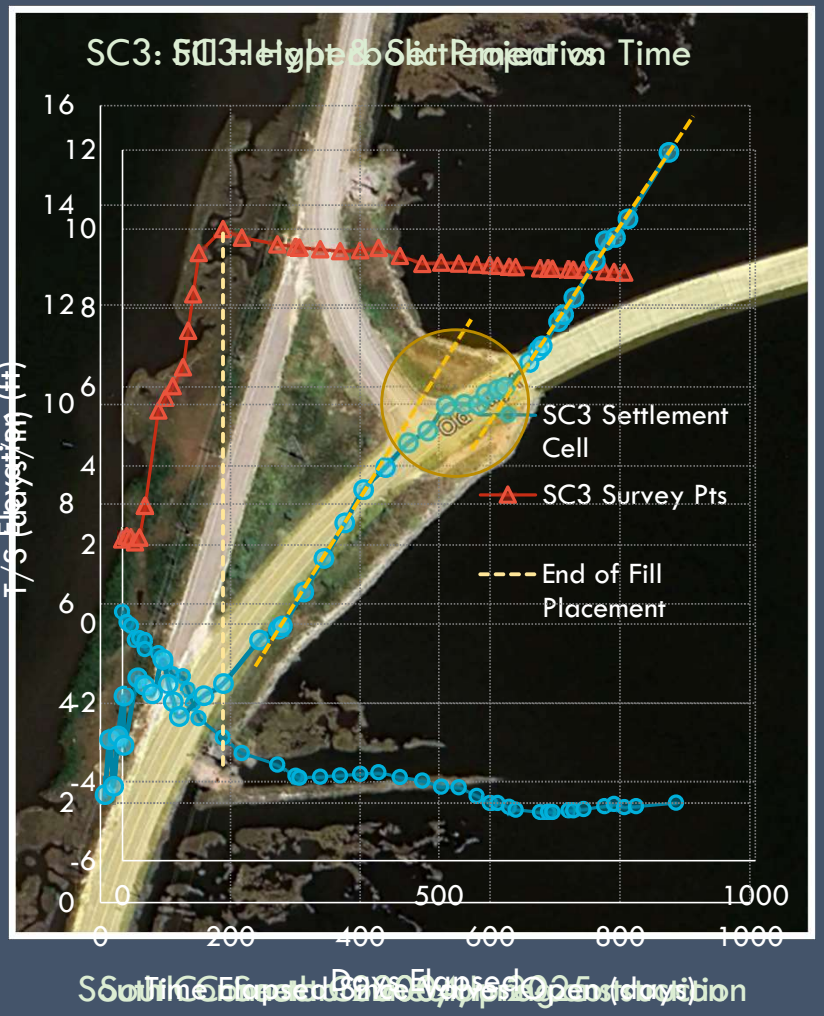


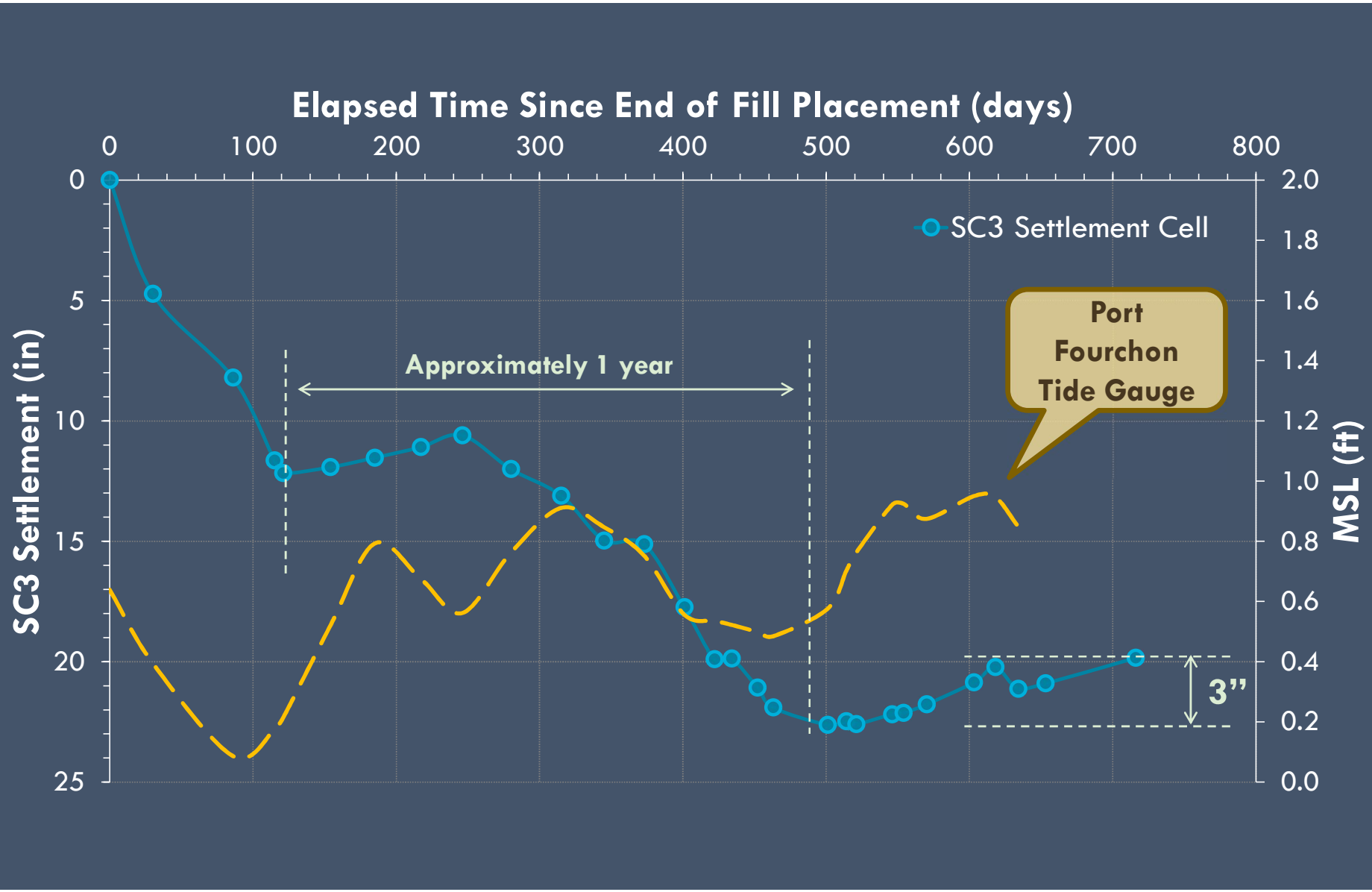

Classification from CPT Soundings Across the Phase 2 Alignment

# EMBANKMENTS & FILL

# EMBANKMENT SETTLEMENT

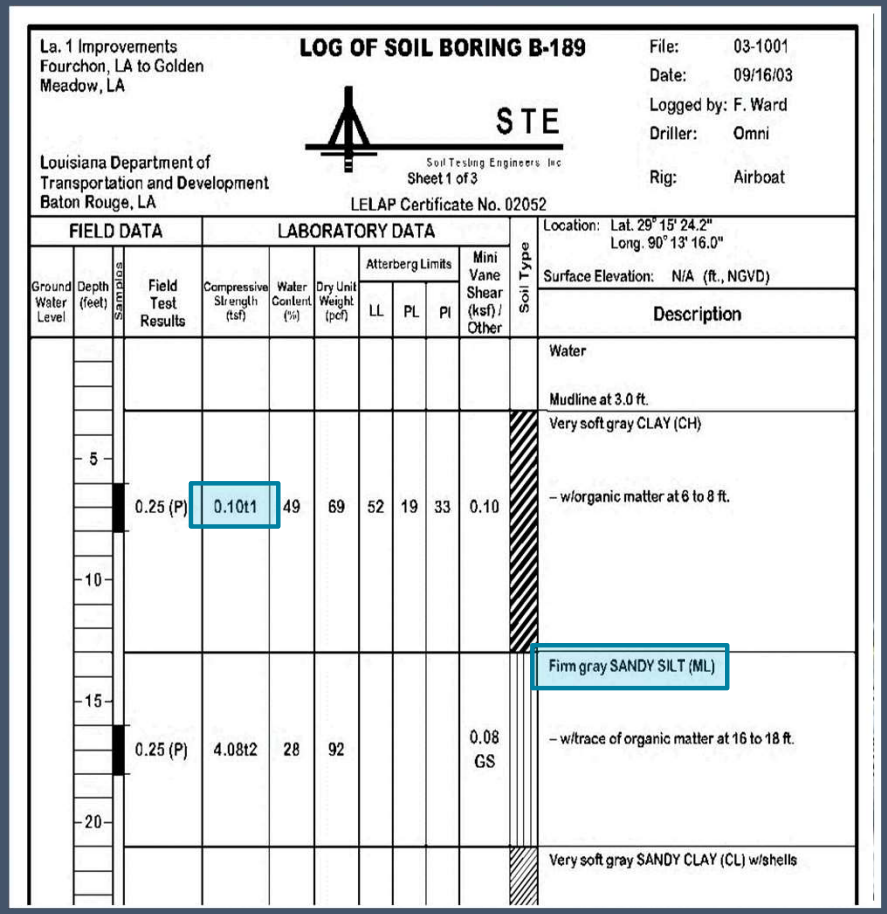
- Embankment needed to transition existing at-grade LA-1 to pile-supported structure
- Design estimates:
  - Needed 4-5' of elevation change
  - Settlement equal to fill added (γ=120 pcf)
- Mitigate with surcharge, wick drains, & lightweight aggregate
- Vibrating wire settlement cells were used to monitor settlement
- Used Hyperbolic Projection to estimate δ @ $T_{100}$
  - What happened here?




Elapsed Time Since End of Fill Placement (days)
0
100
200
300
400
500
600
700
800
SC3 Settlement (in)
0
5
10
15
20
25
MSL (ft)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
SC3 Settlement Cell
Approximately 1 year
Port Fourchon Tide Gauge
3”

# HAUL ROAD CONSTRUCTION

- A 60-foot wide limestone haul road was constructed in the marsh
  - Limestone dumped until stable, volume unknown
  - Near-surface soils are very soft clays with a few sand/silt layers
- Piles driven immediately adjacent to haul road
  - Relatively easy driving
  - PDA integrity: OK
  - Pile heads began moving up to 7” away from haul road after initial surveys



La. 1 Improvements
Fourchon, LA to Golden Meadow, LA

**LOG OF SOIL BORING B-189**

File: 03-1001
Date: 09/16/03
Logged by: F. Ward
Driller: Omni
Rig: Airboat

STE
Soil Testing Engineers, Inc.
Sheet 1 of 3

Louisiana Department of Transportation and Development
Baton Rouge, LA

LELAP Certificate No. 02052

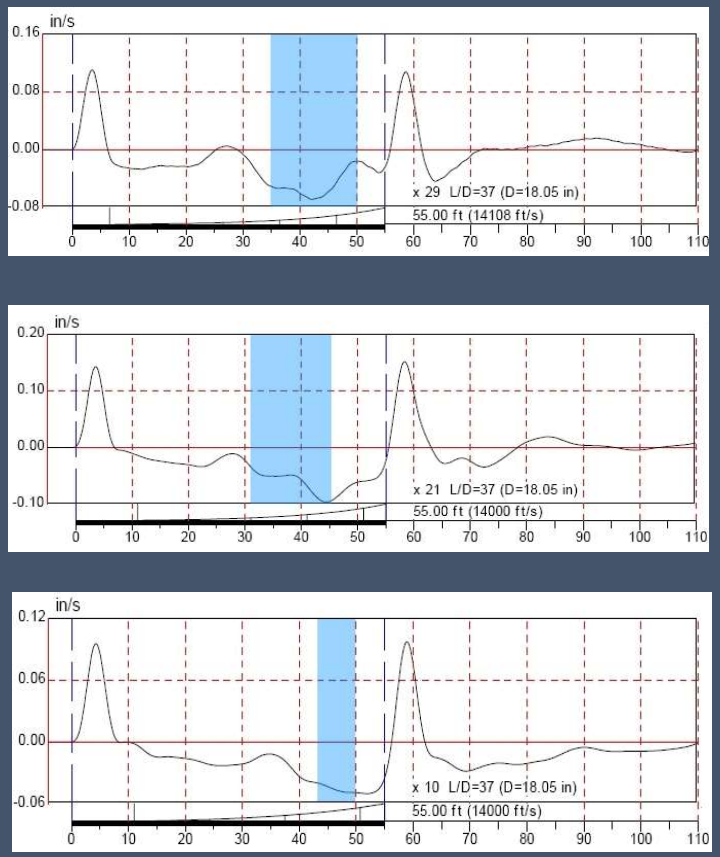
Location: Lat. 29° 15' 24.2"
Long. 90° 13' 16.0"
Surface Elevation: N/A (ft., NGVD)

| Ground Water Level | Depth (feet) | Samples | Field Test Results | Compressive Strength (tsf) | Water Content (%) | Dry Unit Weight (pcf) | Atterberg Limits LL | PL | PI | Mini Vane Shear (ksf) / Other | Soil Type | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Water |
| | | | | | | | | | | | | Mudline at 3.0 ft. |
| | 5 | | 0.25 (P) | 0.10t1 | 49 | 69 | 52 | 19 | 33 | 0.10 | | Very soft gray CLAY (CH) |
| | 10 | | | | | | | | | | | – w/organic matter at 6 to 8 ft. |
| | 15 | | | | | | | | | | | Firm gray SANDY SILT (ML) |
| | | | 0.25 (P) | 4.08t2 | 28 | 92 | | | | 0.08 GS | | – w/trace of organic matter at 16 to 18 ft. |
| | 20 | | | | | | | | | | | Very soft gray SANDY CLAY (CL) w/shells |

Soil Boring Log B-189

# PULSE-ECHO TEST RESULTS

- Pulse-Echo testing performed on approximately 70 piles
- In some cases, damage was detected just above dense layers
- It is possible that the haul road created enough lateral force to bend the piles about the denser sand/silt layers
- Additional piles were driven to replace the damaged piles




Pulse-Echo Test Records for 3 Different Piles
(Blue = Denser Layer Based on Driving Resistance)

# PILE DESIGN

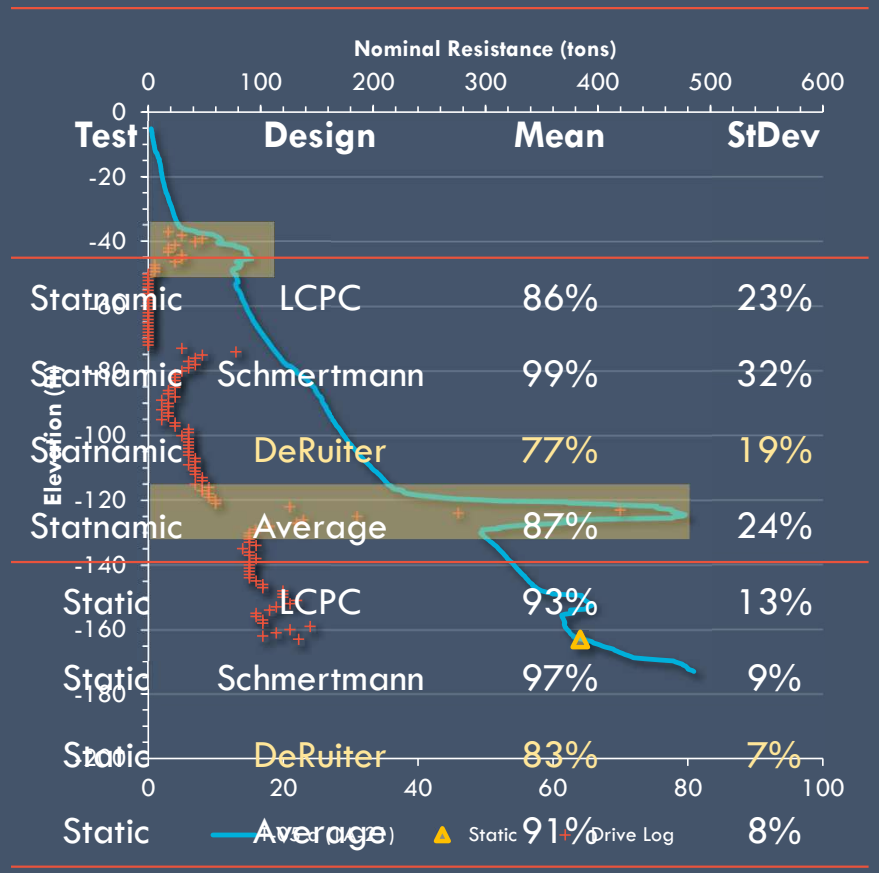
# TEST PILE PROGRAM

- Total tested to date: 24
  - 16” PPC: 1
  - 18” PPC: 1
  - 24” PPC: 12
  - 30” PPC: 7
  - 54” cylinder: 2
  - 30” pipe: 1
- Test Types:
  - Static: 20
  - Statnamic: 4
  - Lateral: 1

Reading Dial Gauges During Static Test

# CPT DIRECT DESIGN EVALUATION

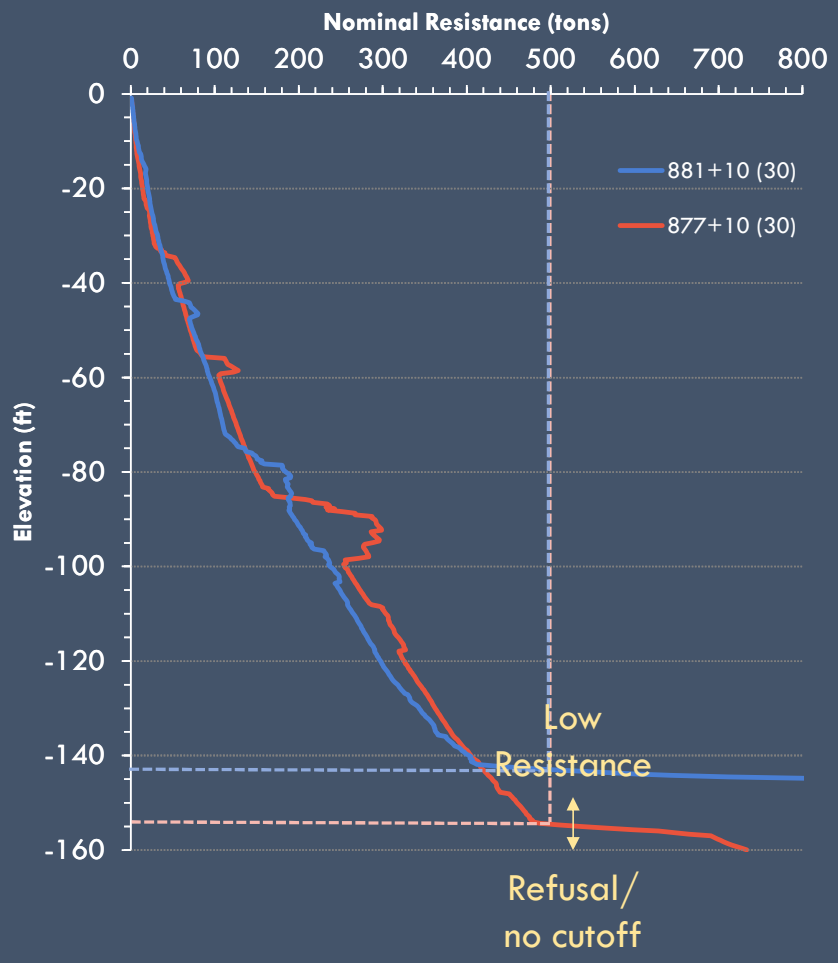
- Direct design methods:
  - deRuiter & Beringen
  - LCPC
  - Schmertmann
  - Average
- Methodology:
  - Plot CPT nominal resistance curve
  - Plot Test Pile driving resistance
    - Verify layering is similar/CPT is representative
  - Compare estimate to load test result as a percentage




Test Pile T-05a (24" sq. Concrete)
Results of Direct Design Method Comparison
CPT 1A-21

# PILE DESIGN CHALLENGES

- End-on construction, timing is critical
- Deep sand stratum
  - Pile refusal within a few feet of penetration
  - Cutoffs limited to 3' due to structural design
- Profile mainly N.C. clay
  - However, many piles do not gain required nominal resistance in side friction only
- Therefore, very narrow window for achieving resistance + drivability
- Compounded by varying sand depths



# PILE DESIGN SUMMARY

- Most of project is composed of spliced PPC piles
- Most driving using D46 hammer
  - Some air hammer use (< 5%)
- Phase 1A and Phase 2 had multiple alternates
  - We designed significantly more than this!
- Monitor Piles had initial drive & restrike, plus sometimes monitoring of bottom portion
  - Actual PDA events were probably 2x greater

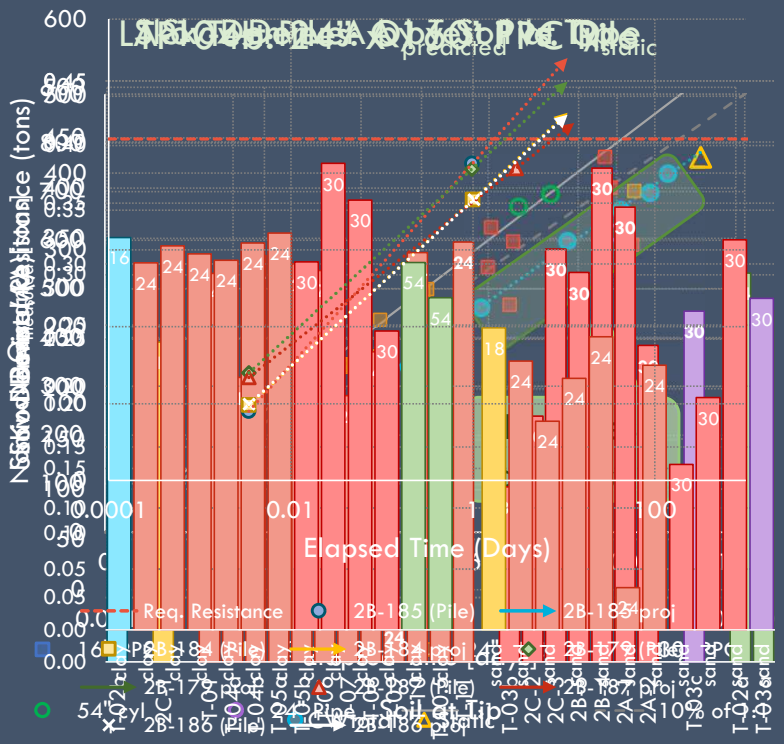
Phase 1 & 2 Pile Summary

| Phase | Bents | Tested w/PDA | Length Driven (miles) |
|---|---|---|---|
| 1B | 269 | 137 | 47 |
| 1A | 436 | 435 | 45 |
| 2E | 38 | 33 | 4 |
| 2A-C * | 524 | 549 | 104 |
| | **1229** | **1154** | **201** |

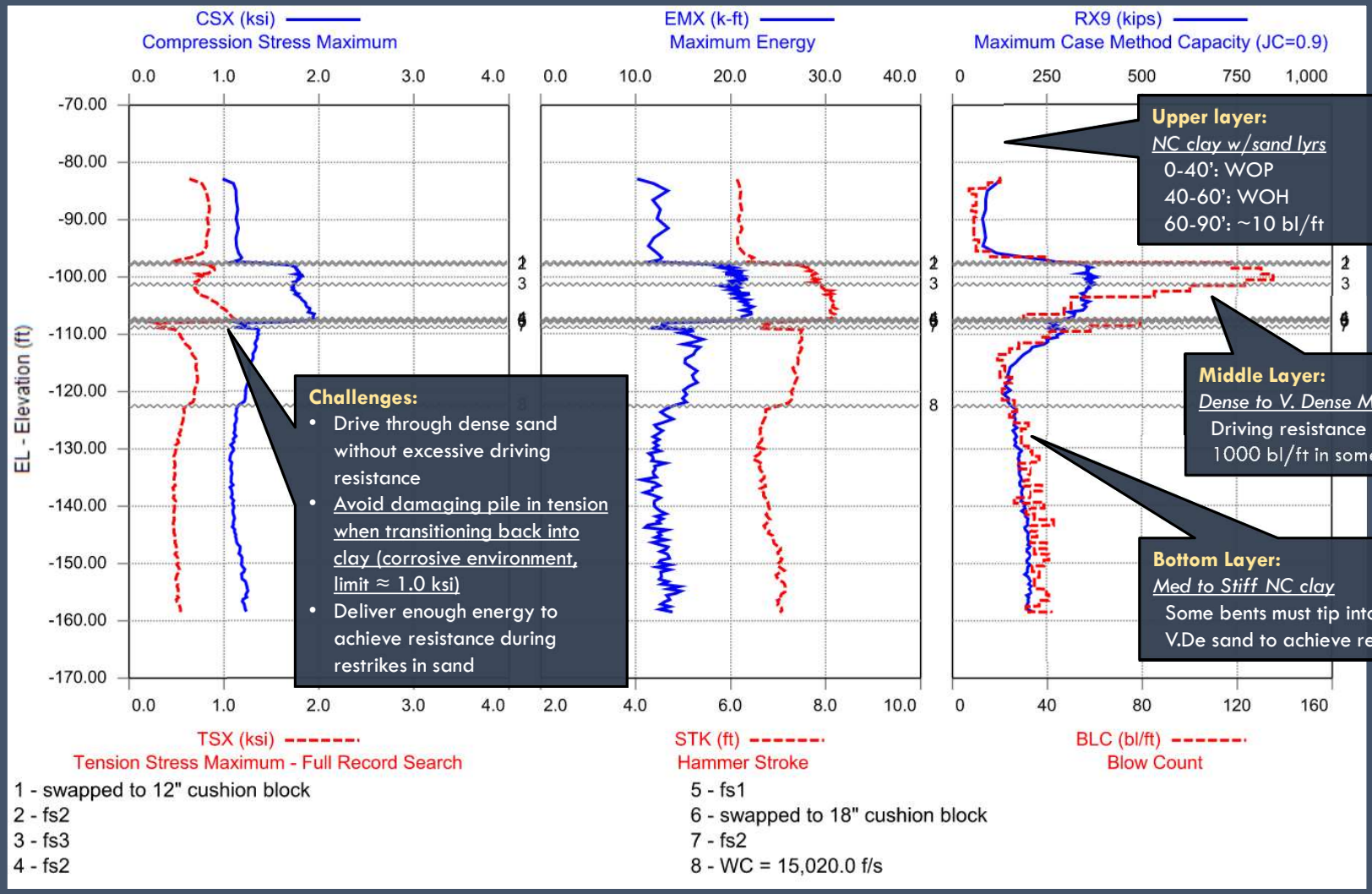
* Totals, currently project is about 60% complete

# PILE MONITORING & ACCEPTANCE

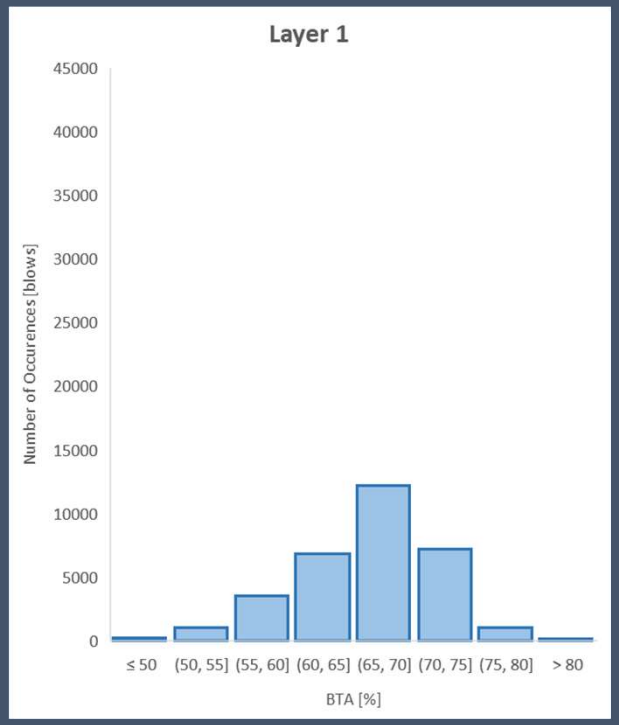
# DYNAMIC TESTING & PILE SETUP

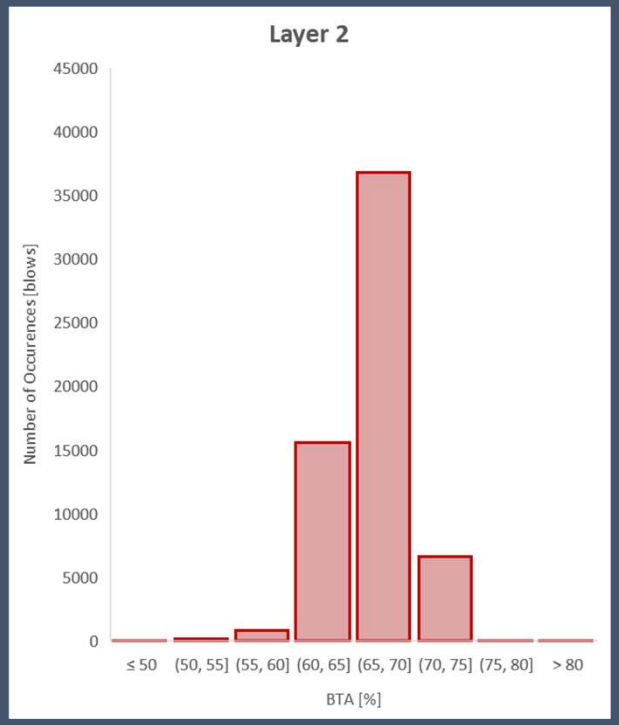


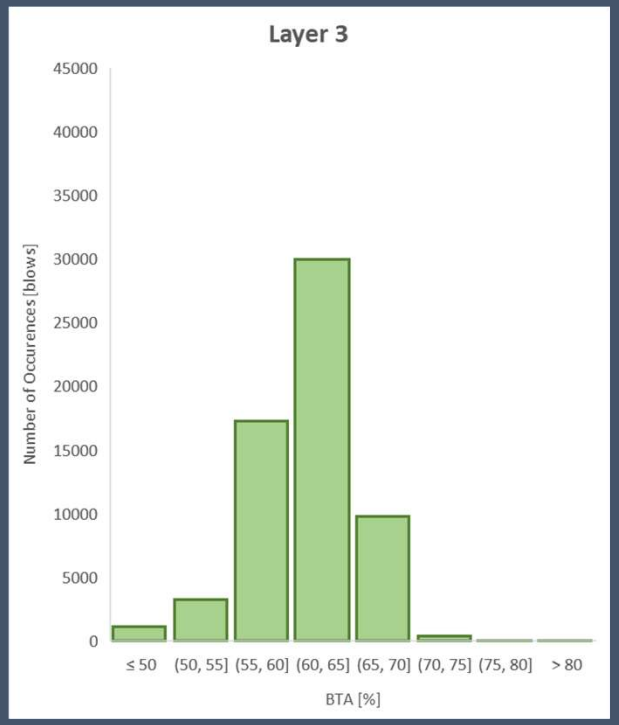

- Piles have very little resistance at EOD
  - Setup projections are necessary to accept piles
- Compare best-fit pile setup resistance (CWtotal) to static load test result
  - $Q_{predicted}$ = 436 tons, $Q_{static}$ = 431 tons
  - $Q_{predicted}$ / $Q_{static}$ = 101%
  - Repeat $Q_{predicted}$ vs $Q_{measured}$ for all 24 TPs
  - Generally best-fit CAPWAP curve predicts static result within 90%
  - Does not tend to overpredict pile resistance
- Should set-up rates (Skov-Denver 'A') be consistent?
  - Clay: $A_{avg}$: 0.31, StDev: 0.1
  - Sand: $A_{avg}$: 0.21, StDev: 0.4


CSX (ki)
Compression Stress Maximum
EMX (k-ft)
Maximum Energy
RX9 (kips)
Maximum Case Method Capacity (JC=0.9)
EL - Elevation (ft)
Upper layer:
NC clay w/sand lyrs
0-40': WOP
40-60': WOH
60-90': ~10 bl/ft
Middle Layer:
Dense to V. Dense ML to SM
Driving resistance exceeds 1000 bl/ft in some bents
Bottom Layer:
Med to Stiff NC clay
Some bents must tip into V.De sand to achieve resistance
Challenges:
• Drive through dense sand without excessive driving resistance
• Avoid damaging pile in tension when transitioning back into clay (corrosive environment, limit ≈ 1.0 ksi)
• Deliver enough energy to achieve resistance during restrikes in sand
TSX (ksi)
Tension Stress Maximum - Full Record Search
STK (ft)
Hammer Stroke
BLC (bl/ft)
Blow Count
1 - swapped to 12" cushion block
2 - fs2
3 - fs3
4 - fs2
5 - fs1
6 - swapped to 18" cushion block
7 - fs2
8 - WC = 15,020.0 f/s

# PHASE 2B BY LAYER: BTA/PILE INTEGRITY

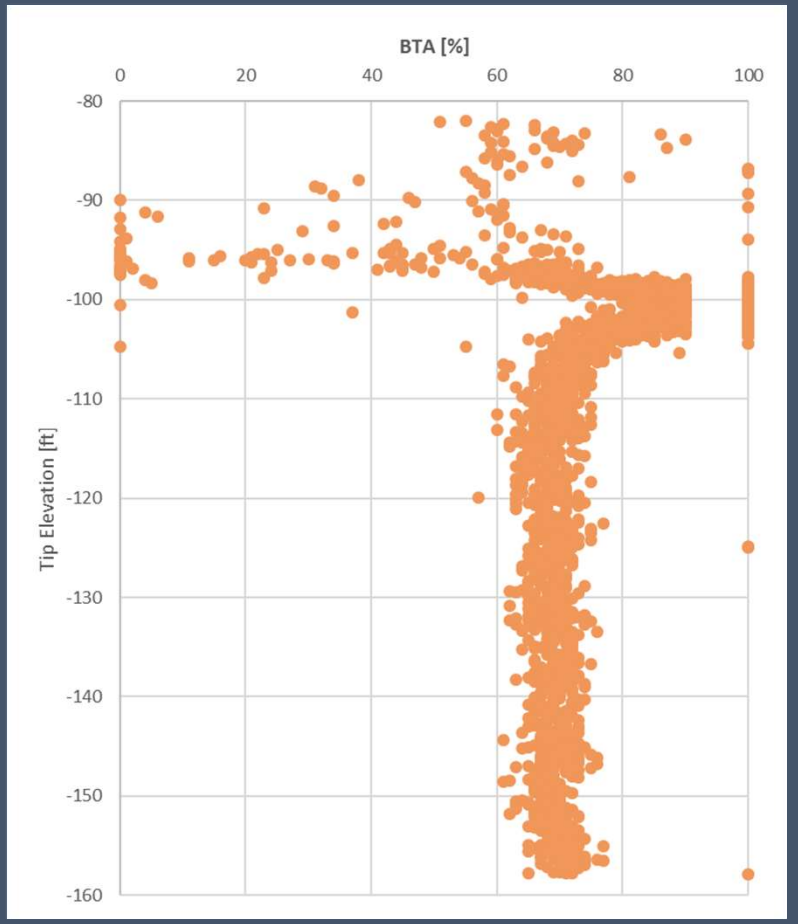


# OBSERVATIONS

- BTA:
  - Lower than average on Phase 1A
  - These are larger piles
  - This is a different type of splice
- Can't look at BTA in a vacuum:
  - Need to understand the splice's "signature"
  - Is splice deteriorating throughout drive?
    - No
  - Tension seems to impact BTA here:
    - Inconsistent in easy driving
    - Increases (better) in sand layer
    - Decreases after penetrating sand, but approaches a consistent value for remainder of drive



# PROJECT TAKEAWAYS

# LA-1 RELOCATED: PROJECT TAKEAWAYS

- Embankments
  - Seasonal tidal changes impacted settlement monitoring
  - Needed more than a year of data to identify trends
  - *Tidal Influence on Embankment Settlement in Coastal LA* (Tsai et. al., 2010)
  - Lateral squeeze appears to have damaged piles
- CPT Direct Design
  - Direct methods are viable → all of Phase 2 designed using direct methods
  - deRuiter & Beringen chosen for consistency + conservatism
  - *Update the Pile Design by CPT Software to Incorporate Newly Developed Pile-CPT Methods and Other Design Features* (Abu-Farsakh et. al., 2023)

# LA-1 RELOCATED: PROJECT TAKEAWAYS

- Pile Setup Rate (Skov-Denver 'A')
  - Consistent in clays ($A_{avg}$ = 0.31) if pile is mobilized during all restrikes
  - Does not appear to be highly dependent upon pile size
  - Dynamic monitoring best-fit setup predicts static resistance to within ~90%, does not overpredict
  - *Field Instrumentation & Testing to Study Set-Up Phenomenon of Piles Driven into Louisiana Clayey Soils*, LTRC Project 11-2GT (Abu-Farsakh et. al, 2015)
- Pile Splices
  - Different behavior between Phases 1 and 2
  - Use PDA data to look at aggregate behavior over many piles
  - STGEC 2024: *Concrete Pile Splices* (Sternberg & Rauser)

# LA-1 RELOCATED: PROJECT TAKEAWAYS

- Pile Design & Acceptance:
  - Even with large number of explorations, very narrow margin for error
  - Acceptance is daily activity – requires rapid access to boring/CPT data, pile driving records, hammer performance, and CAPWAP records
- Project Scale:
  - 169 Borings, 562 CPTs
  - 1229 Bents, over 200 miles of pile driven (by end of project)
  - 24 pile load tests, 1154 piles tested with PDA
  - Going forward, can we develop standards, databases, and tools to leverage all of the data?