Field Investigation of Downdrag on Concrete Piles in Sandy Soil

BDV25 TWO977-67

GRIP 2022

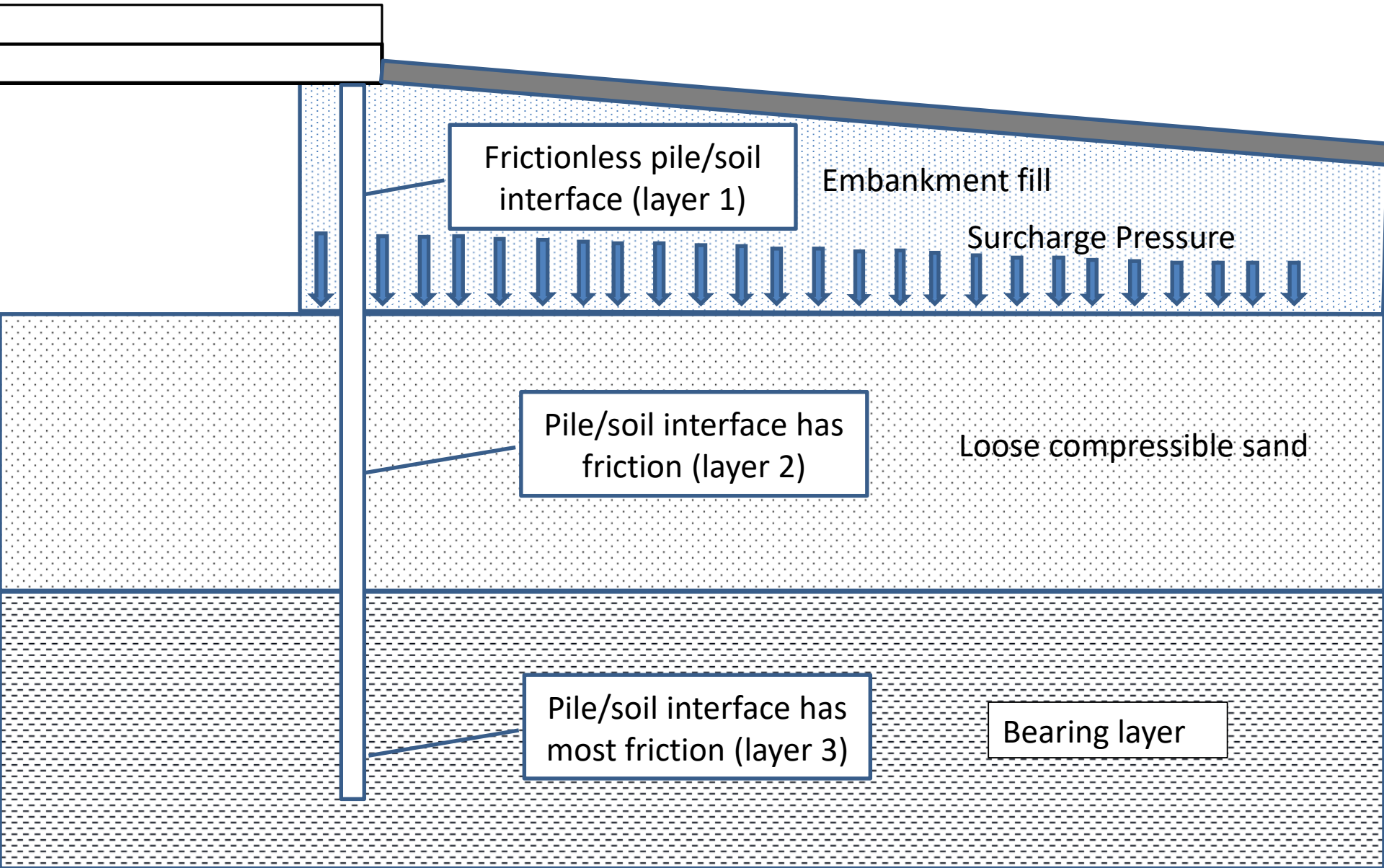
Malaak Araujo, E.I. and Gray Mullins, Ph.D., P.E.
Project Manager: Larry Jones, P.E.

Problem Statement

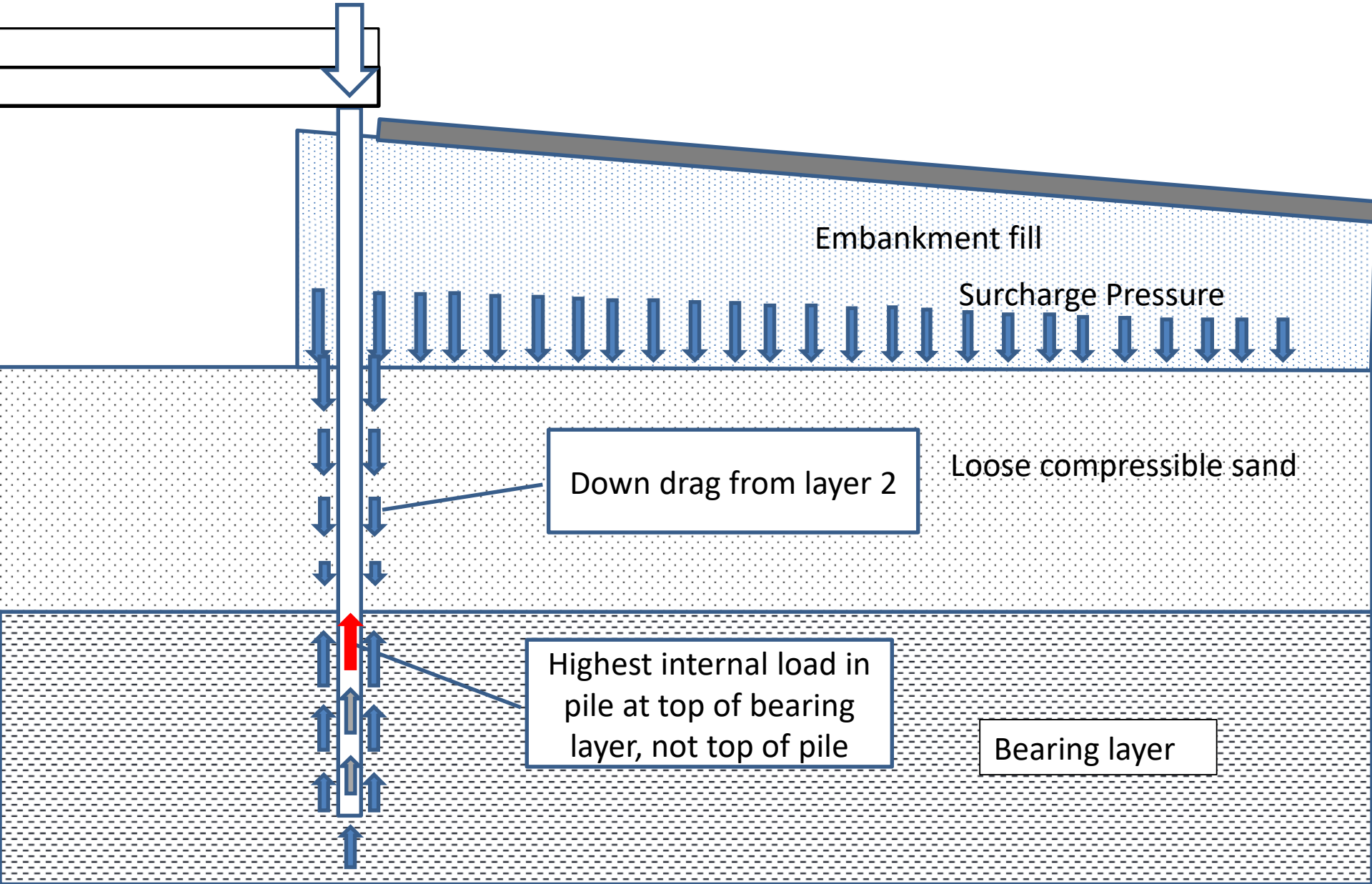
- Piles in end bents are often subjected to settlement induced surcharge loads in addition to structural bridge loads.
- Depending on the site-specific conditions it is conceivable that the additional loads may exceed the structural and/or geotechnical pile capacity.
- This study investigates these conditions.

- Misconception: sandy soils settle immediately so there are no downdrag forces

Simple Embankment Model



Can DL + LL cause enough elastic compression to offset/reverse downdrag side shear on piles???



Approach

- Instrument and monitor three bridge sites for pile forces and ground settlement

Project Tasks

- Literature Review
- Instrumentation and Monitoring
- Data Analysis and Scenario Evaluation
- Develop Recommendations
- Draft Final Report
- Final Report

Task 2: Field Instrumentation and Monitoring

- Select sites with compressible sand beneath embankment
- Evaluate for potential downdrag
- Instrument piles for internal loads
- Instrument existing soils with settlement sensors
- Long-term monitoring

SR 23 Northbound over CR-739B Sandridge Road

- Clay County, District 2
- Bridge No. 710113
- (6) 18-inch square prestressed concrete piles
- End Bent 1, Pile 4
- Pile instrumented: 3/29/21
- Site instrumented: 5/4/21 – 5/5/21

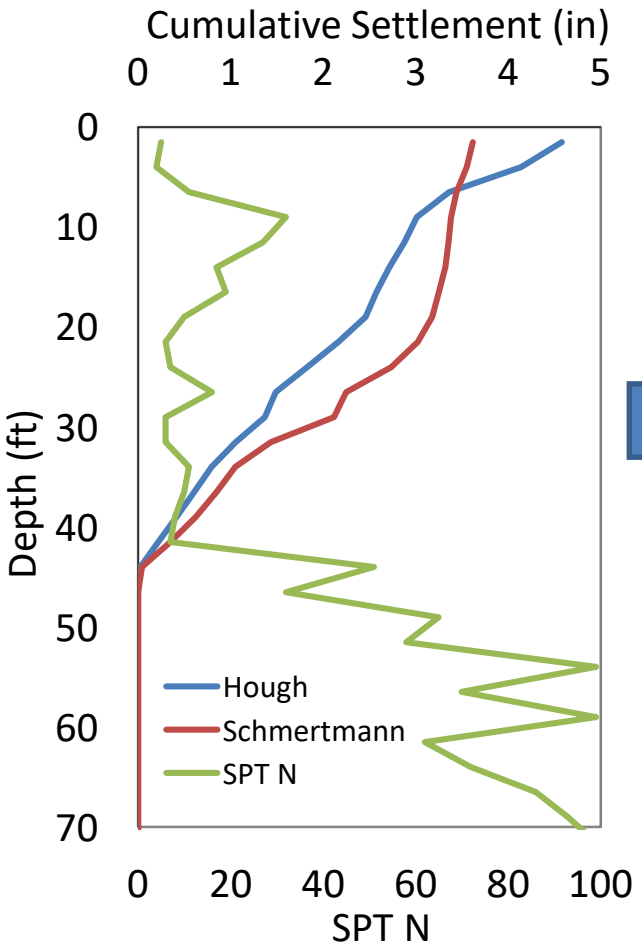
Paseo al Mar Boulevard I-75 Flyover

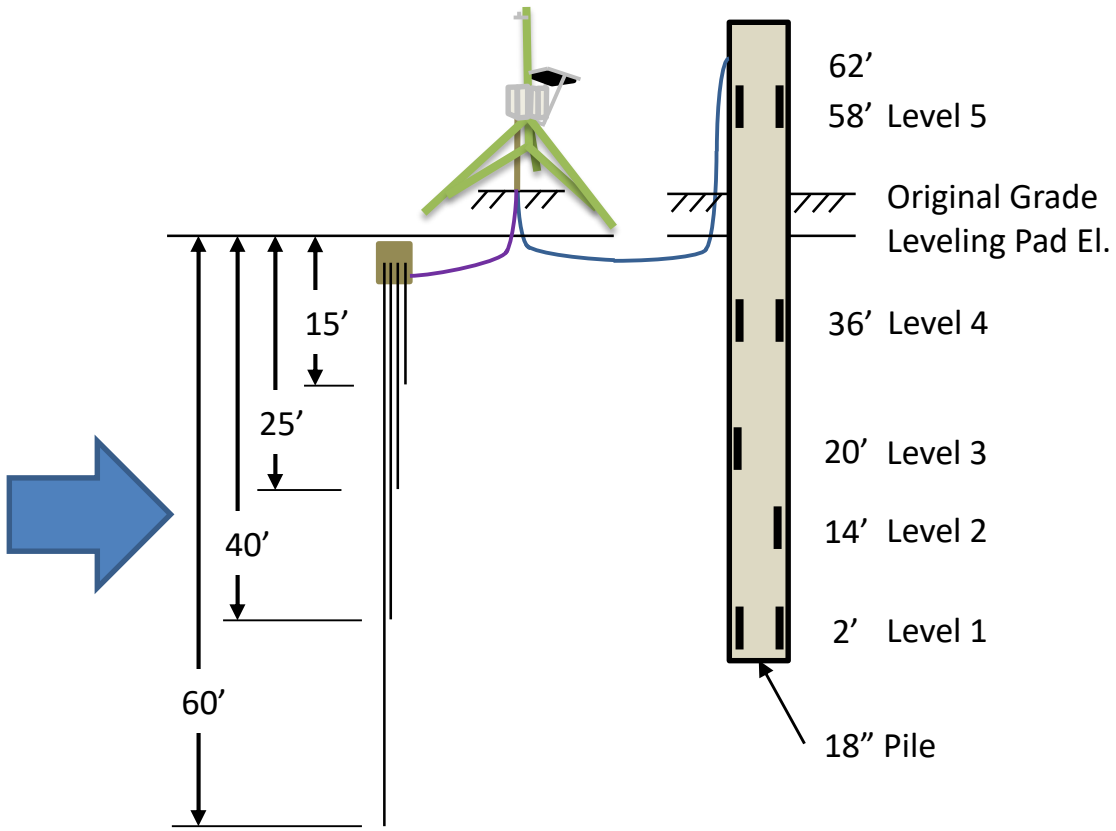
- Hillsborough County, District 7
- Bridge No. 104495
- (16) 24-inch square prestressed concrete piles
- End Bent 3, Pile 12
- Pile instrumented: 4/15/21
- Site instrumented: 5/1/21 and 5/3/21

SR 23 Southbound over CR-739 Henley Road

- Clay County, District 2
- Bridge No. 710120
- (5) 24-inch square prestressed concrete piles
- End Bent 1, Pile 3
- Pile instrumented: 1/28/21
- Site instrumented: 9/6/21 – 9/8/21

Sandridge Road





Pile Instrumentation

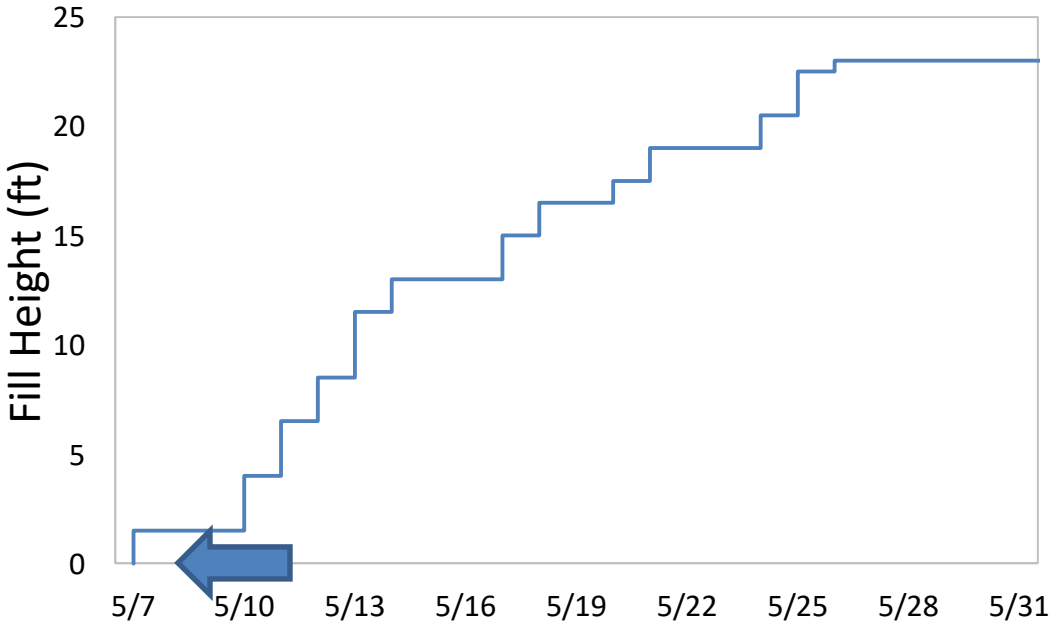
Pile Instrumentation

Settlement Instrumentation

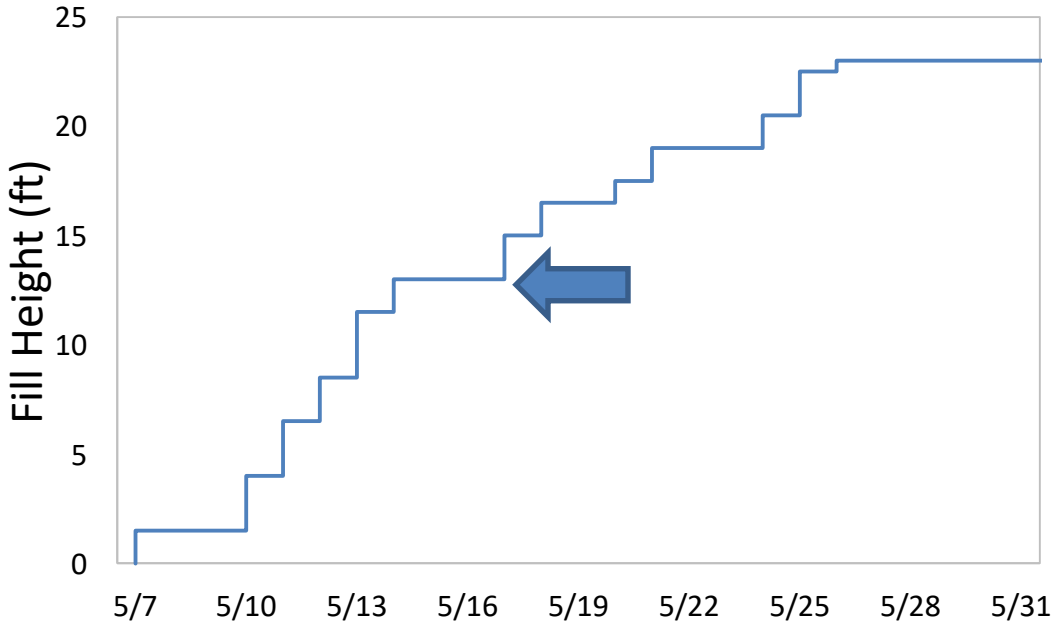
Settlement Instrumentation

Monitoring Systems

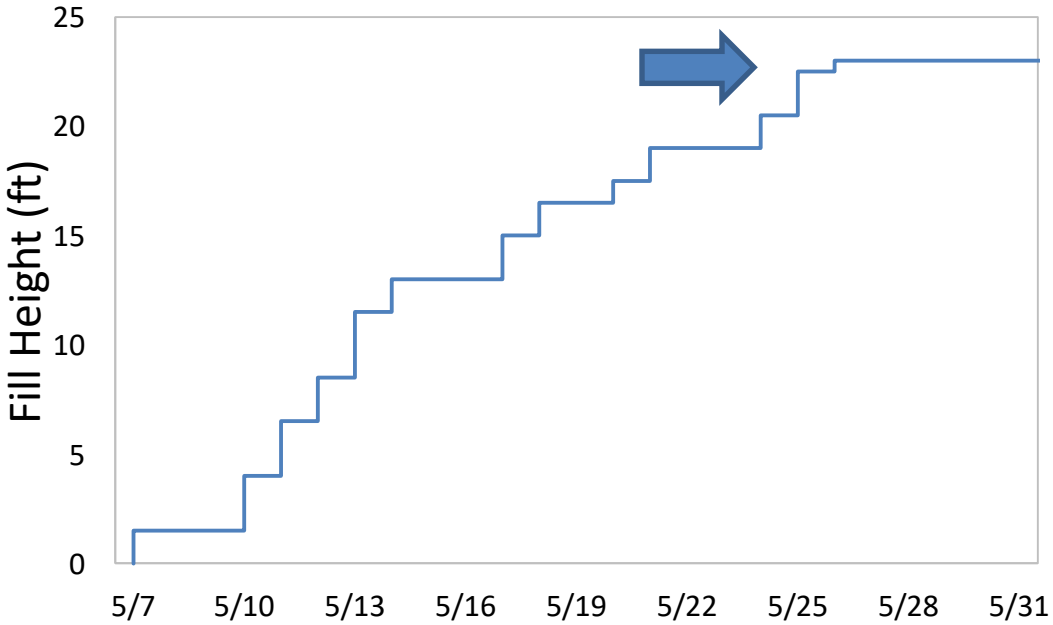
Sandridge Road Backfill



Sandridge Road Backfill

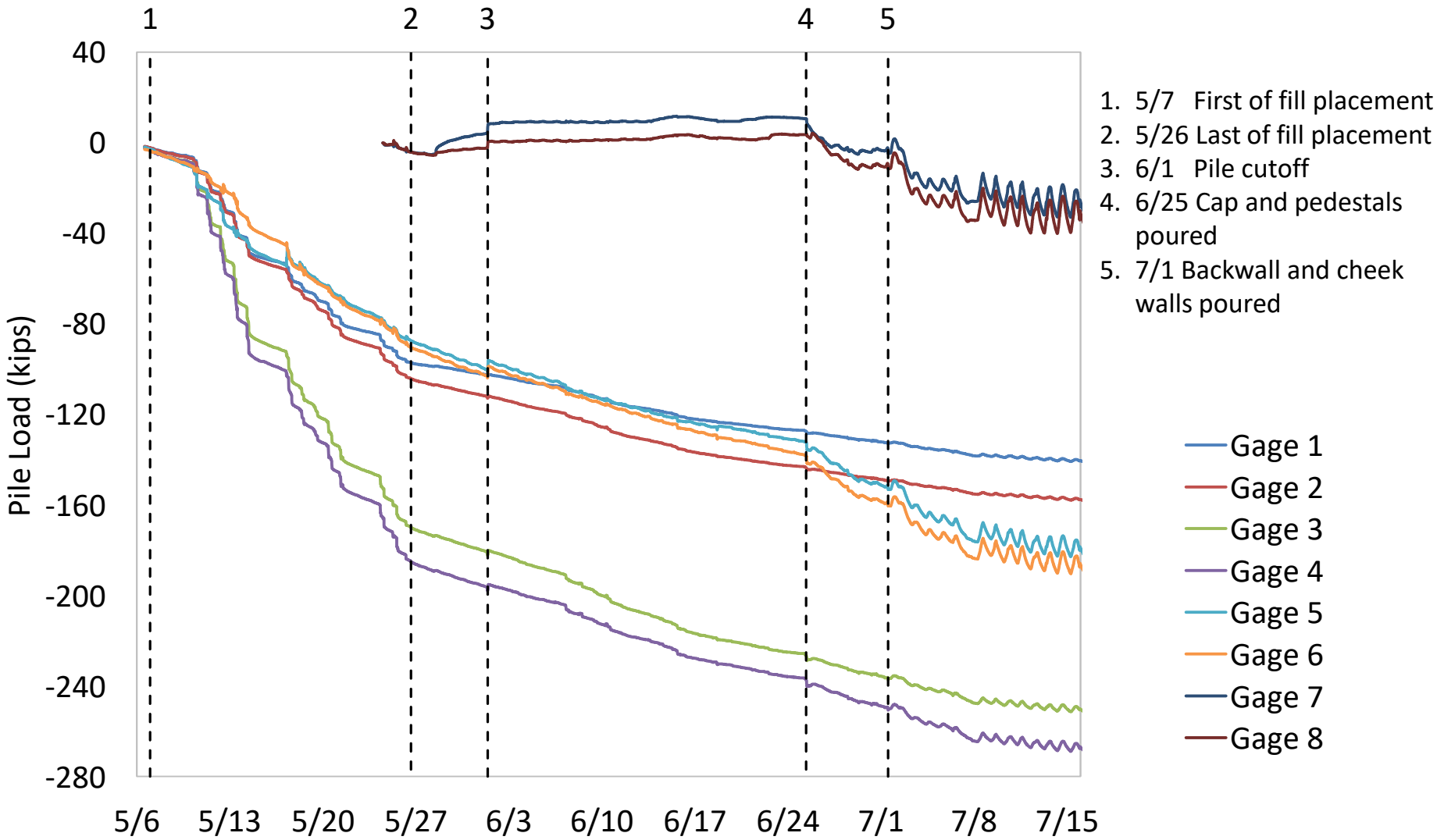


Sandridge Road Backfill

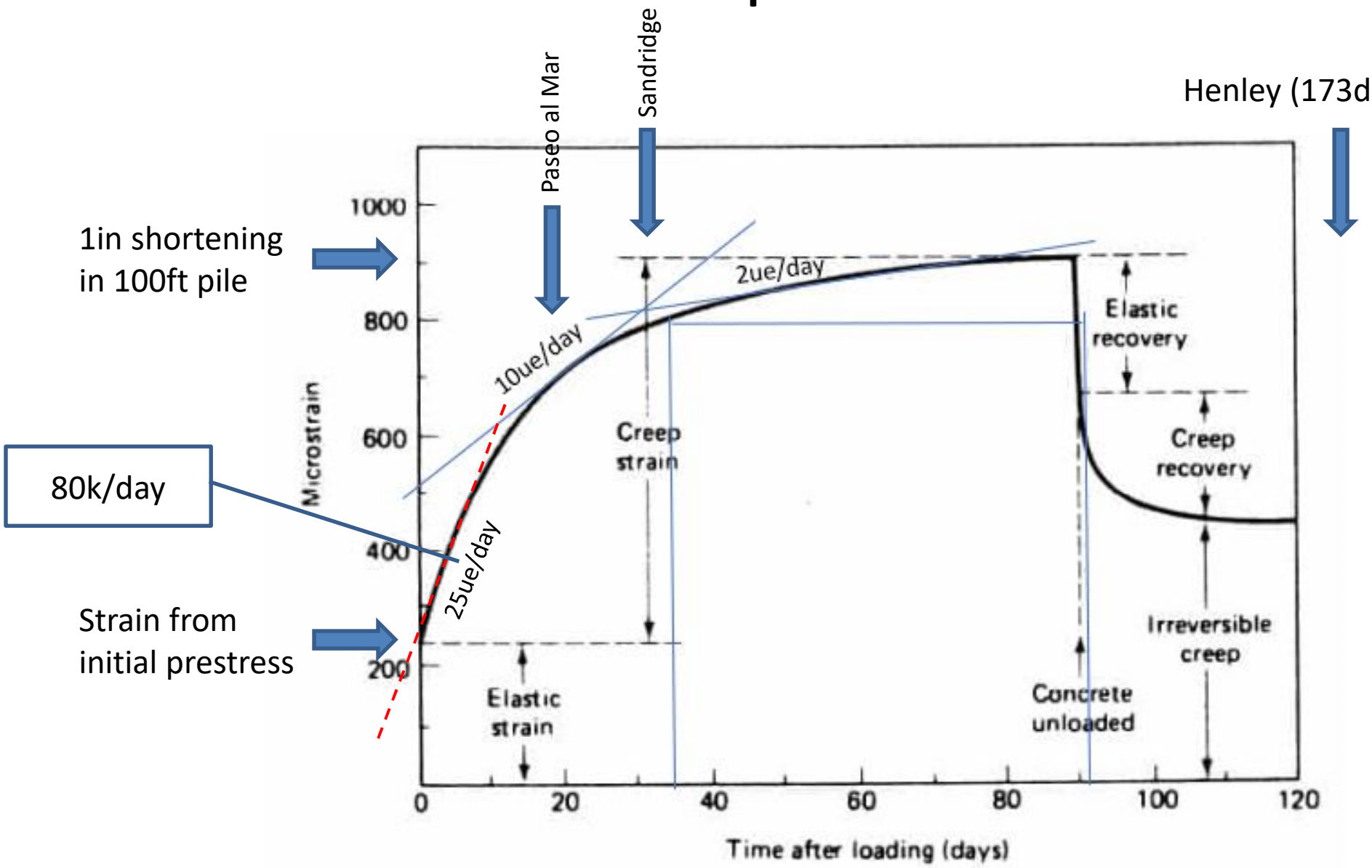


September 8, 2021

Sandridge Road (Raw Pile Force)

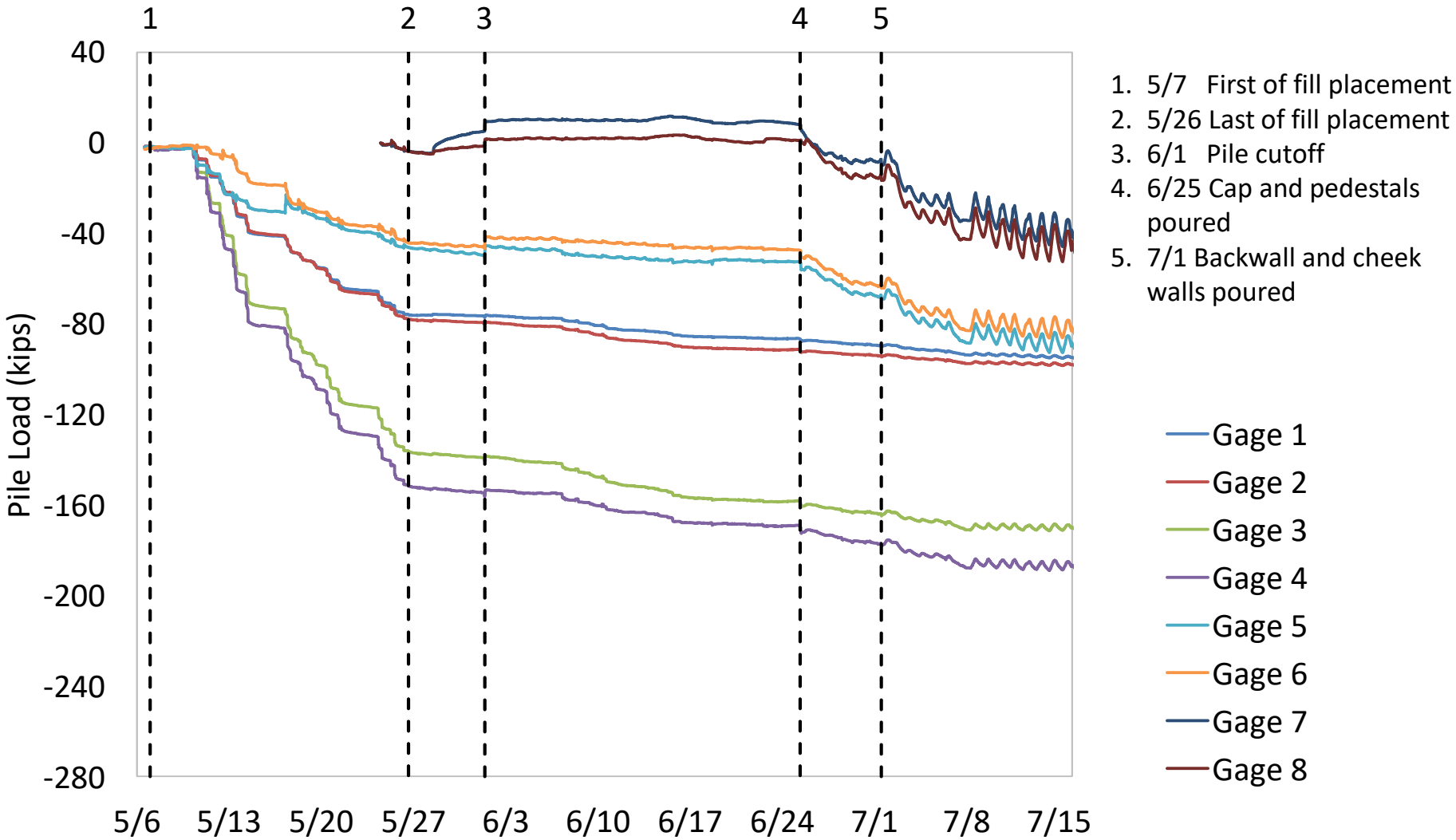


Creep

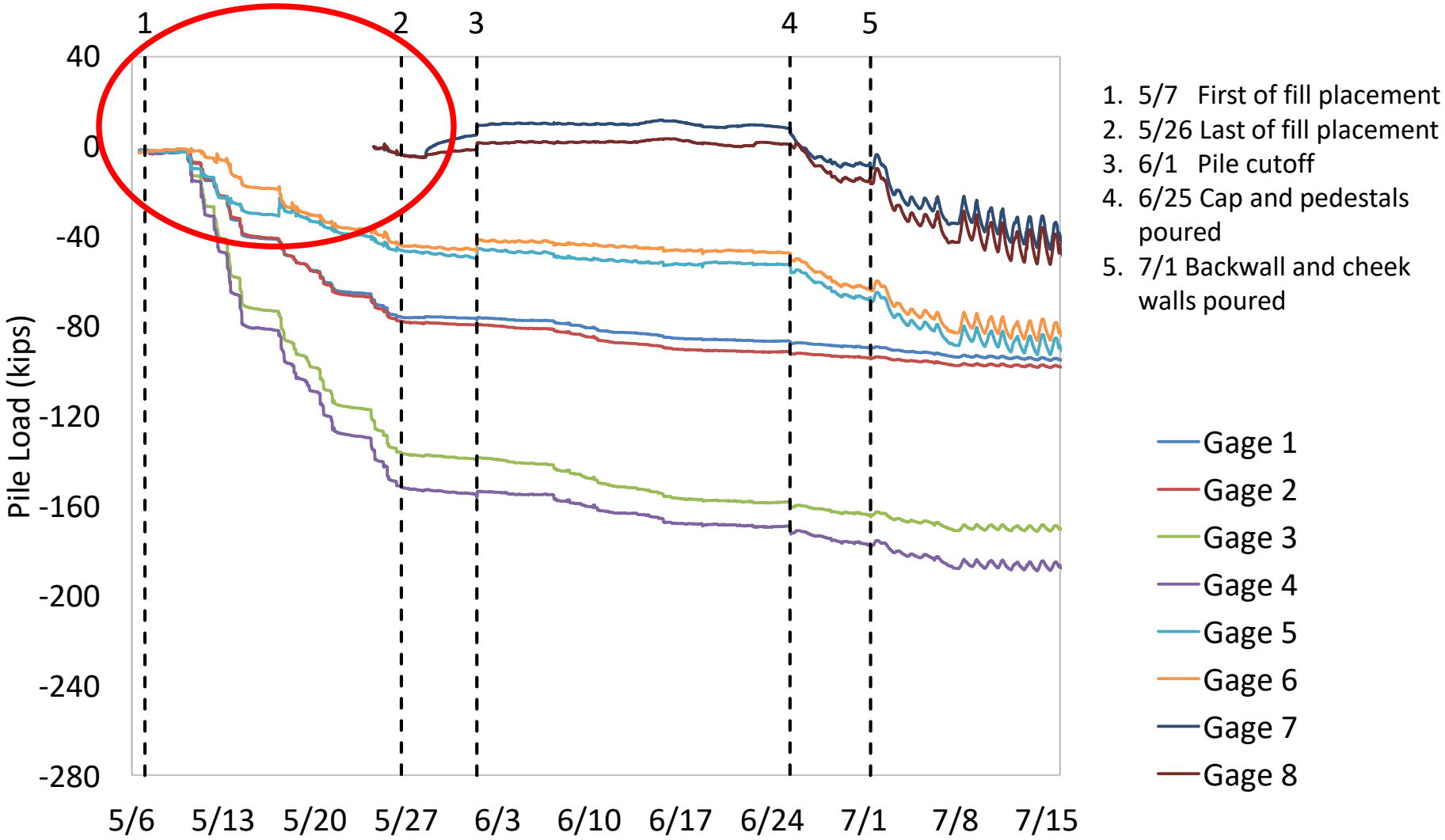


https://civildigital.com/concrete-creep-definition-creep-deformation-stages-design-strategies/

Sandridge Road (Corrected Pile Force)

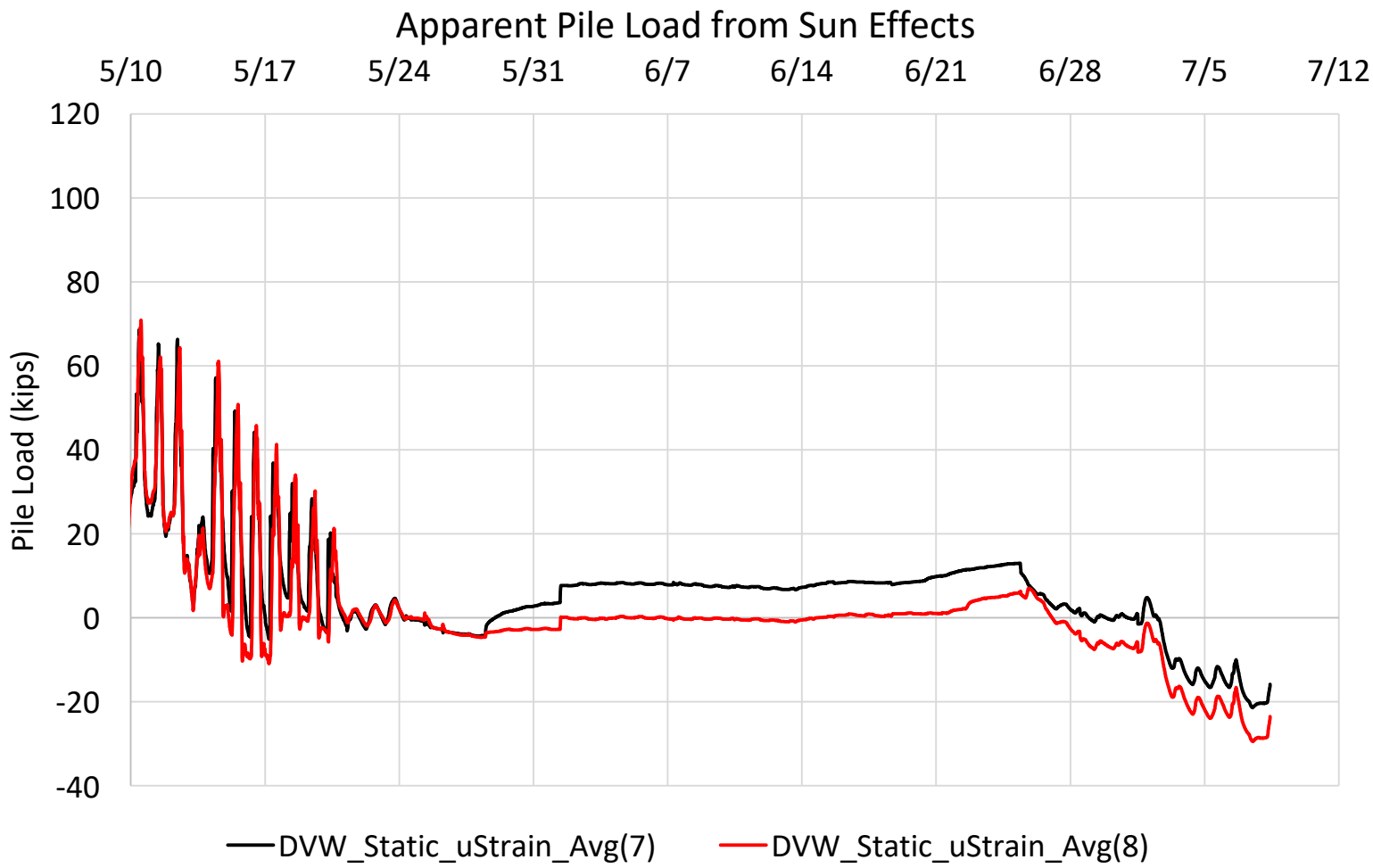


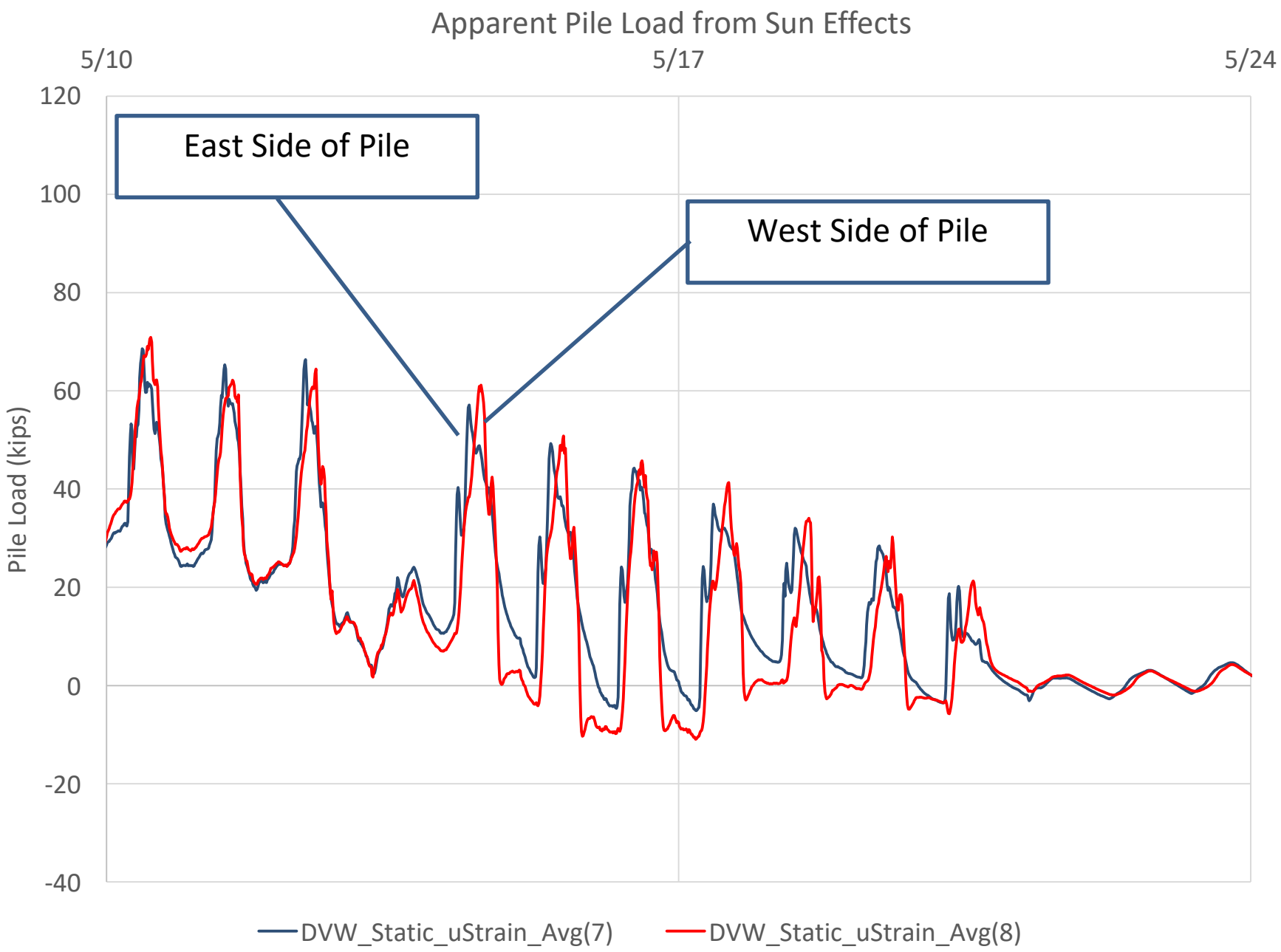
Sandridge Road (Corrected Pile Force)



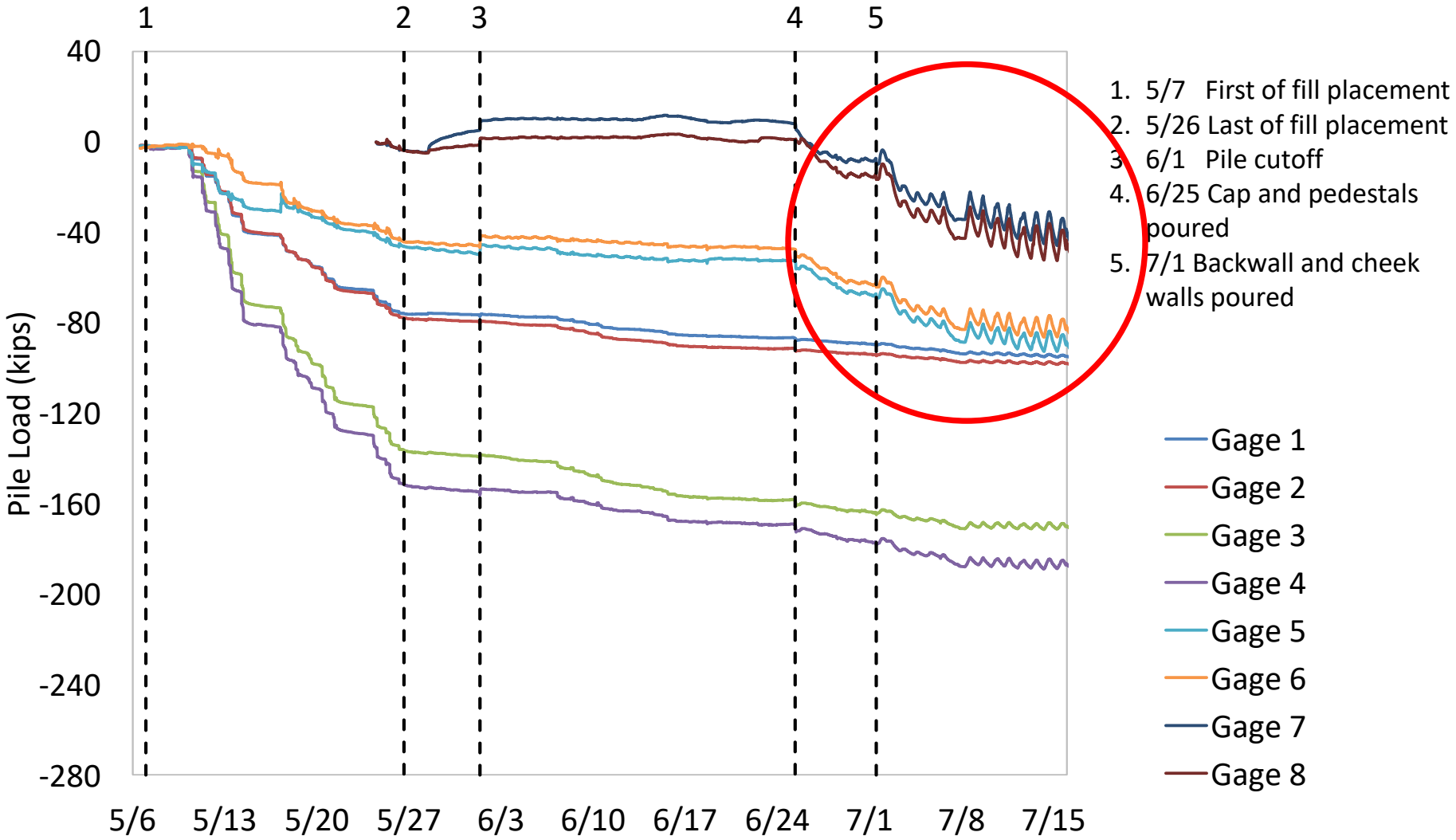
Sandridge Road

(Top of Pile Gauges)

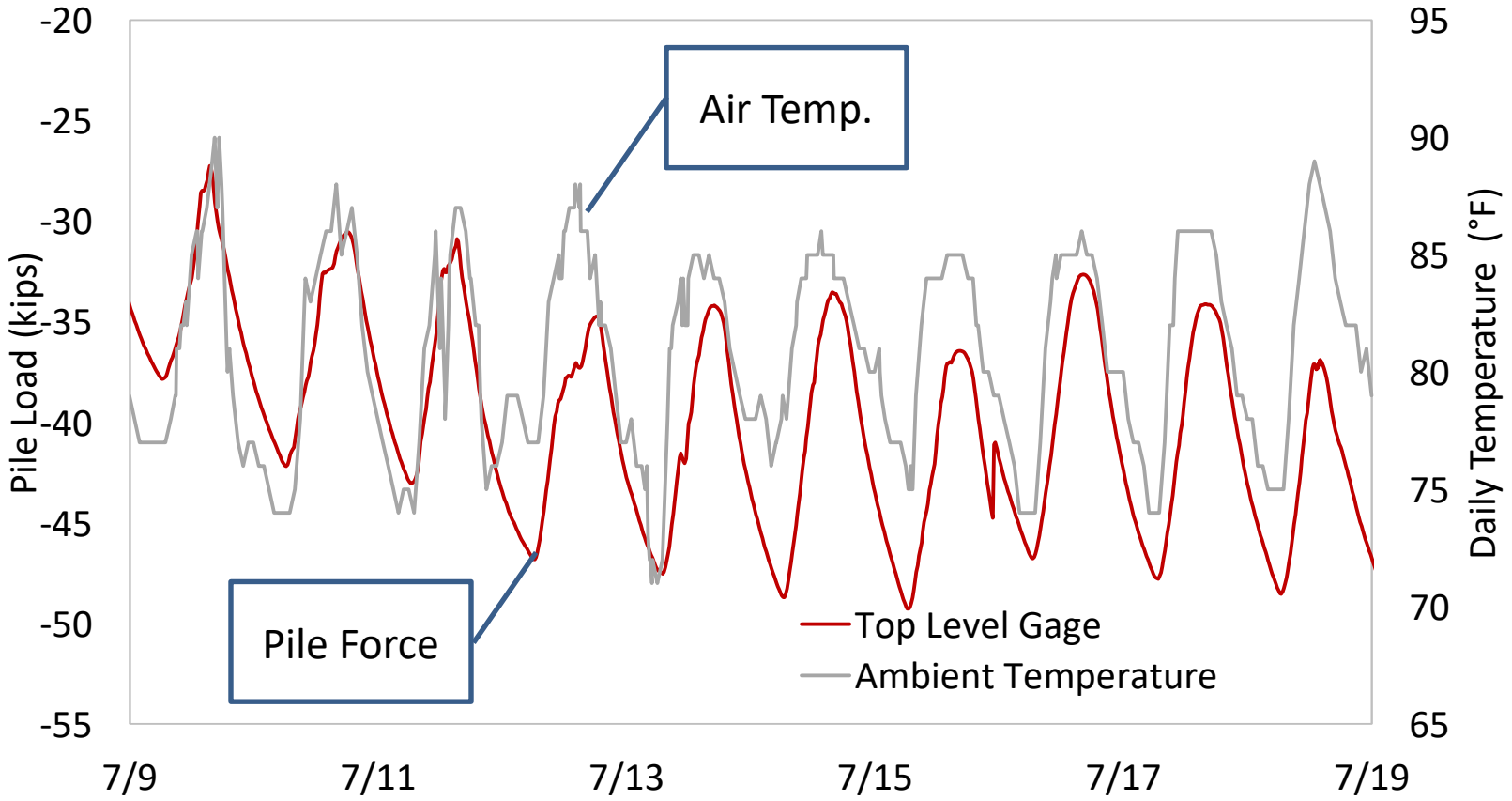


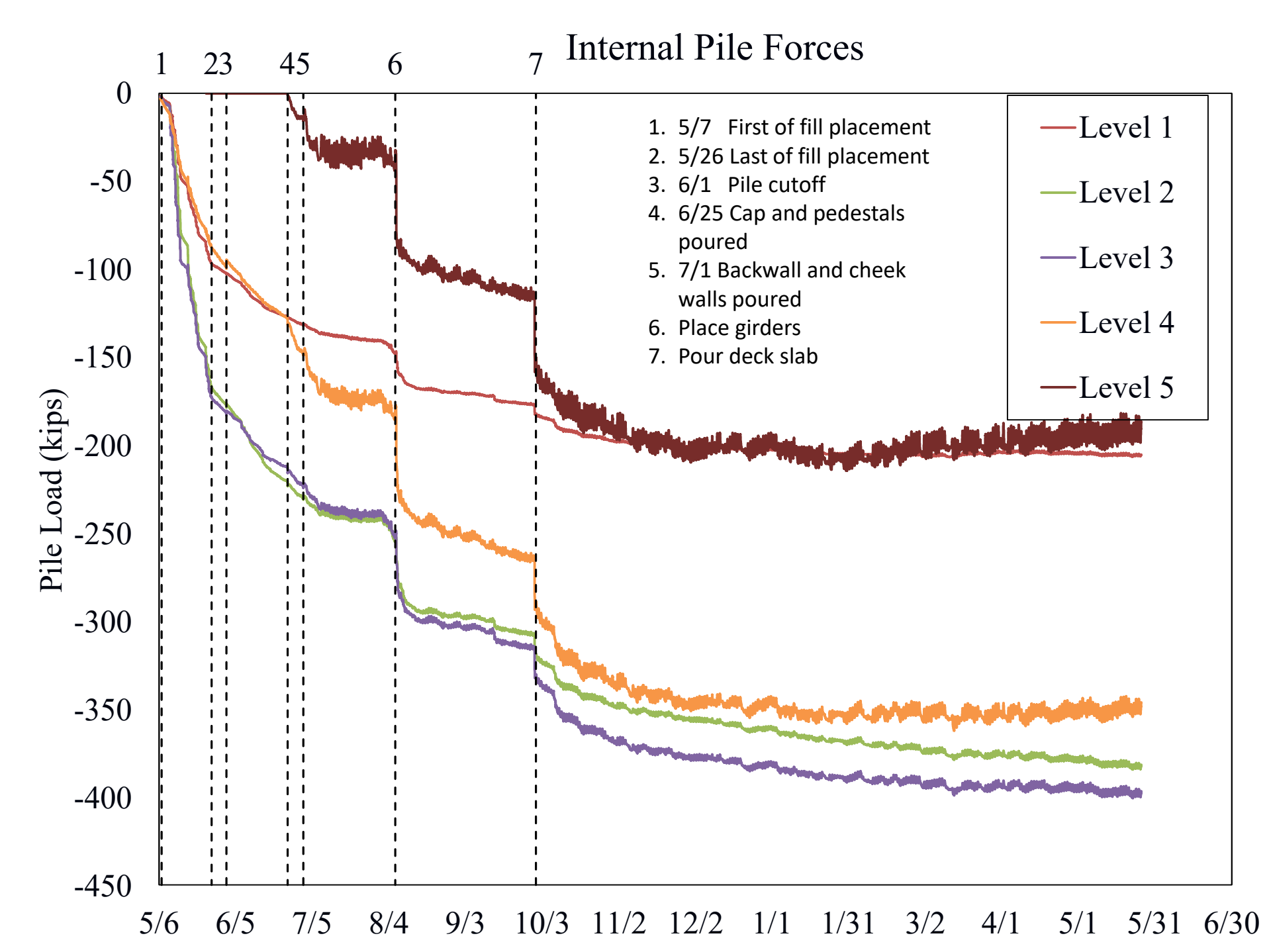

Apparent Pile Load from Sun Effects
5/10
5/17
5/24
120
100
80
60
40
20
0
-20
-40
Pile Load (kips)
East Side of Pile
West Side of Pile
DVW_Static_uStrain_Avg(7)
DVW_Static_uStrain_Avg(8)

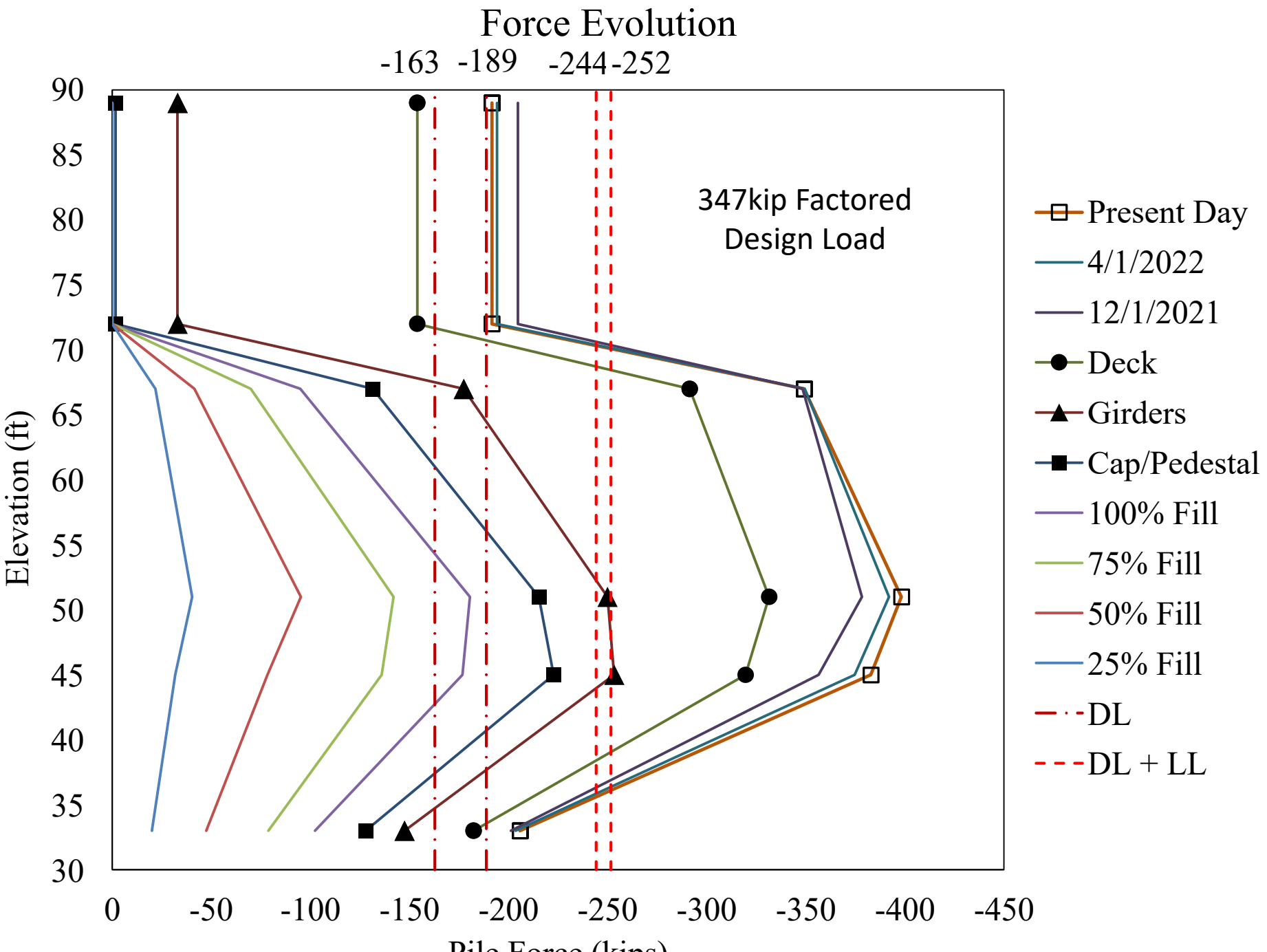
Sandridge Road (Corrected Pile Force)



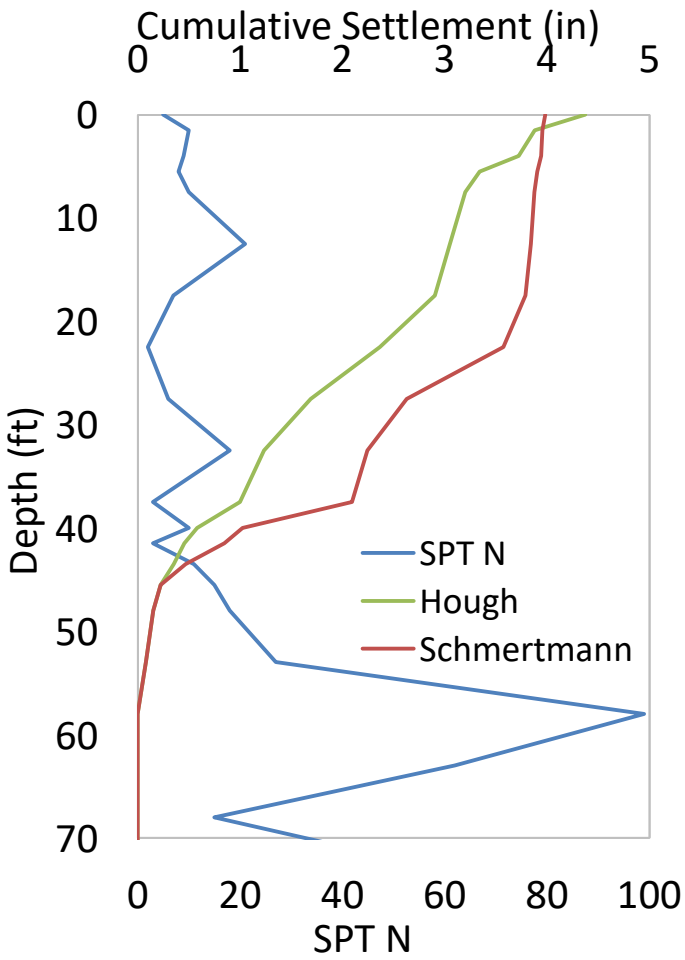
Sandridge Road

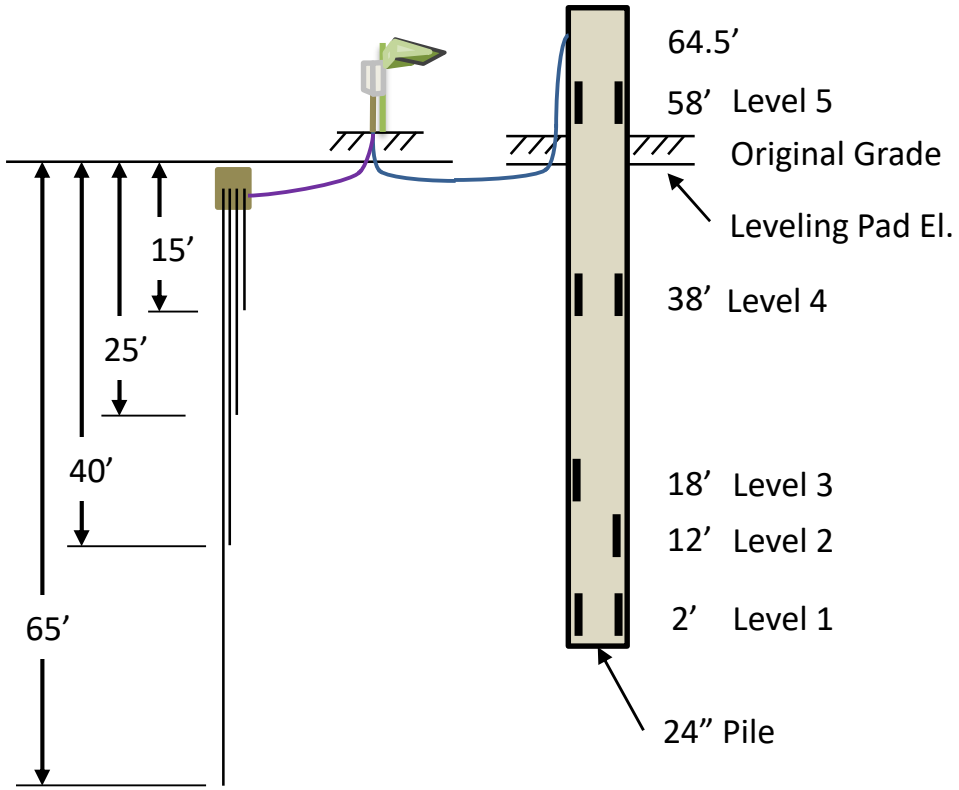



Internal Pile Forces
1
23
45
6
7
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
Pile Load (kips)
1. 5/7 First of fill placement
2. 5/26 Last of fill placement
3. 6/1 Pile cutoff
4. 6/25 Cap and pedestals poured
5. 7/1 Backwall and cheek walls poured
6. Place girders
7. Pour deck slab
Level 1
Level 2
Level 3
Level 4
Level 5
5/6
6/5
7/5
8/4
9/3
10/3
11/2
12/2
1/1
1/31
3/2
4/1
5/1
5/31
6/30

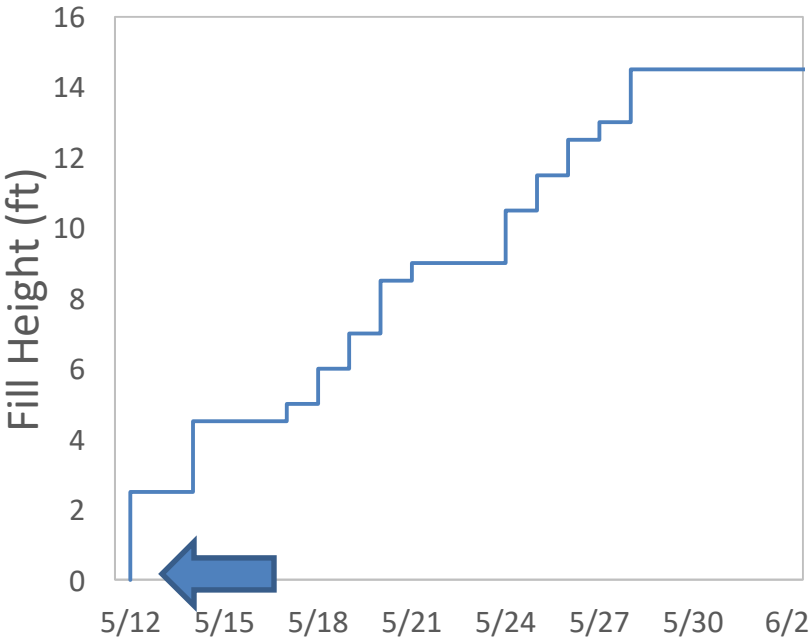

Force Evolution
-163 -189 -244 -252
347kip Factored Design Load
Present Day
4/1/2022
12/1/2021
Deck
Girders
Cap/Pedestal
100% Fill
75% Fill
50% Fill
25% Fill
DL
DL + LL
Elevation (ft)
90
85
80
75
70
65
60
55
50
45
40
35
30
0
-50
-100
-150
-200
-250
-300
-350
-400
-450

Paseo Al Mar Blvd

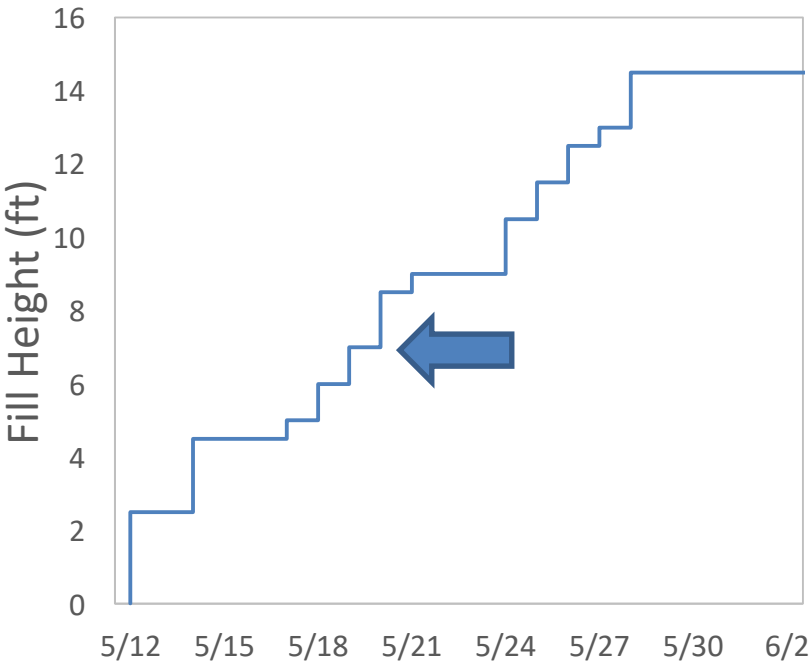




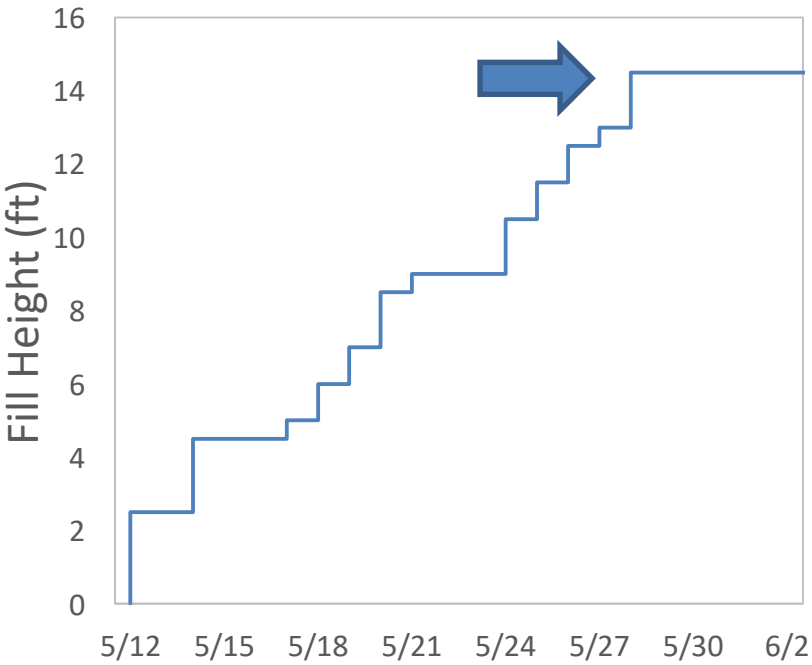
Paseo Al Mar Blvd Backfill



Paseo Al Mar Blvd Backfill



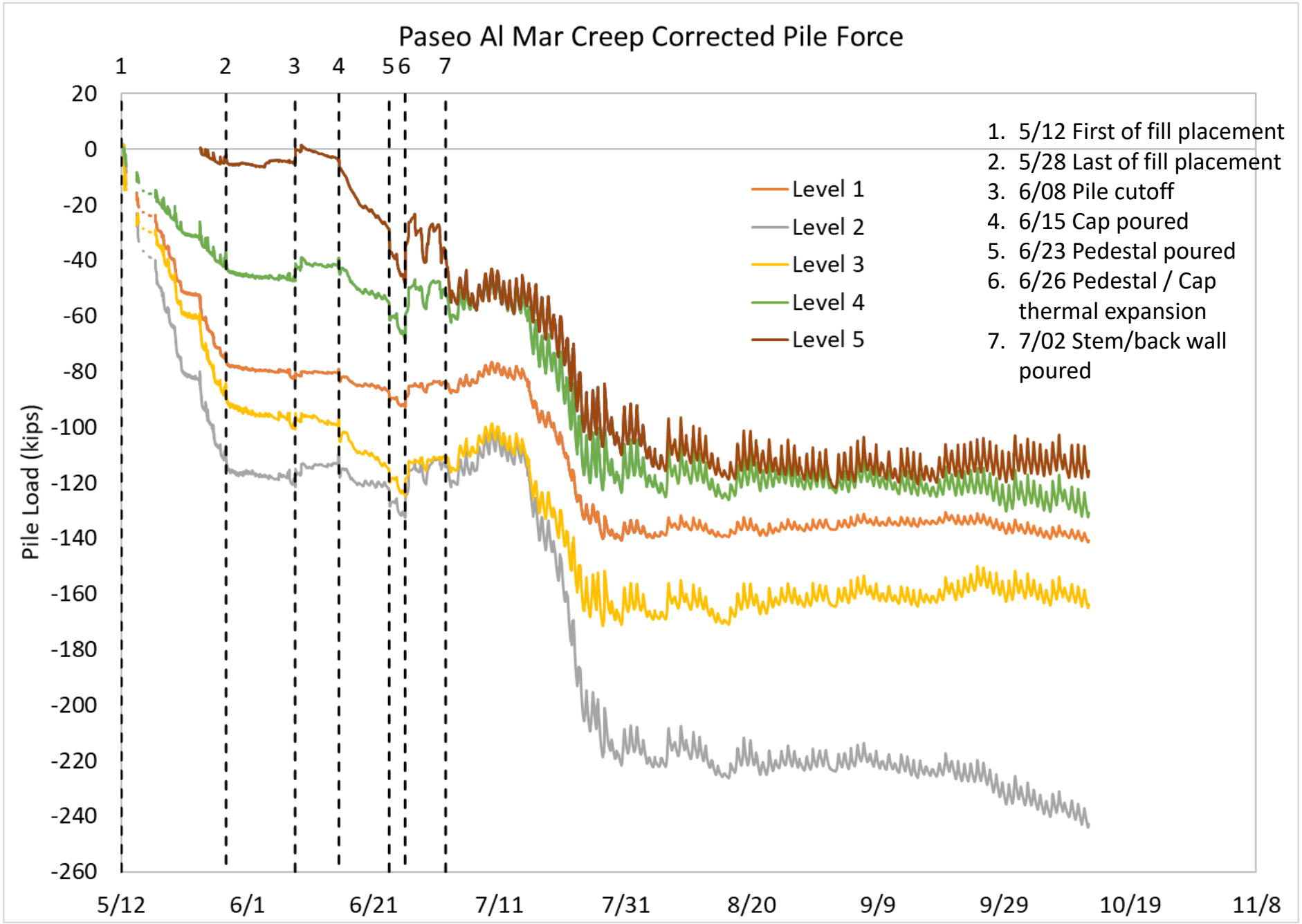
Paseo Al Mar Blvd Backfill

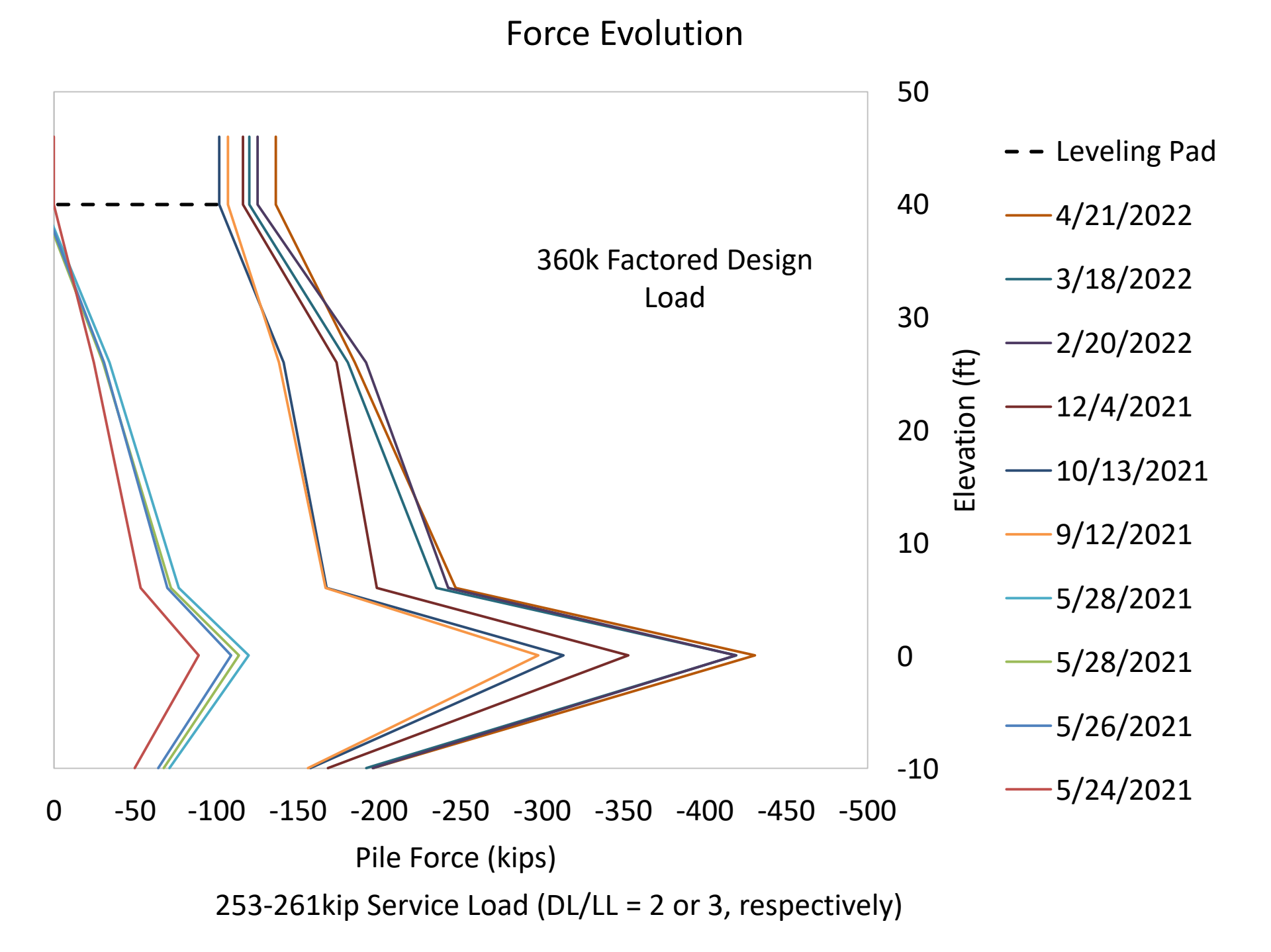


October 12, 2021

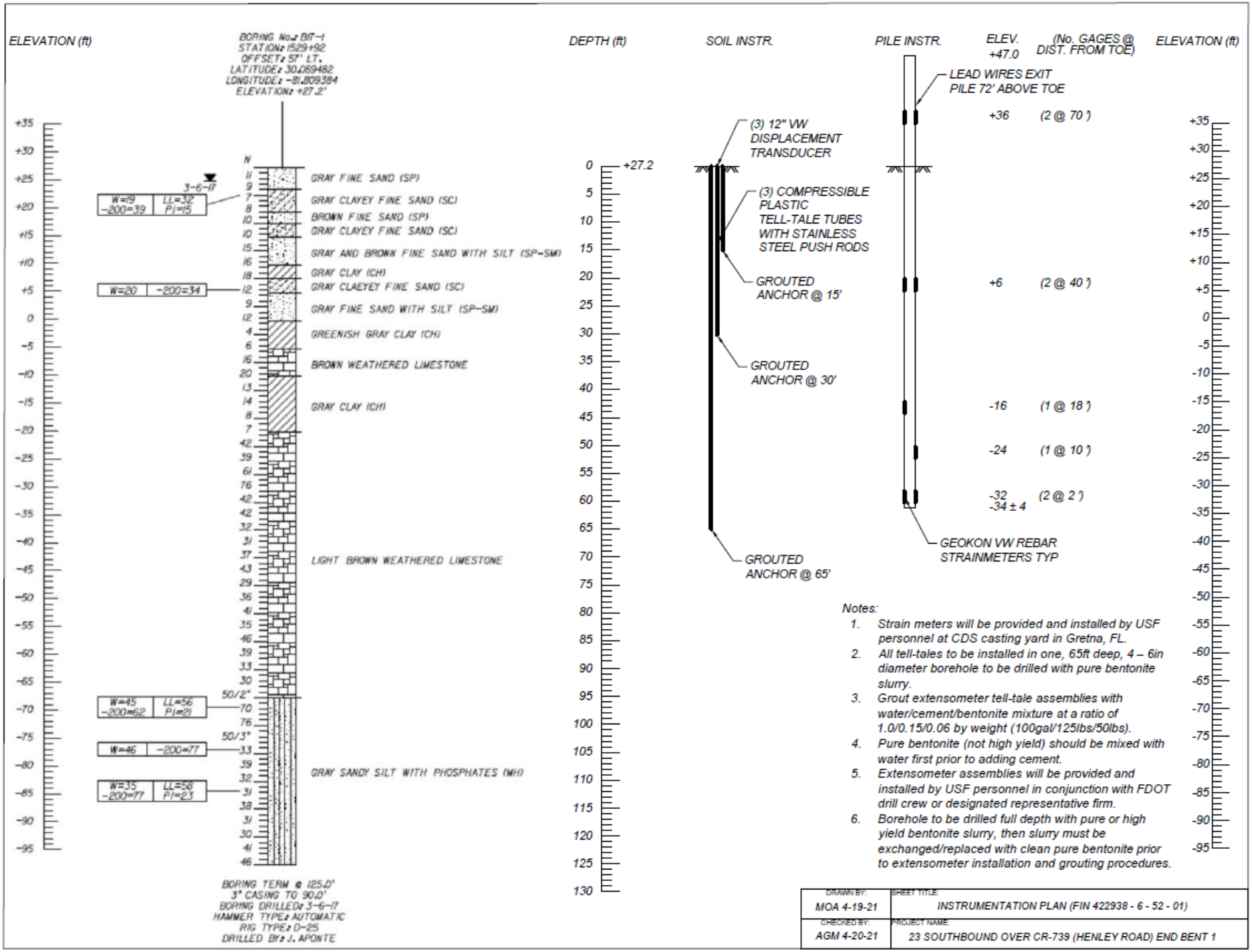
East End (EB 3) Looking West


East End (EB 3) Looking East
Down Approach Embankment


Paseo Al Mar Creep Corrected Pile Force
1
2
3
4
5
6
7
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
Pile Load (kips)
5/12
6/1
6/21
7/11
7/31
8/20
9/9
9/29
10/19
11/8
Level 1
Level 2
Level 3
Level 4
Level 5
1. 5/12 First of fill placement
2. 5/28 Last of fill placement
3. 6/08 Pile cutoff
4. 6/15 Cap poured
5. 6/23 Pedestal poured
6. 6/26 Pedestal / Cap thermal expansion
7. 7/02 Stem/back wall poured


Force Evolution
360k Factored Design Load
50
40
30
20
10
0
-10
Elevation (ft)
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
Pile Force (kips)
253-261kip Service Load (DL/LL = 2 or 3, respectively)
Leveling Pad
4/21/2022
3/18/2022
2/20/2022
12/4/2021
10/13/2021
9/12/2021
5/28/2021
5/28/2021
5/26/2021
5/24/2021

Henley Rd Instrumentation



Henley Rd.

- Additional instruments
- Rain gauge
- Air temperature
- Digital camera


HENLEYRD SEP 08, 2021 16:13 302K


HENLEYRD SEP 10, 2021 17:00 300K


HENLEYRD SEP 15, 2021 12:00 305K


HENLEYRD SEP 16, 2021 07:00 295K


HENLEYRD SEP 17, 2021 10:00 301K


HENLEYRD SEP 21, 2021 09:00 299K


HENLEYRD SEP 21, 2021 15:00 307K


HENLEYRD
SEP 21, 2021 17:00 299K


HENLEYRD SEP 23, 2021 10:00 298K


HENLEYRD SEP 23, 2021 11:00 301K


HENLEYRD SEP 23, 2021 15:00 305K


HENLEYRD
SEP 24, 2021 15:00 304K


HENLEYRD SEP 29, 2021 09:00 297K


HENLEYRD SEP 30, 2021 08:00 293K


HENLEYRD
OCT 04, 2021 09:00 302K


HENLEYRD
OCT 05, 2021 15:00 307K


HENLEYRD
OCT 12, 2021 15:00 304K


HENLEYRD
OCT 18, 2021 14:00 300K

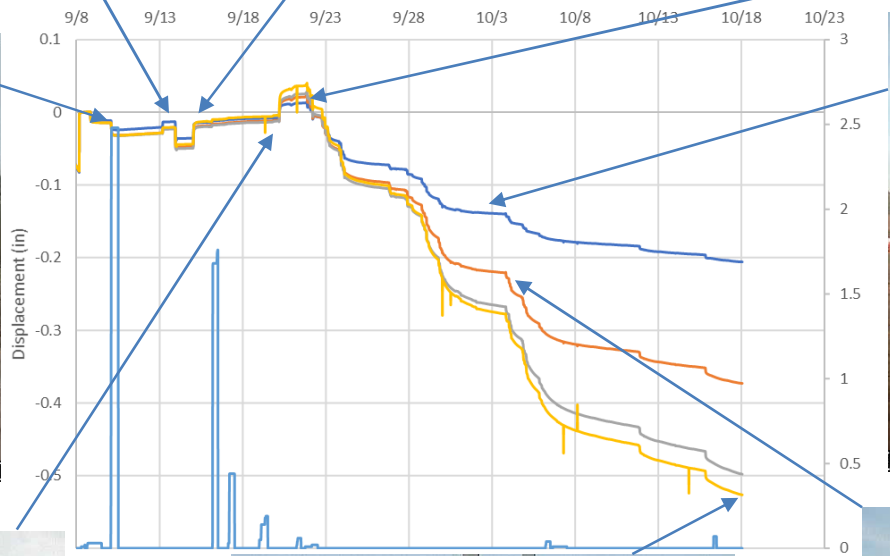

HENLEYRD JUL 13, 2022 11:00 309K


Stacked
Soil
HENLEYRD SEP 14, 2021 12:00 307K


Excavate for wall pad
HENLEYRD SEP 15, 2021 13:00 305K


Begin
embankment
HENLEYRD SEP 22, 2021 09:00 301K


Rain
LEYRD SEP 10, 2021 16:00 30

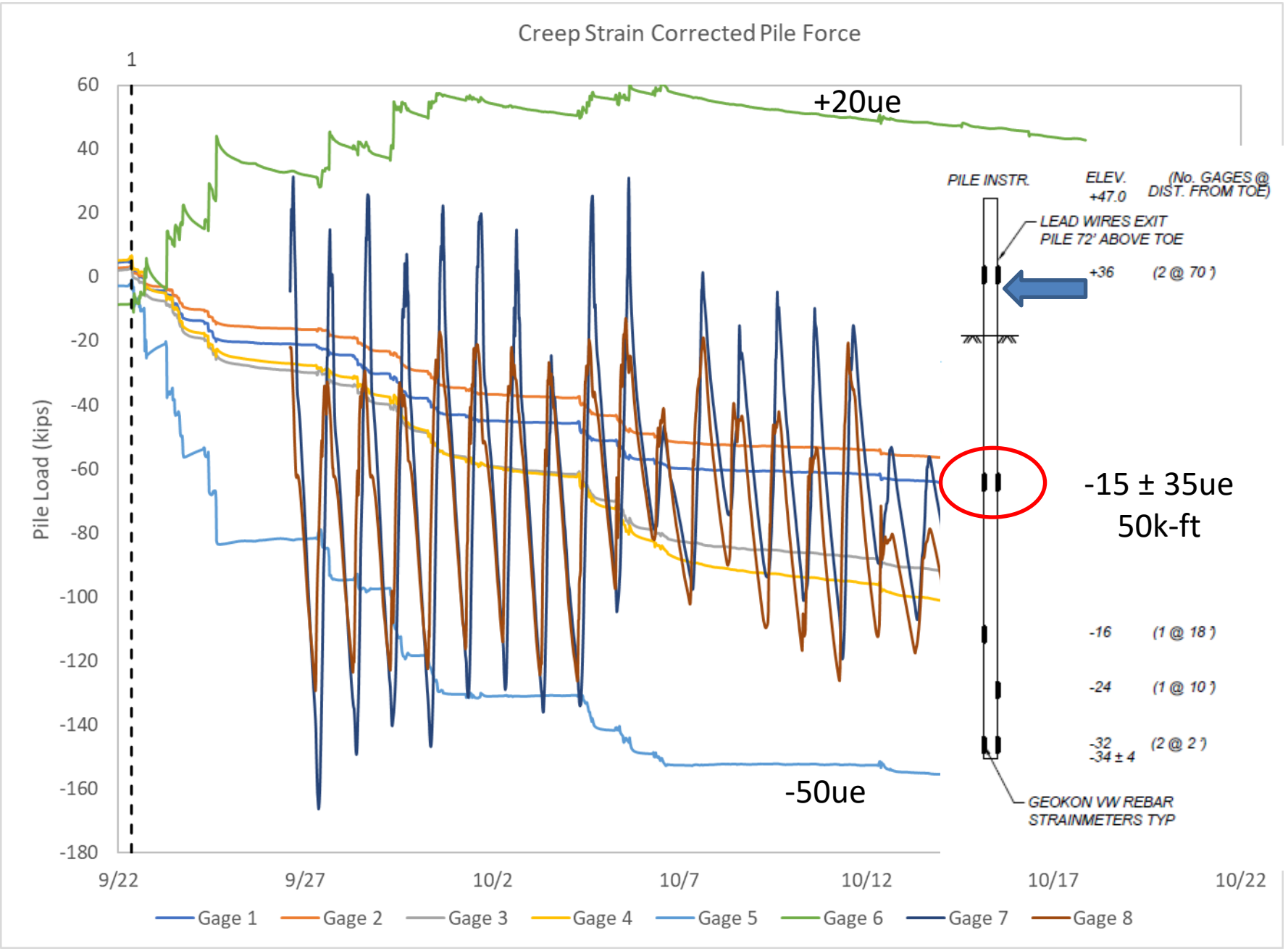

9/8
9/13
9/18
9/23
9/28
10/3
10/8
10/13
10/18
10/23
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Displacement (in)
3
2.5
2
1.5
1
0.5
0


YRD OCT 04, 2021 07:00 292K


Remove
soil
HENLEYRD SEP 20, 2021 15:00 301K


HENLEYRD OCT 18, 2021 14:00 300K


HENLEYRD OCT 04, 2021 14:00 308K

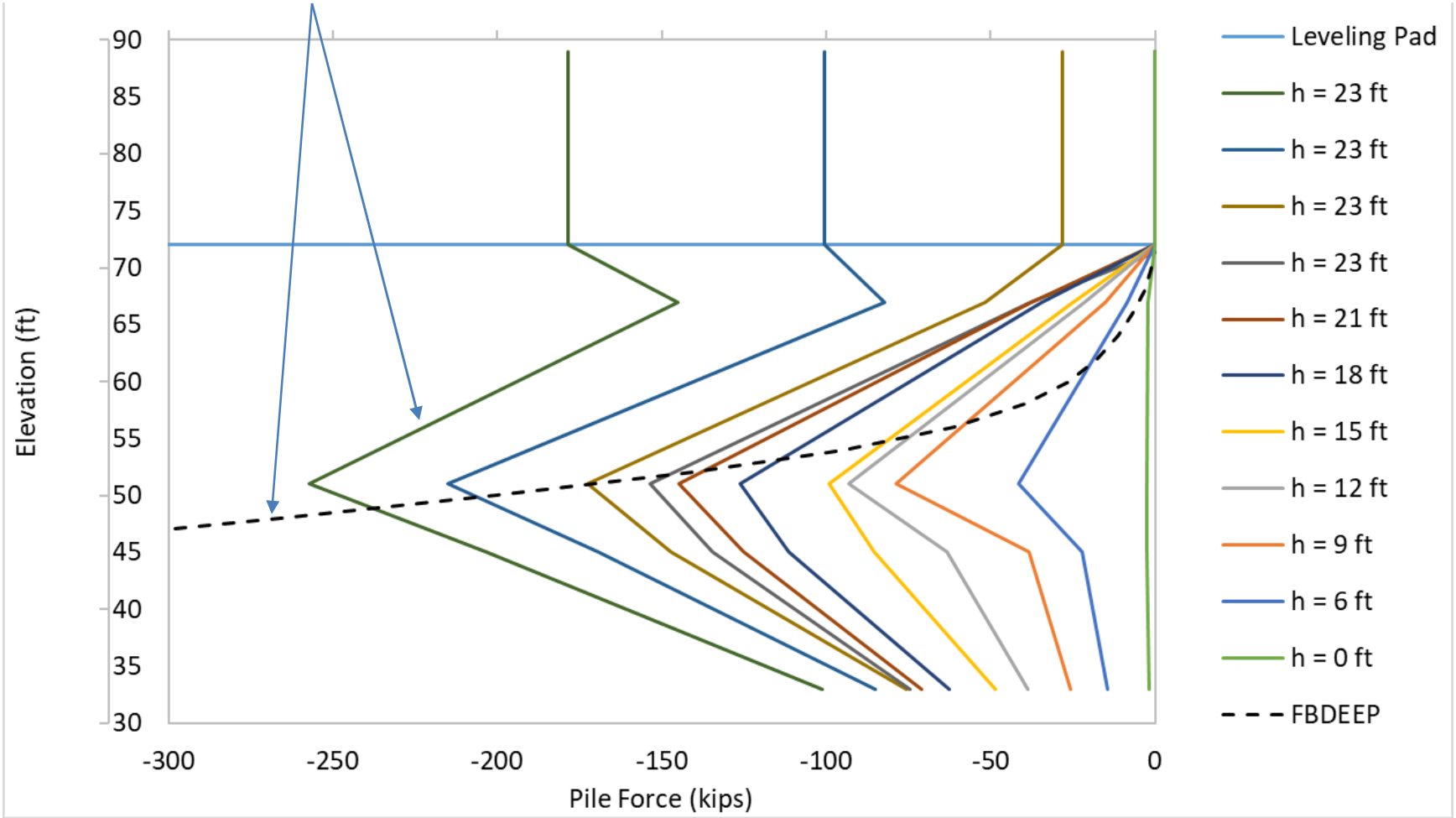

Creep Strain Corrected Pile Force
1
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
Pile Load (kips)
+20ue
-50ue
-15 ± 35ue
50k-ft
PILE INSTR.
ELEV.
+47.0
(No. GAGES @ DIST. FROM TOE)
ELEVATION (f
LEAD WIRES EXIT PILE 72' ABOVE TOE
+36
(2 @ 70')
-16
(1 @ 18')
-24
(1 @ 10')
-32
-34 ± 4
(2 @ 2')
GEOKON VW REBAR STRAINMETERS TYP
+35
+30
+25
+20
+15
+10
+5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
9/22
9/27
10/2
10/7
10/12
10/17
10/22
Gage 1
Gage 2
Gage 3
Gage 4
Gage 5
Gage 6
Gage 7
Gage 8

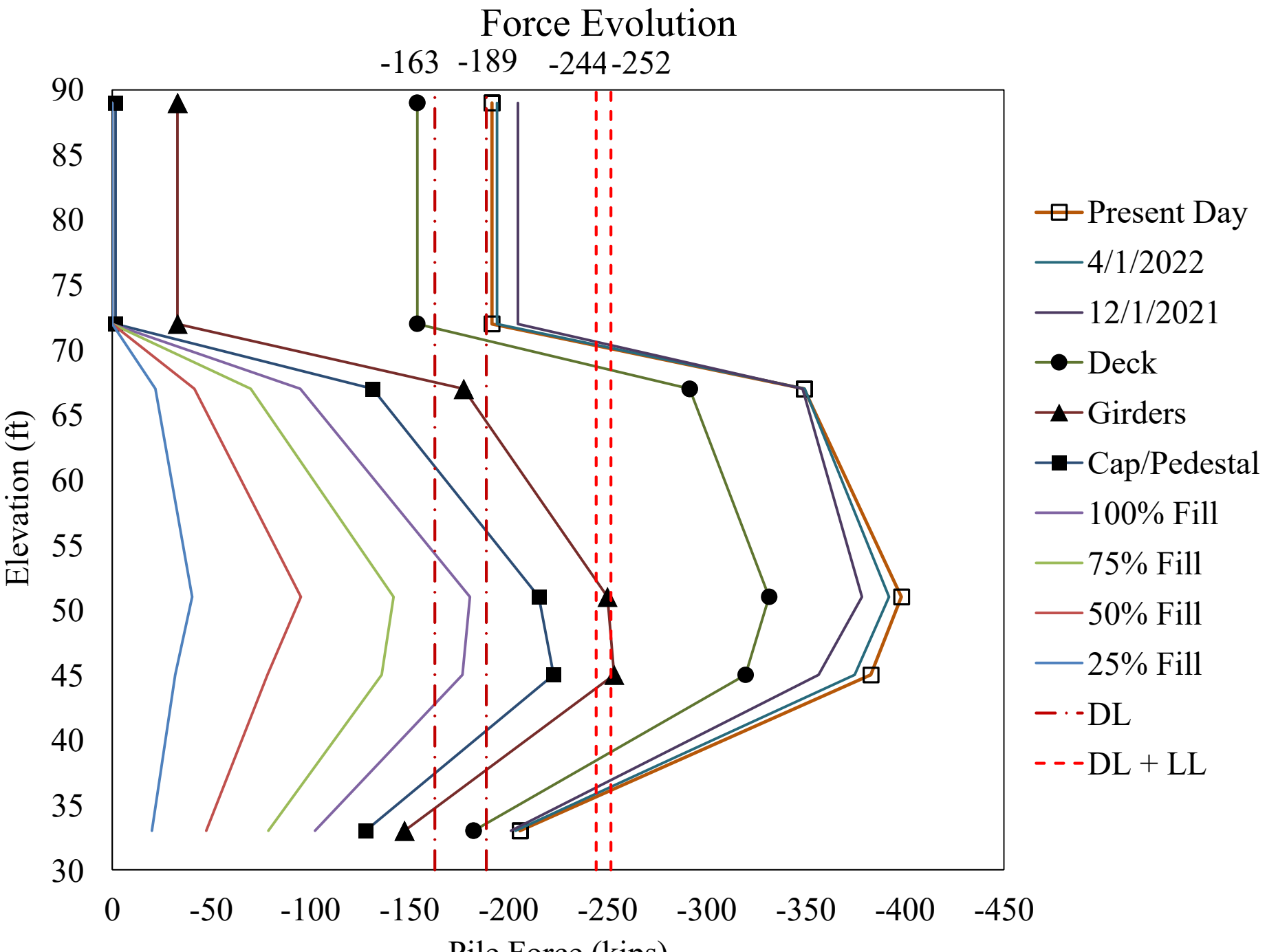
Moving Forward

- Effects of structural load progressing (side shear reversal??)
- High speed sampling of live loading events also pending but will help to identify appropriateness of load combinations.
- Construction slower than expected
- Planned project end date May ~~2022~~ now 2023

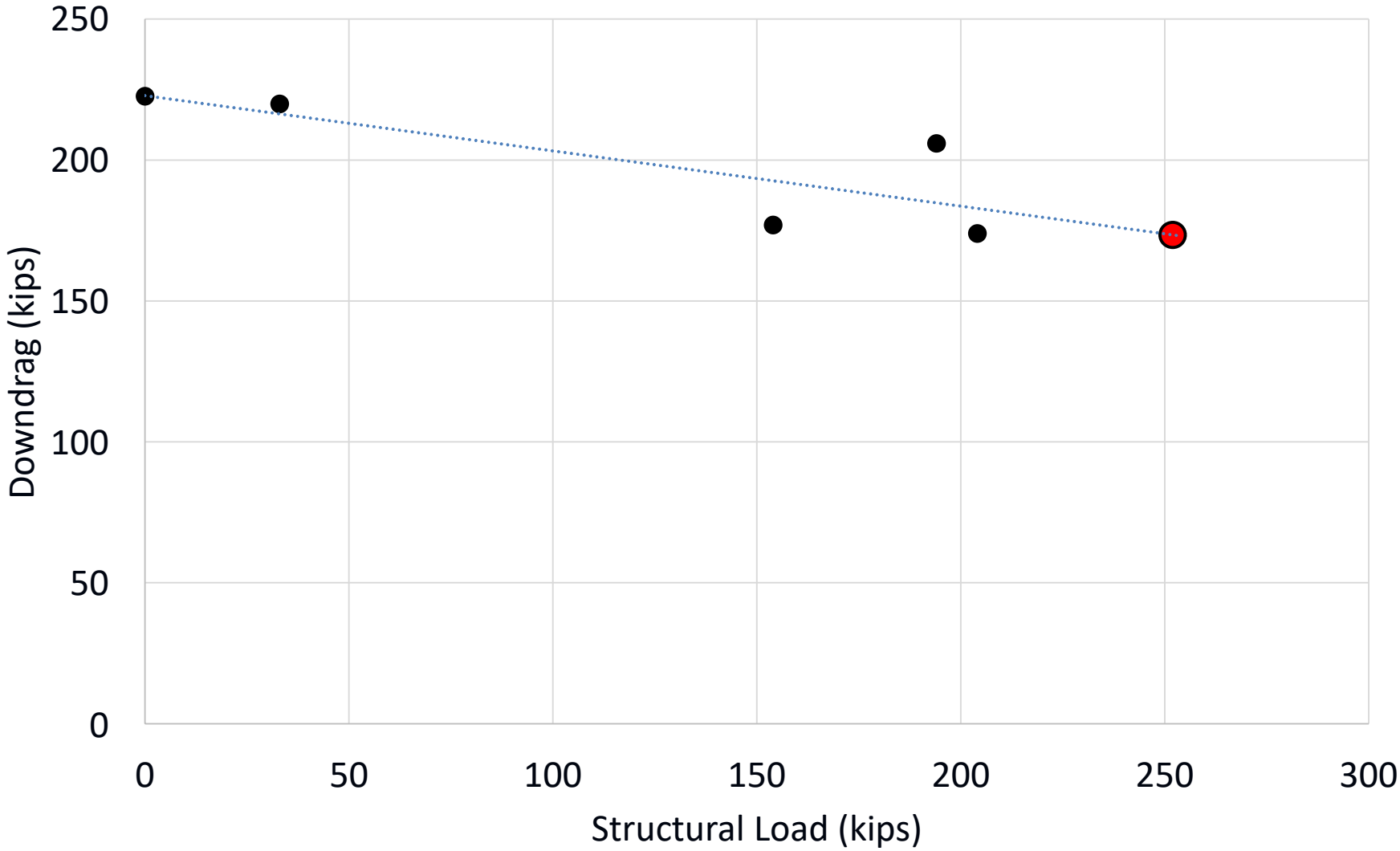
Quick Observations

Surcharge loading makes downdrag soil strata stronger than FBDEEP prediction




Force Evolution
-163
-189
-244
-252
90
85
80
75
70
65
60
55
50
45
40
35
30
Elevation (ft)
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
Present Day
4/1/2022
12/1/2021
Deck
Girders
Cap/Pedestal
100% Fill
75% Fill
50% Fill
25% Fill
DL
DL + LL

Estimate Remaining Downdrag at Full Bridge Load



Preliminary Findings

- Downdrag forces are significant
- FBDEEP side shear predictions, while conservative for strength considerations are unconservative for downdrag estimation.
- Actual settlement about 1/3 that predicted by typical settlement computations.
- Live loads are not large enough to reverse side shear and offset downdrag.
- Downdrag should be included in most embankment designs

Acknowledgments

- CSD Manufacturing
- EXP U.S. Services Inc.
- FDOT District Engineers
- FDOT Project Manager and Reviewers
- FDOT SMO Drill Crew
- FGE, LLC
- GRL Engineers, Inc.
- HNTB Corporation
- Prince Construction
- SACYR Construccion
- Southern Concrete Products
- and Numerous Graduate Students

Questions