301 MISSION

REFINED FOUNDATION RETROFIT

LERA Structural Engineers
ENGEO Incorporated

13 September 2018

PRESENTATION OUTLINE

1) Introduction
2) Refined Retrofit Design Overview
3) Refined Retrofit Performance
4) Next Steps
5) Conclusion

REFINED RETROFIT DESIGN OVERVIEW

Foundation Retrofit Components:

1. New piles to rock to arrest settlement and resist a portion of gravity and seismic load **(approximately 132 total, reduced from 232 total)**

2. Existing piles to sand to carry reduced gravity loads and seismic loads.

REFINED RETROFIT DESIGN OVERVIEW

Areas of refinement:

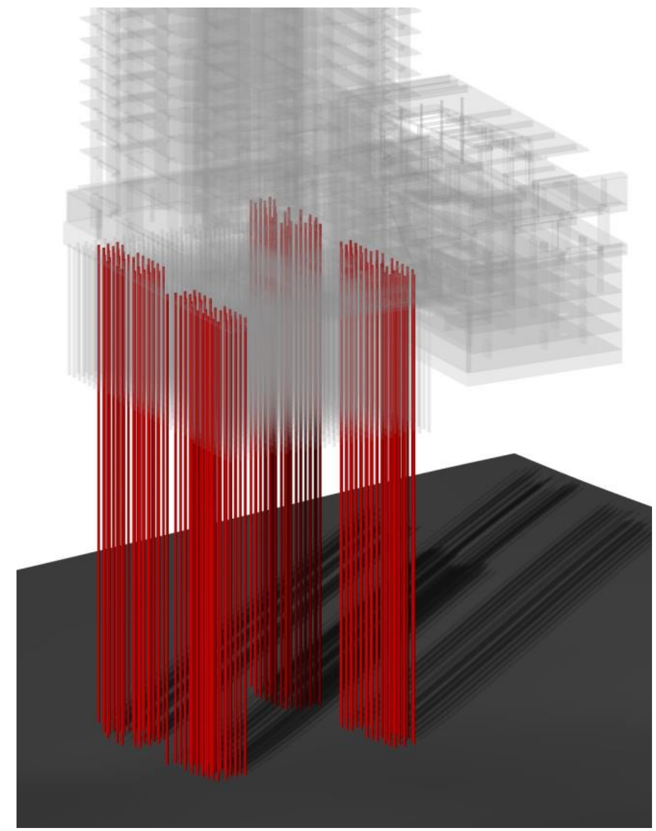
1. Targeted load carried to bedrock is 35% $\pm$ 5% (previous was 55% $\pm$ 10%)
   - Targeting 35% brings the Old Bay Clay stresses in line with other existing 30-40 story buildings in the area
2. Evaluation of existing precast piles as groups instead of individually
3. Updated Pile Design – Push Pile
   - Less steel area (Removes center bar and reduces outer casing length)
   - Eliminates ground loss concerns and densifies soil around existing piles
   - Load test every pile during installation
4. Lower pile count reduces impact to tower mat
5. Parking garage remains fully operational
6. Reduced Cost: Estimated Pile Pricing - $35 Million

REFINED RETROFIT DESIGN OVERVIEW

REVISED SCHEME:

- Install 66± 9 5/8” diameter piles to rock on west
- Lock off each rock pile with 550k± compression

- Install 66± 9 5/8” diameter piles to rock on east
- Lock off each rock pile with 550k± compression



OUR JOINT VENTURE CONSISTS OF THE TWO LARGEST MICROPILE CONTRACTORS IN NORTH AMERICA

– Nicholson Construction

– Hayward Baker Inc.

NICHOLSON CONSTRUCTION IS

- a nationally-renowned geotechnical engineering and construction firm with more than 60 years of experience.

- the north American subsidiary of Soletanche Bachy, a France-based global leader in geotechnical and civil engineering construction.

HAYWARD BAKER IS

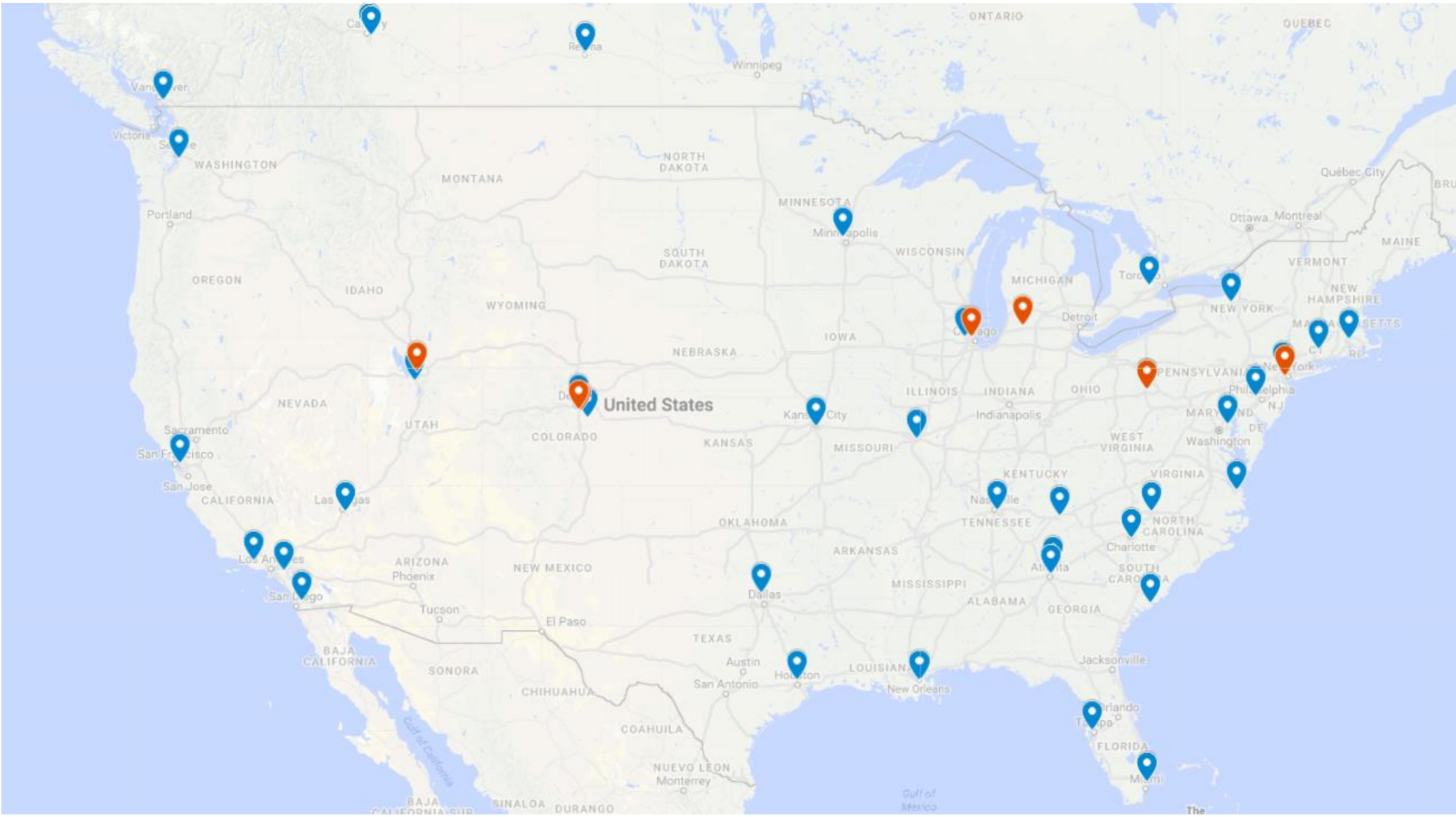
- a nationally-renowned geotechnical engineering and construction firm with more than 70 years of experience.

HAYWARD BAKER
A KELLER COMPANY

- the largest business unit of Keller, the worlds largest geotechnical solutions specialist.

KELLER

TOGETHER WE HAVE OVER 40 OFFICES IN THE US



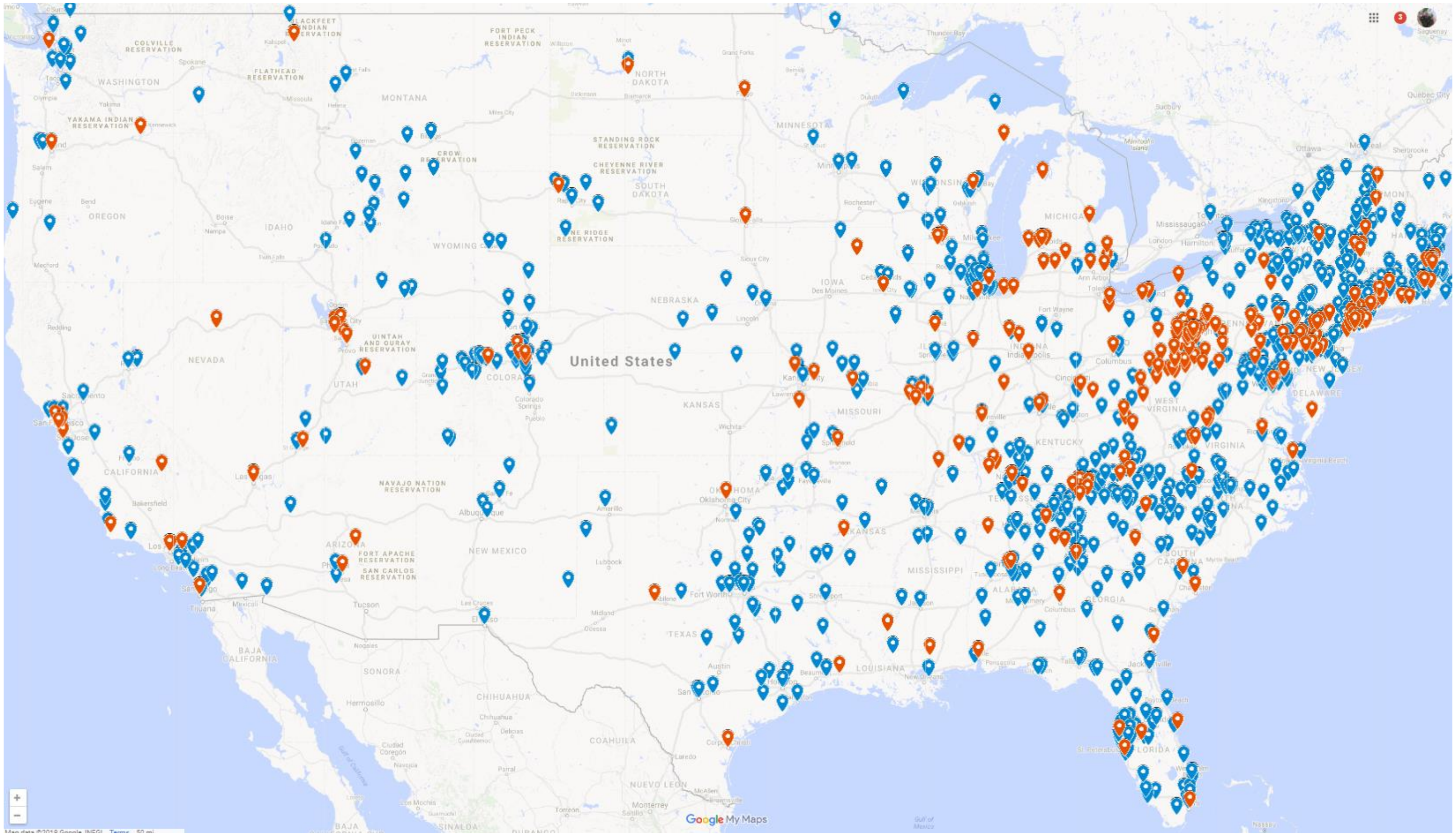
WE ARE THE TWO MOST EXPERIENCED MICROPILE INSTALLERS IN THE WORLD

- Combined we have performed over 3,000 individual micropile projects and over $1,500,000,000 of micropile work in North America over 40 years

- We have underpinned hundreds of important buildings across the country

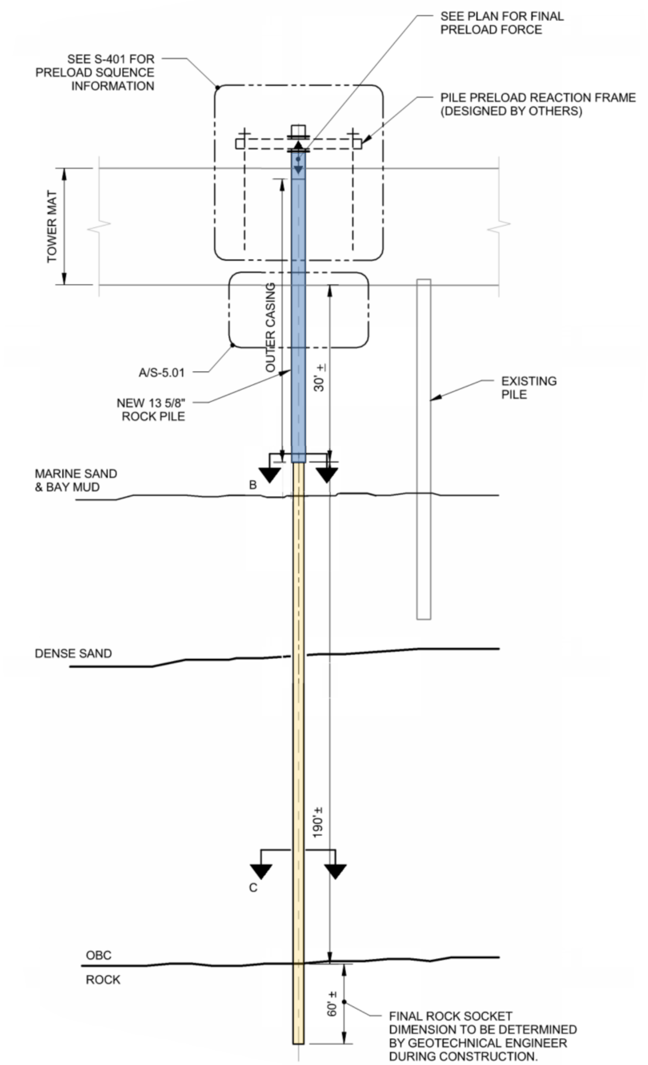
- We have more experience with high capacity, deep and low headroom micropiles than any other contractor

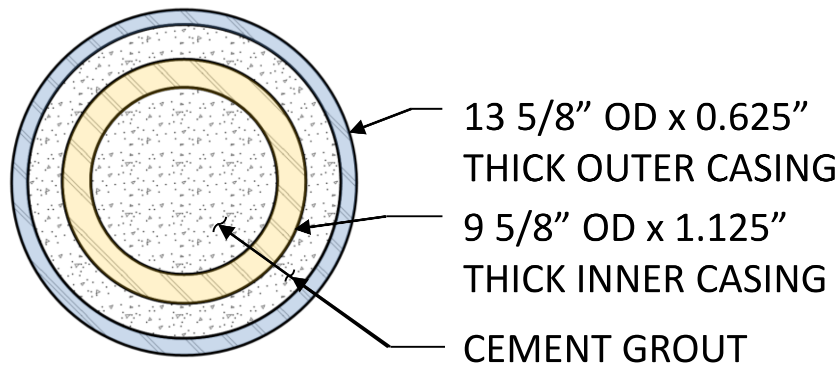
COMBINED WE HAVE INSTALLED OVER $1,500,000,000 OF MICROPILE WORK IN 40 YEARS



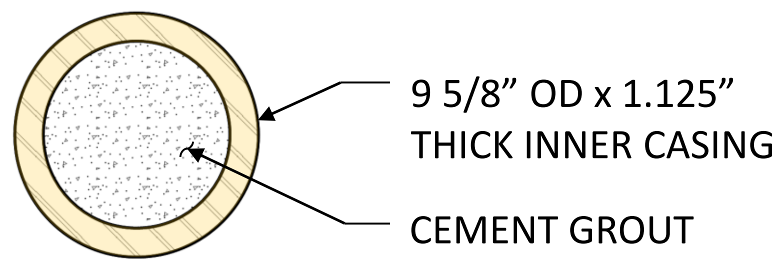
PUSH PILE DESIGN

PILE DESIGN CAPACITY
1000k ALLOWABLE
2000k ULTIMATE





Top 30’ For Improved Bending Performance



Typical Cross Section

RETROFIT CONSTRUCTION SEQUENCE

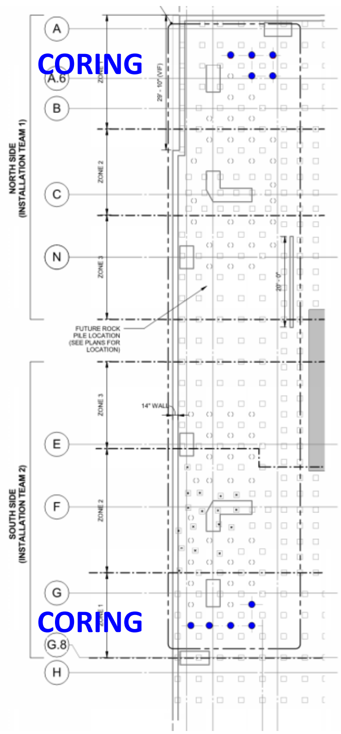
- PILE INSTALLATION SEQUENCE

Three Operation Teams:

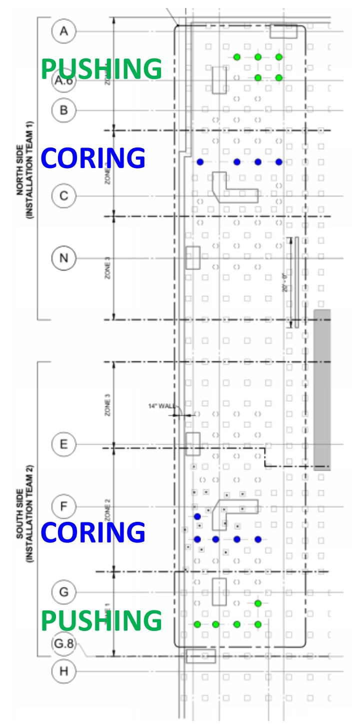
1) Coring through the mat
2) Installing the pile
3) Grouting the pile and completing connection to the mat

TOTAL PILE INSTALLATION DURATION = 12 MONTHS

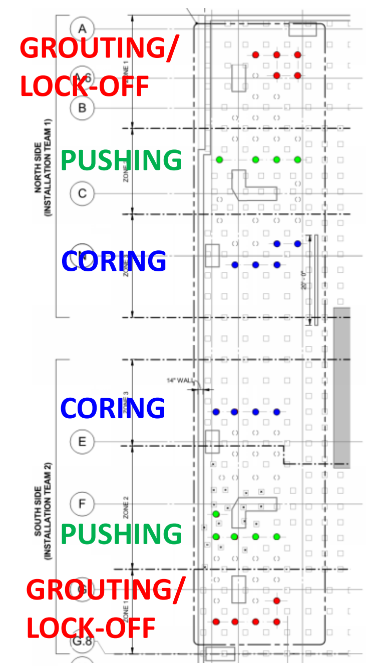
1



2



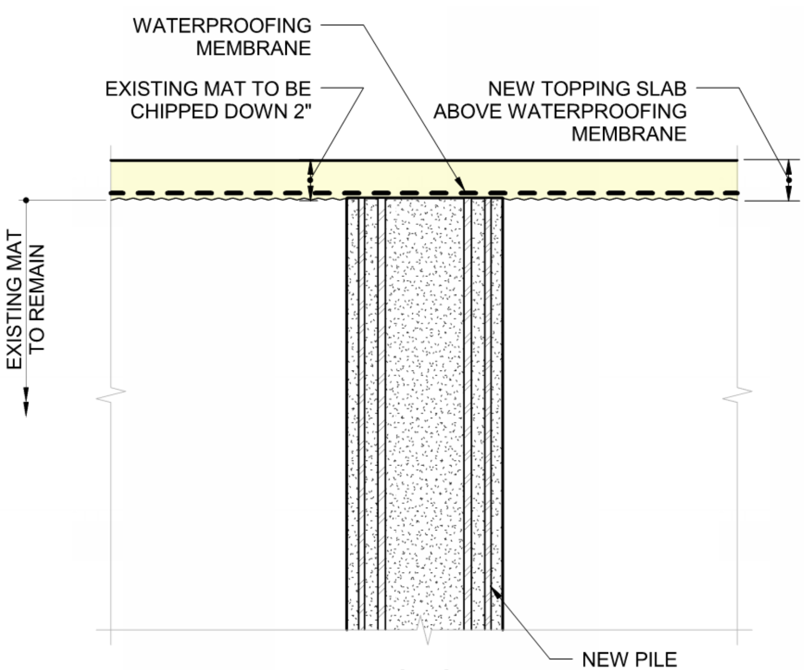
3



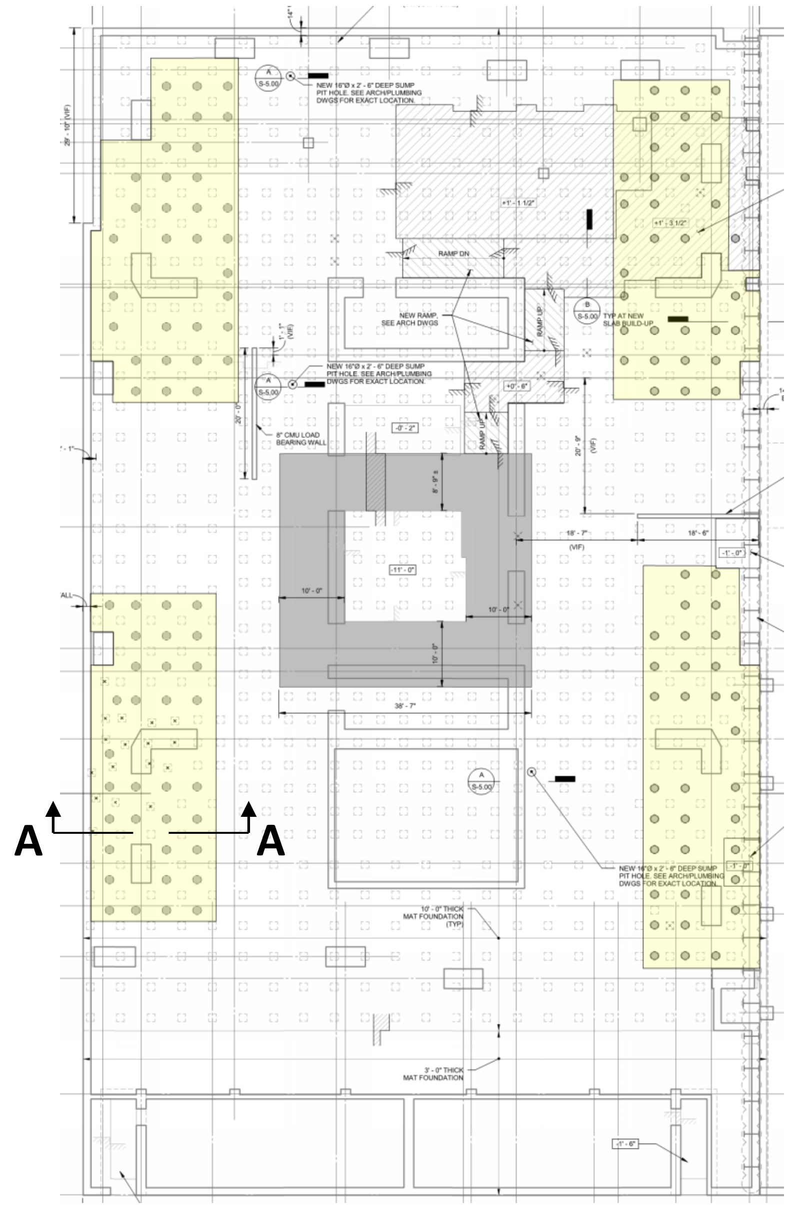
NICHOLSON | HAYWARD BAKER JOINT VENTURE

WATERPROOFING

INDICATES AREAS WHERE MAT CONCRETE IS TO BE CHIPPED DOWN 2" TO ALLOW FOR INSTALLATION OF NEW WATERPROOFING MEMBRANE. REPLACEMENT 2" TOPPING SLAB TO BE CAST ABOVE NEW MEMBRANE AFTER INSTALLATION.



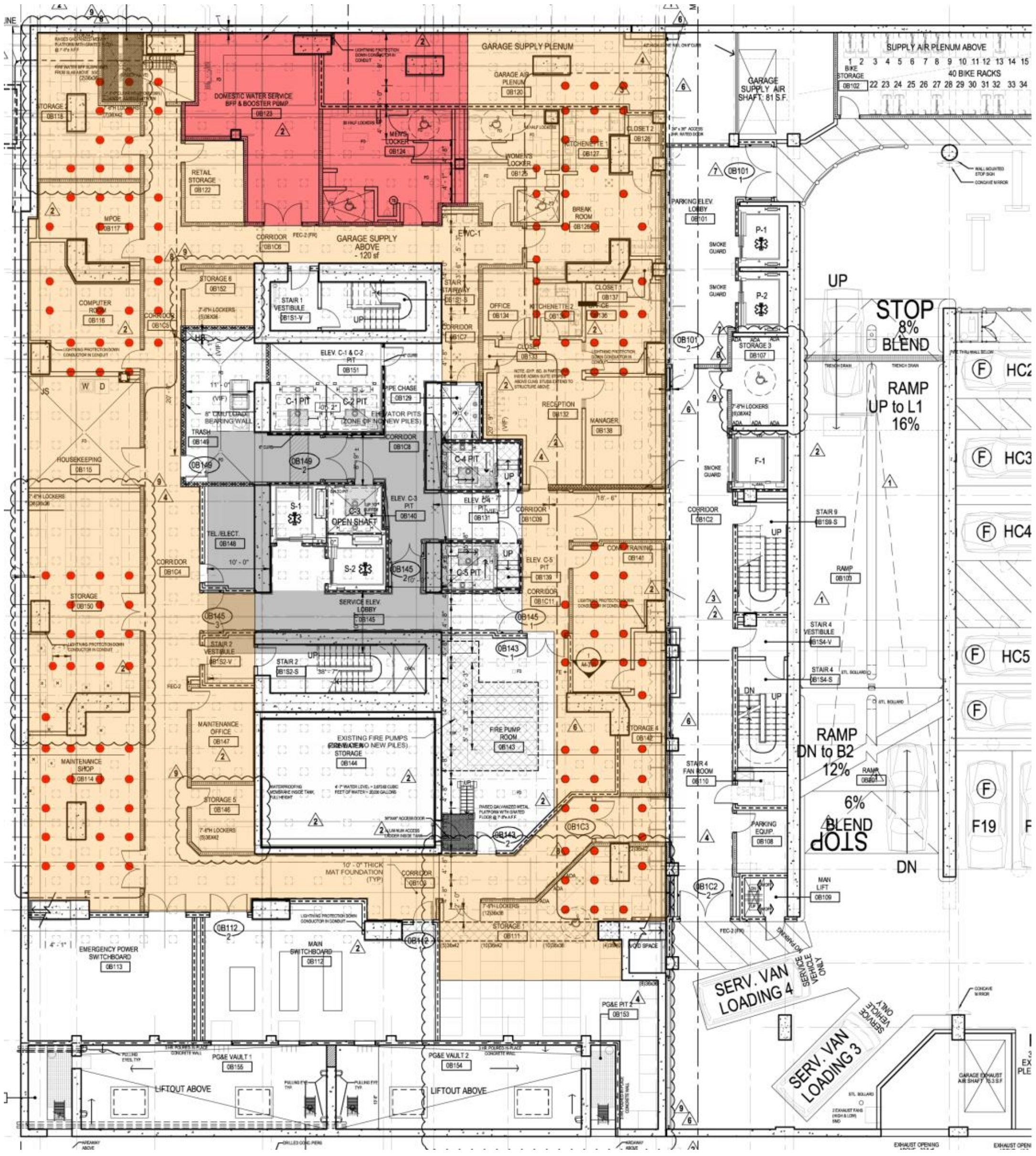
A-A



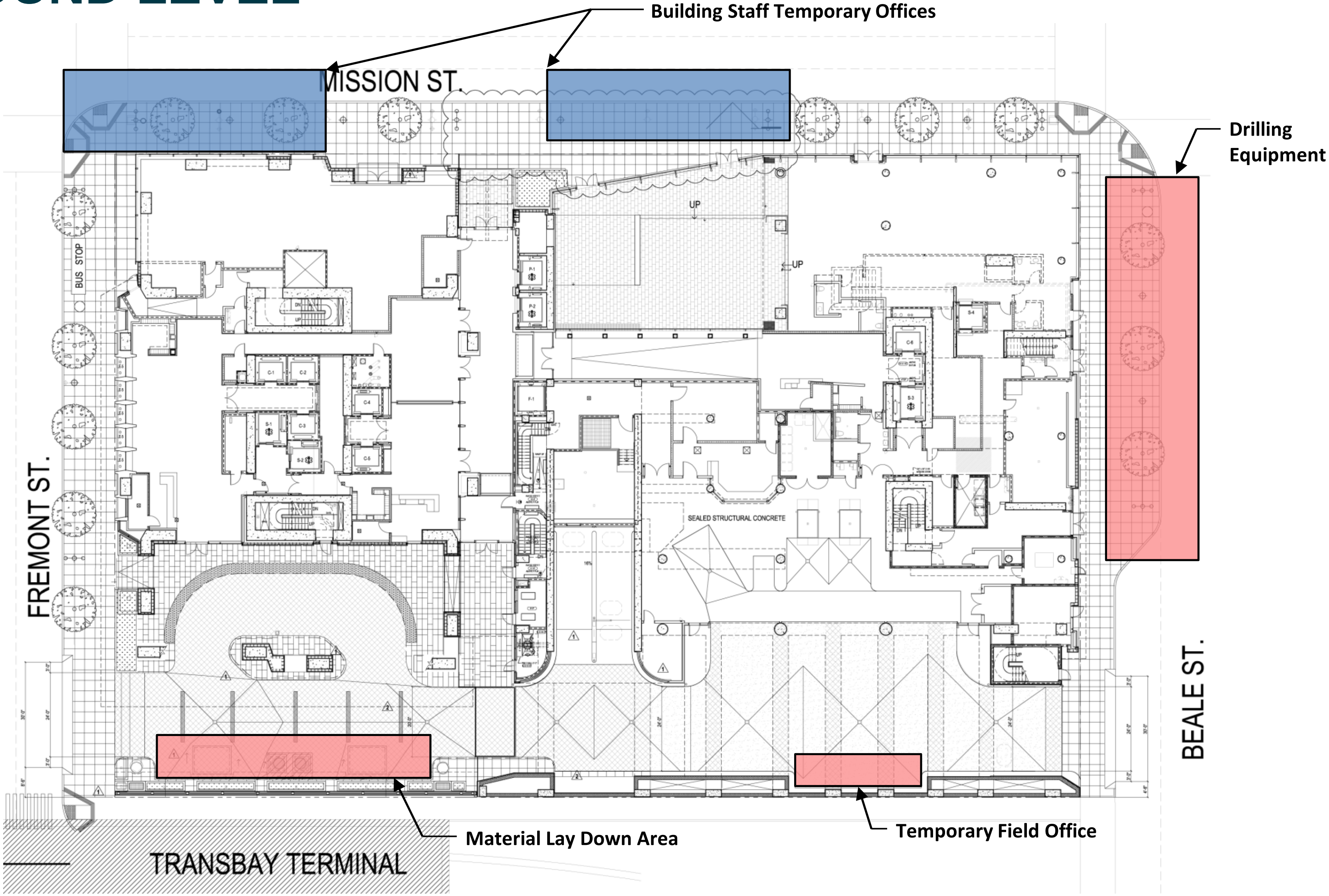
B1 LEVEL

AREAS TO BE DEMOLISHED TO ALLOW PILE INSTALLATION WORK TO BE ACCOMPLISHED

MATERIAL LAY DOWN AREA (APPROXIMATELY 1000 ft^2)



GROUND LEVEL



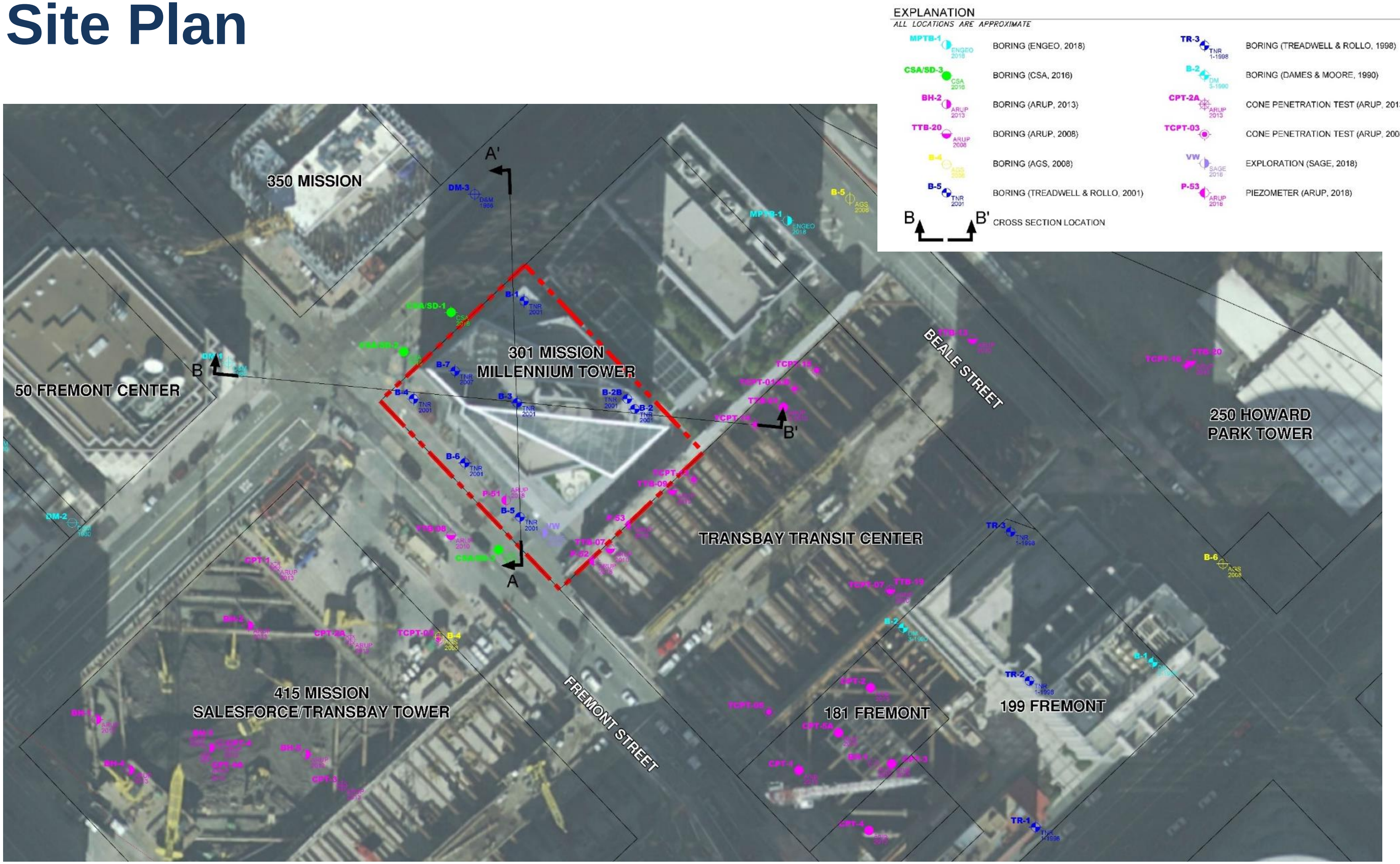
REFINED RETROFIT DESIGN OVERVIEW

RETROFIT STAT SHEET:

- Building Weight: 240,000 kips *(Note: 1kip = 1000lb)*
- 132 ± new piles to rock
- Allowable capacity of retrofit piles: 132,000 kips
- Retrofit increases foundation load carrying capacity by **55%**
- At retrofit completion:
    - **30-40%** of building weight on new piles to rock
    - **60-70%** of building weight on existing piles

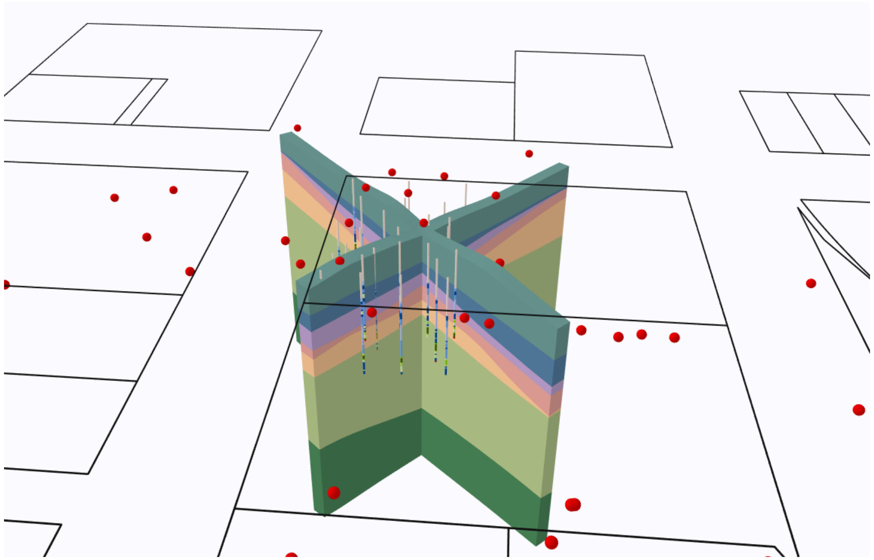
REFINED RETROFIT PERFORMANCE

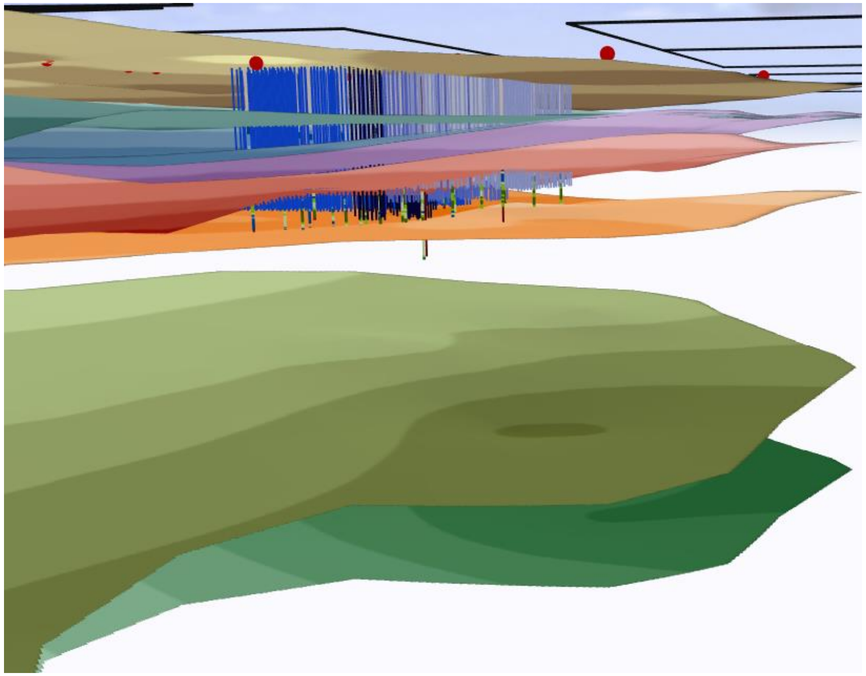
Site Plan



LERA ENGEO Expect Excellence NICHOLSON HAYWARD BAKER JOINT VENTURE

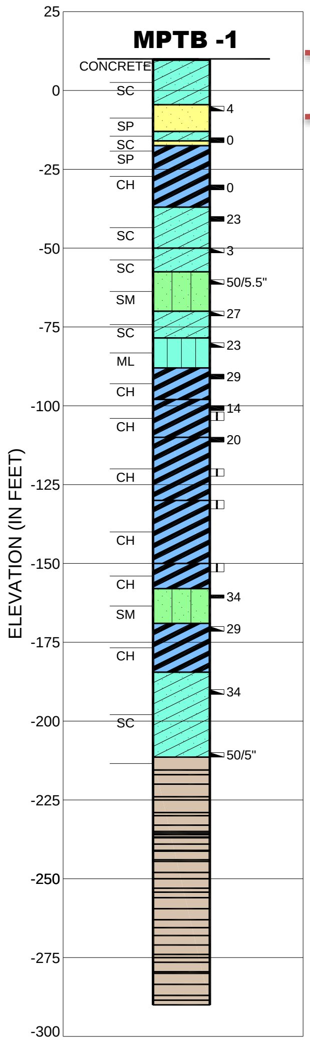
3-D GIS Database of Soil Below the Tower

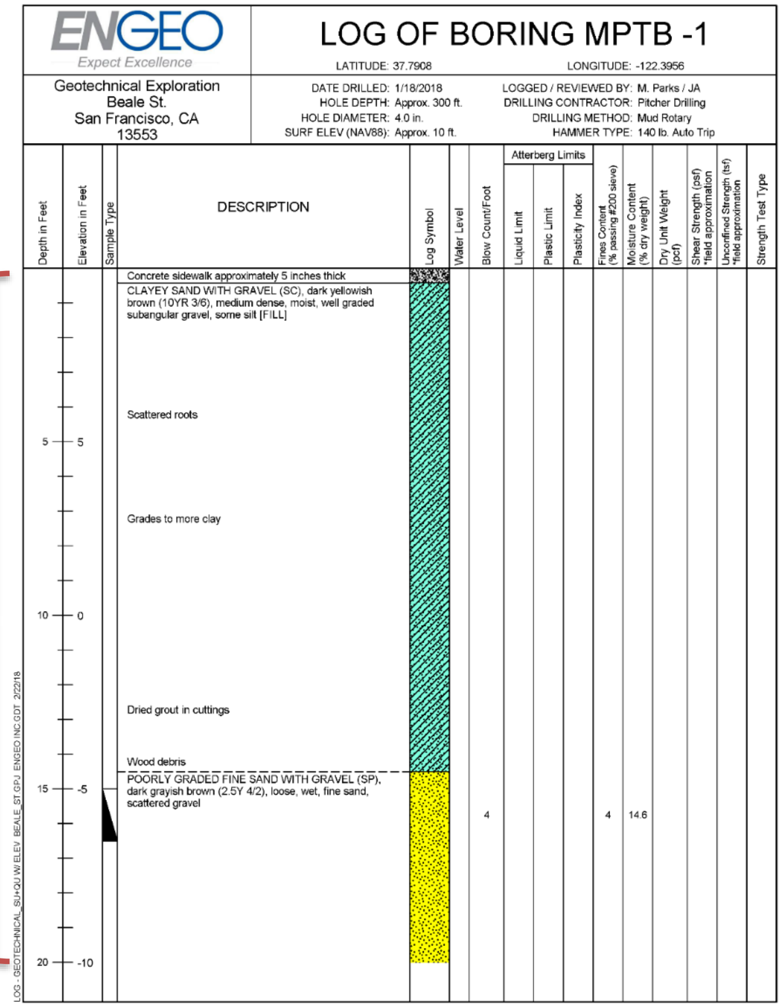




- Holocene 1 (YBM1)
- Holocene 2 (Marine Sand1)
- Holocene 3 (YBM2)
- Holocene 4 (Marine Sand2)
- Pleistocene 1 (Sand/Clayey Sand)
- Pleistocene 2 (OBC)
- Pleistocene 3 (OBC2 + Melange/Gravels)

Typical Log of Coring





ENGEO Expect Excellence

LOG OF BORING MPTB -1

LATITUDE: 37.7908 LONGITUDE: -122.3956

Geotechnical Exploration
Beale St.
San Francisco, CA
13553

DATE DRILLED: 1/18/2018
HOLE DEPTH: Approx. 300 ft.
HOLE DIAMETER: 4.0 in.
SURF ELEV (NAV88): Approx. 10 ft.

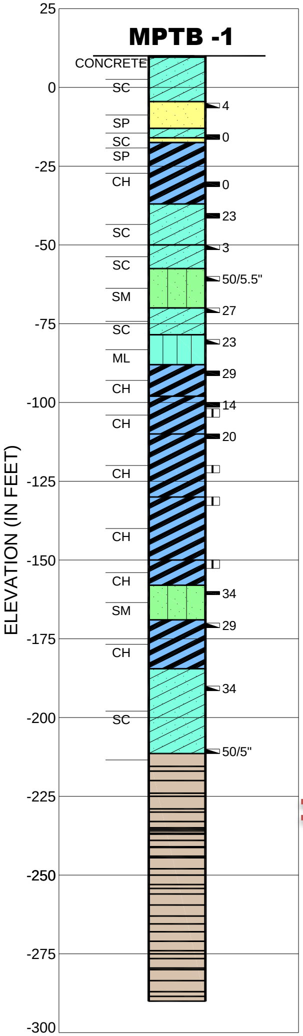
LOGGED / REVIEWED BY: M. Parks / JA
DRILLING CONTRACTOR: Pitcher Drilling
DRILLING METHOD: Mud Rotary
HAMMER TYPE: 140 lb. Auto Trip

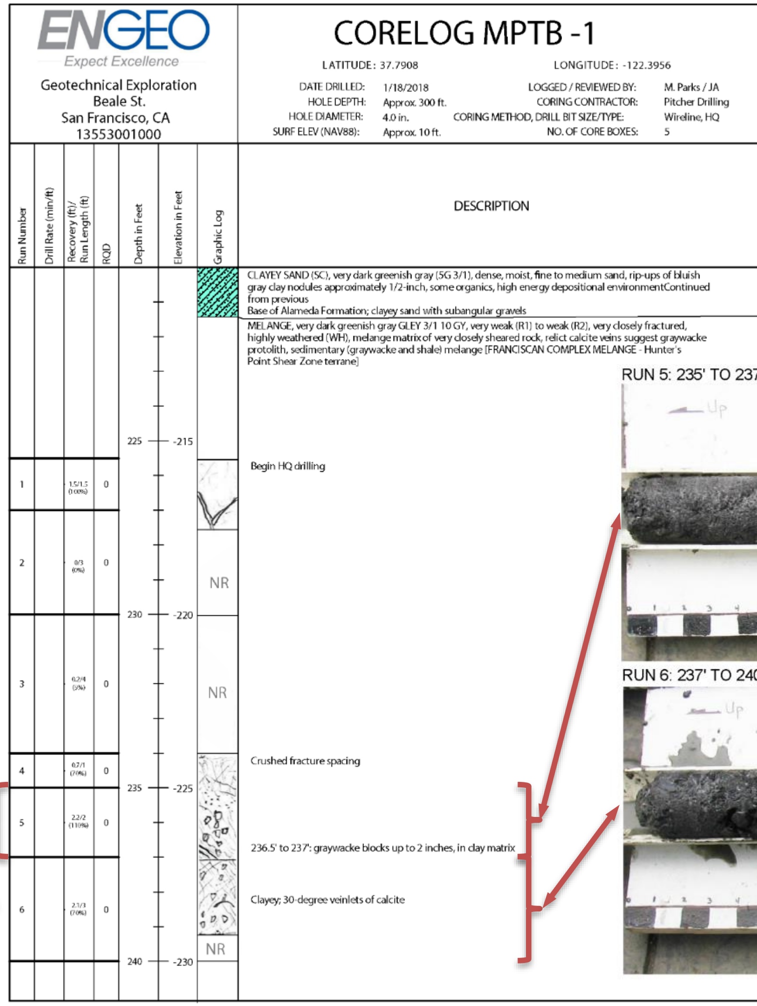
Depth in Feet	Elevation in Feet	Sample Type	DESCRIPTION	Log Symbol	Water Level	Blow Count/Foot	Atterberg Limits: Liquid Limit	Atterberg Limits: Plastic Limit	Atterberg Limits: Plasticity Index	Fines Content (% passing #200 sieve)	Moisture Content (% dry weight)	Dry Unit Weight (pcf)	Shear Strength (psf) *field approximation	Unconfined Strength (tsf) *field approximation	Strength Test Type
			Concrete sidewalk approximately 5 inches thick												
			CLAYEY SAND WITH GRAVEL (SC), dark yellowish brown (10YR 3/6), medium dense, moist, well graded subangular gravel, some silt [FILL]												
			Scattered roots												
5	5														
			Grades to more clay												
10	0														
			Dried grout in cuttings												
			Wood debris												
			POORLY GRADED FINE SAND WITH GRAVEL (SP), dark grayish brown (2.5Y 4/2), loose, wet, fine sand, scattered gravel												
15	-5					4				4	14.6				
20	-10														

LOG - GEOTECHNICAL_SU+QU W/ ELEV BEALE ST.GPJ ENGEO INC.GDT 2/22/18

LERA ENGEO Expect Excellence NICHOLSON HAYWARD BAKER JOINT VENTURE

Typical Log of Coring




ENGEO
Expect Excellence

Geotechnical Exploration
Beale St.
San Francisco, CA
13553001000

CORELOG MPTB -1

LATITUDE: 37.7908 LONGITUDE: -122.3956

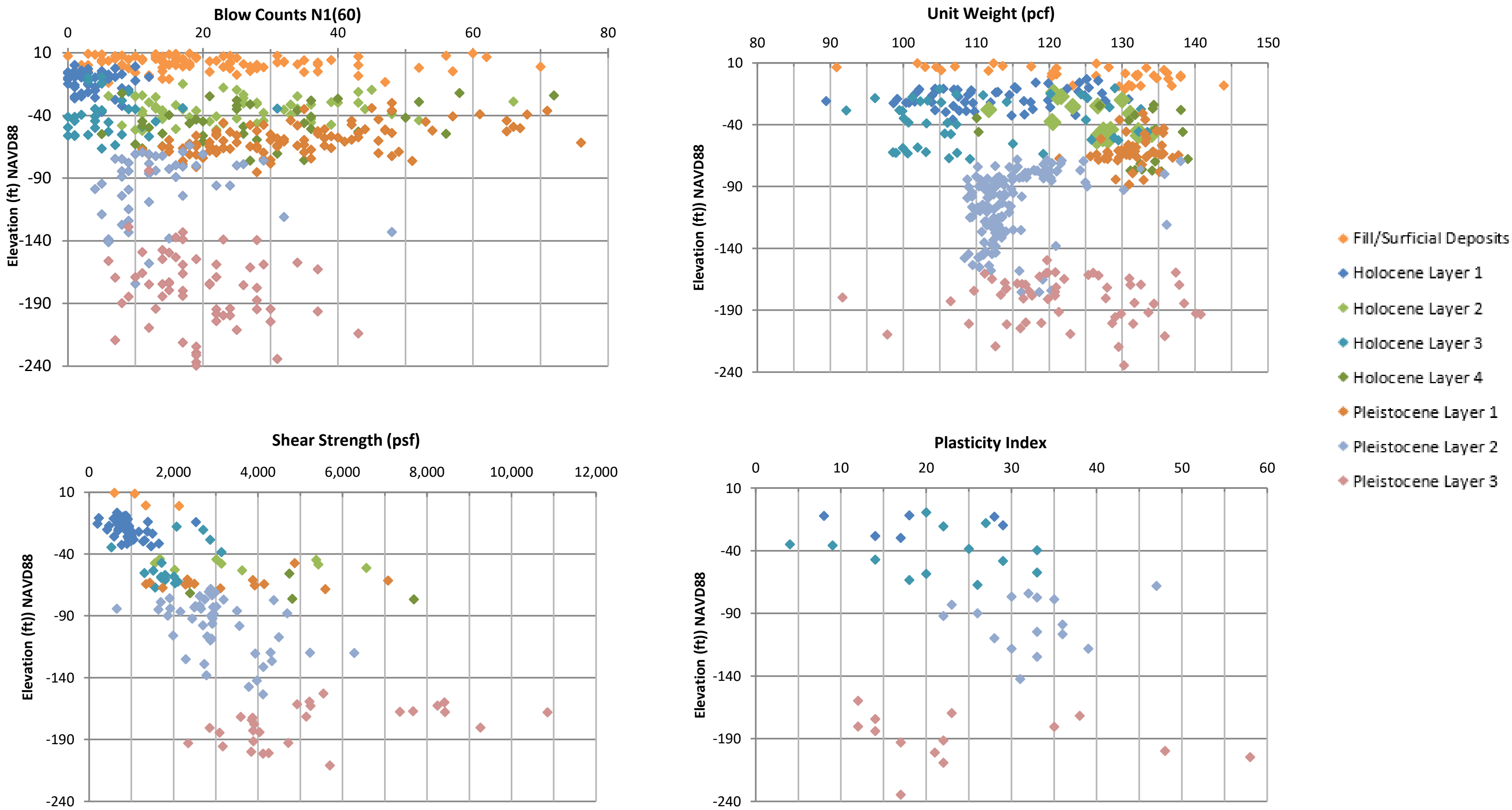
DATE DRILLED: 1/18/2018 LOGGED / REVIEWED BY: M. Parks / JA
HOLE DEPTH: Approx. 300 ft. CORING CONTRACTOR: Pitcher Drilling
HOLE DIAMETER: 4.0 in. CORING METHOD, DRILL BIT SIZE/TYPE: Wireline, HQ
SURF ELEV (NAV88): Approx. 10 ft. NO. OF CORE BOXES: 5

Run Number	Drill Rate (min/ft)	Recovery (ft)/ Run Length (ft)	RQD	Depth in Feet	Elevation in Feet	Graphic Log	DESCRIPTION
							CLAYEY SAND (SC), very dark greenish gray (5G 3/1), dense, moist, fine to medium sand, rip-ups of bluish gray clay nodules approximately 1/2-inch, some organics, high energy depositional environmentContinued from previous Base of Alameda Formation; clayey sand with subangular gravels
							MELANGE, very dark greenish gray GLEY 3/1 10 GY, very weak (R1) to weak (R2), very closely fractured, highly weathered (WH), melange matrix of very closely sheared rock, relict calcite veins suggest graywacke protolith, sedimentary (graywacke and shale) melange [FRANCISCAN COMPLEX MELANGE - Hunter's Point Shear Zone terrane]
				225	-215		
1		1.5/1.5 (100%)	0				Begin HQ drilling
2		0/3 (0%)	0			NR	
				230	-220		
3		0.2/4 (5%)	0			NR	
4		0.7/1 (70%)	0				Crushed fracture spacing
				235	-225		
5		2.2/2 (110%)	0				236.5' to 237': graywacke blocks up to 2 inches, in clay matrix
6		2.1/3 (70%)	0				Clayey; 30-degree veinlets of calcite
						NR	
				240	-230		

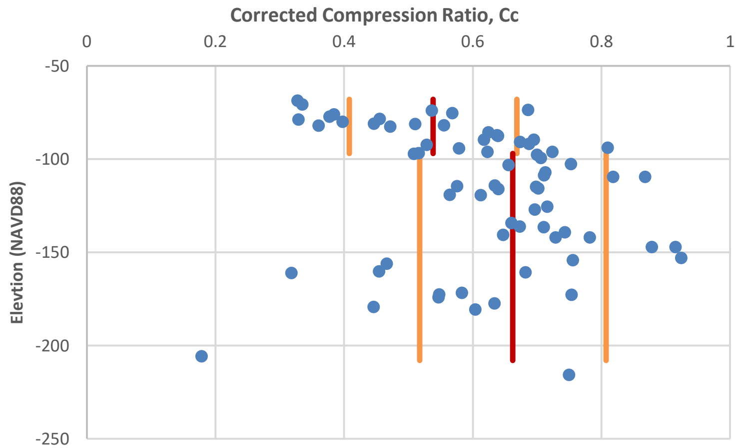
RUN 5: 235' TO 237'

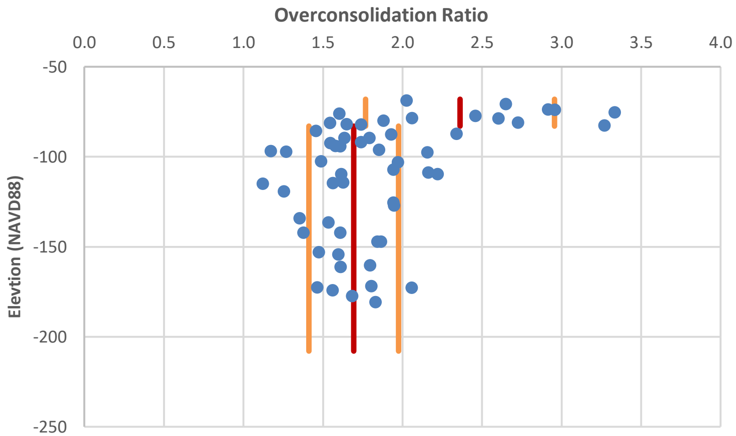
RUN 6: 237' TO 240'

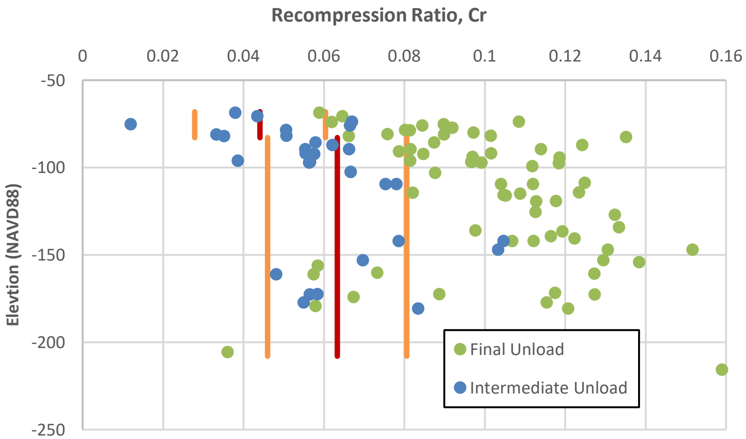
Soil Properties

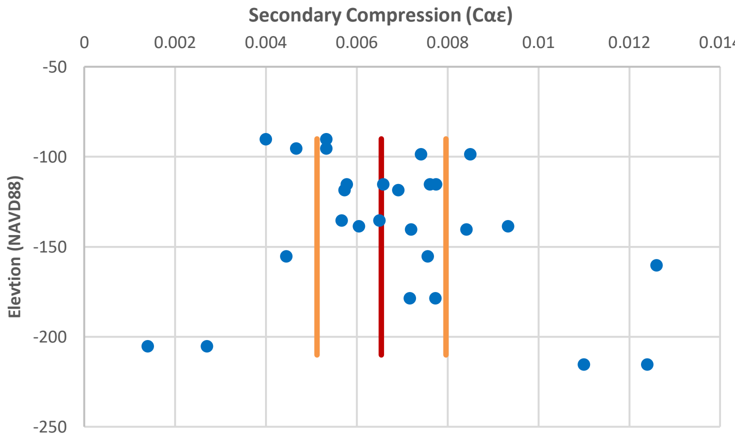


Soil Properties

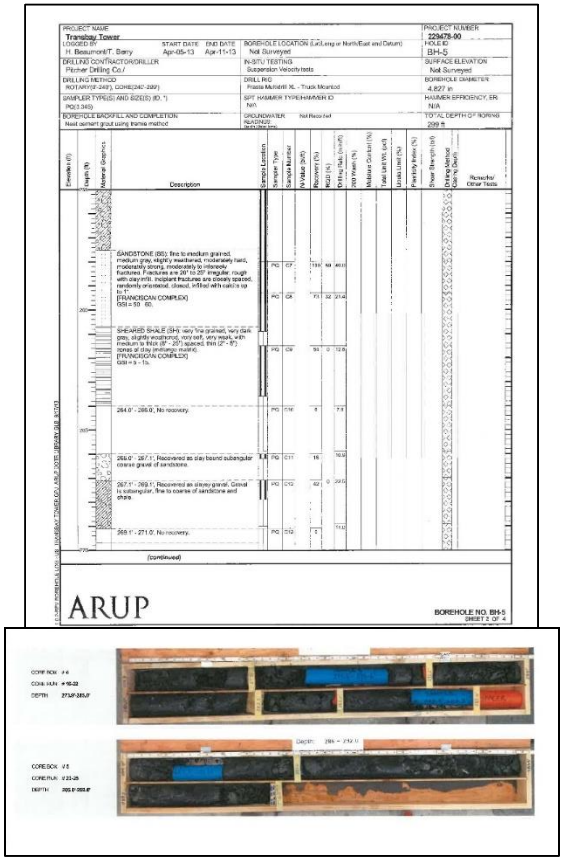


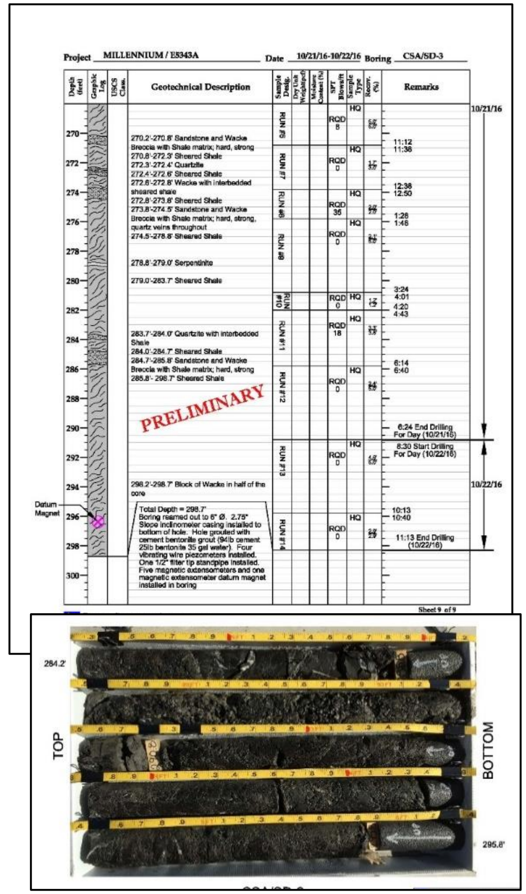


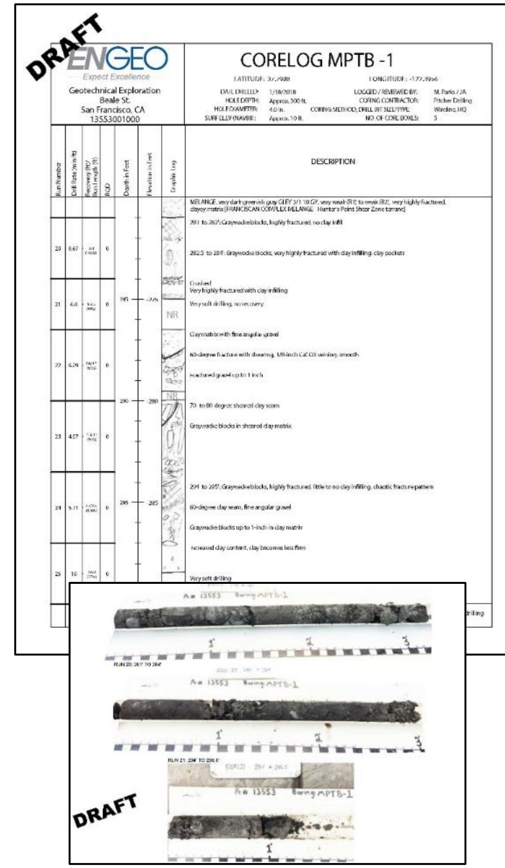




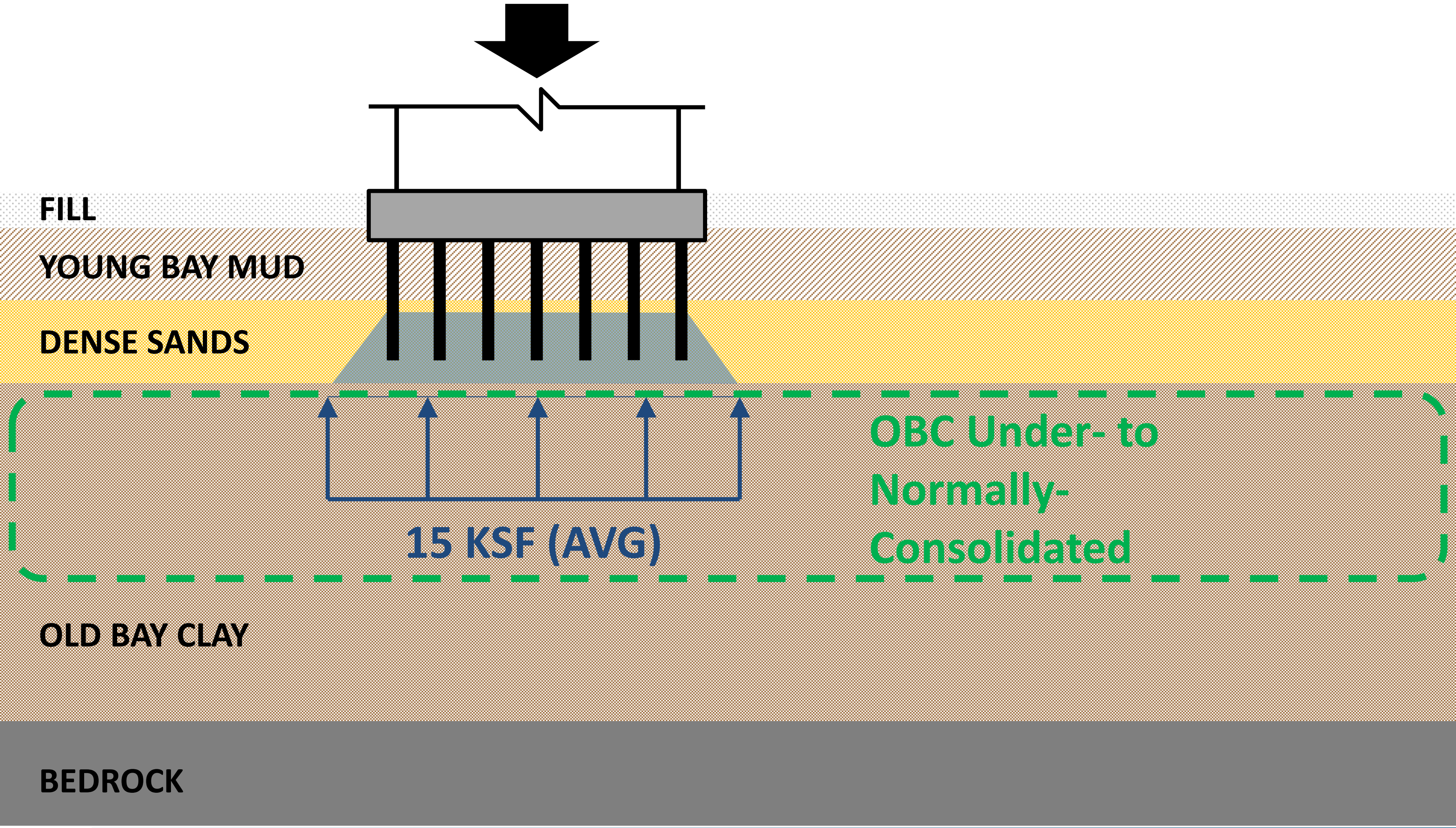
Analysis of Coring Performed in Site Vicinity



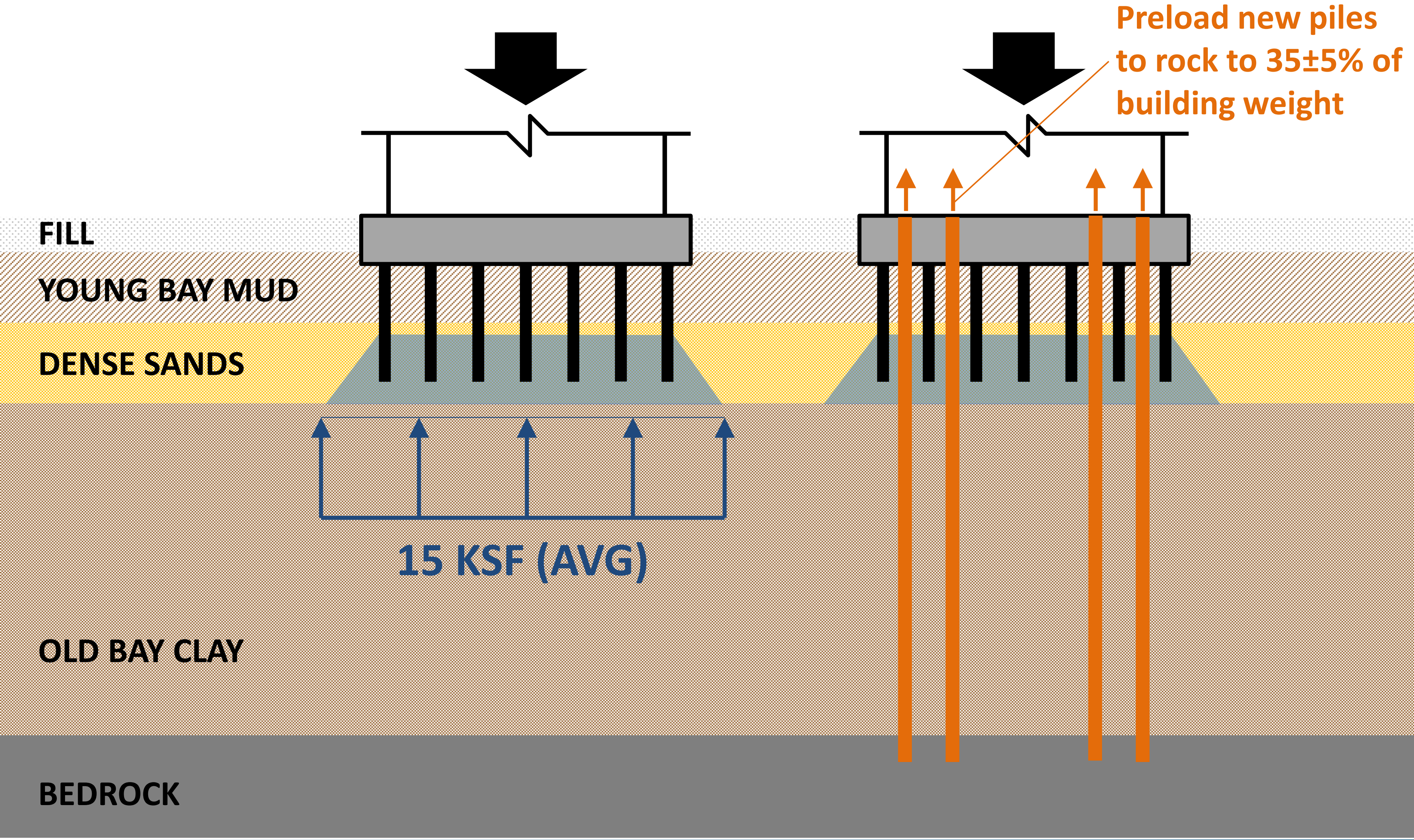




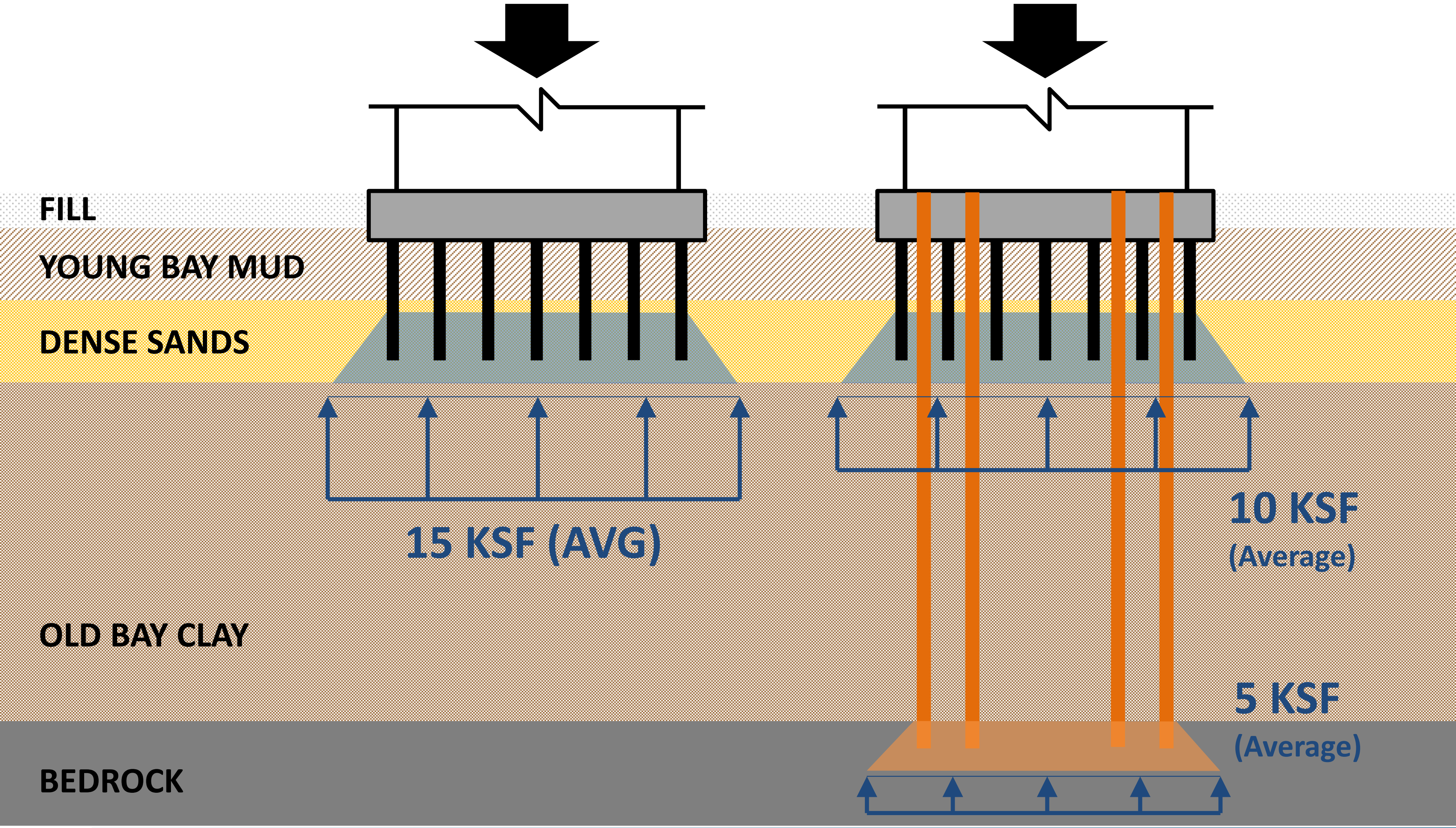
CURRENT STRESS IMPOSED ON OLD BAY CLAY



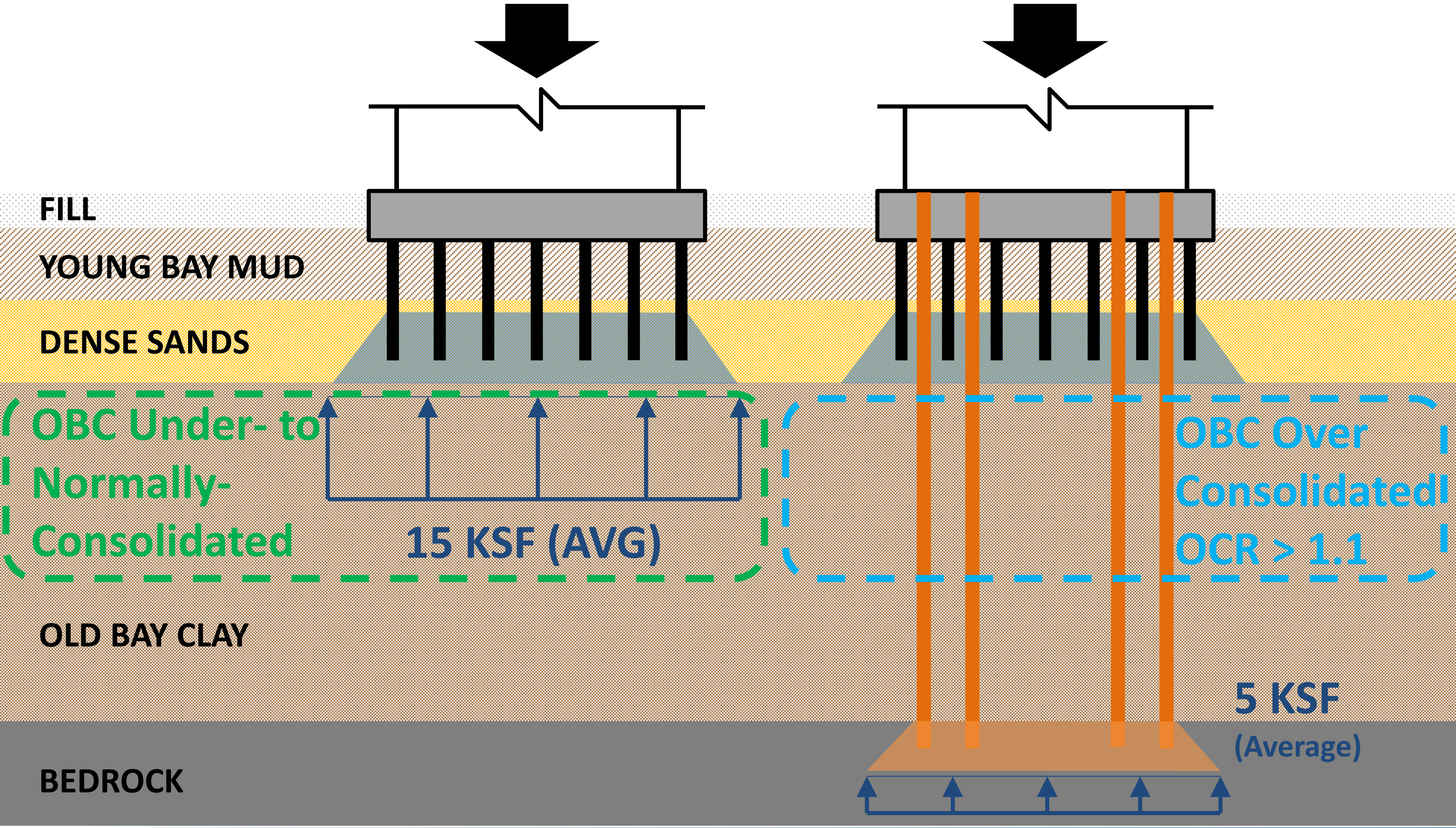
CURRENT STRESS IMPOSED ON OLD BAY CLAY



CURRENT STRESS IMPOSED ON OLD BAY CLAY



CURRENT STRESS IMPOSED ON OLD BAY CLAY



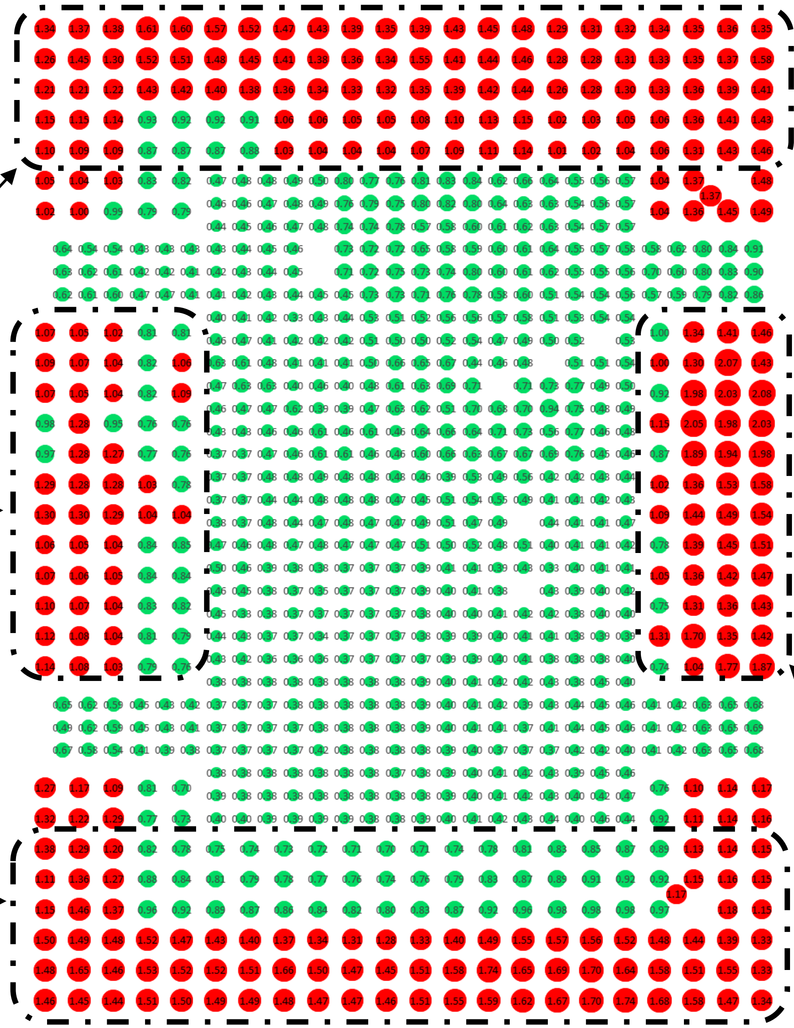
GRAVITY EVALUATION – SFBC CODE CHECKS

SFBC ASD Gravity Load Combination: $1.0D + 1.0L_{reduced}$

	CONSTRUCTION PHASE	POST-RETROFIT

Existing Piles:

- Pile Force < Allowable
- Pile Force > Allowable



	Vertical Stiffness	
	Static	*Dynamic*
Existing Piles	AVG	AVG
Rock Piles	N/A	N/A

$$P_{ALLOW} = P_{ULT} / 2.0$$

Global Avg DCR = 0.78
Global Max DCR = 2.0

LERA ENGEO Expect Excellence NICHOLSON HAYWARD BAKER JOINT VENTURE

GRAVITY EVALUATION – SFBC CODE CHECKS

SFBC ASD Gravity Load Combination: $1.0D + 1.0L_{reduced}$

	CONSTRUCTION PHASE	POST-RETROFIT

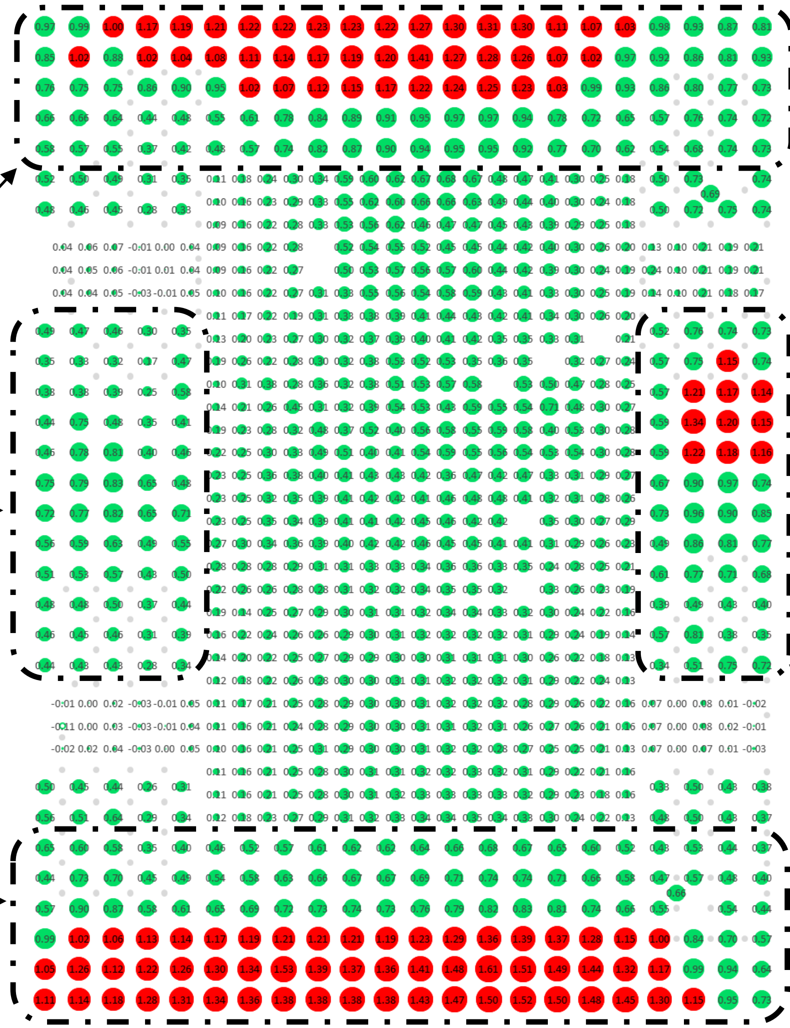
Existing Piles:

- Pile Force < Allowable
- Pile Force > Allowable
- New Piles

Avg DCR = 0.86

Avg DCR = 0.50

Avg DCR = 0.86



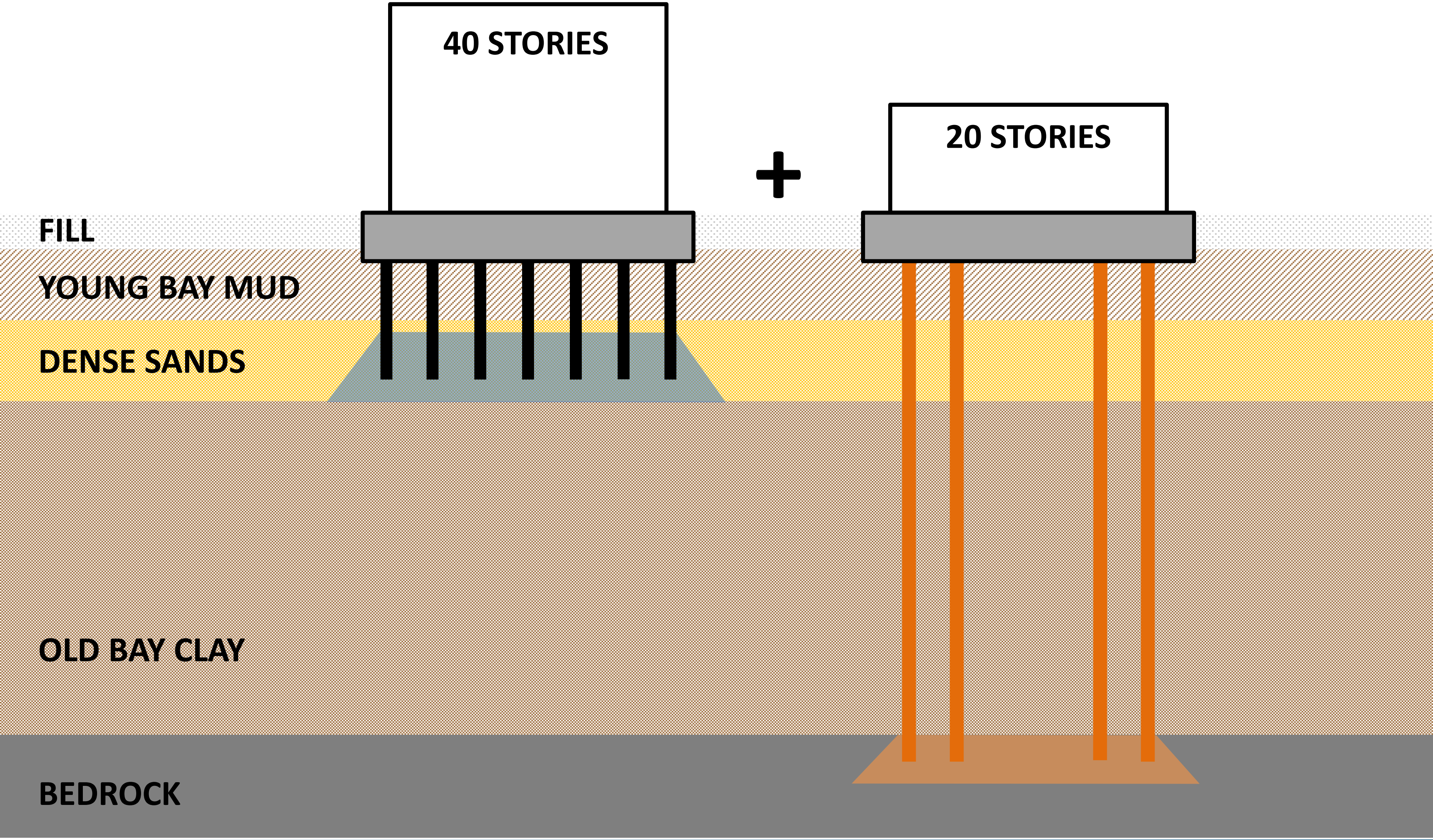
Avg DCR = 0.77

	Vertical Stiffness	
	Static	*Dynamic*
Existing Piles	UB	UB
Rock Piles	LB	LB

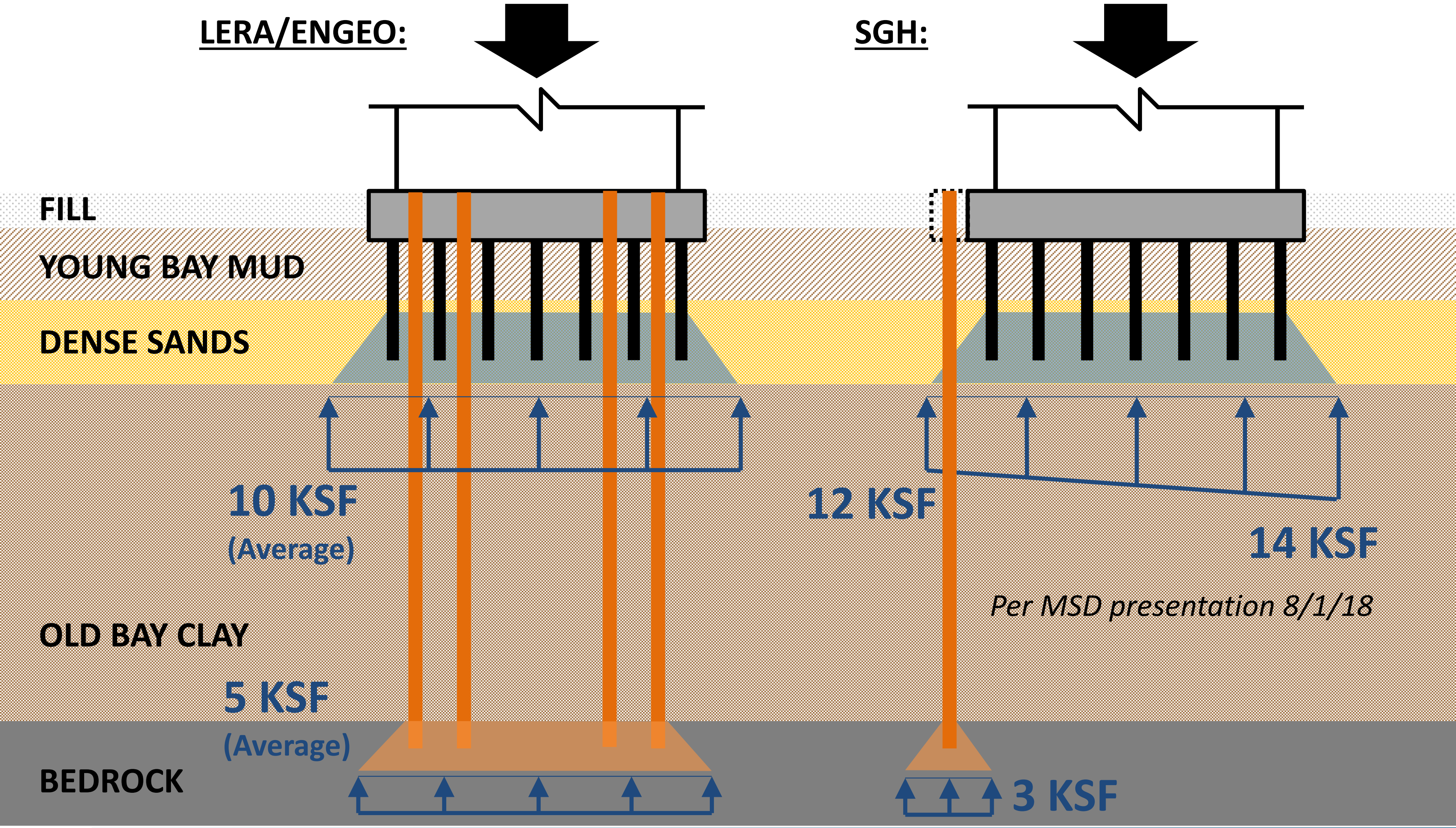
$P_{ALLOW} = P_{ULT} / 2.0$

Global Avg DCR = 0.50
Global Max DCR = 1.61

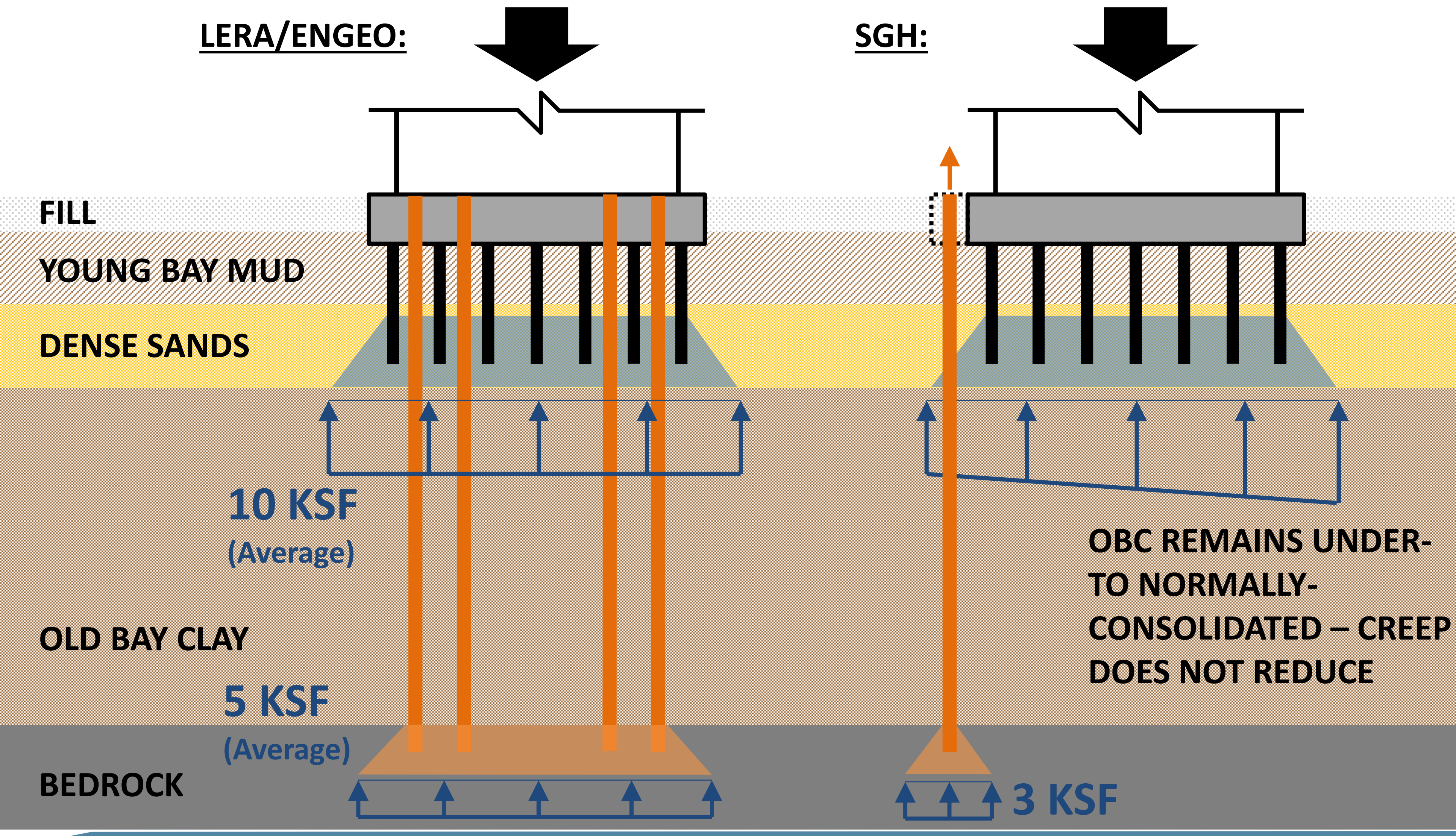
REDUCED STRESS IMPOSED ON OLD BAY CLAY



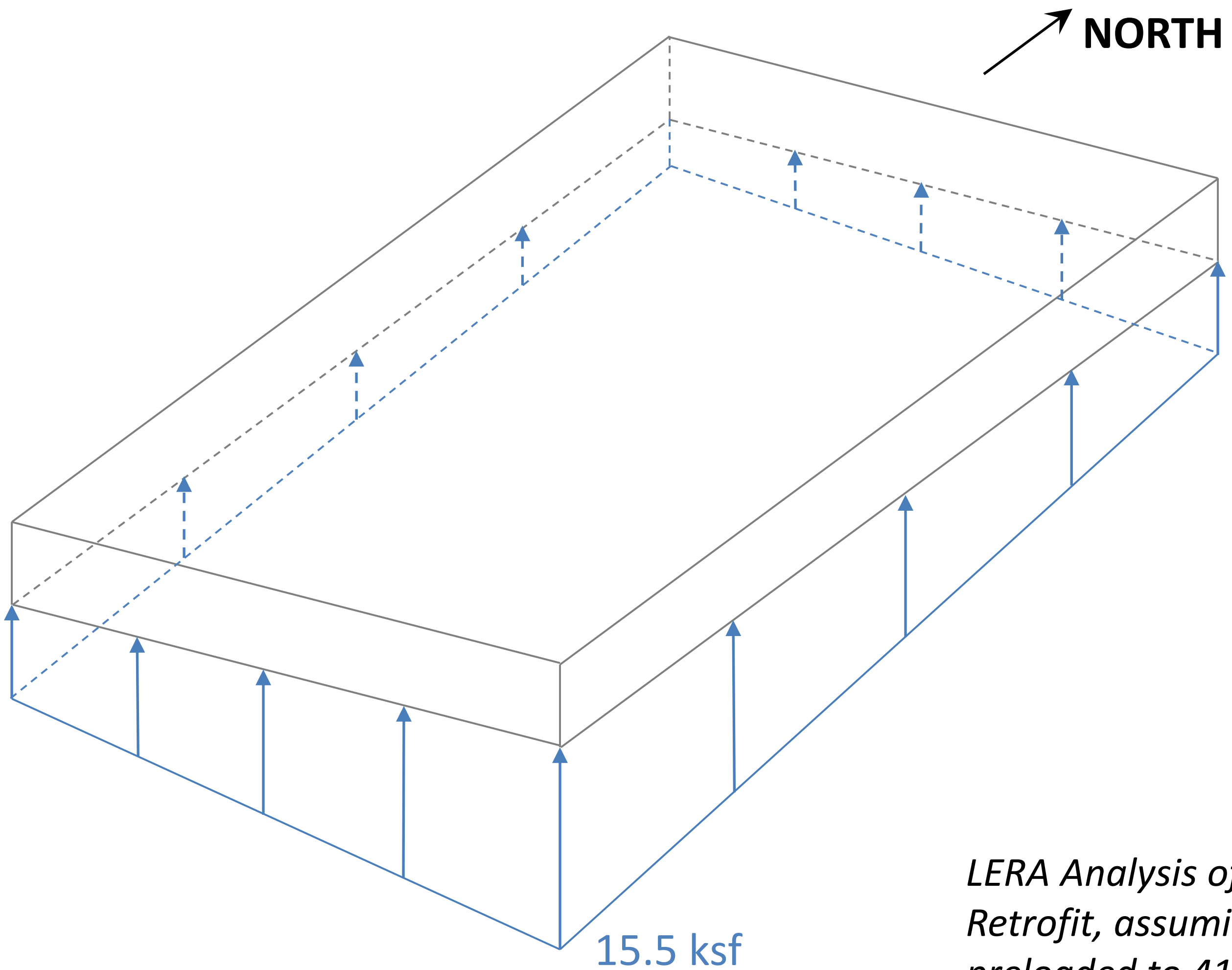
COMPARISON WITH SGH PROPOSAL



COMPARISON WITH SGH PROPOSAL



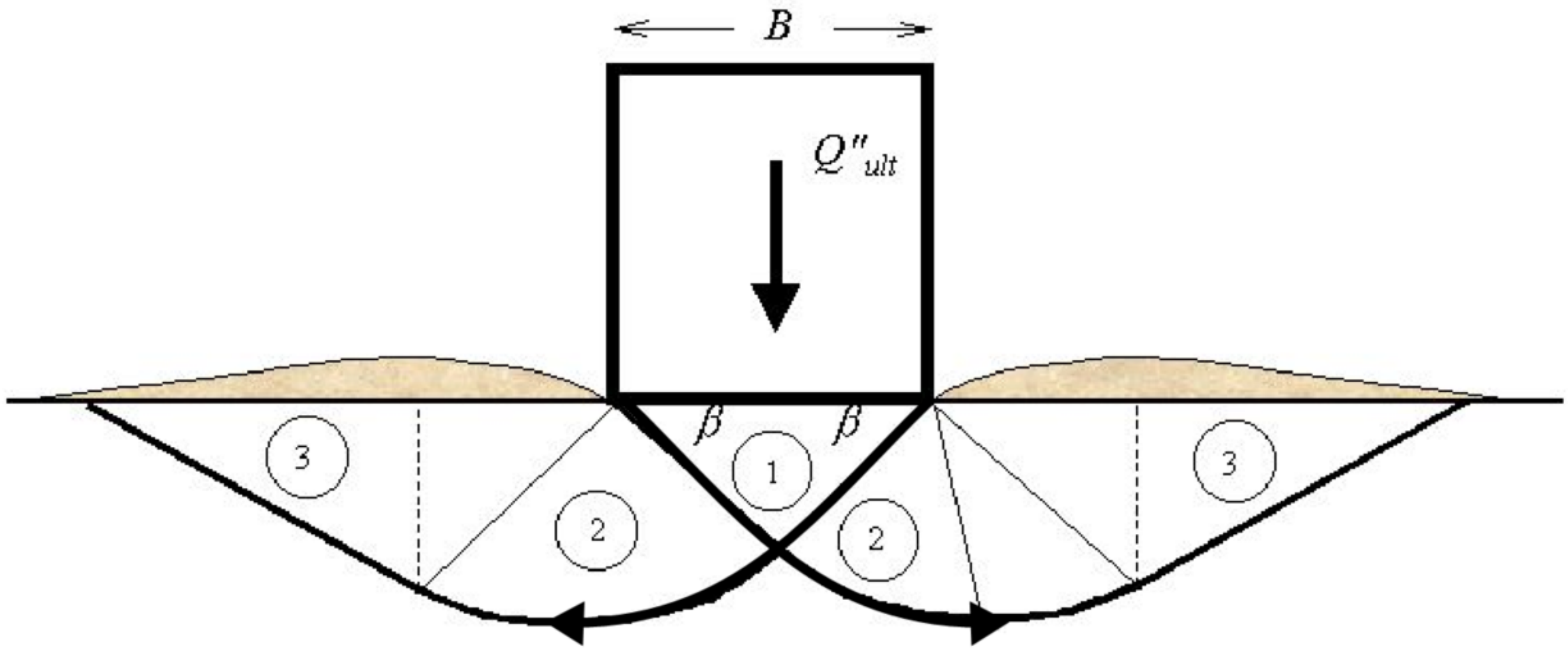
SGH PROPOSAL



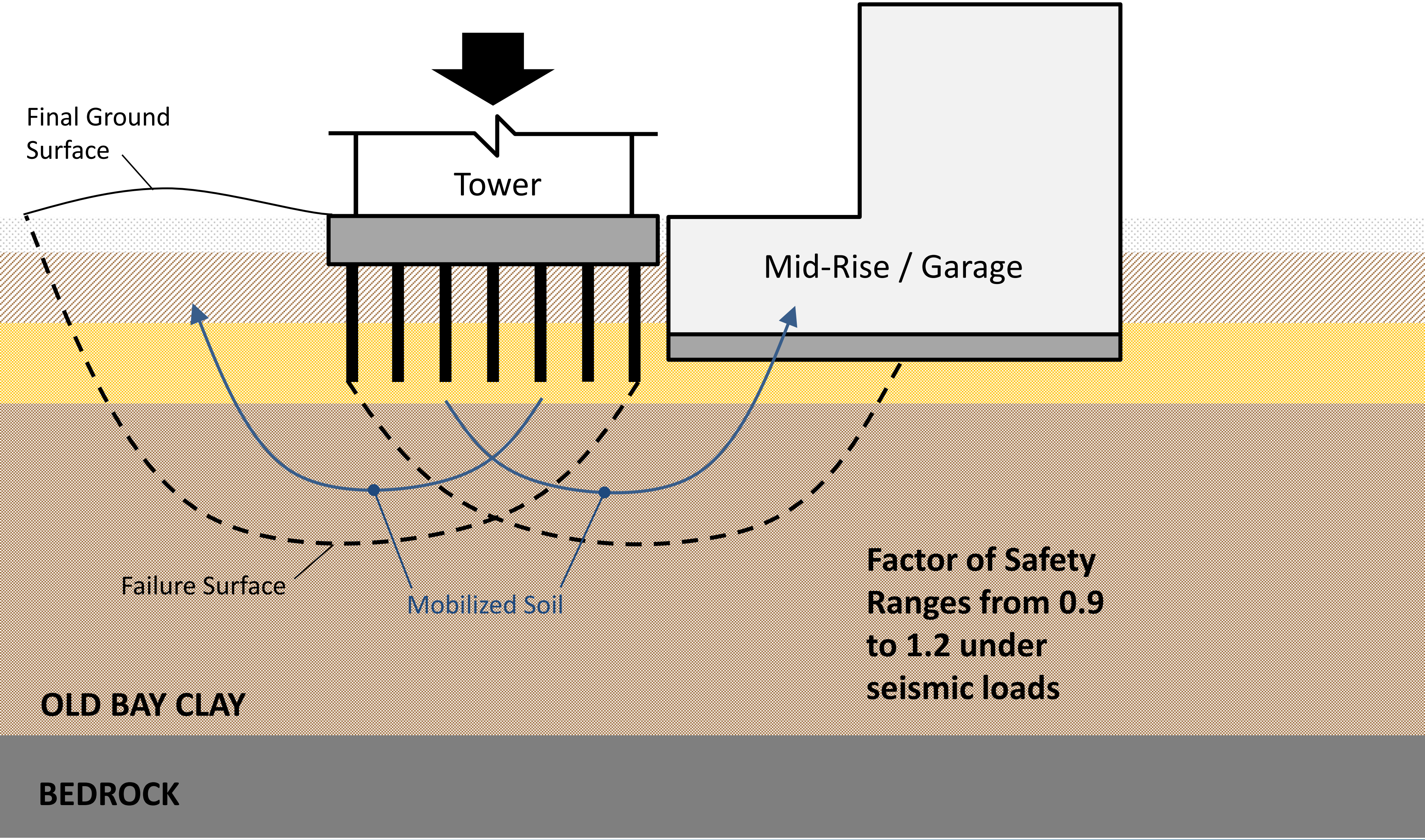
LERA Analysis of SGH Proposed Retrofit, assuming 52 piles, preloaded to 41,000 kips on North and West sides only

GLOBAL SHEAR FAILURE

GLOBAL SHEAR FAILURE

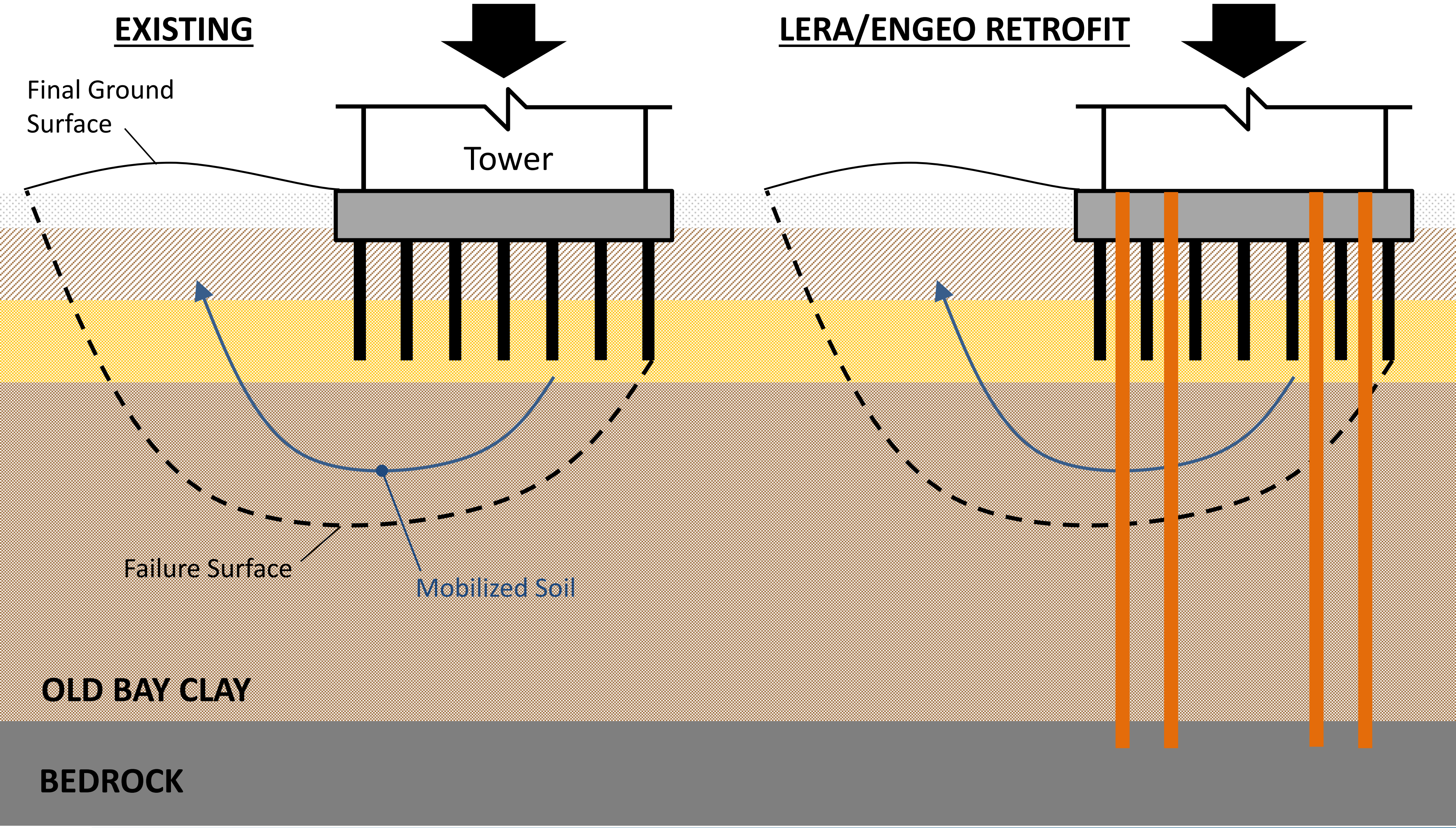


GLOBAL SHEAR FAILURE

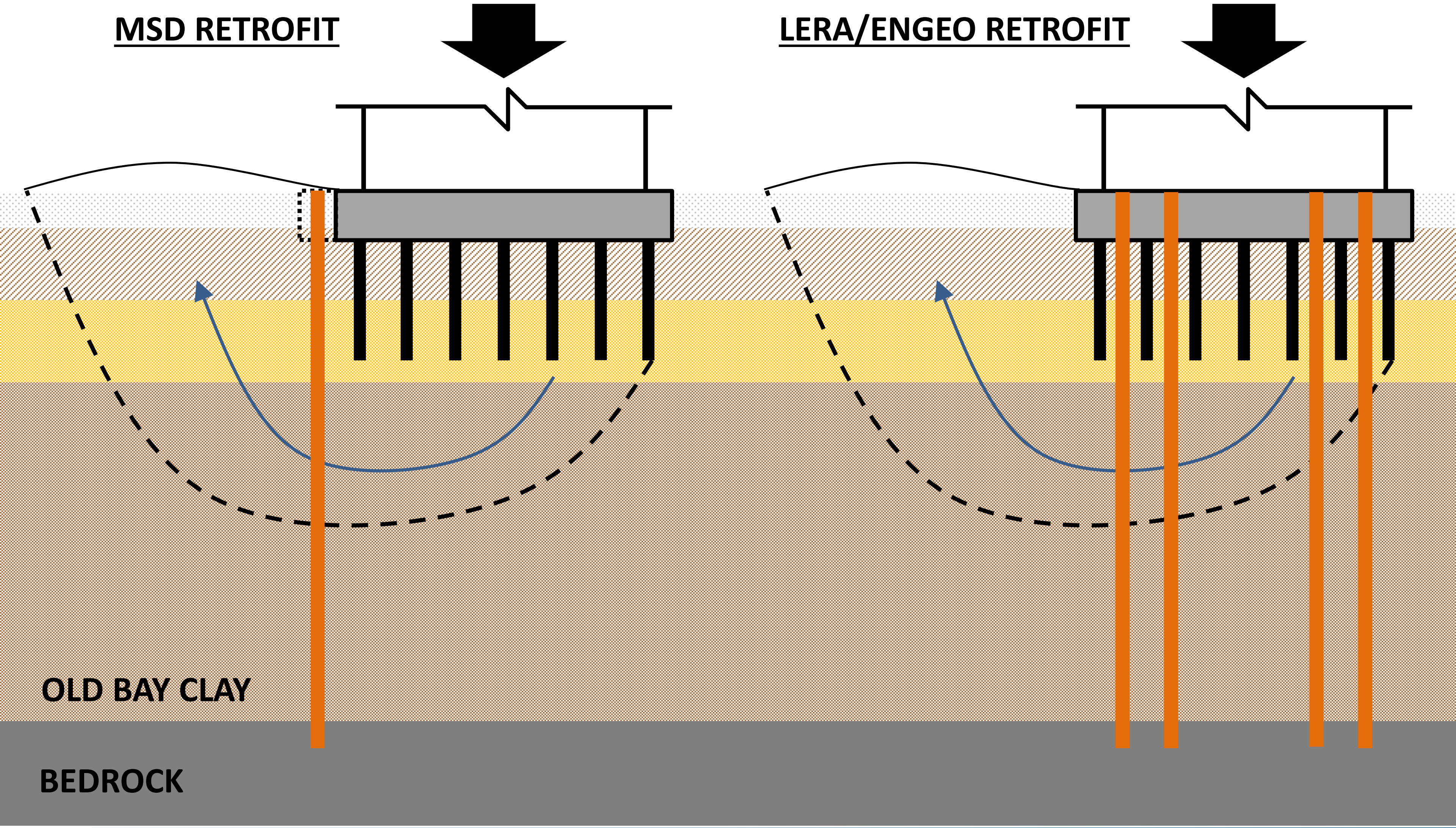


Factor of Safety Ranges from 0.9 to 1.2 under seismic loads

GLOBAL SHEAR FAILURE

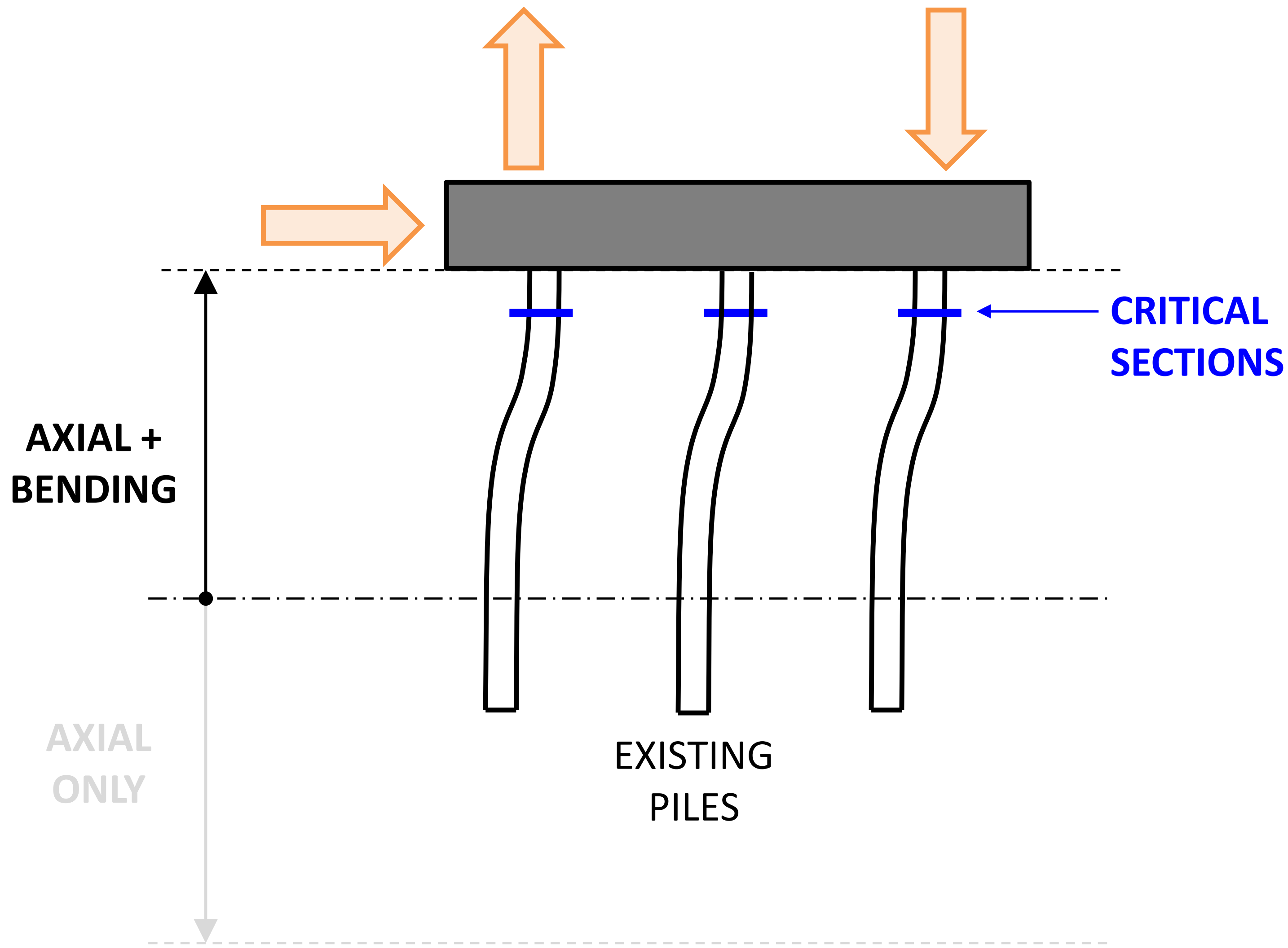


GLOBAL SHEAR FAILURE



SEQUENTIAL PILE FAILURE

REFINED RETROFIT PERFORMANCE

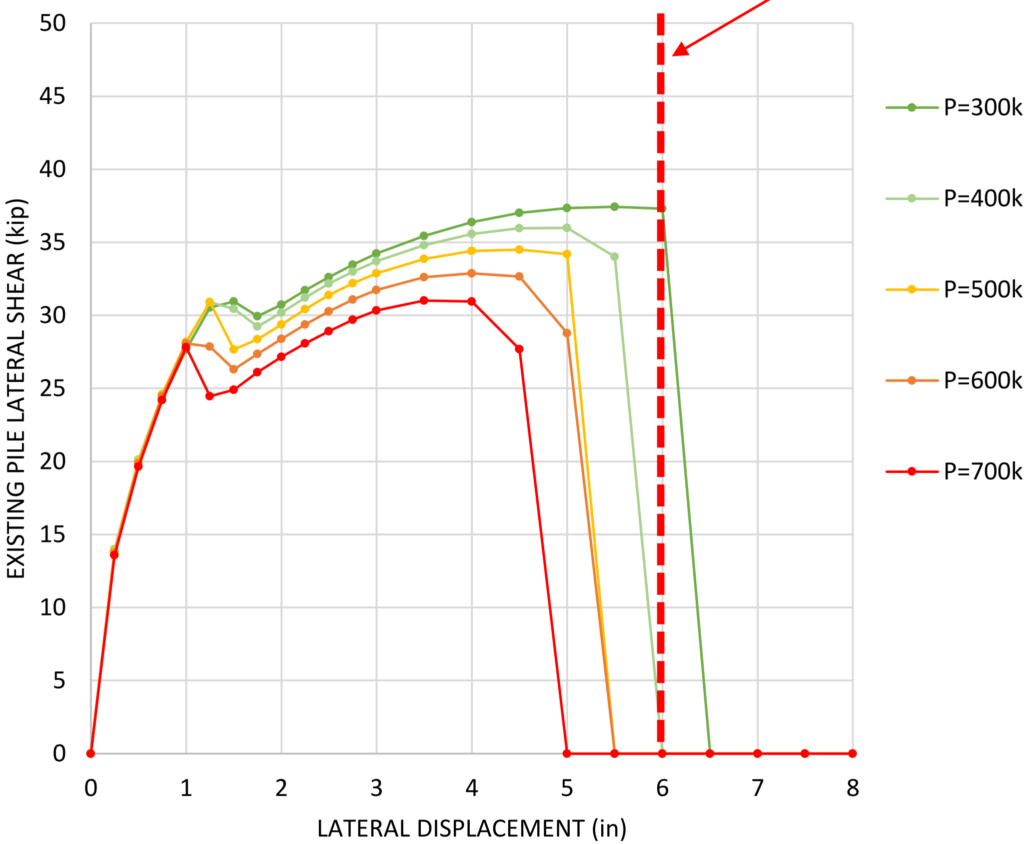


REFINED RETROFIT PERFORMANCE

For the typical range of axial loads (300k – 700k), None of the existing piles can withstand greater than 6" lateral displacement

LERA Individual Pile Backbones:

0° Initial Pile Rotation | Average Soil Properties



SGH Individual Pile Backbones:

Δmax ≈ 3.75"

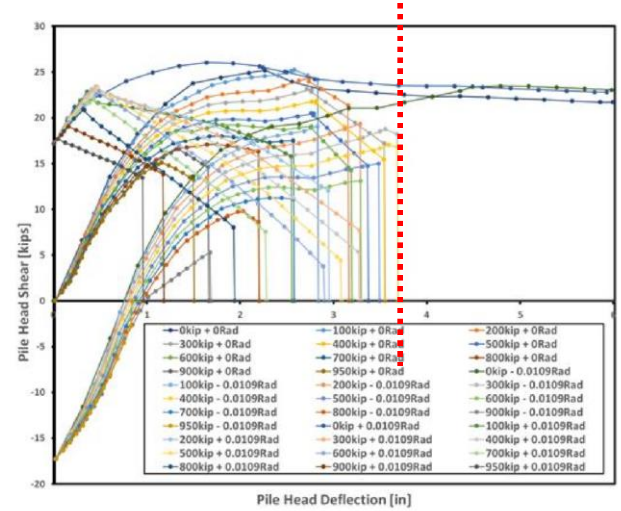
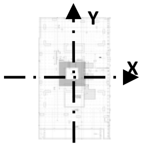


Figure 21. Pile nonlinear force-deformation plots

from SGH Report dated 26 July 2017

BSE-2N (MCE$_R$) NLTHA ENVELOPE RESULTS



Ext Foundation Displacements:

Ground Motion	Maximum Mat Displacement (Average of 4 Corners)				
	Ux (in)		Uy (in)		Uxy (in)
	Pushing East	Pushing West	Pushing North	Pushing South	Resultant
RSN178_IMPVALL	3.46	0.71	0.85	1.42	3.70
RSN184_IMPVALL	NC	NC	NC	NC	NC
RSN316_WESMORL	NC	NC	NC	NC	NC
RSN802_LOMAP	NC	NC	NC	NC	NC
RSN832_LANDERS	NC	NC	NC	NC	NC
RSN1163_KOCAELI	3.35	0.16	0.59	3.34	4.72
RSN1261_CHICHI	NC	NC	NC	NC	NC
RSN1511_CHICHI	4.27	0.37	0.25	2.56	4.88
RSN5827_SIERRA	5.44	0.21	0.21	3.42	6.25
RSN6890_DARFIELD	3.84	0.23	0.59	3.67	4.79
RSN6959_DARFIELD	2.29	0.18	0.28	2.07	2.99
Median of 11 Ground Motions[1]	***5.44***	***0.71***	***0.85***	***3.67***	***6.25***

Refined Retrofit Displacements:

Ground Motion	Maximum Mat Displacement (Average of 4 Corners)				
	Ux (in)		Uy (in)		Uxy (in)
	Pushing East	Pushing West	Pushing North	Pushing South	Resultant
RSN178_IMPVALL	1.95	0.01	0.60	1.23	2.19
RSN184_IMPVALL	5.48	0.53	0.53	1.65	5.49
RSN316_WESMORL	4.00	0.01	0.27	0.95	4.04
RSN802_LOMAP	4.30	0.07	0.92	0.64	4.32
RSN832_LANDERS	4.43	0.02	0.12	1.53	4.61
RSN1163_KOCAELI	1.99	0.04	0.42	1.84	2.68
RSN1261_CHICHI	3.82	0.06	0.14	0.84	3.87
RSN1511_CHICHI	2.19	0.08	0.14	1.54	2.46
RSN5827_SIERRA	2.75	0.03	0.09	2.39	3.36
RSN6890_DARFIELD	1.98	0.01	0.17	2.41	2.79
RSN6959_DARFIELD	1.32	0.03	0.11	1.27	1.72
Average of 11 Ground Motions	***3.11***	***0.08***	***0.32***	***1.48***	***3.41***

Pile Lateral Stiffness	Pile Force
Lower Bound	Gravity

Notes:

1) For the existing foundation, the median ground motion response for each direction (6th largest out of 11) was chosen to represent the average performance to account for non-convergences.

"NC" indicates a ground motion that did not analytically converge

BSE-2N (MCE_R) NLTHA ENVELOPE RESULTS

SGH Analysis Results:

(8/1/18 Mediation Presentation)

10/11 GMs Exceed 3.75" Displacement (Existing Condition)

6/11 GMs Exceed 3.75" Displacement (After Retrofit)

Ground Motion Record	EXISTING CONDITION				AFTER RETROFIT			
	Max X	Min X	Max Y	Min Y	Max X	Min X	Max Y	Min Y
RSN#178 Imperial Valley-06	6.0	-1.1	4.4	-3.0	4.1	-2.4	3.7	-2.4
RSN#184 Imperial Valley-06	0.3	-11.4	1.6	-2.2	0.3	-7.9	1.3	-1.7
RSN#316 Westmorland	1.1	-9.9	4.8	-1.2	0.8	-7.3	3.7	-1.4
RSN#802 Loma Prieta	3.6	-5.4	1.6	-1.7	3.0	-4.0	1.1	-1.4
RSN#832 Landers	2.7	-3.6	4.1	-4.2	2.2	-3.2	2.9	-3.3
RSN#1163 Kocaeli	0.7	-4.3	1.9	-1.8	0.7	-3.5	1.5	-1.4
RSN#1261 Chi-Chi	1.9	-2.4	3.5	-3.1	2.0	-1.8	2.7	-2.5
RSN#1511 Chi-Chi	1.2	-1.4	3.2	-4.1	1.1	-1.1	2.8	-3.1
RSN#5827 El Mayor-Cucapah_Mexico	3.9	-1.8	2.9	-3.0	3.0	-1.6	2.3	-2.4
RSN#6890 Darfield NZ	1.8	-2.9	0.9	-5.9	1.7	-2.5	2.0	-4.2
RSN#6959 Darfield NZ	1.8	-2.2	5.6	-2.8	1.6	-2.1	4.0	-2.2
Average of 11 Ground Motions	2.3	-4.2	3.1	-3.0	1.9	-3.4	2.6	-2.4

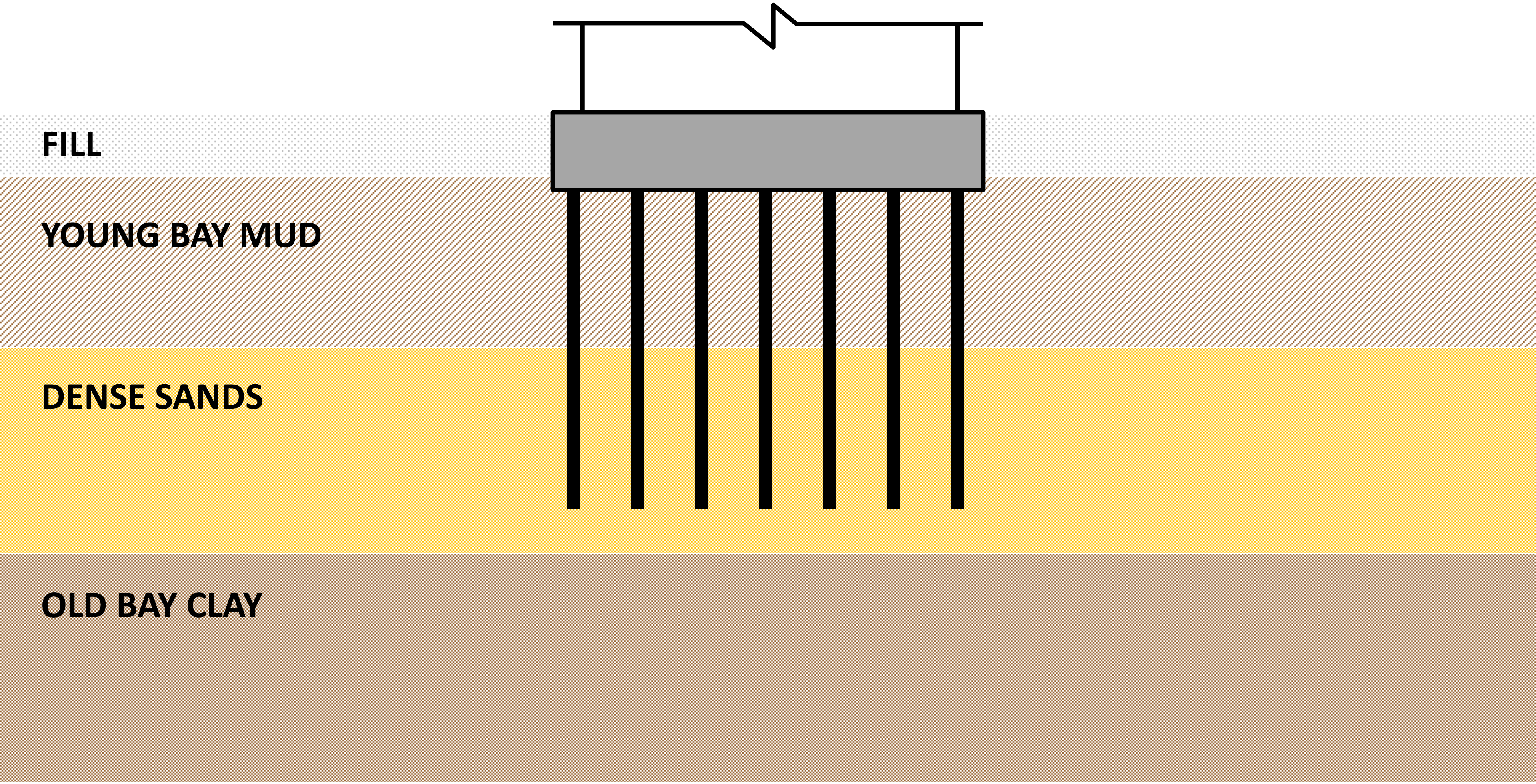
LERA Analysis Results:

5/11 GMs Exceed 6" Displacement (Existing Condition)

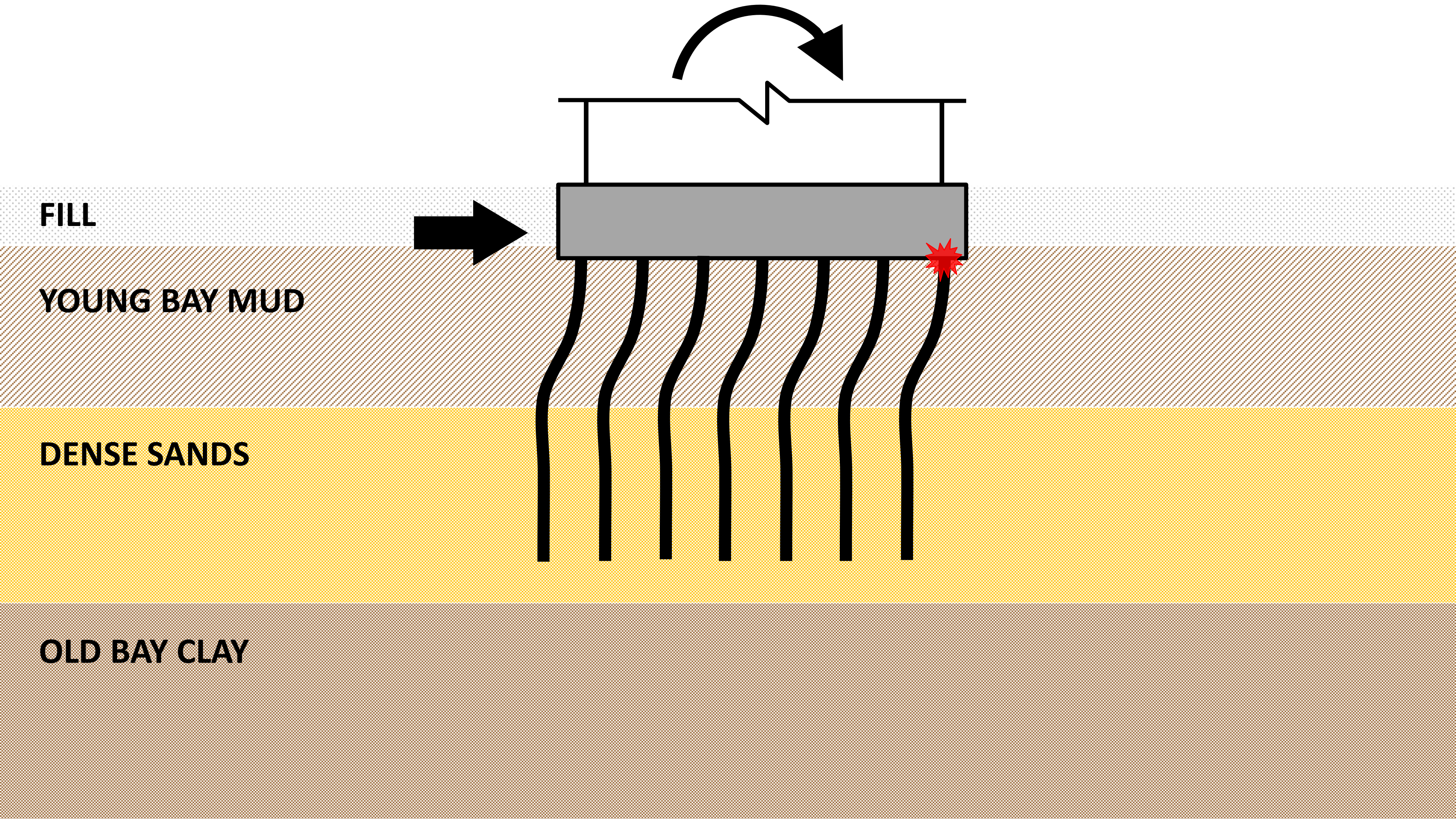
0/11 GMs Exceed 6" Displacement (After Retrofit)

Ground Motion Record	EXISTING CONDITION				AFTER RETROFIT			
	Ux (in)		Uy (in)		Ux (in)		Uy (in)	
	Pushing East	Pushing West	Pushing North	Pushing South	Pushing East	Pushing West	Pushing North	Pushing South
RSN178_IMPVALL	3.46	0.71	0.85	1.42	1.95	0.01	0.60	1.23
RSN184_IMPVALL	NC	NC	NC	NC	5.48	0.53	0.53	1.65
RSN316_WESMORL	NC	NC	NC	NC	4.00	0.01	0.27	0.95
RSN802_LOMAP	NC	NC	NC	NC	4.30	0.07	0.92	0.64
RSN832_LANDERS	NC	NC	NC	NC	4.43	0.02	0.12	1.53
RSN1163_KOCAELI	3.35	0.16	0.59	3.34	1.99	0.04	0.42	1.84
RSN1261_CHICHI	NC	NC	NC	NC	3.82	0.06	0.14	0.84
RSN1511_CHICHI	4.27	0.37	0.25	2.56	2.19	0.08	0.14	1.54
RSN5827_SIERRA	5.44	0.21	0.21	3.42	2.75	0.03	0.09	2.39
RSN6890_DARFIELD	3.84	0.23	0.59	3.67	1.98	0.01	0.17	2.41
RSN6959_DARFIELD	2.29	0.18	0.28	2.07	1.32	0.03	0.11	1.27
Average of 11 Ground Motions	***5.44***	***0.71***	***0.85***	***3.67***	***3.11***	***0.08***	***0.32***	***1.48***

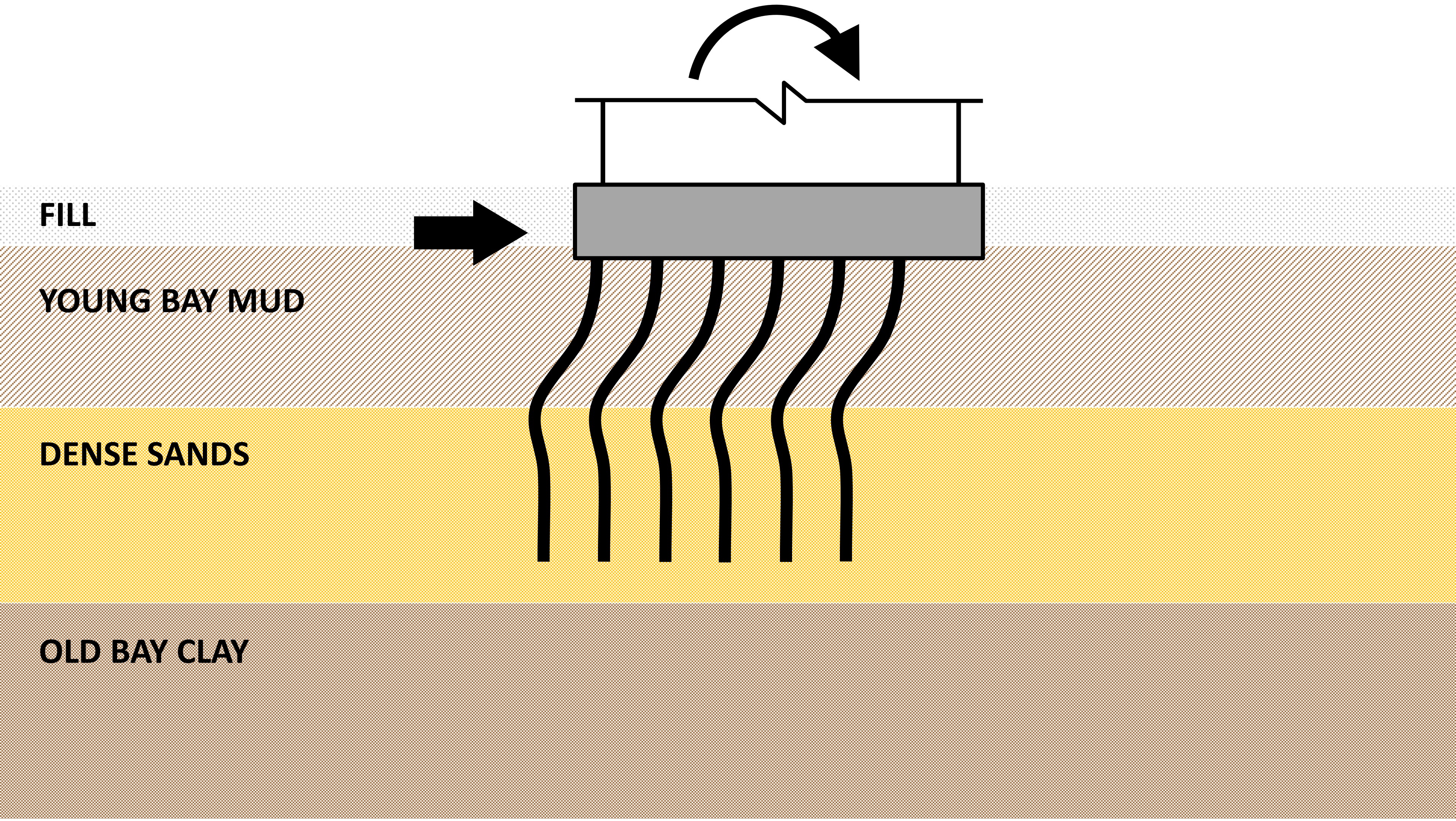
SEQUENTIAL PILE FAILURE



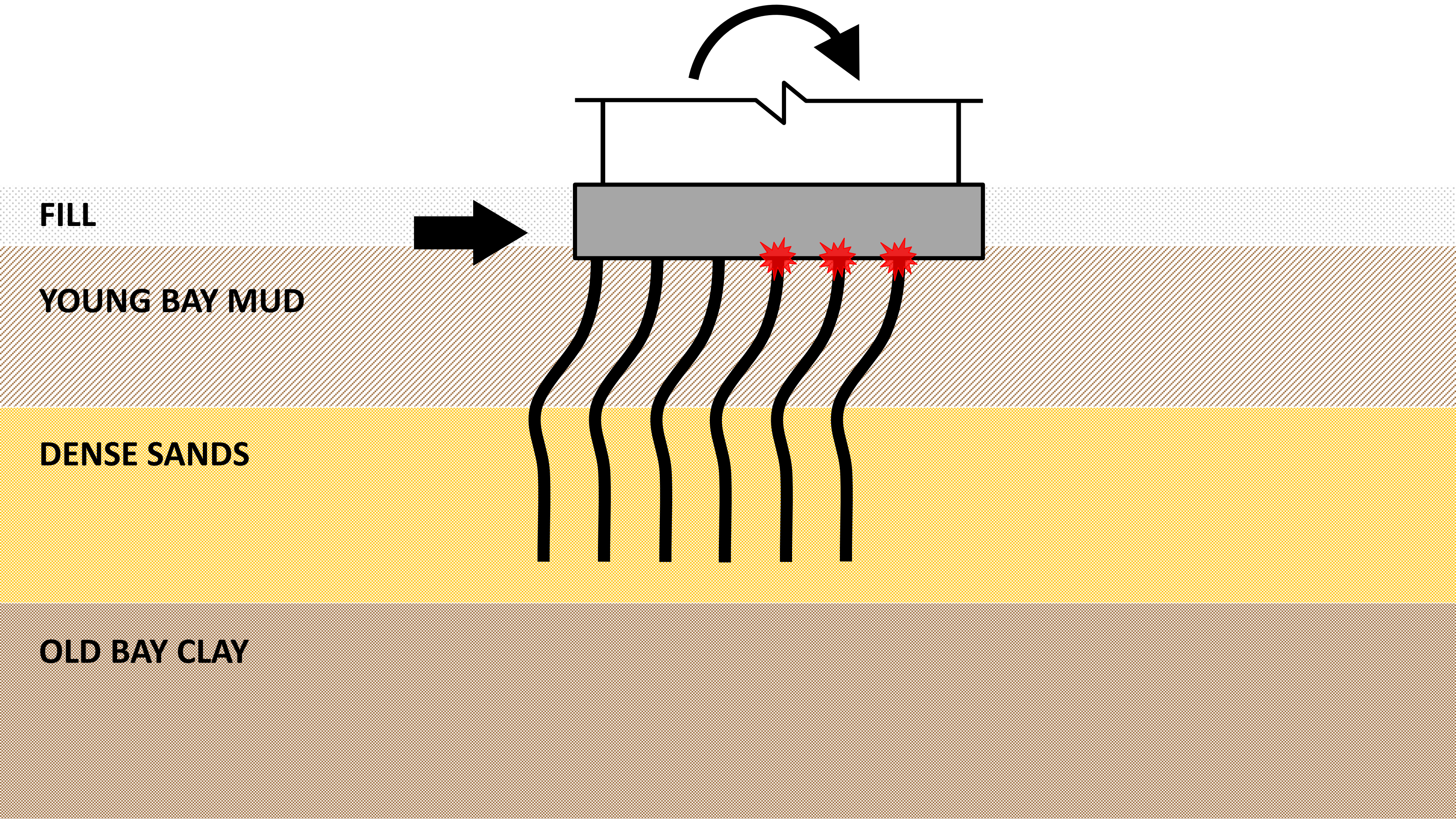
SEQUENTIAL PILE FAILURE



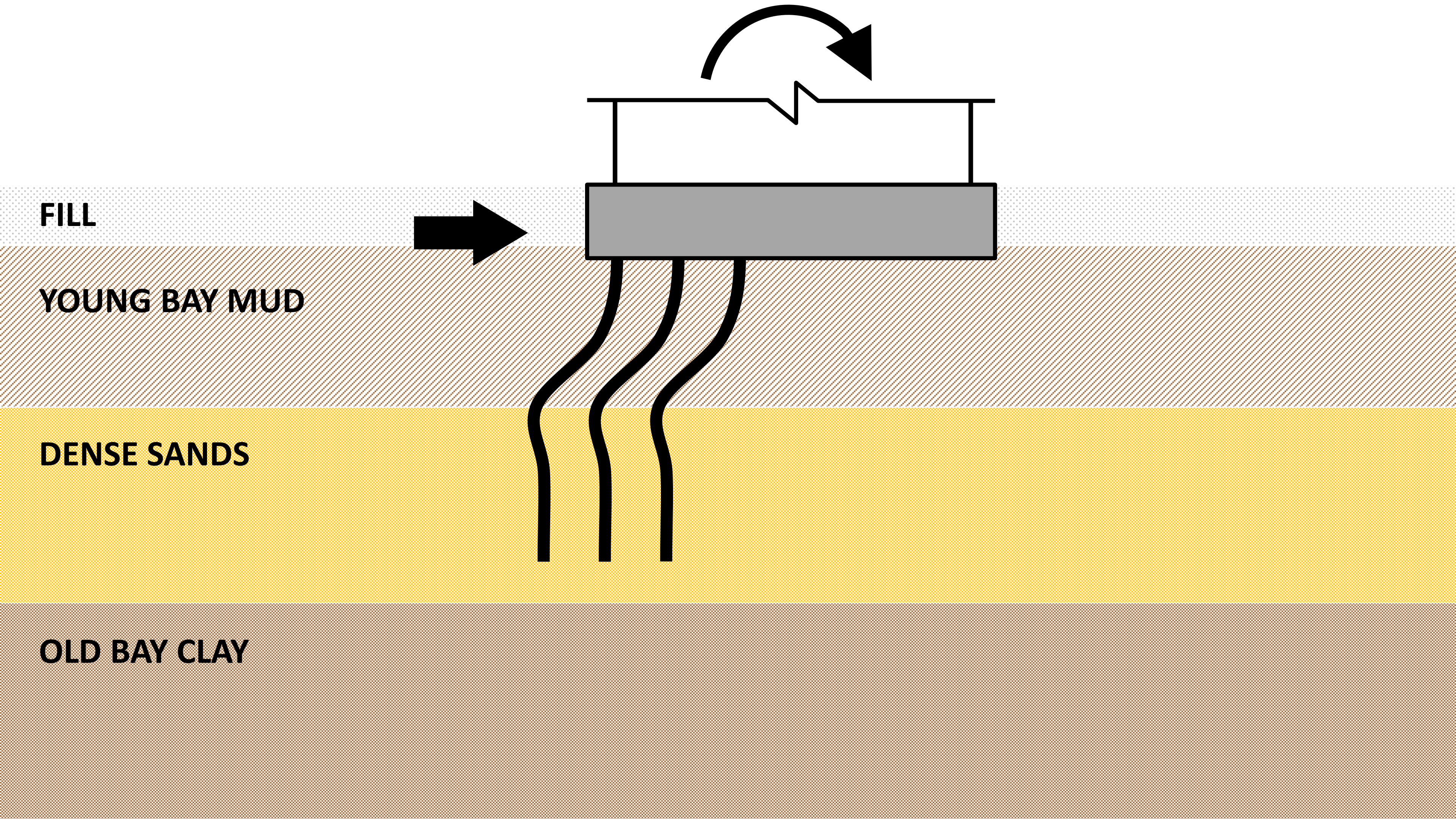
SEQUENTIAL PILE FAILURE



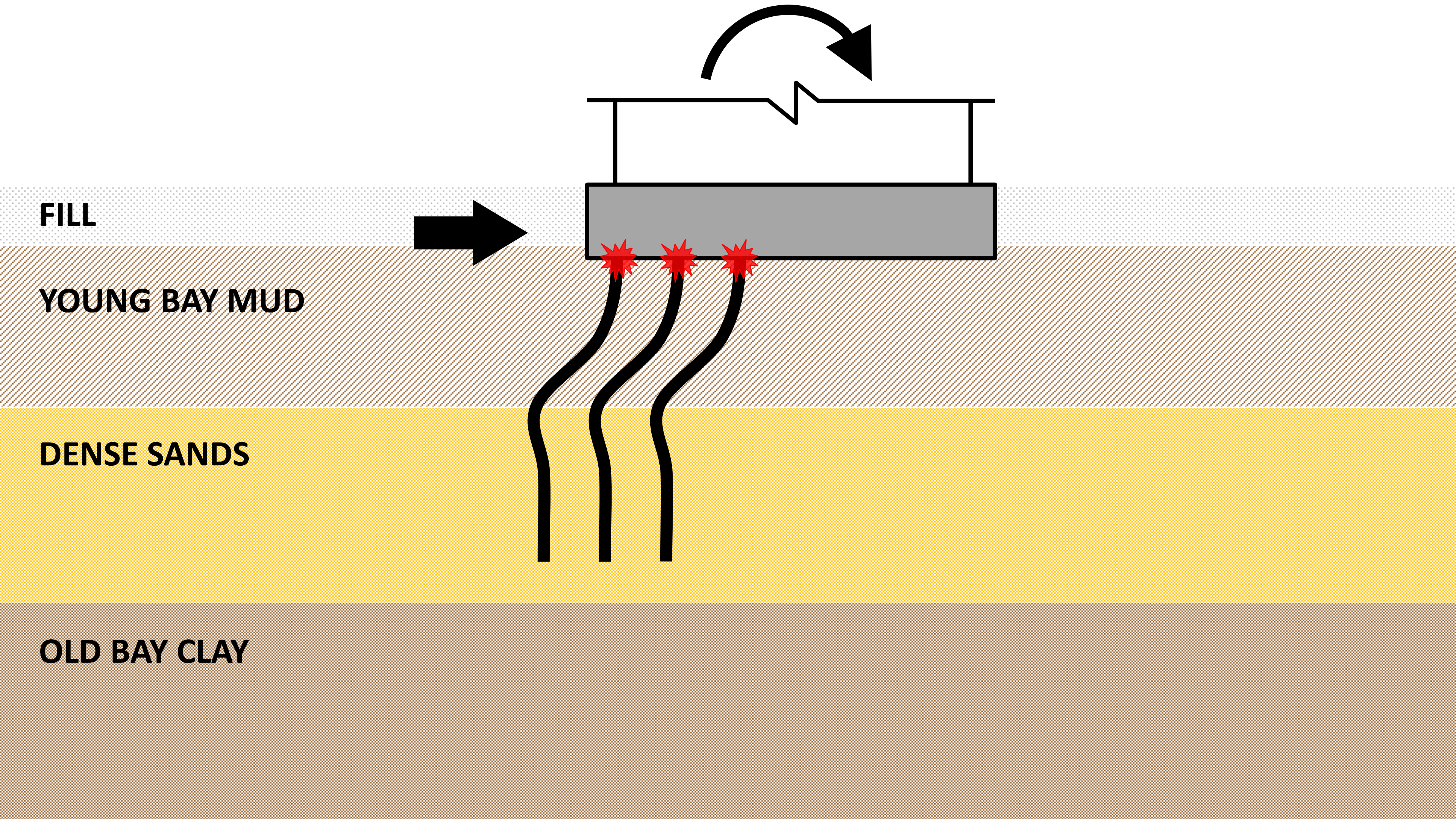
SEQUENTIAL PILE FAILURE



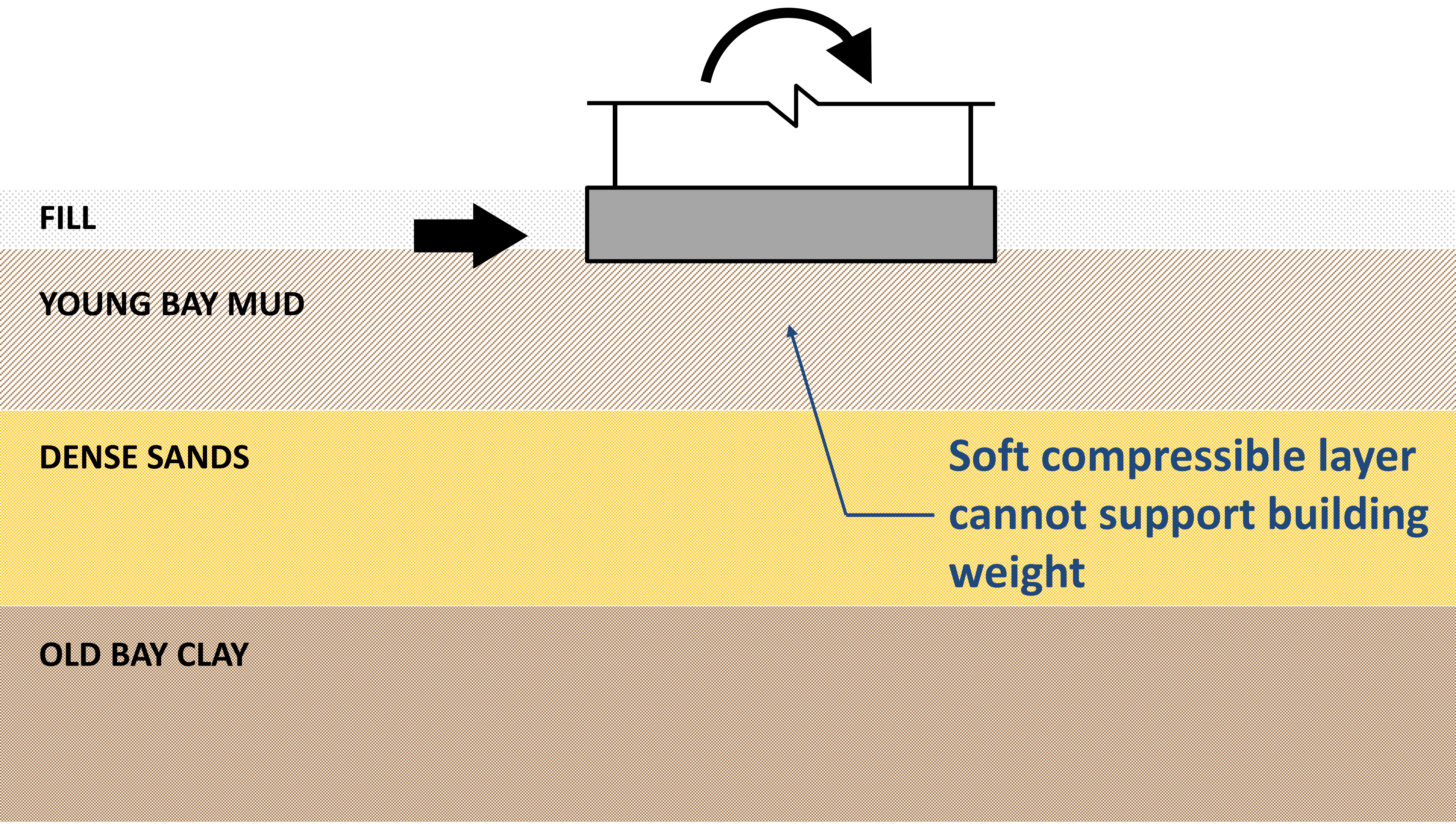
SEQUENTIAL PILE FAILURE



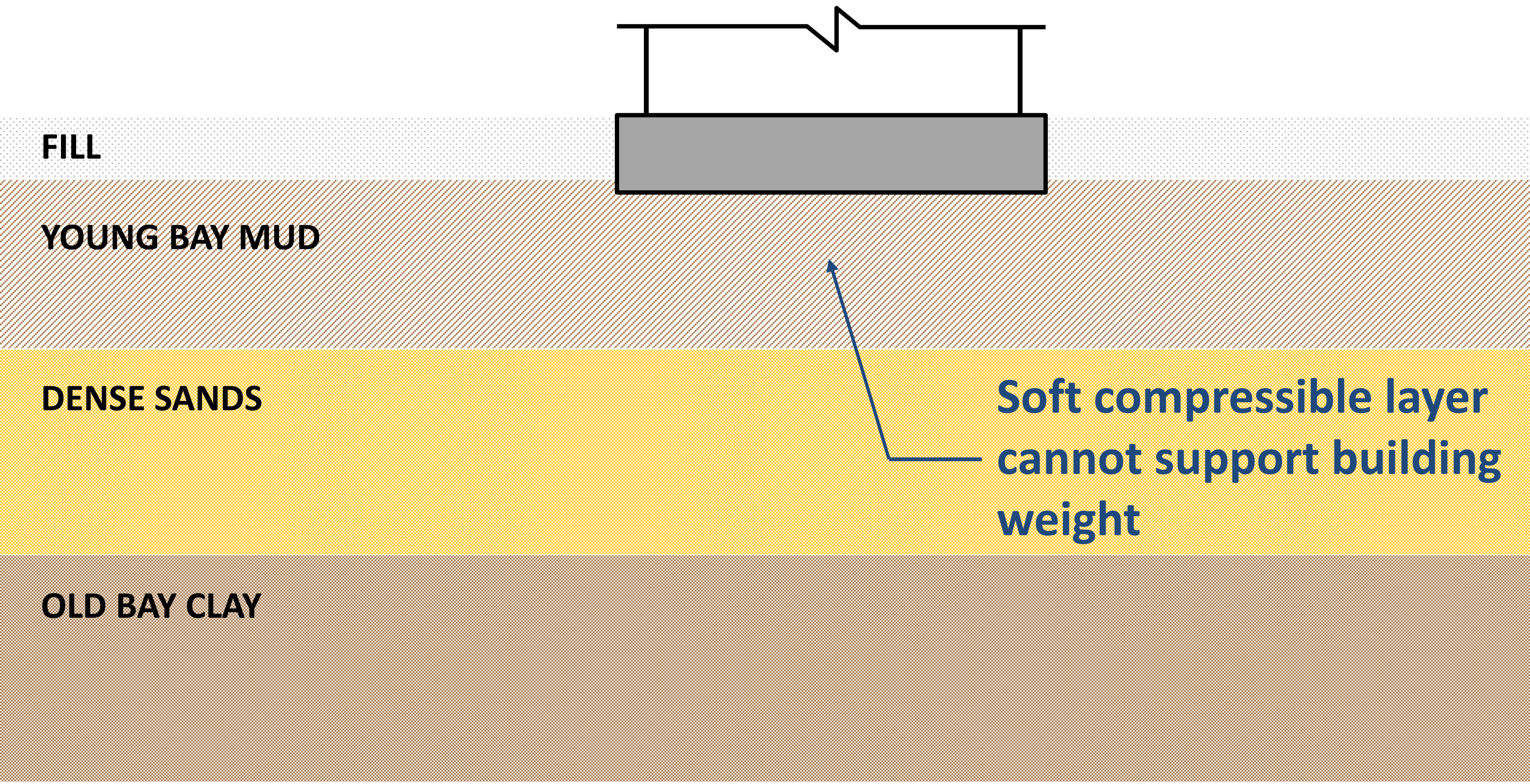
SEQUENTIAL PILE FAILURE



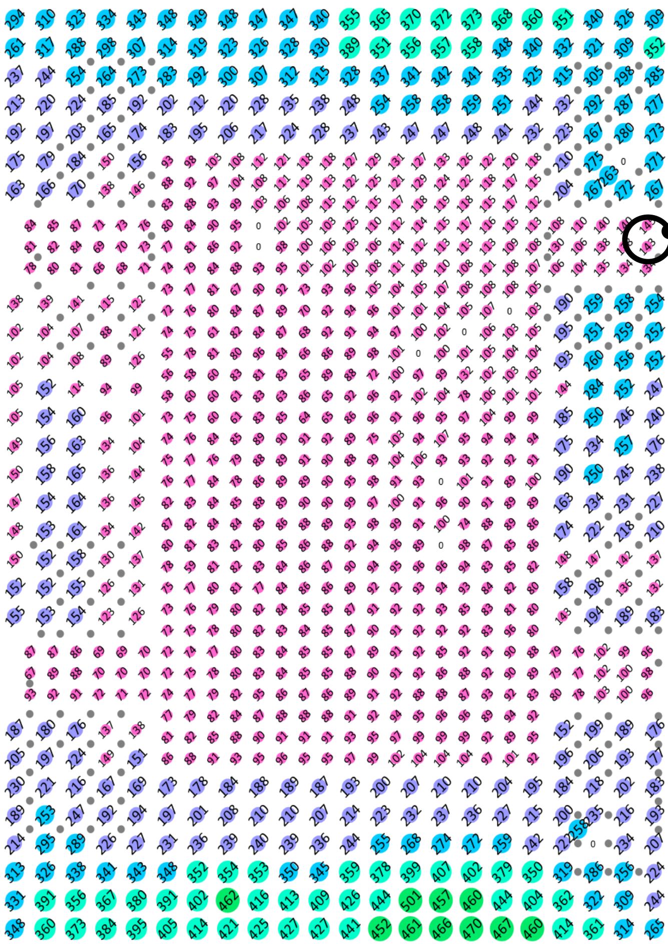
SEQUENTIAL PILE FAILURE



SEQUENTIAL PILE FAILURE



Sequential Pile Failure Review (with Retrofit Piles installed)

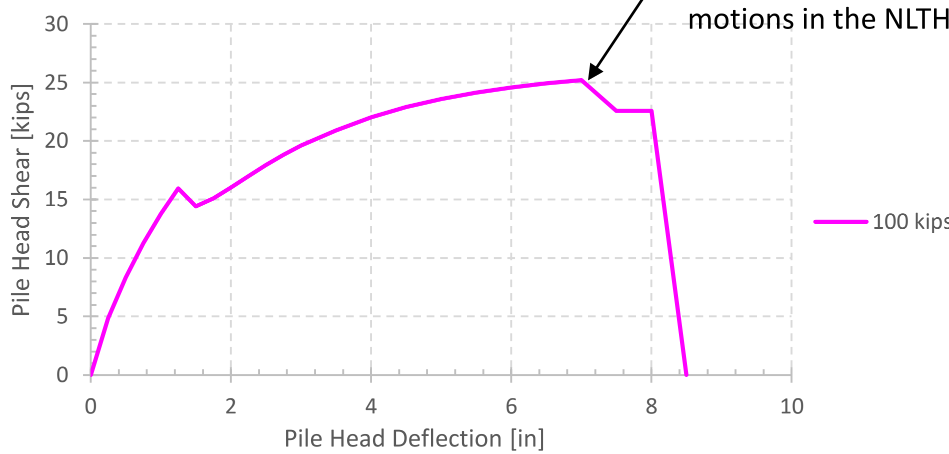


Looking at one pile under the NE outrigger:

$P_{GRAVITY}$ = 143 kips (rounded to 100k for analysis)

$\Theta_{INITIAL}$ = 0.25° (detrimental for easterly motion)

Individual pile lateral backbone selected for resistance to easterly motions in the NLTHA



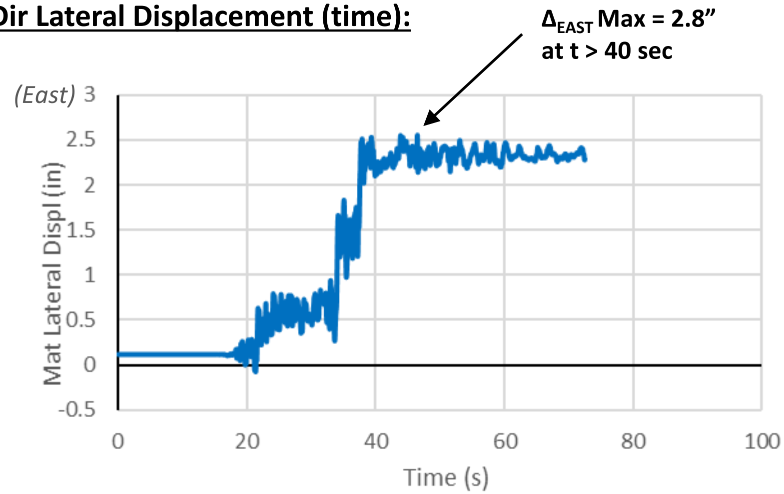
Pile Axial Forces (Gravity)

LERA Individual Pile Lateral Backbone Curve (0.25° Head Rotation)

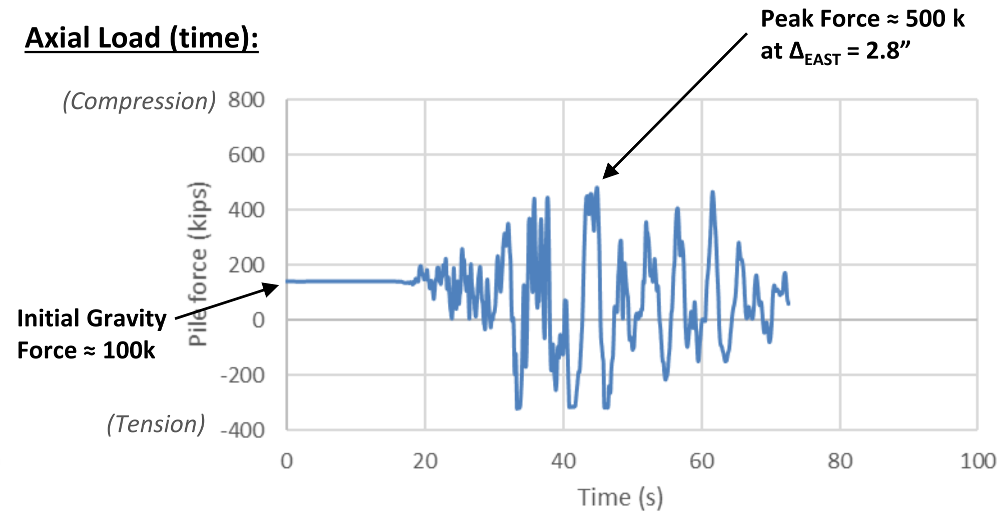
Sequential Pile Failure Review (with Retrofit Piles installed)

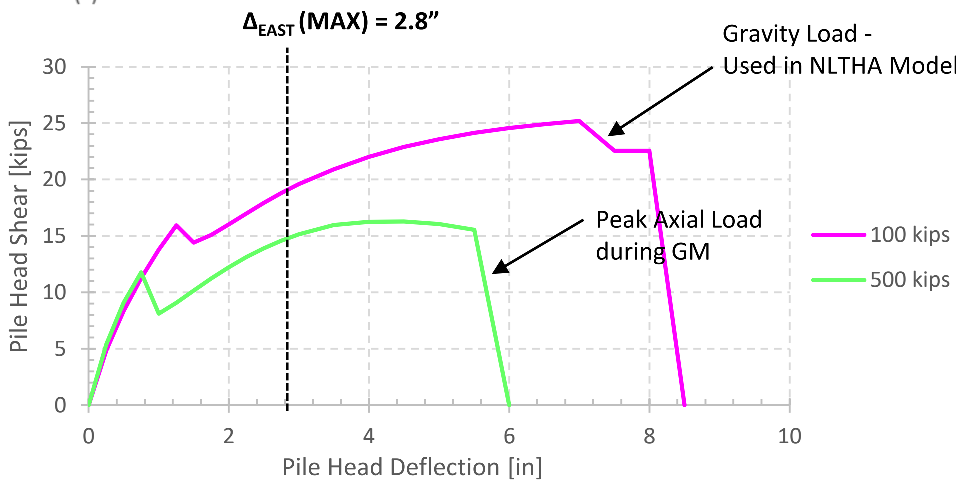
Looking at one pile under the NE outrigger in **Median** BSE-2N (MCE_R) Time History RSN5827:

X-Dir Lateral Displacement (time):



Axial Load (time):





LERA Individual Pile Lateral Backbone Curves (0.25° Head Rotation)

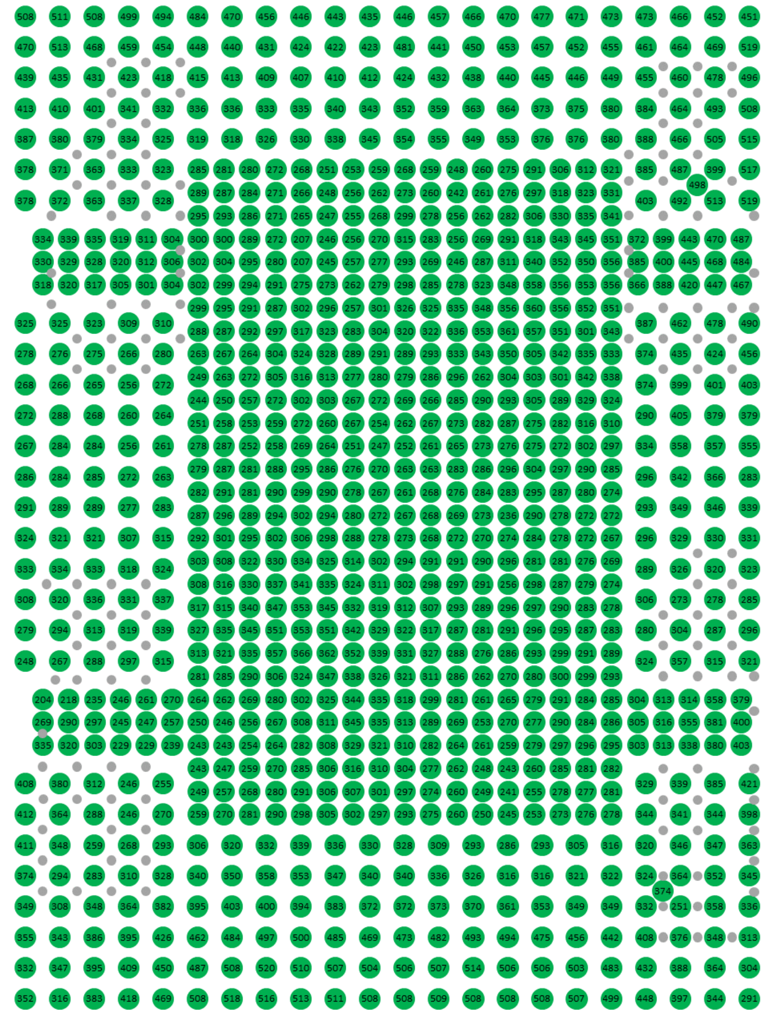
This pile would not fail, even if the lateral backbone correctly accounted for changes in axial load through the time history analysis

Sequential Pile Failure Review (with Retrofit Piles installed)

Mapping of all piles that would fail in the Median ground motion (RSN5827):

- Failures due to **Eastern Motion**:

Peak lateral displacement = 2.8” at t > 40 sec



For the median MCE_R ground motion with retrofit installed, no piles would fail, even if sequential pile failure were properly accounted for.

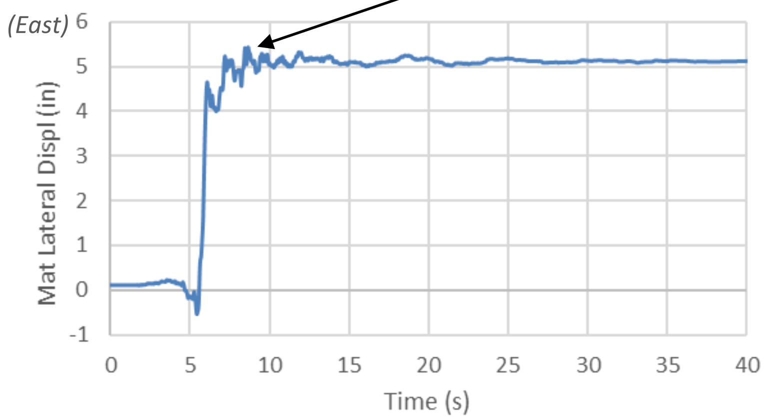
The same is true for 10 of the 11 ground motions evaluated.

Sequential Pile Failure Review (with Retrofit Piles installed)

Looking at one pile under the NE outrigger in Maximum BSE-2N (MCE_R) Time History RSN184:

X-Dir Lateral Displacement (time):

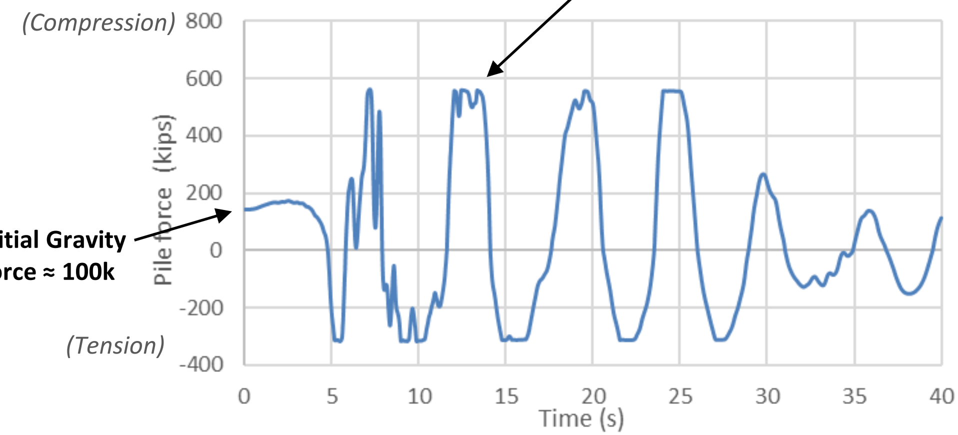
Δ_{EAST} **Max = 5.5" at t > 8 sec**

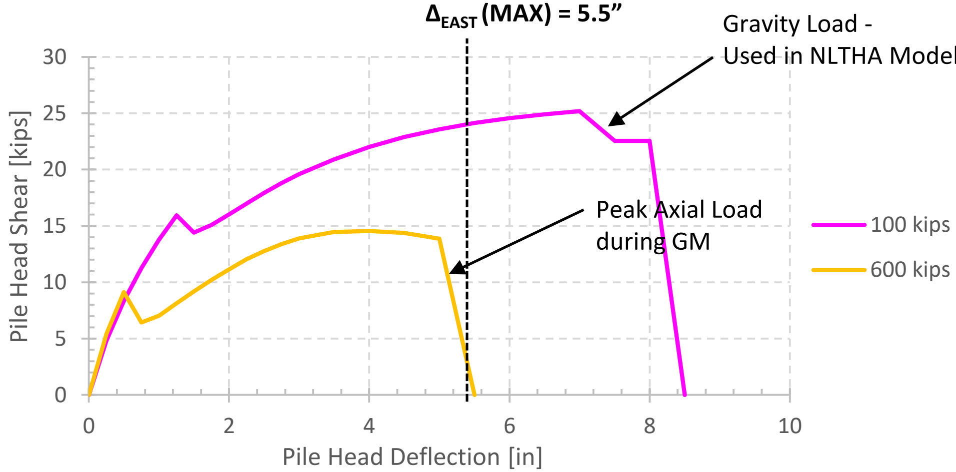


Axial Load (time):

Peak Force ≈ 600 k at Δ_{EAST} **= 5.5"**

Initial Gravity Force ≈ 100k





LERA Individual Pile Lateral Backbone Curves (0.25° Head Rotation)

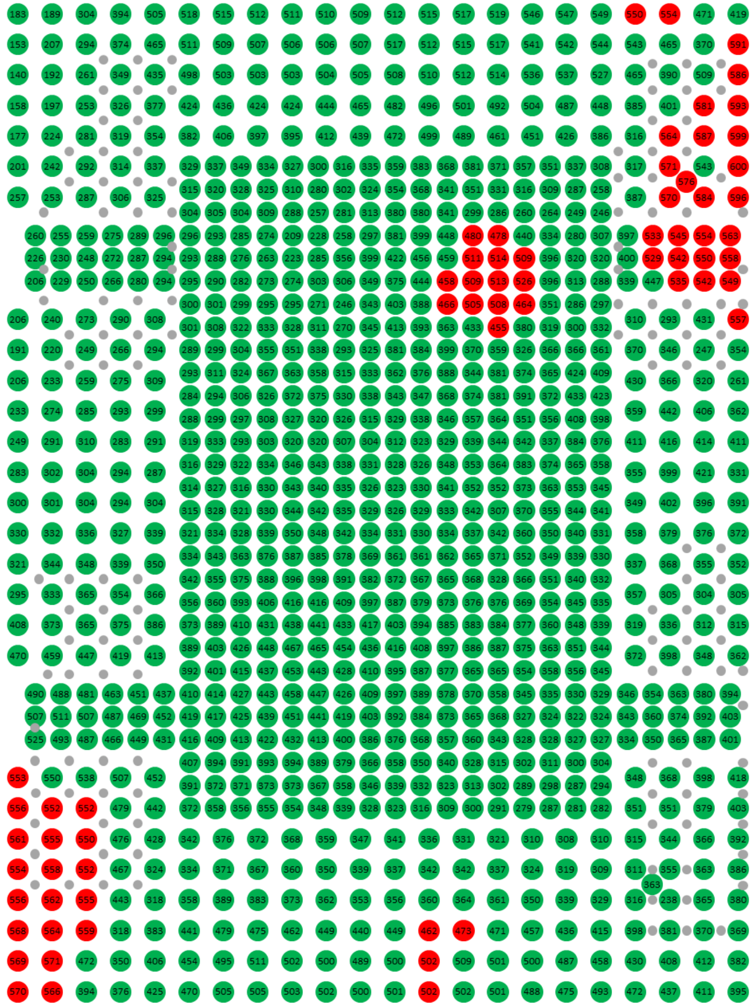
This pile would have failed if the lateral backbone correctly accounted for changes in axial load through the time history analysis

Sequential Pile Failure Review (with Retrofit Piles installed)

Mapping of all piles that would fail in the Maximum ground motion (RSN5827):

- Failures due to **Eastern Motion**:

Peak lateral displacement = 5.5” at t > 8 sec



For the maximum MCE_R ground motion with retrofit installed, we lose 65 piles (7% of the total). The analysis may not converge when sequential pile failure is properly accounted for.

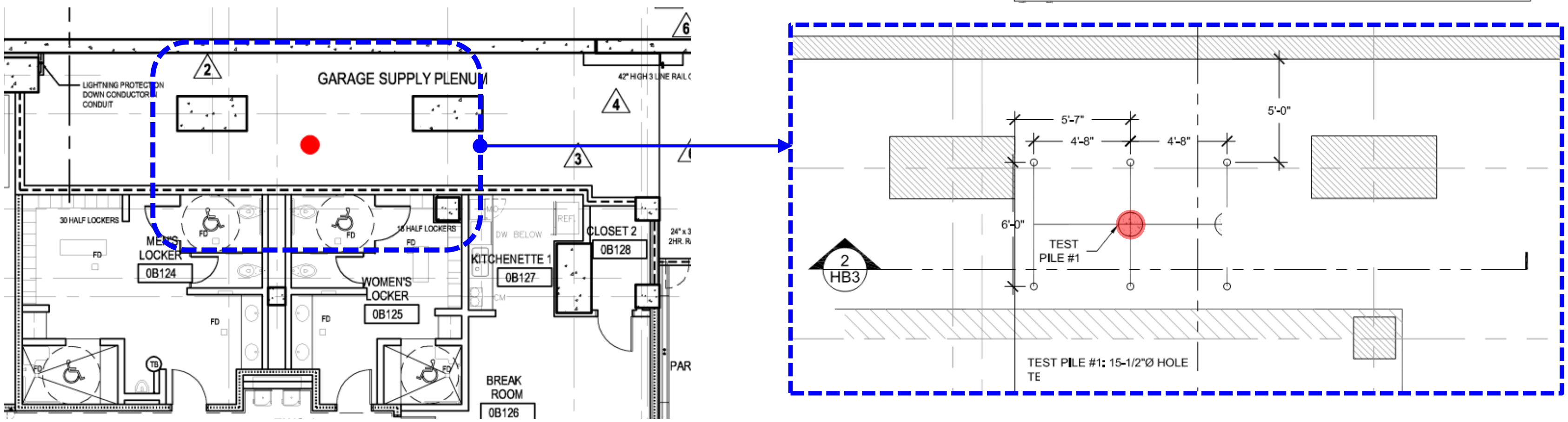
NEXT STEPS

NEXT STEPS

1) Test New Push Pile in Tower Basement

- Propose to reuse mat connection test hole:

PRELIMINARY DRAWINGS
PRIVILEGED AND CONFIDENTIAL



2) Refine analysis to finalize pile count and design

3) Complete permit drawing set for submission to DBI

CONCLUSION

REFINED RETROFIT SUMMARY:

- 132 new piles to rock
  - Balanced between east and west
  - Work completed entirely in basement (no need to purchase city land)
  - Reliably arrests settlement
- New Push Pile Design
  - Simplified operation saves time and cost
  - Displacement process protects existing piles
  - No ductile fuse required
- Reduced impact on tower basement and parking garage
- Addresses sequential pile and global shear failure concerns
- Estimated Pile Installation Cost: $35 Million

END