Update on the Investigation of the Effects of Boring Sample Size (3″ vs 5″) on Measured Cohesion in Soft Clays

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Reason for the Debate

- NOD uses 5" undisturbed borings for its major projects
- Federal Projects require a non-federal sponsor to cost share
  - Percentages vary based on project types
- Non-federal sponsors are allowed to perform work-in-kind as part of cost share
- Work-in-kind can consist of field investigation and lab testing
  - Most drillers & Labs are only equipped for 3-inch dia. borings
  - The Cost of 5-inch soil boring and 3-point testing
- Does boring sample size effect the measured cohesion in soft clay?

To be discussed…

- Why soil borings are taken
- Differences in sampling techniques (3” vs 5” soil borings)
- Differences in equipment and staffing
- Sample disturbance
- Differences in testing procedures
- Variations in Field Investigation & Lab testing for study
- Sensitivity analysis (Reduction in strength vs cost)
- Conclusion

Why are Soil Borings Taken?

- To identify the soil type existing below the surface
- To measure the strength of the soils
- To measure the thickness of the layers or strata

Differences in Sampling Techniques

There are two sizes of piston type samplers used in South Louisiana

- 2-7/8-inch diameter sampler
  - commonly referred to as 3-inch diameter
- 5-inch diameter sampler
  - Hvorslev sampling device was specifically developed to reduce the sample disturbance in soft soils

Equipment & Staff Required for Sampling
(3" vs 5" diameter sampler)

- In general, the same drill rig equipment may collect both types of samples
- The staff required is about the same for both types
- The 5-inch diameter sample tubes weigh more when full
- The sample head and rods used are the same
- Continuous sampling would require a large inventory of tubes if samples are extruded in the lab

Drill Rig Mast and Kelley

3-inch Diameter Sampling

- Two main methods are used:
  - Continuous sampling – each sample is retained for laboratory testing (extruded in the field or lab - most commonly in the field)
  - Non-continuous sampling (more common) – selected "representative" samples are retained for laboratory testing; much of the boring is washed and discarded in the field

Field extruding with truck mounted ram

Field Classification and packaging of 3-inch samples

Sample Remains

5-inch Diameter Sampling

- Continuous sampling method
- 5-inch samples are transported to the lab for extrusion (in a confined state)
- High effort to minimize disturbance

(This method can also be used for the 3-inch diameter sampling)

Sealing and preparing for transport of 5-inch samples

Extruding 5-inch dia. samples in soils lab.

Classification in soils lab of 5-inch dia. samples

(controlled environment)

Sample Disturbance

Facts

- "Undisturbed" samples are needed to determine engineering properties
- <u>All samples are disturbed</u>
- Degree of disturbance varies with sample diameter

Effect sample disturbance has on soil properties

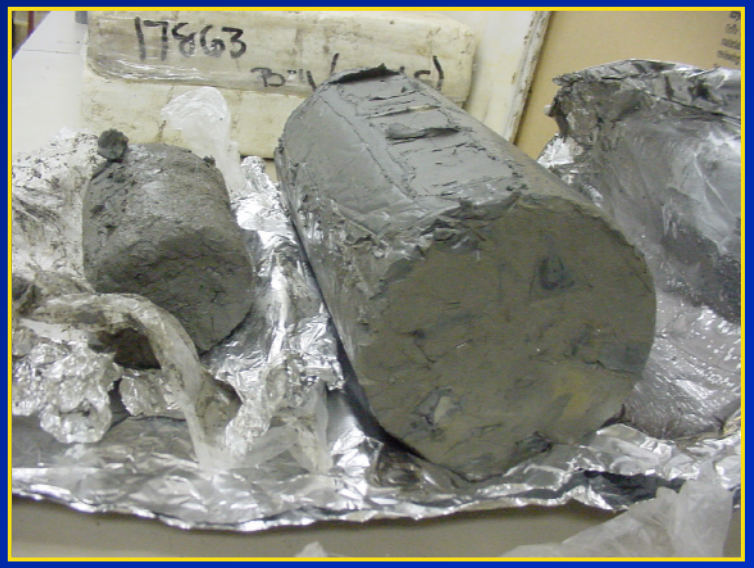
(Based on Corps EM 1110-1-1804)

Factor	Effect
Physical disturbance from sampling and transportation	Effect on shear strength: a. Reduces UU and UCT strength b. Little effect on CD strengths Effect on consolidation test results: a. Reduces preconsolidation pressure b. Reduces compression index c. Reduces coefficient of consolidation
Changed stress conditions from in-situ to ground surface locations	Similar to physical disturbance but less severe

Photos demonstrating disturbance

POI-46U &

POI-46UG



POI-48U &

POI-48UG

Photos demonstrating disturbance

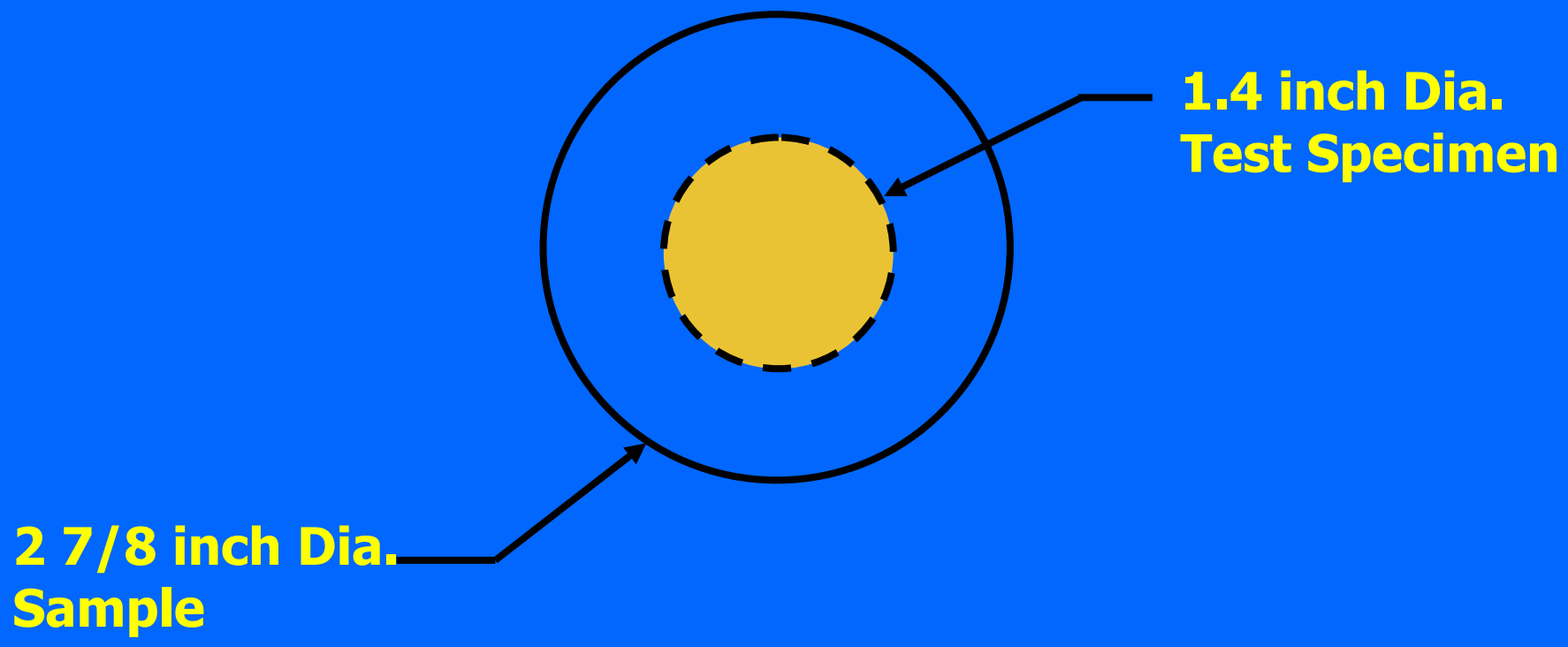
Sample Disturbance reduces reliability!!!

Differences in Testing Procedures

3-inch Diameter Sample

- Only a single test at a single confining state may be performed
- Statistical advantage of redundant testing is lost
- If the test does not produce satisfactory results, the designer must test another specimen from another location within the boring

Typical Cross Section of a 3 inch Sample

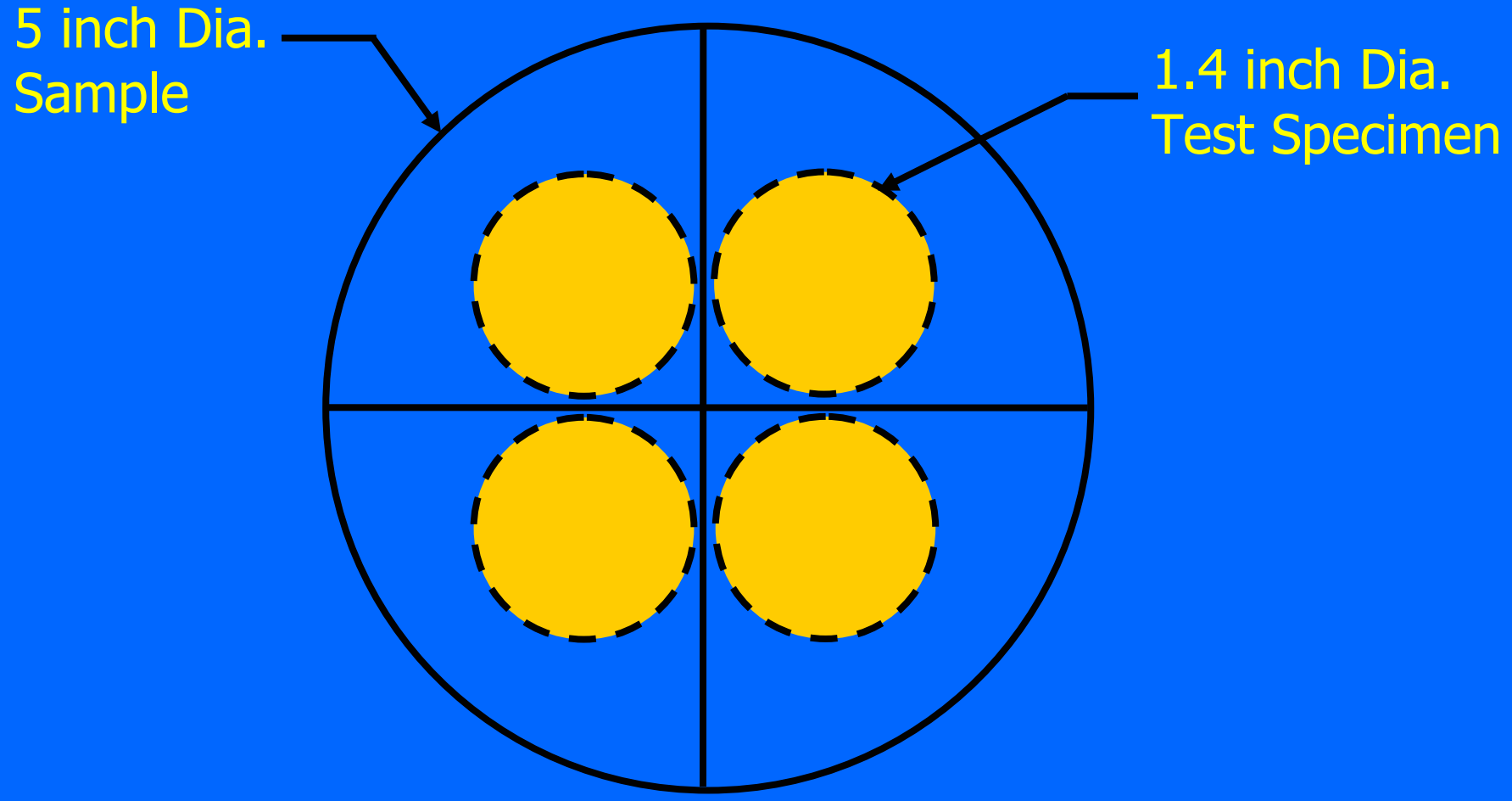


5-inch Diameter Sample

- Sample is sectioned and cut to supply four test specimen from a single layer for shear testing at <u>various confining stresses</u>
- Typically, three specimen are tested, and the fourth is reserved as a spare
- The redundant testing allows for a statistical advantage

THIS INCREASES THE RELIABILITY OF THE RESULTING SHEAR STRENGTH

Typical Cross Section of a 5 inch Sample



Quartering 5-inch diameter sample

Trimming specimen for triaxial shear testing

(wire saw)

Variations in Field Investigation
&
Lab Testing
for
Study

Field Investigation consisted of:

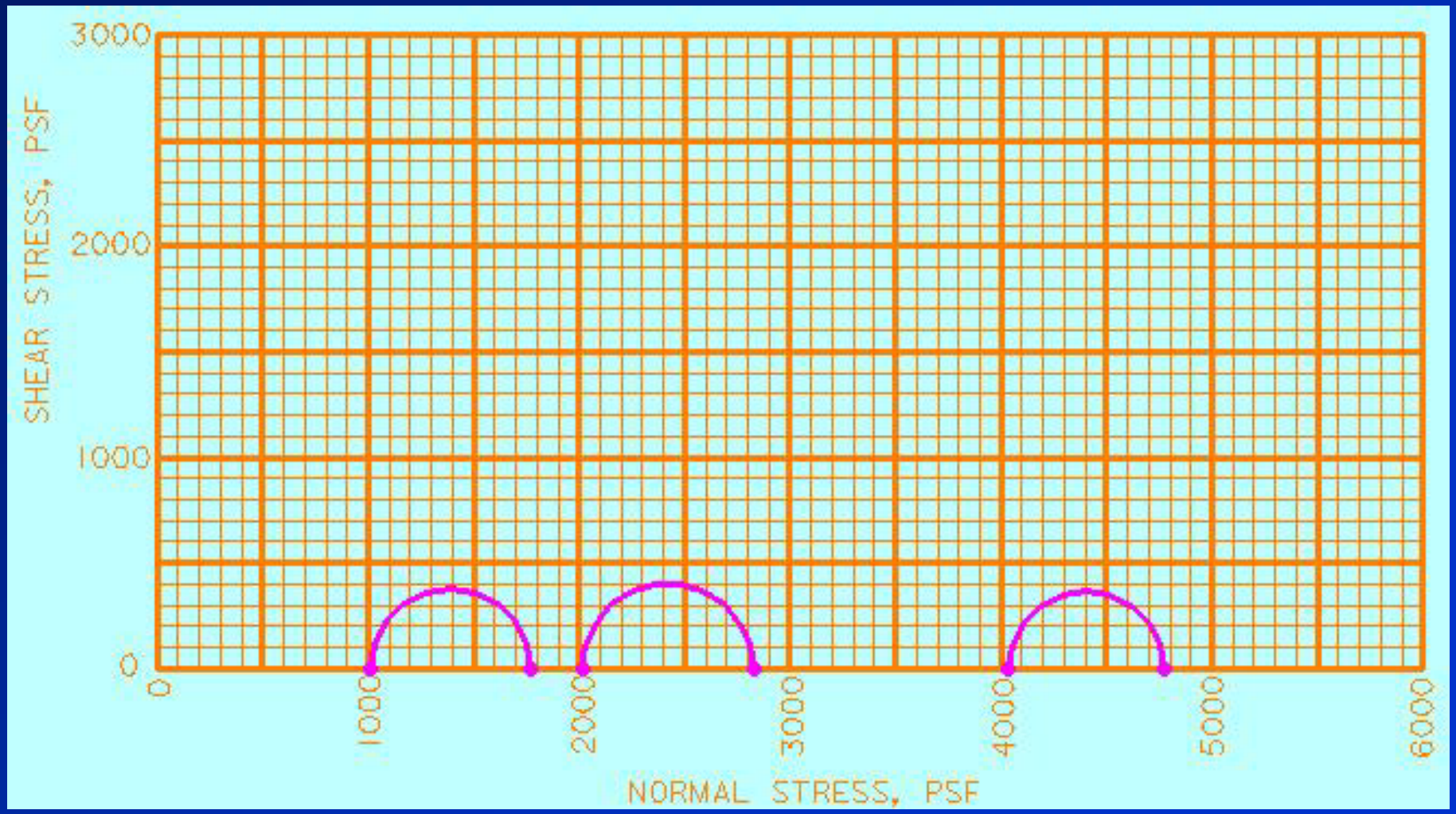
- 5-inch undisturbed borings (reference datum)
- 3-inch general type borings (non-continuous) (5)
- 3-inch continuous borings extruded in the field (3)
- 3-inch continuous borings extruded in the lab (2)
- Locations: Natural Ground &
  Through Existing Levees

Lab Testing Procedures:

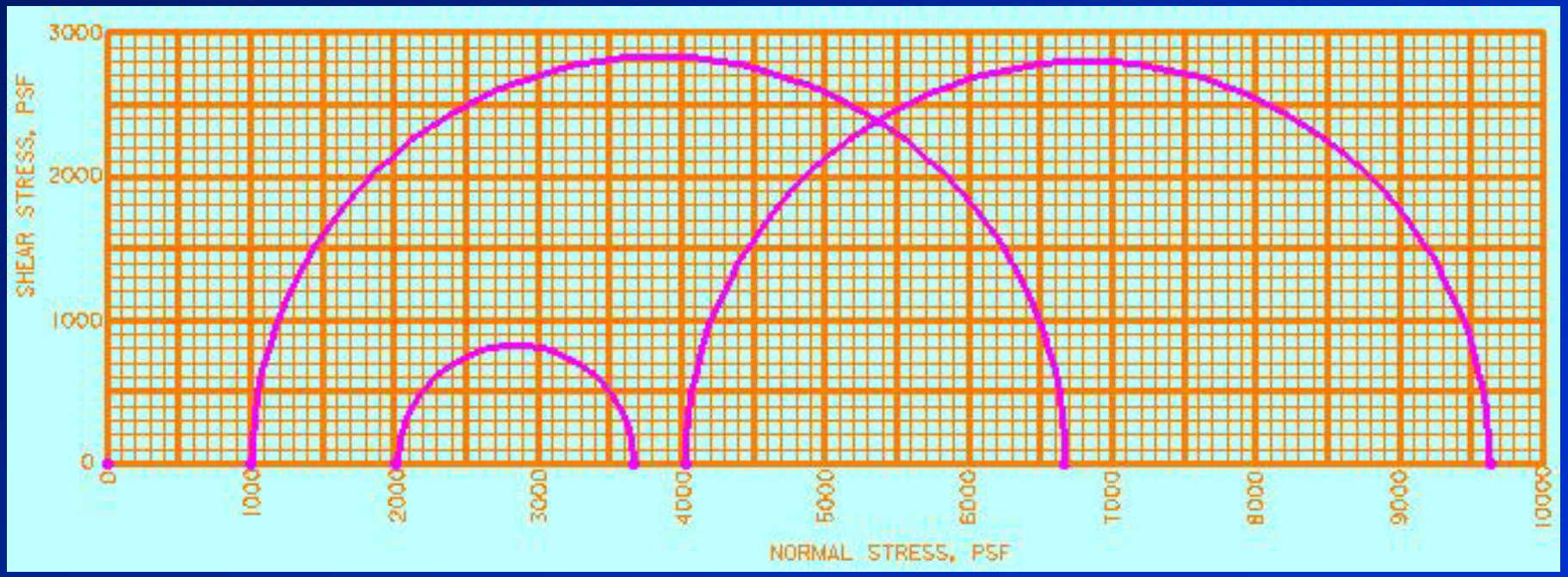
5” Samples – 3-pt UU tests & UCTs

3” Samples – 1 pt UU tests trimmed & untrimmed and UCTs

Ideal Unconsolidated-Undrained Test



Example Unconsolidated-Undrained Test

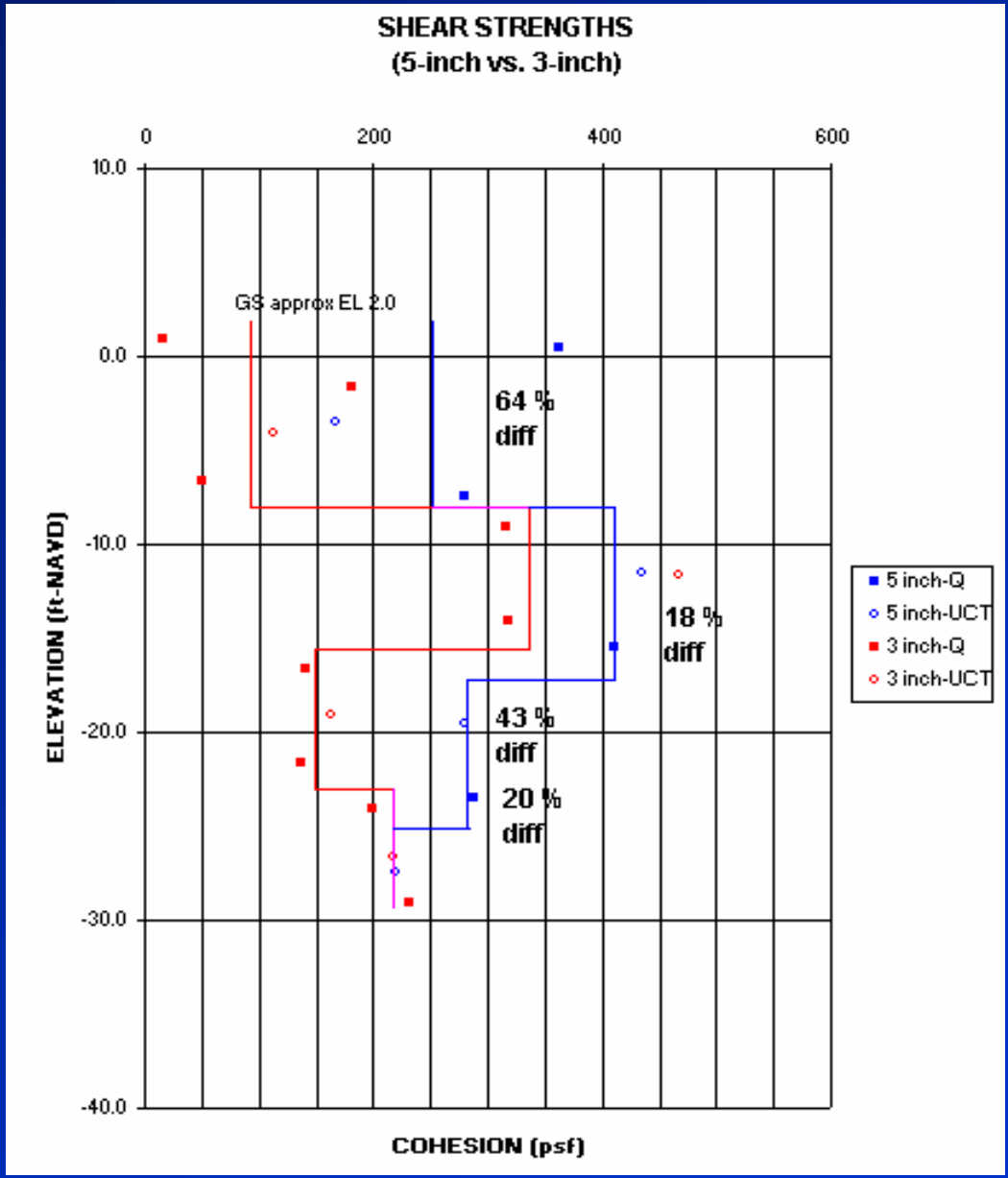


* May be over designed

Comparing 3" vs 5" Boring Data

POI-43U (5-inch)

POI-43UG (3-inch)



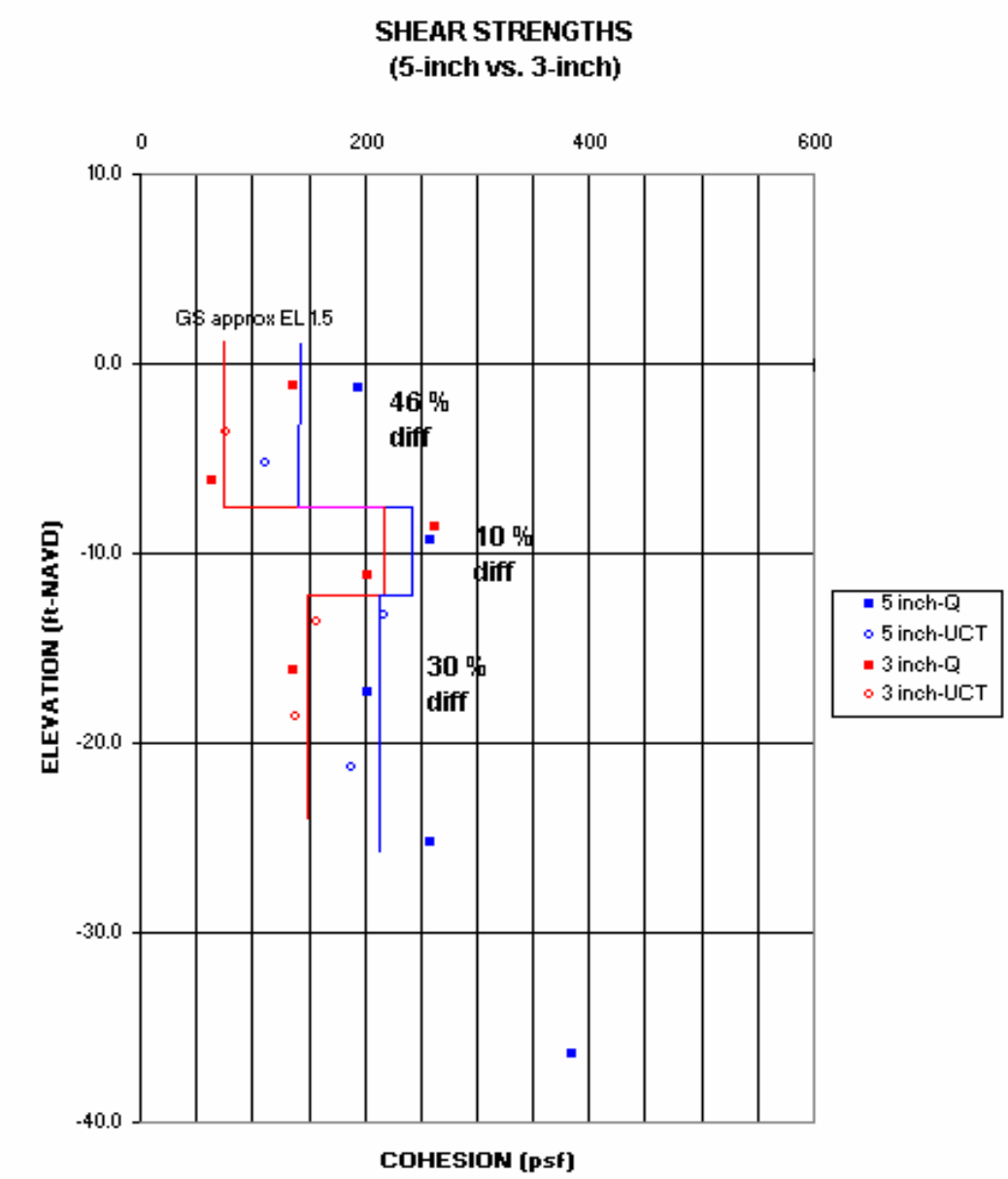
0% - 64%

NOTE: 3" BORING IS NON-CONTINUOUS

Comparing 3” vs 5” Boring Data

POI-46U (5-inch)

POI-46UG (3-inch)



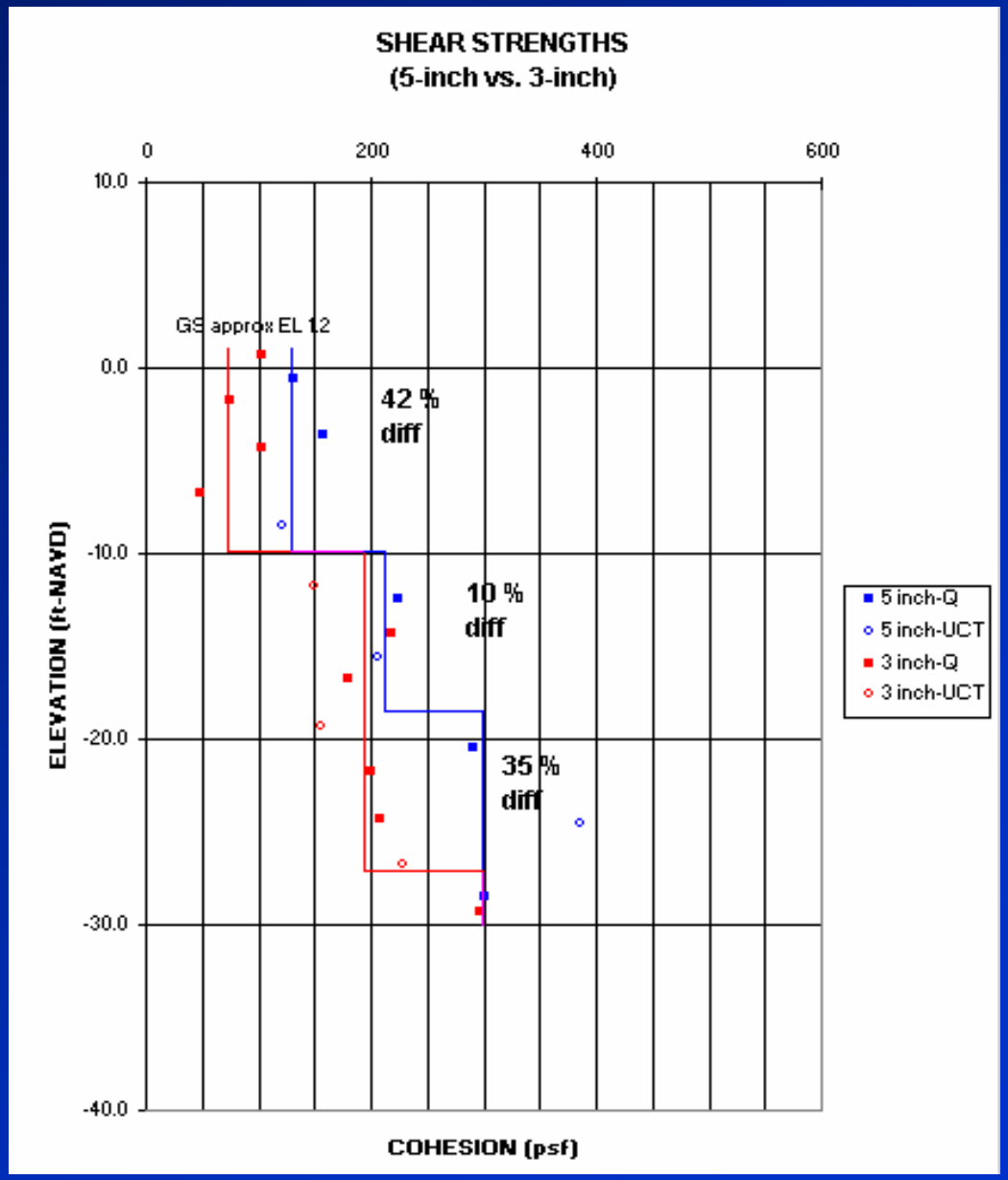
10% - 46%

NOTE: 3” BORING IS NON-CONTINUOUS

Comparing 3” vs 5” Boring Data

POI-48U (5-inch)

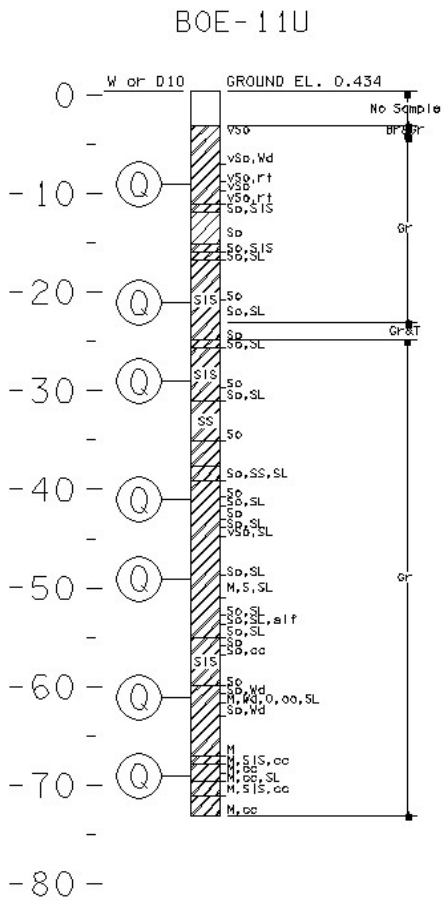
POI-48UG (3-inch)

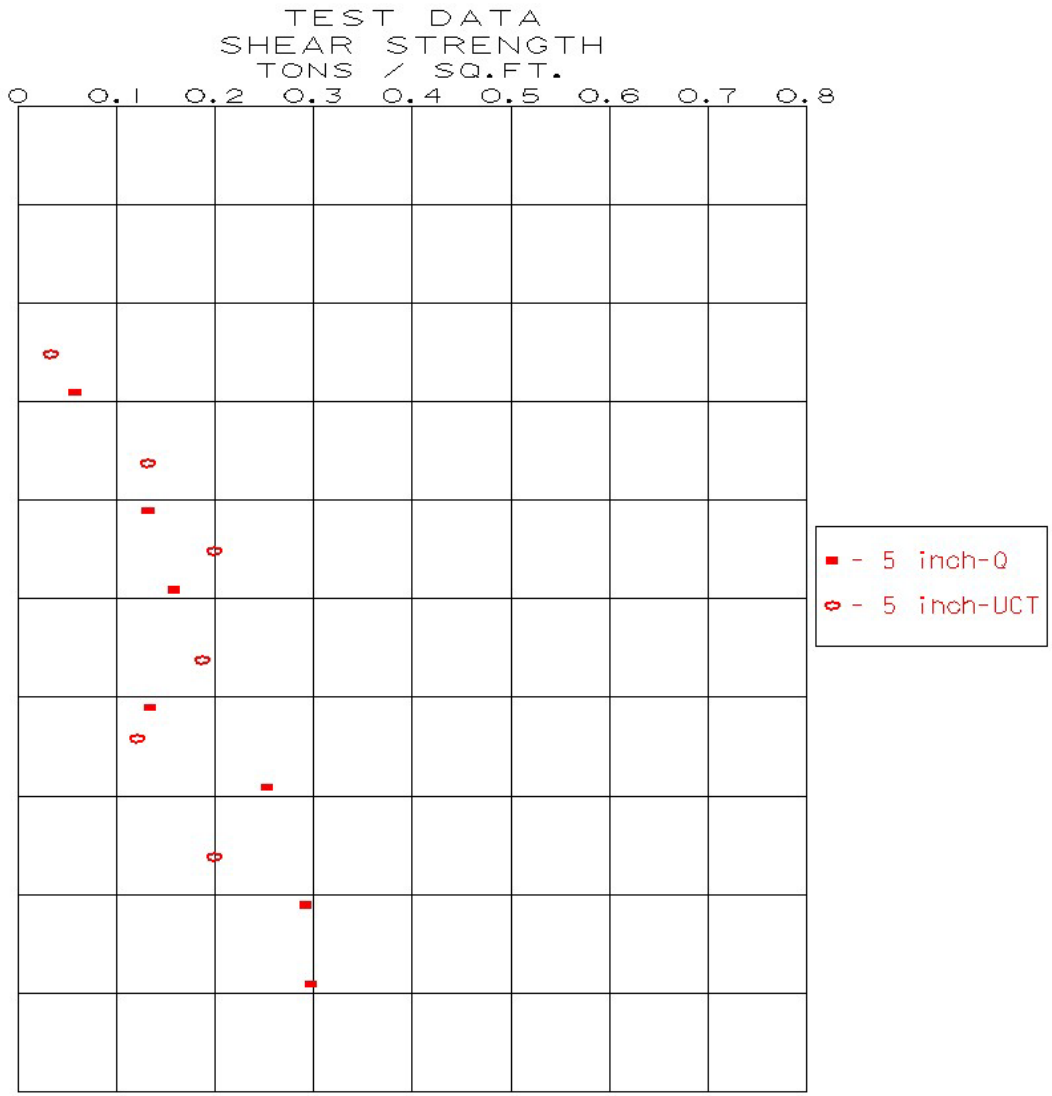


10% - 42%

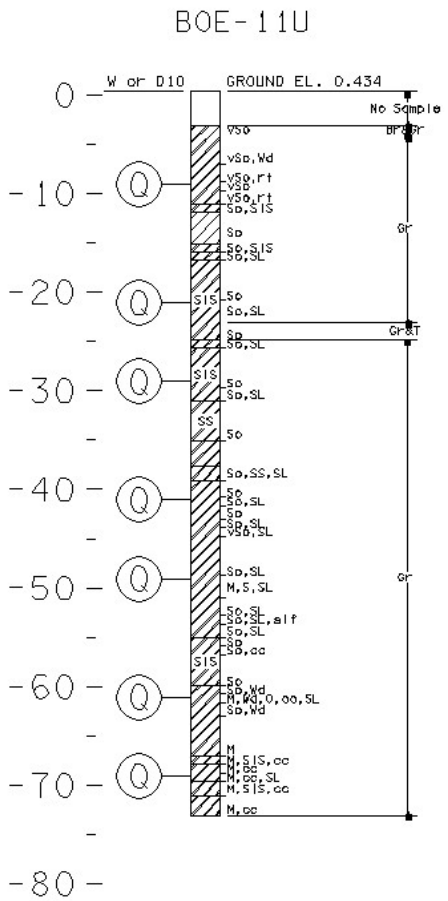
NOTE: 3” BORING IS NON-CONTINUOUS

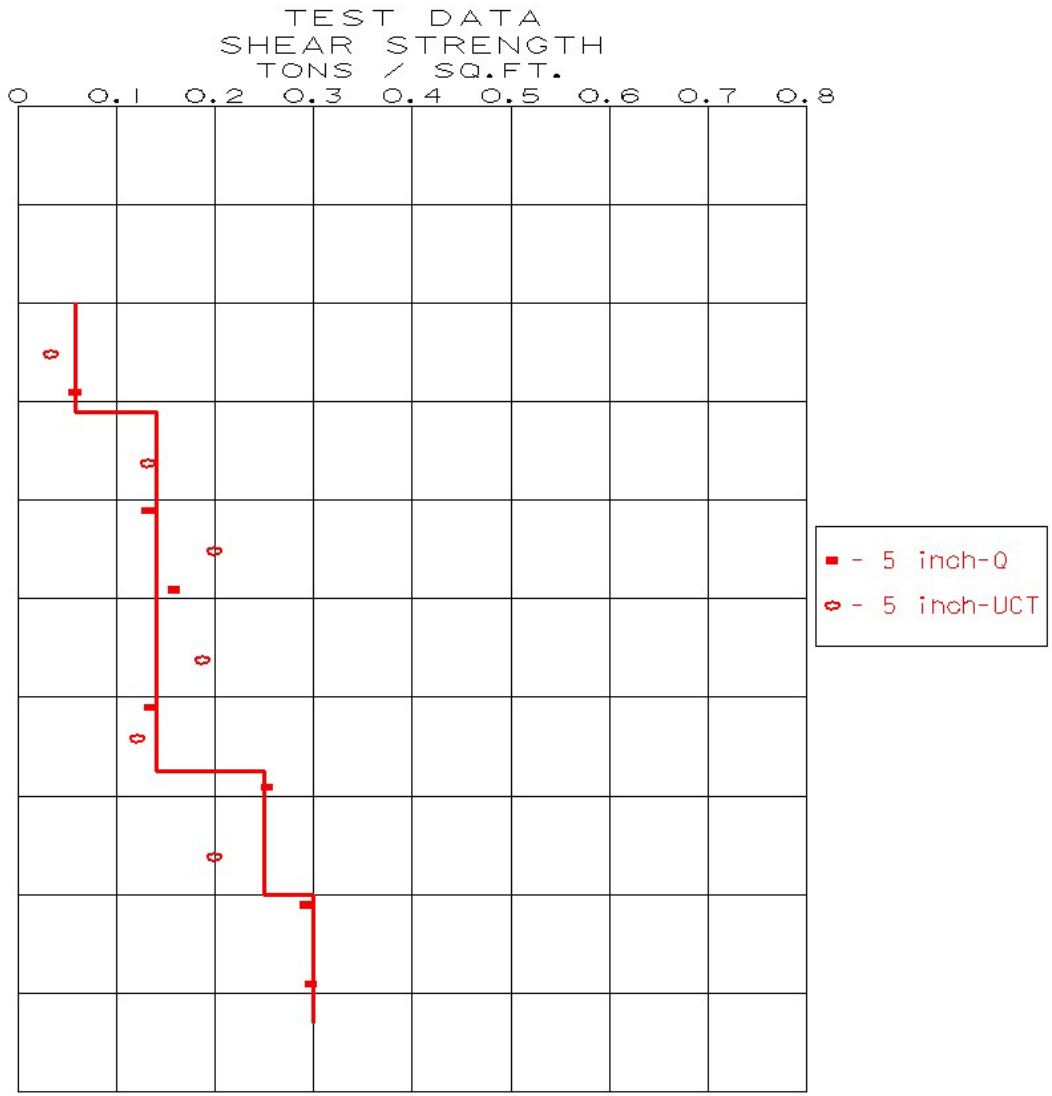
5-inch undisturbed boring



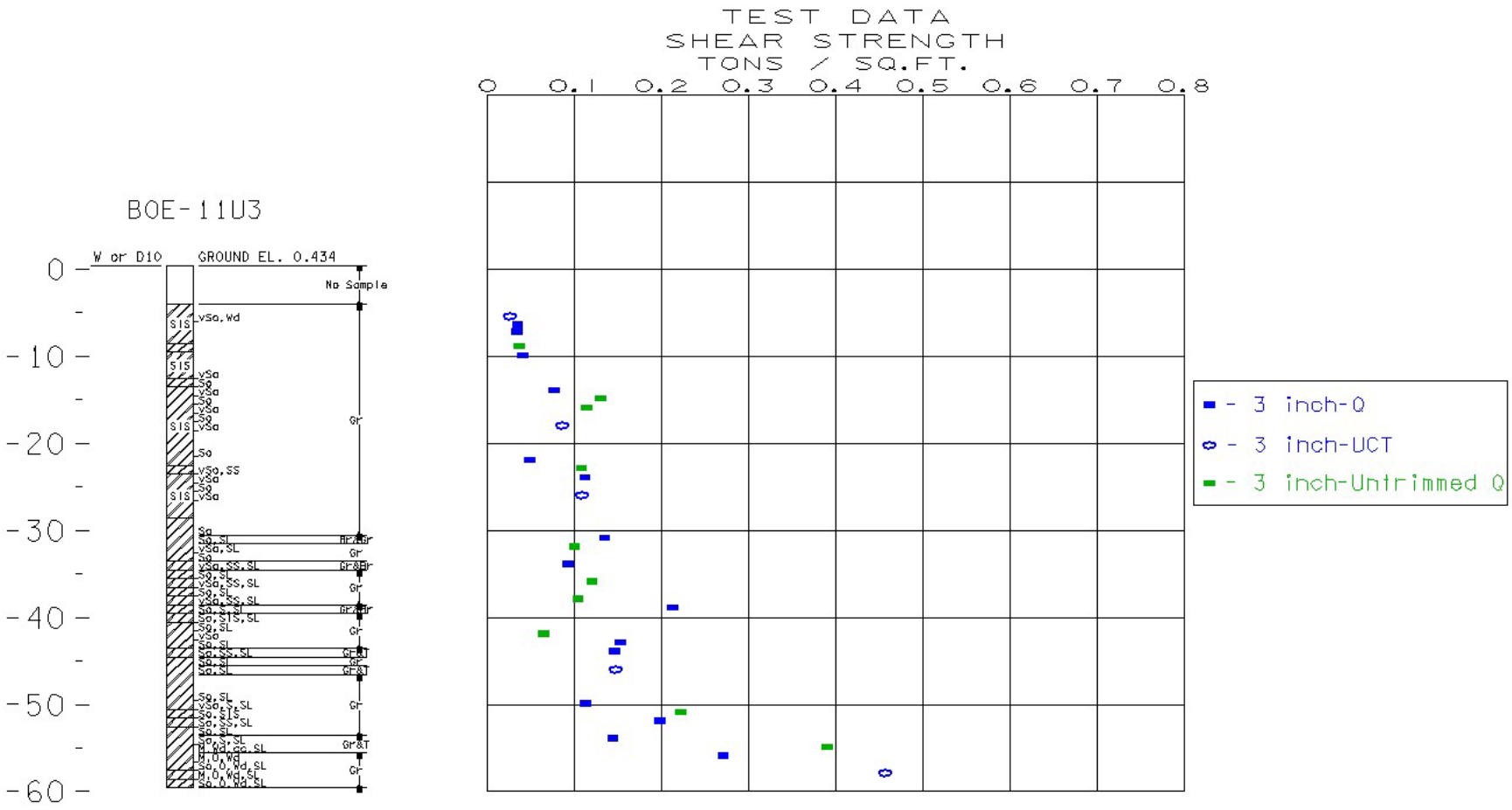


5-inch undisturbed boring

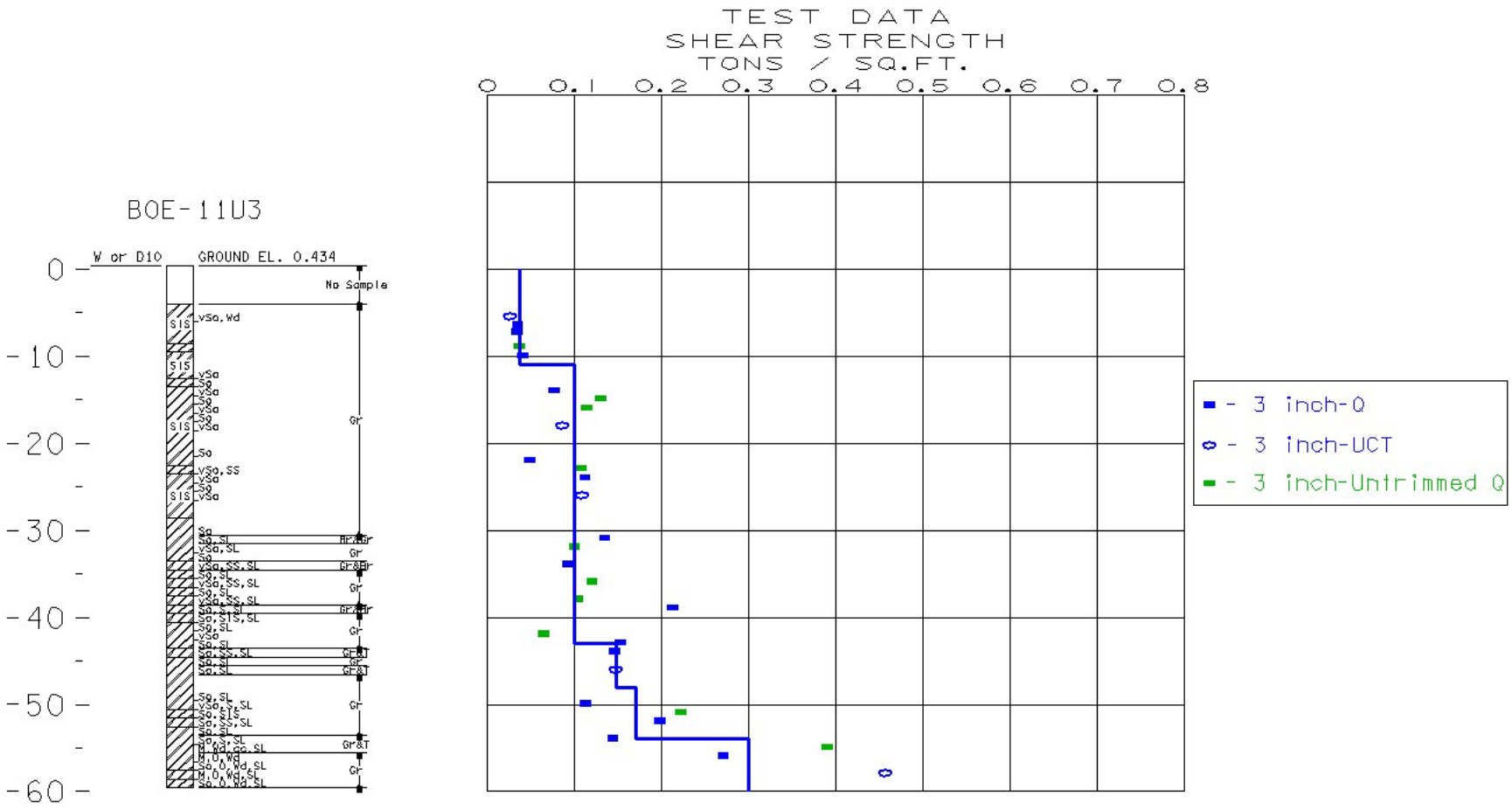




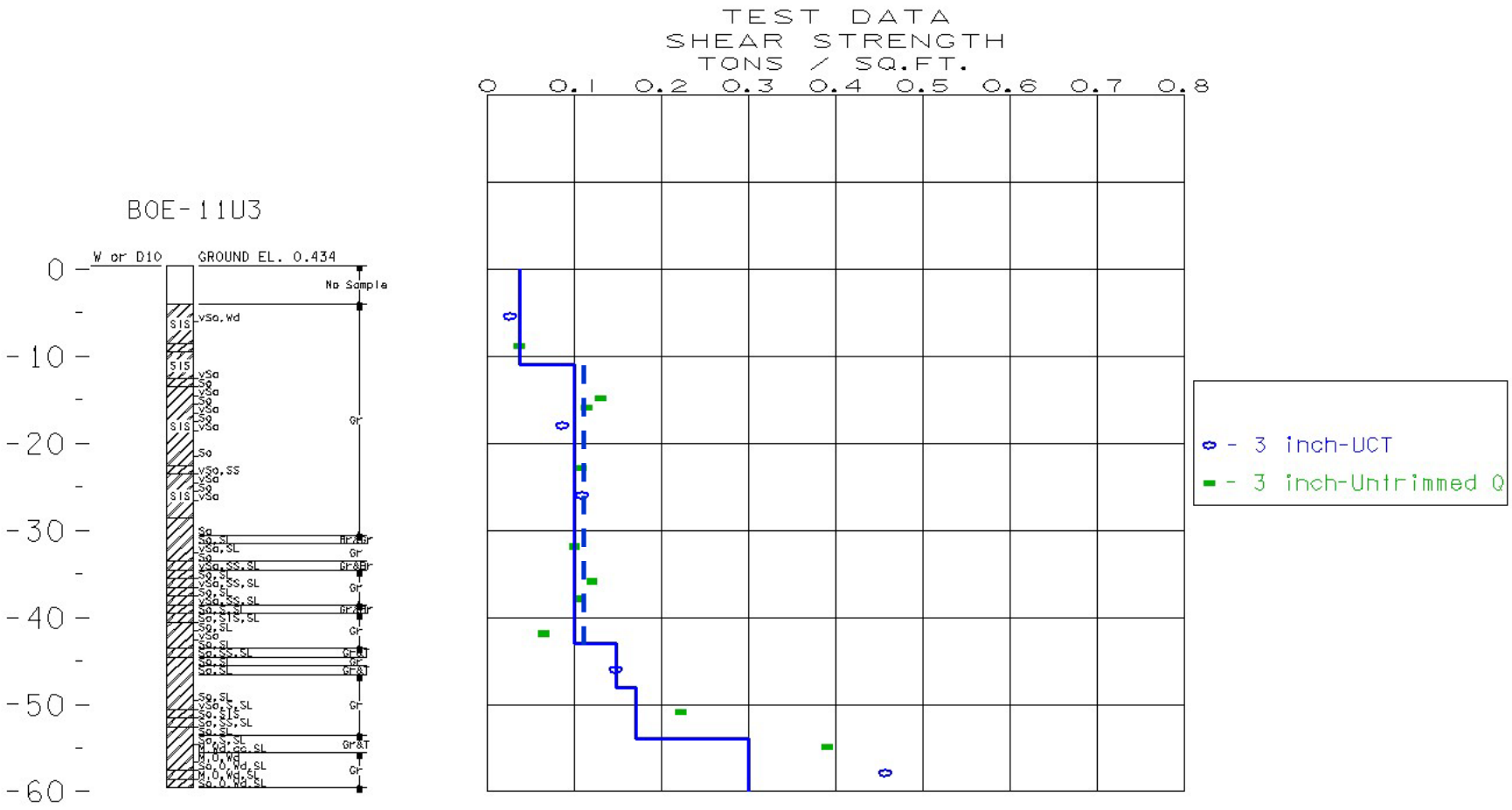
3-inch continuous boring – extruded in the lab



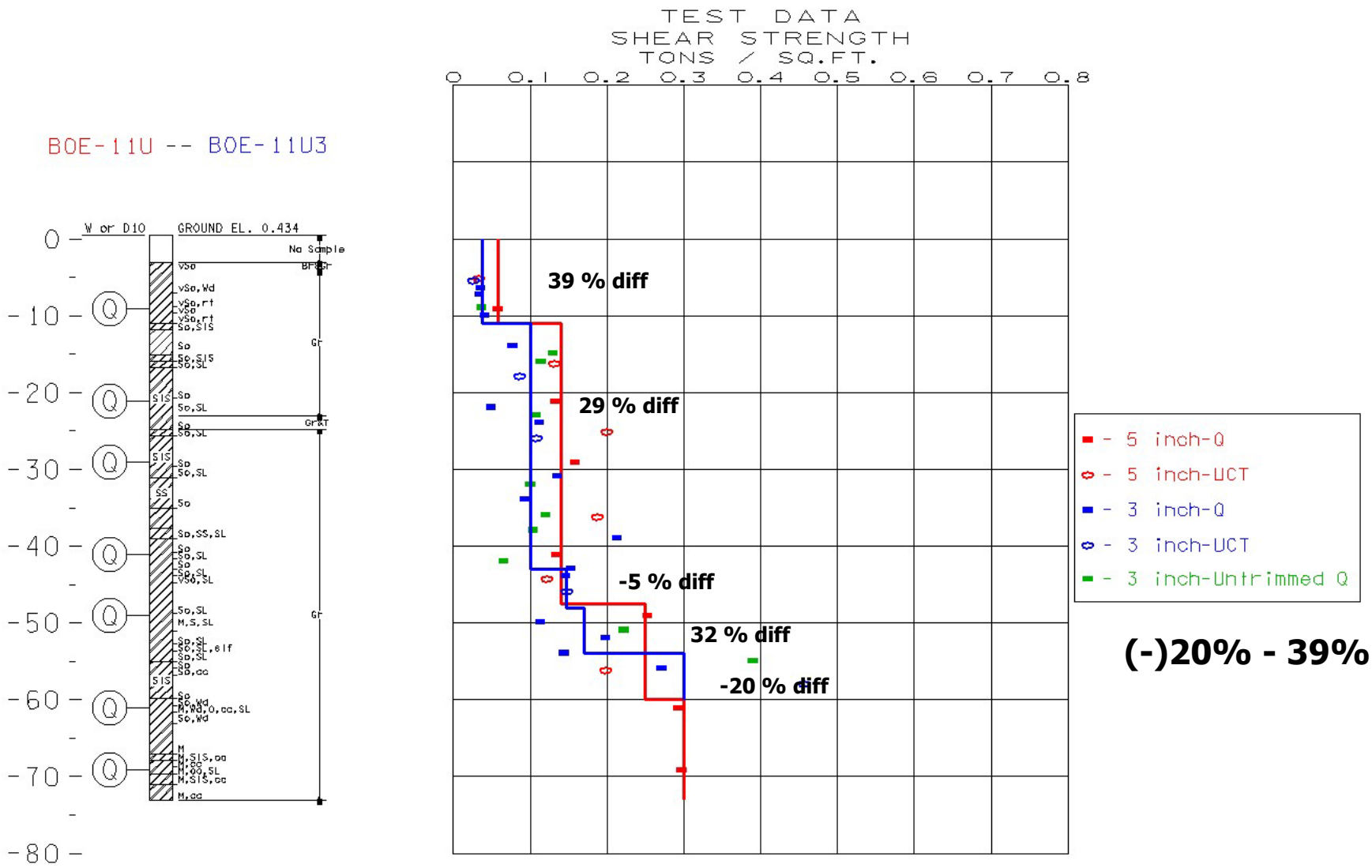
3-inch continuous boring – extruded in the lab



3-inch continuous boring – extruded in the lab

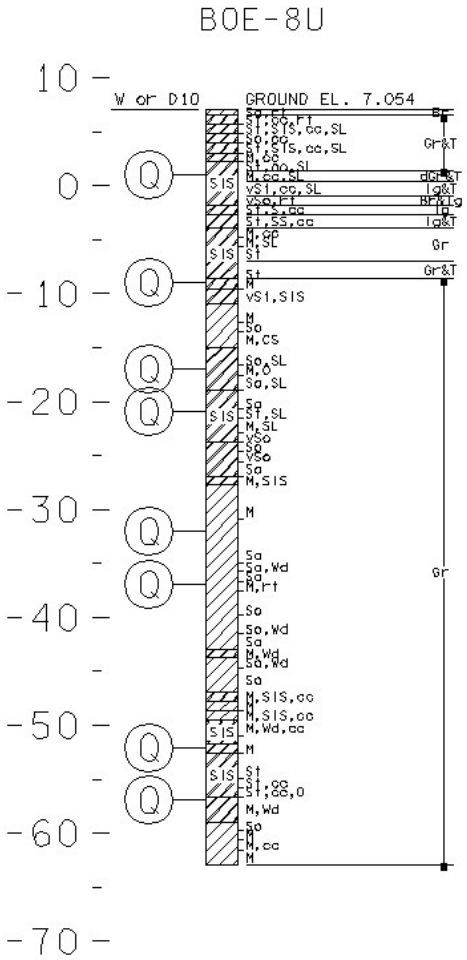


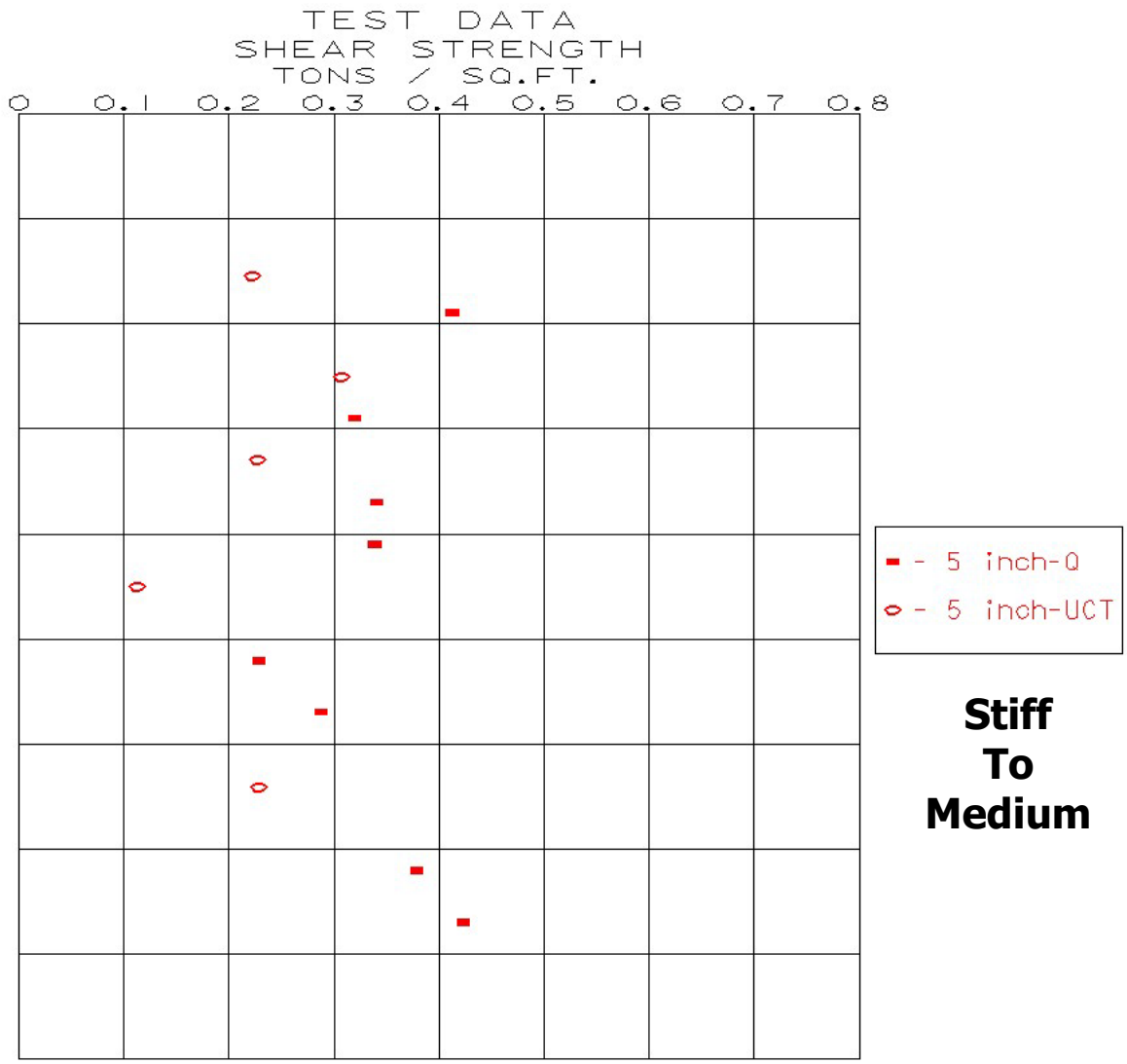
5-inch undisturbed boring
vs.
3-inch continuous boring – extruded in the lab



(-)20% - 39%

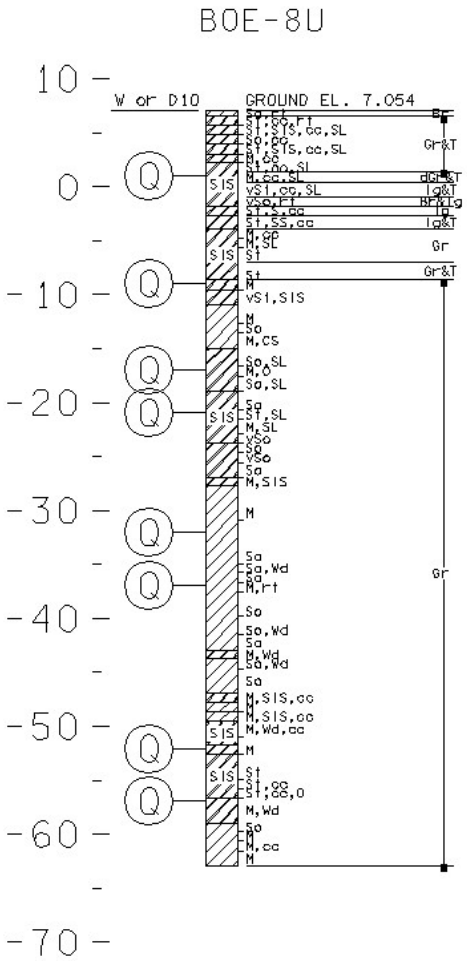
5-inch undisturbed boring

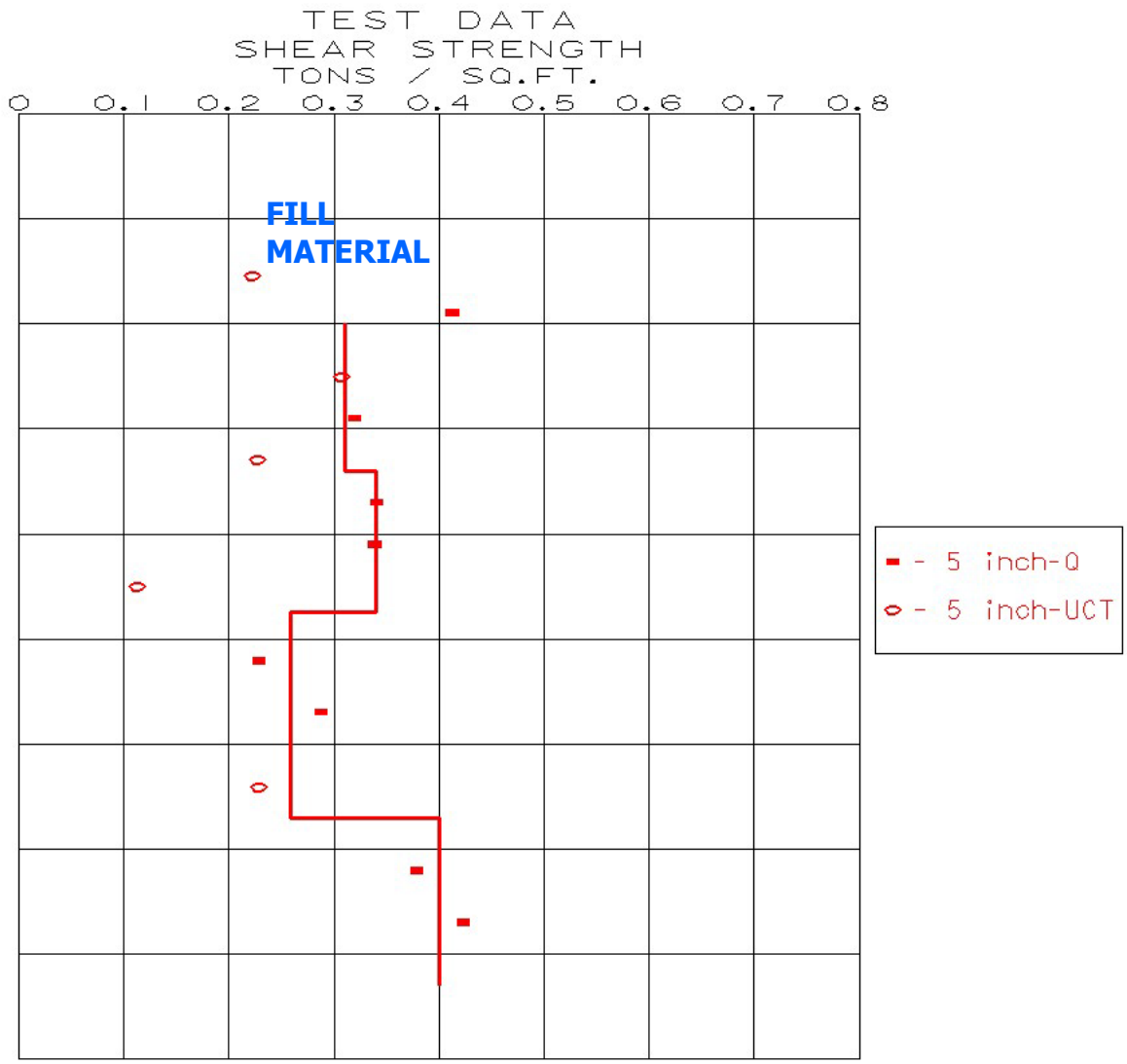




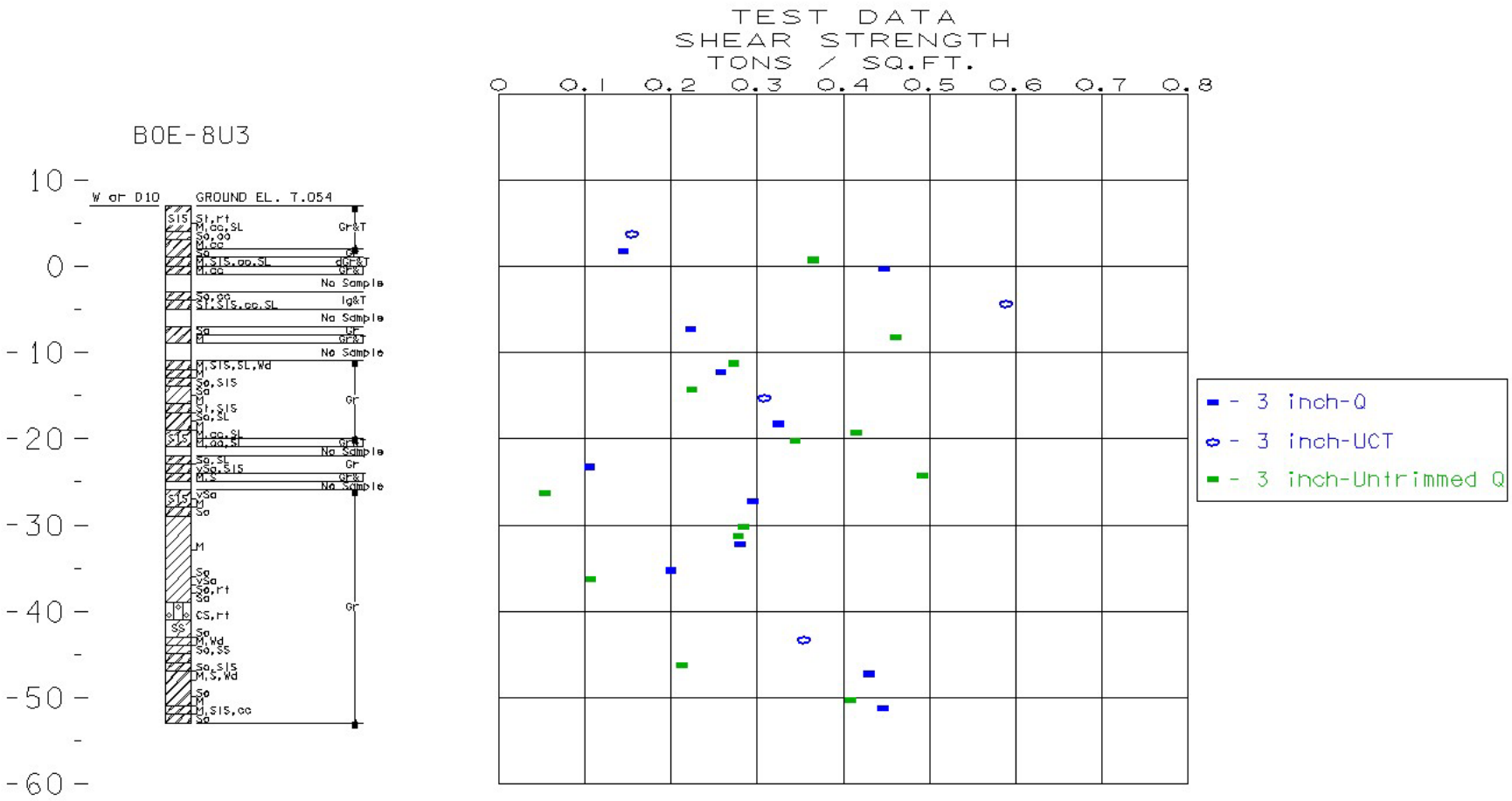
Stiff To Medium

5-inch undisturbed boring

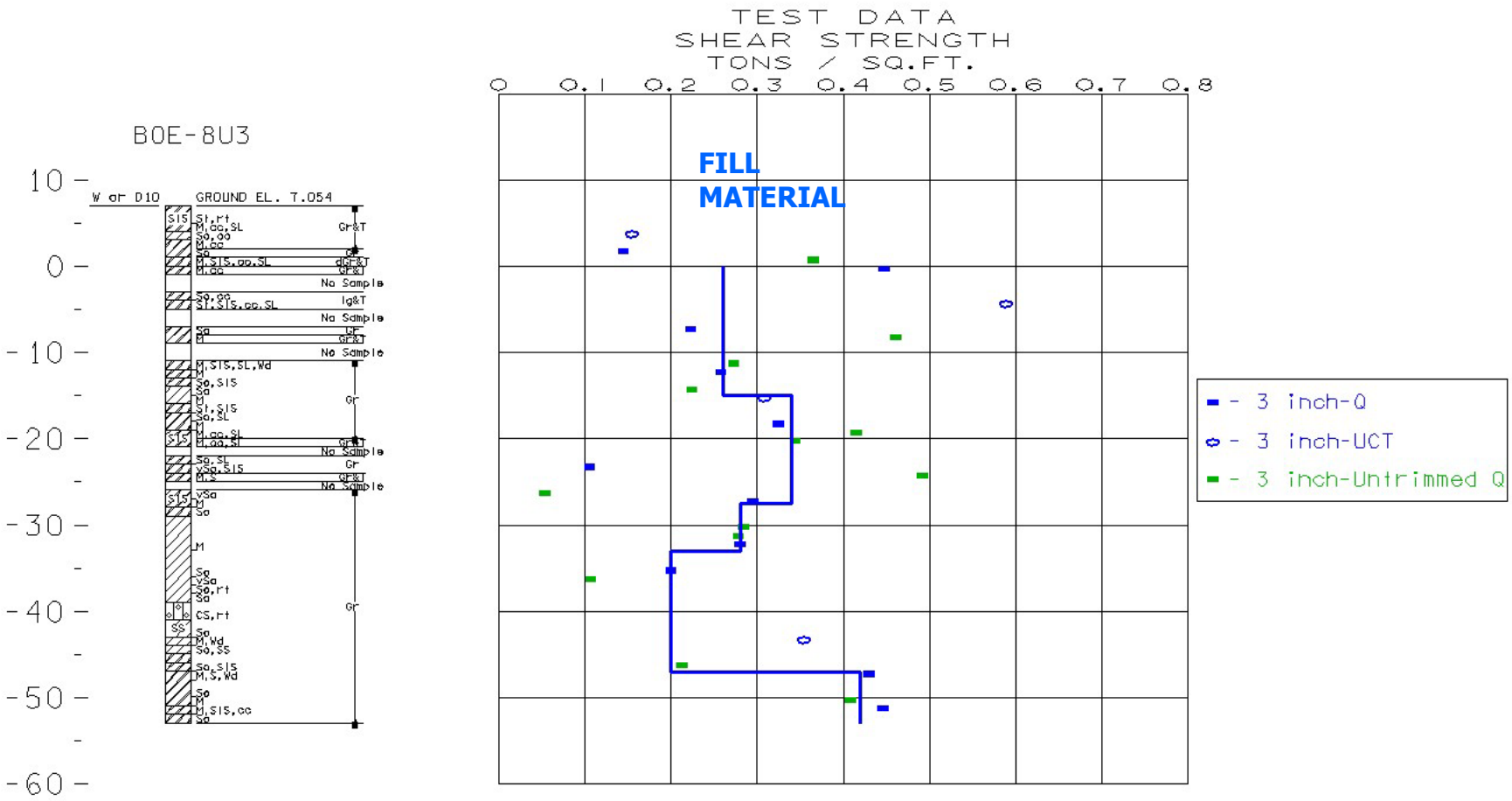




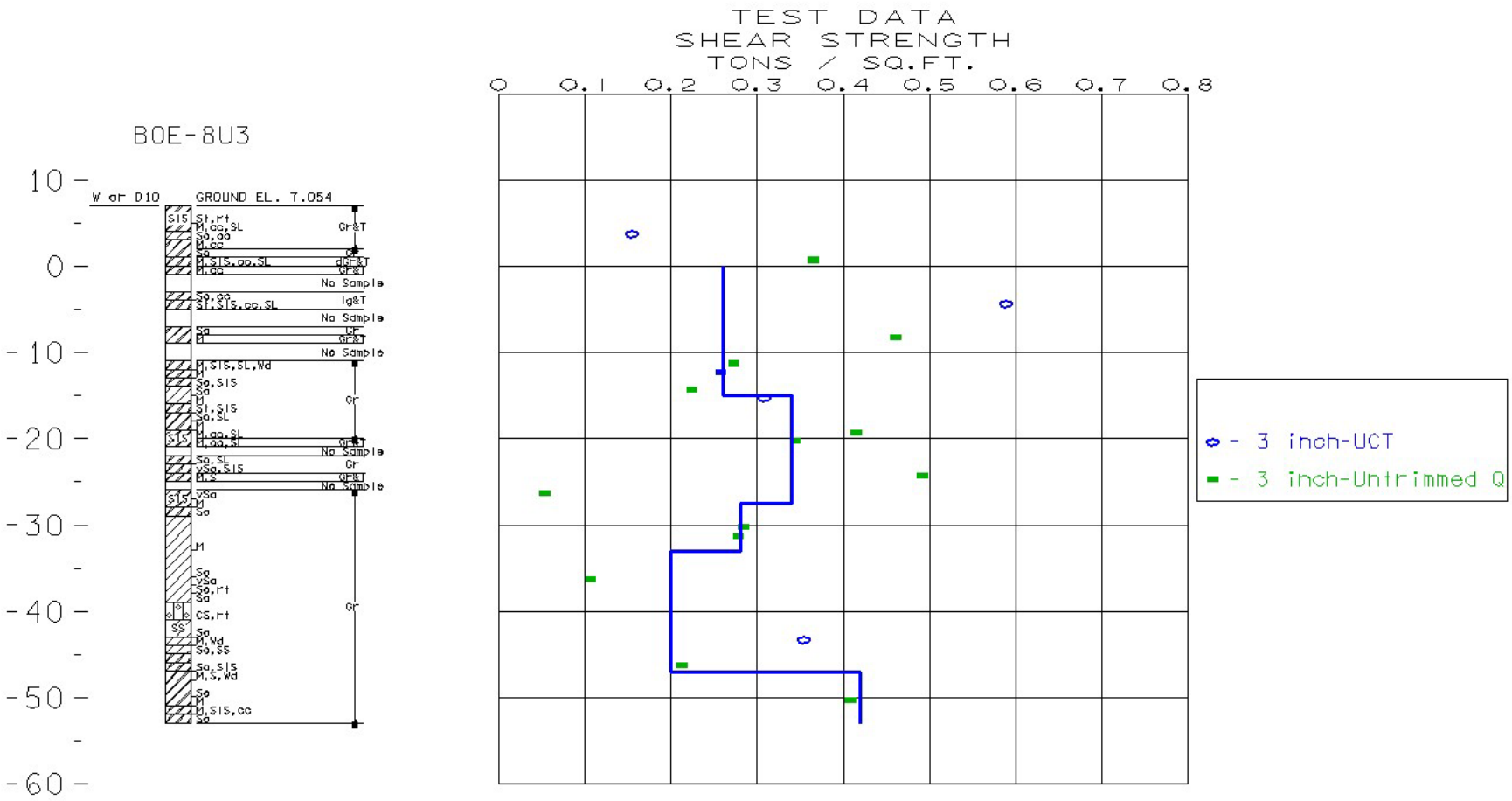
3-inch continuous boring – extruded in the lab



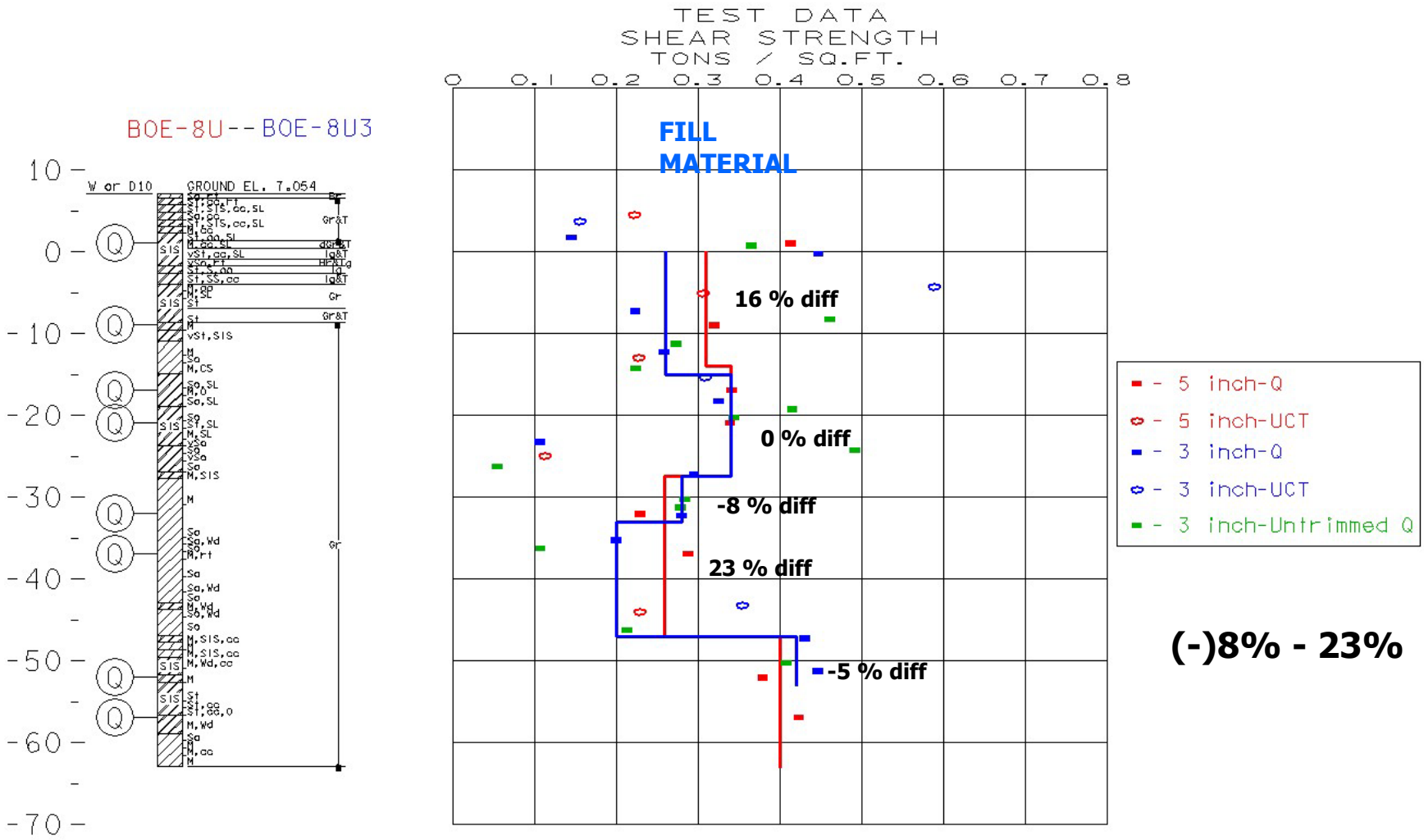
3-inch continuous boring – extruded in the lab



3-inch continuous boring – extruded in the lab

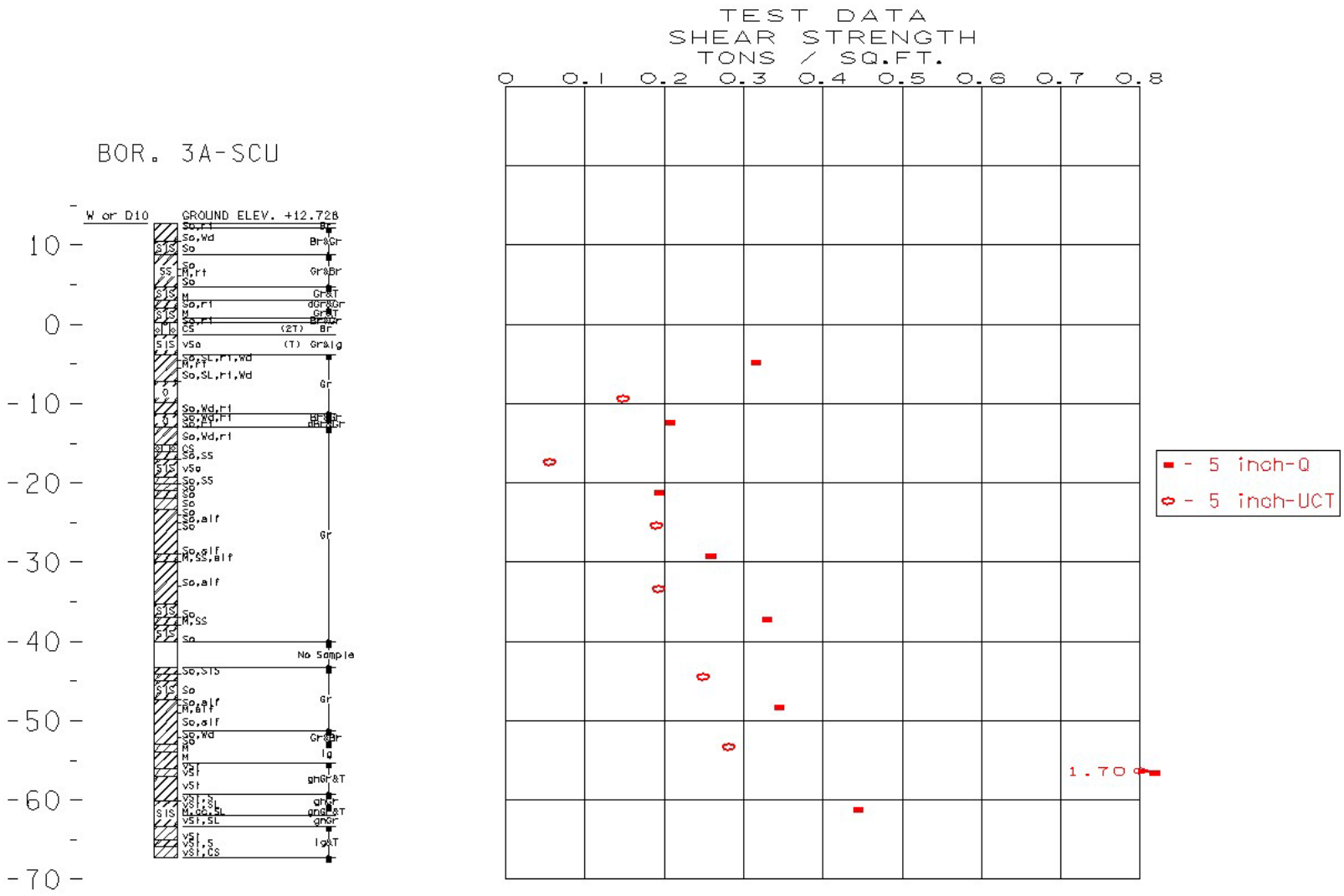


5-inch undisturbed boring
vs.
3-inch continuous boring – extruded in the lab

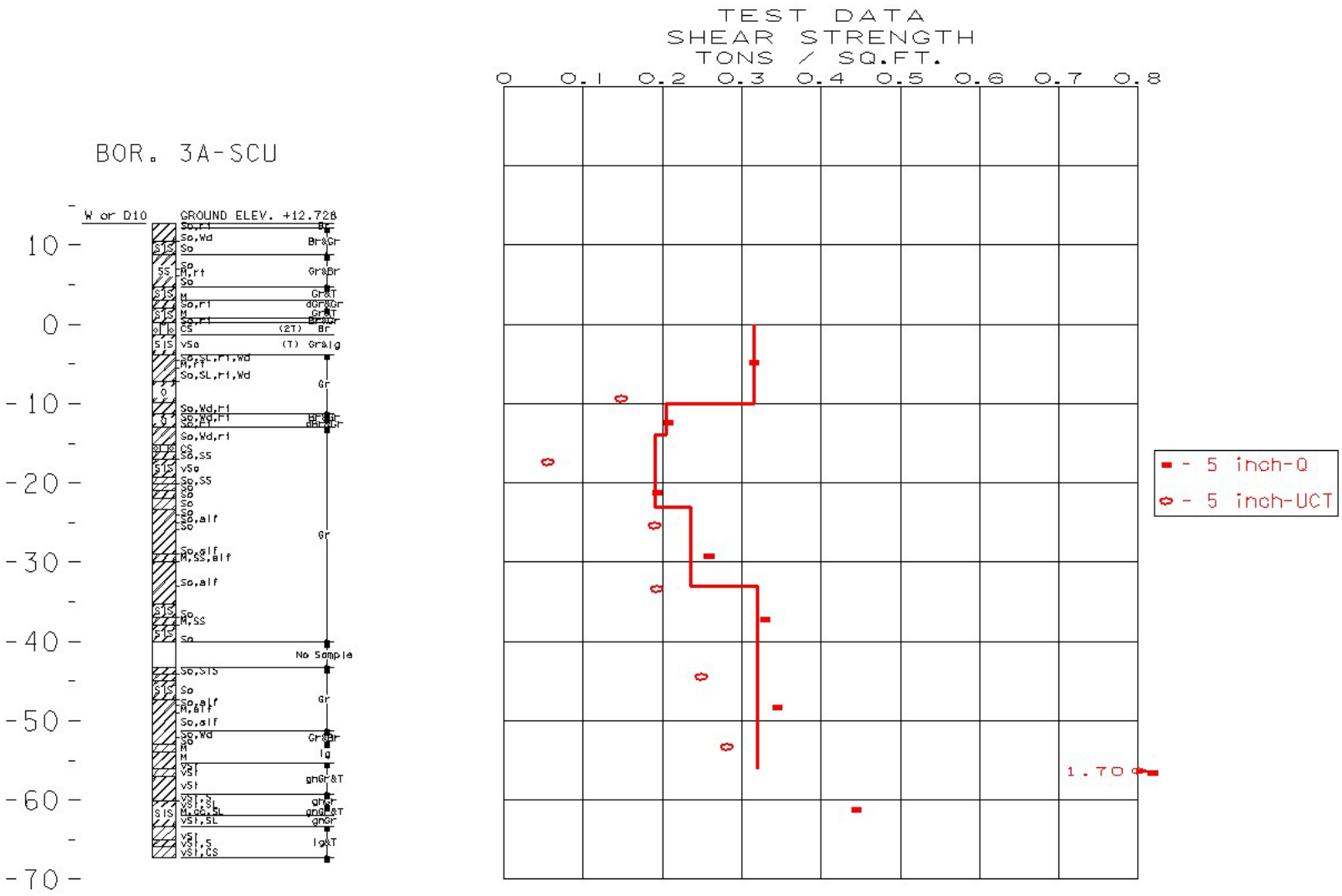


(-)8% - 23%

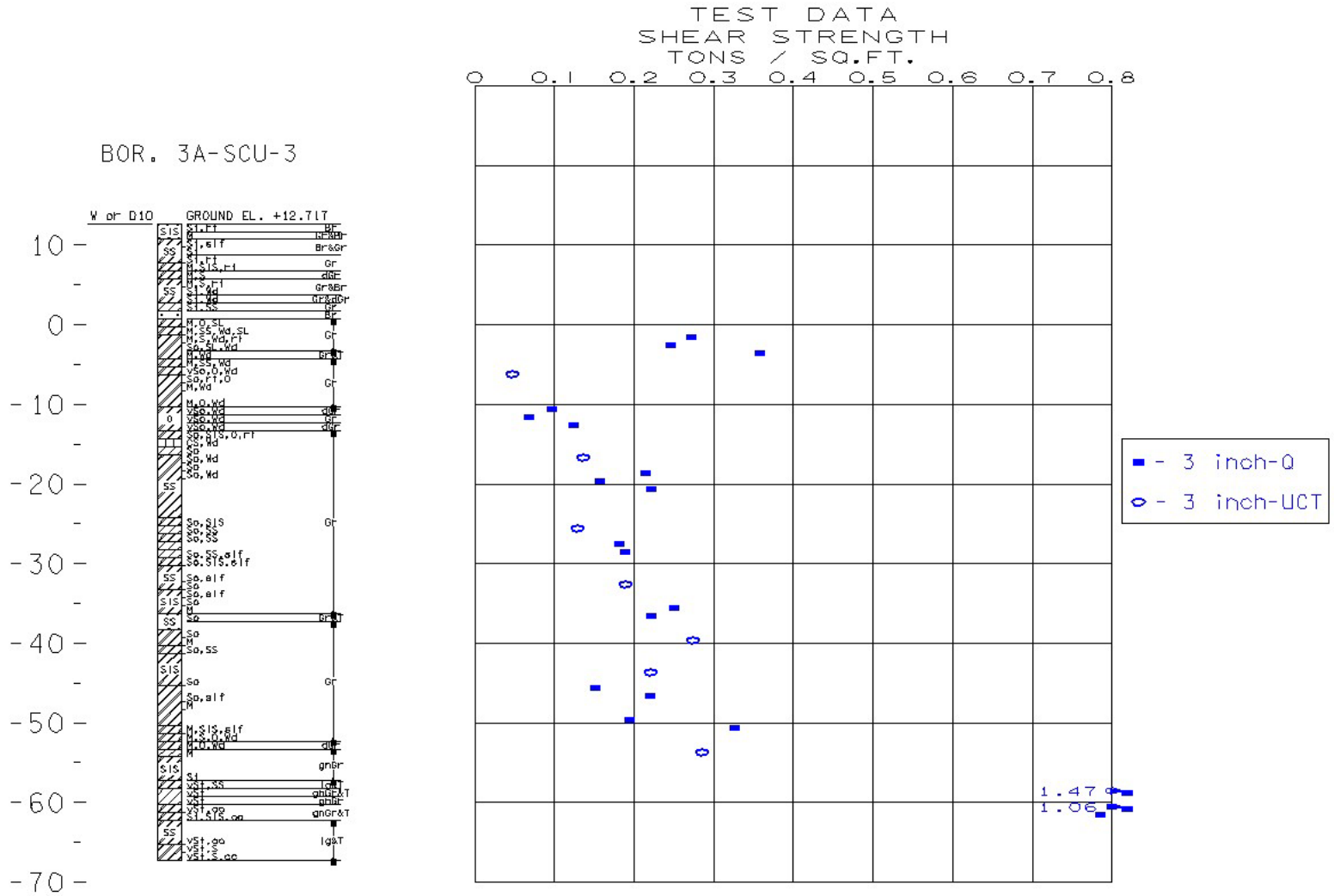
5-inch undisturbed boring



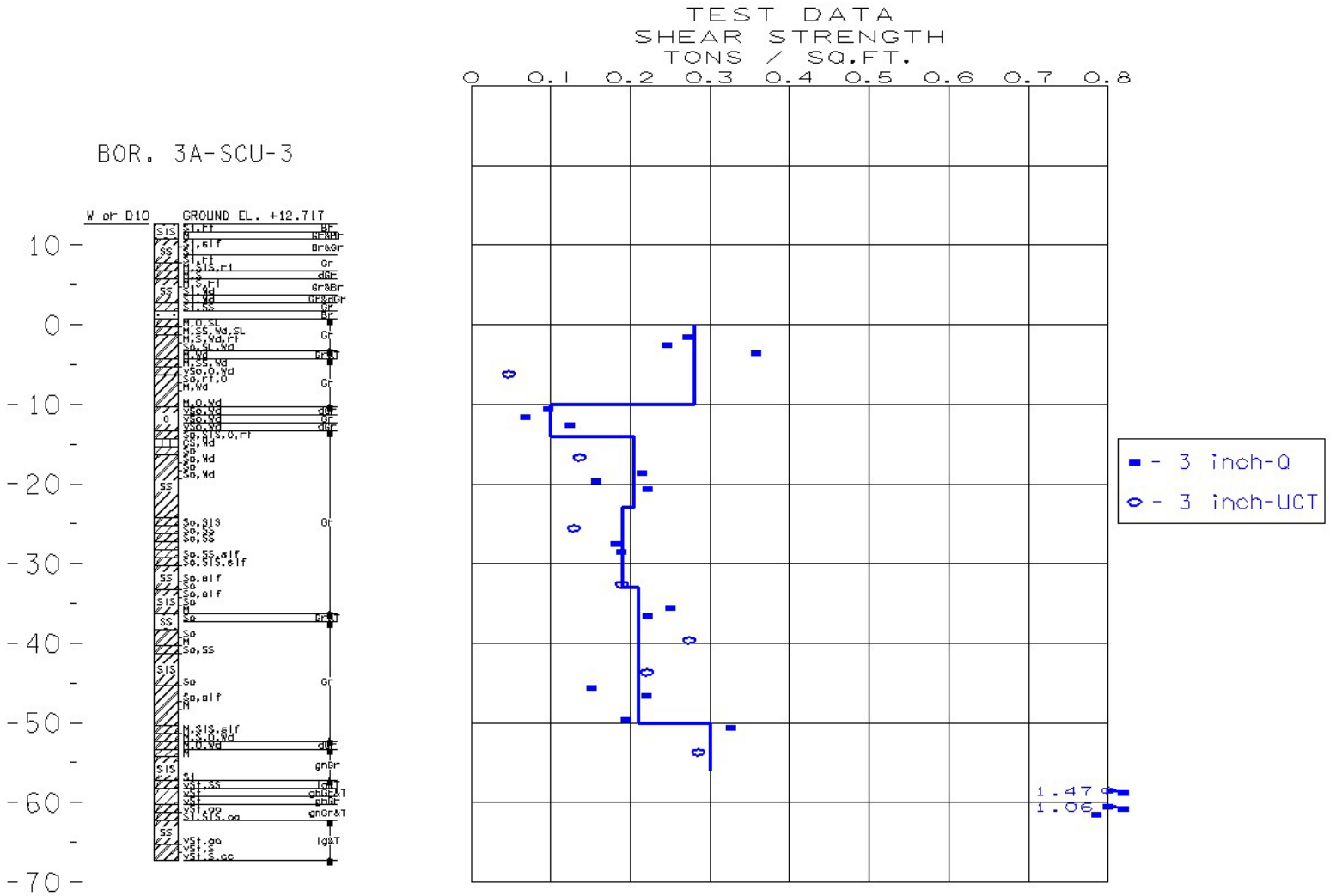
5-inch undisturbed boring



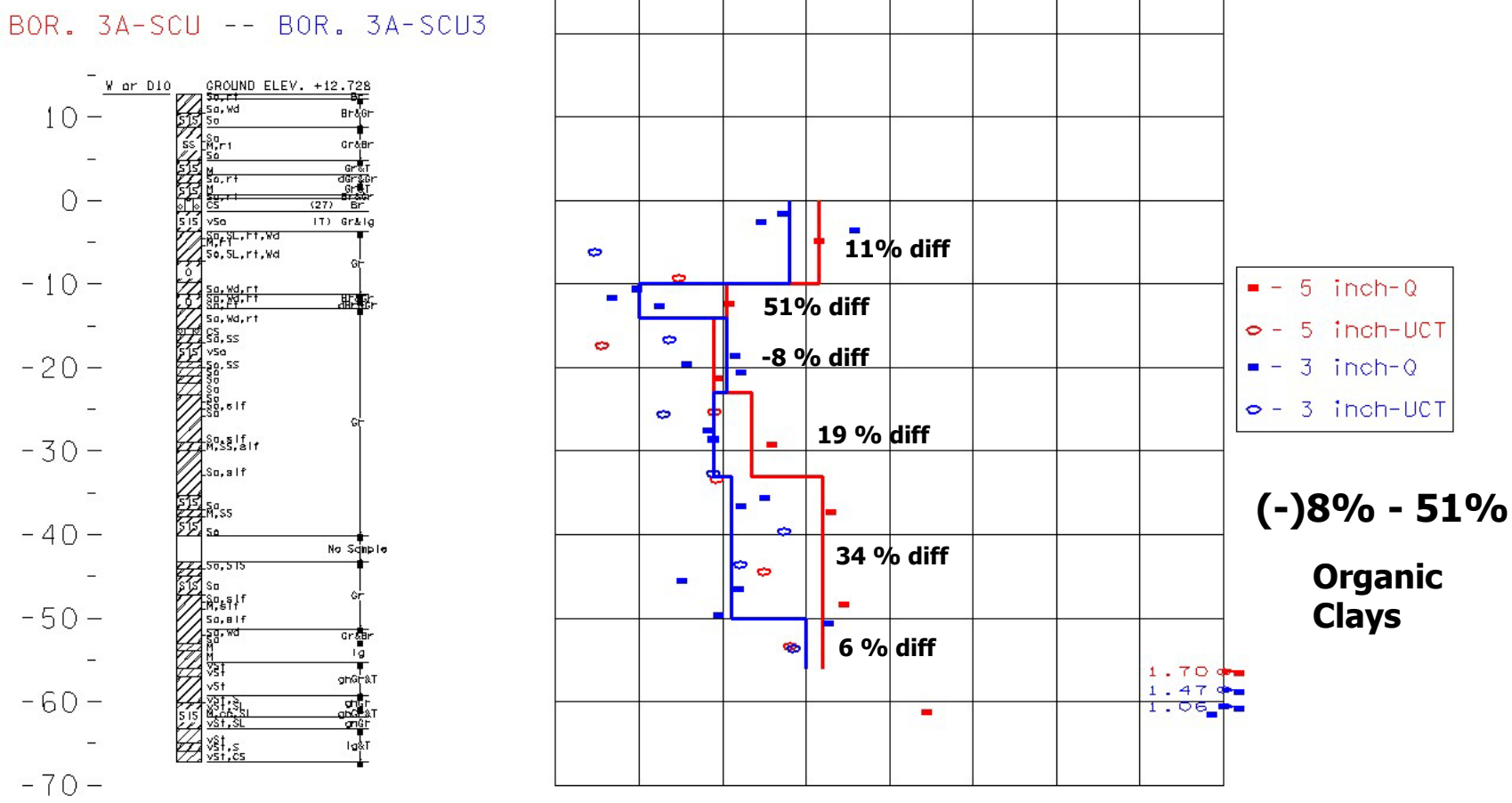
3-inch continuous boring – extruded in the field



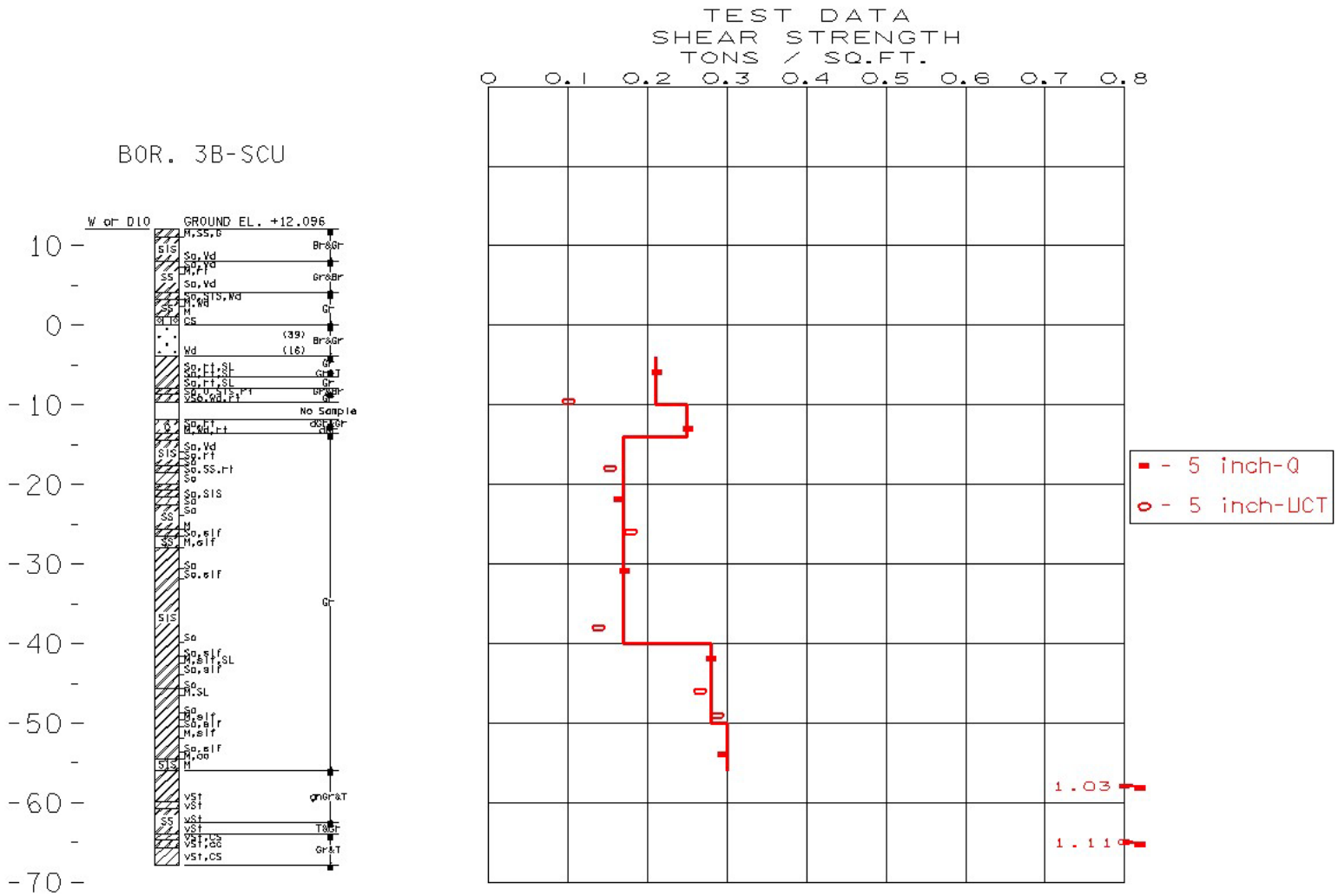
3-inch continuous boring – extruded in the field



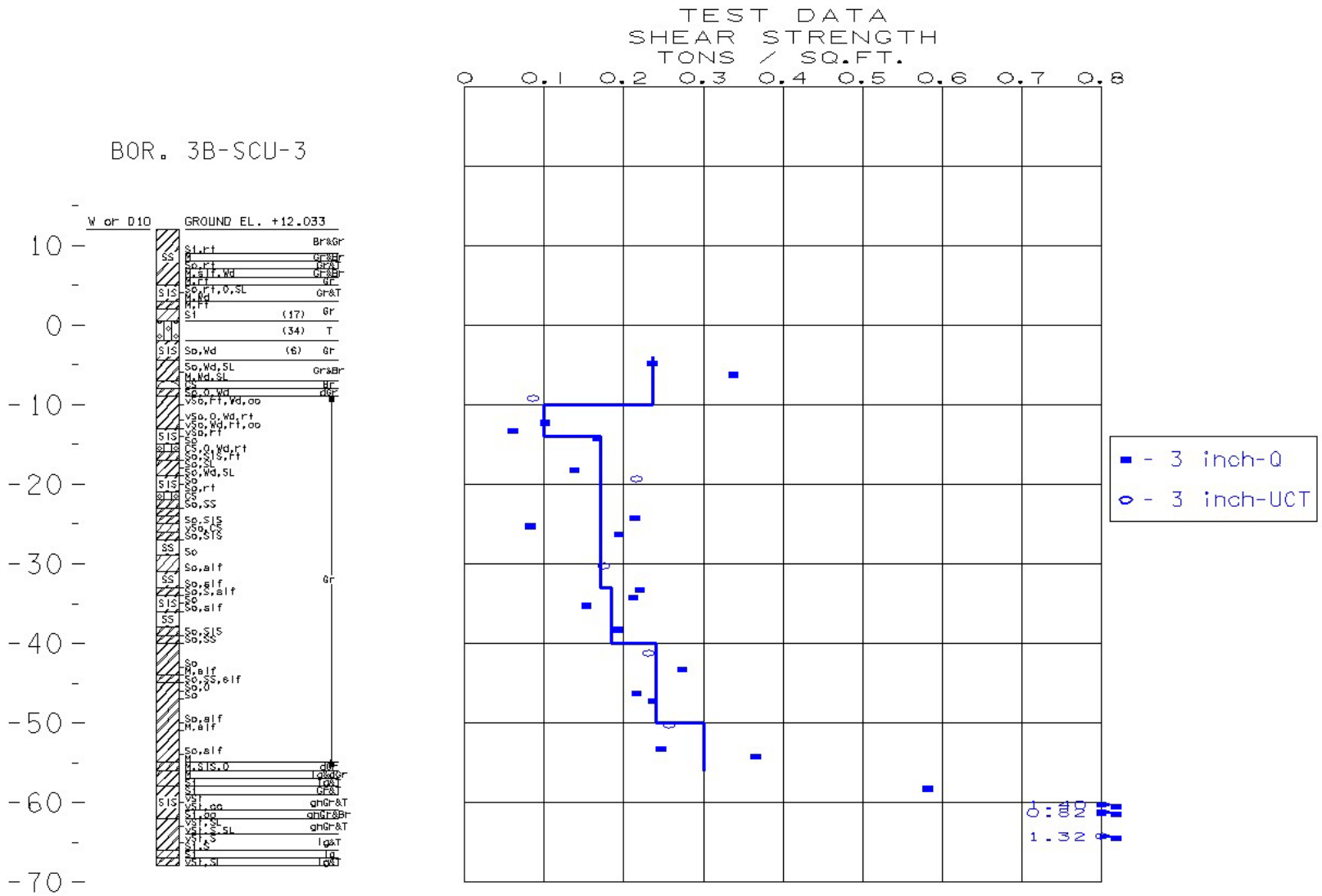
5-inch undisturbed boring
vs.
3-inch continuous boring – extruded in the field



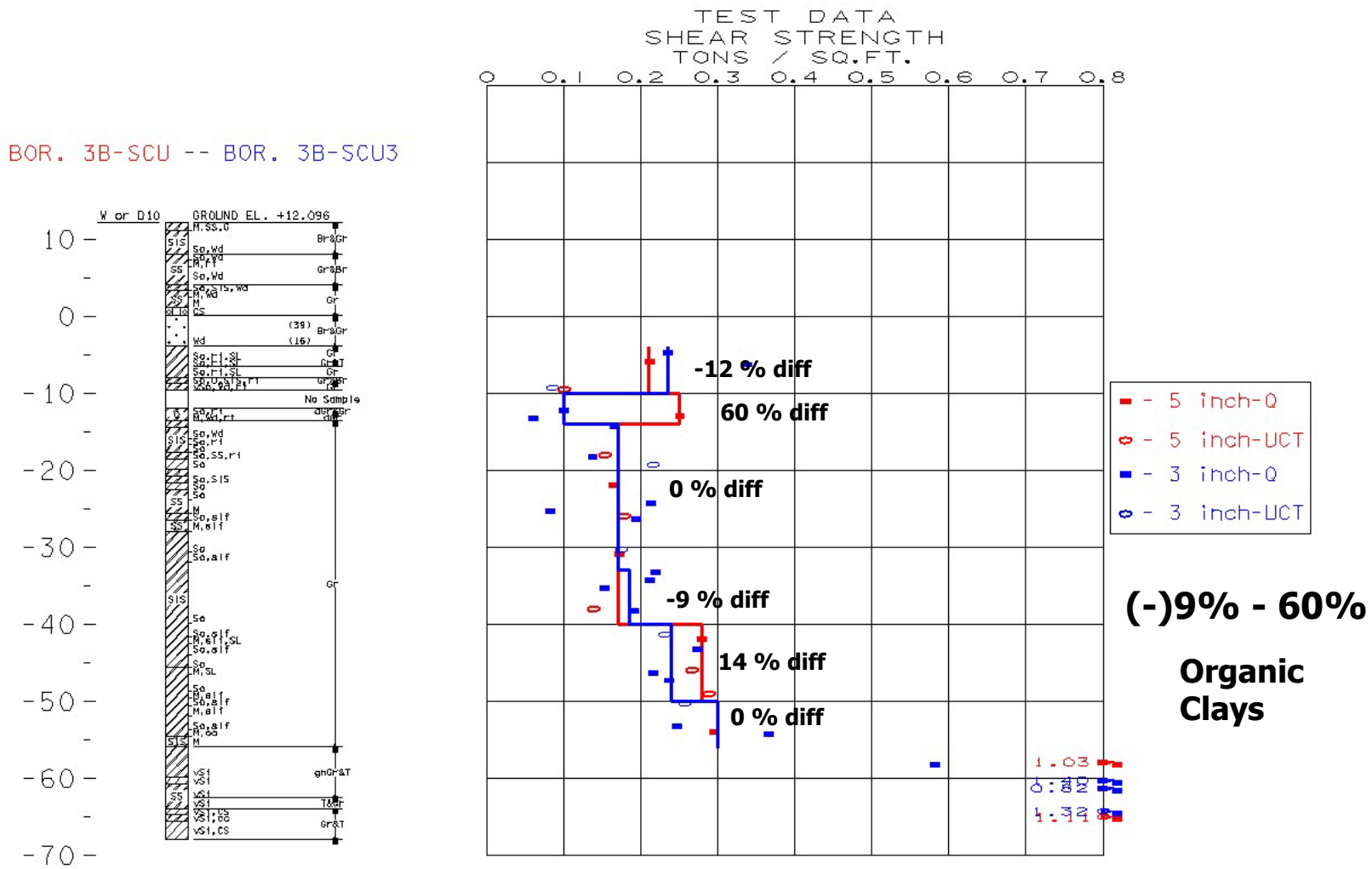
5-inch undisturbed boring



3-inch continuous boring – extruded in the field



5-inch undisturbed boring
vs.
3-inch continuous boring – extruded in the field



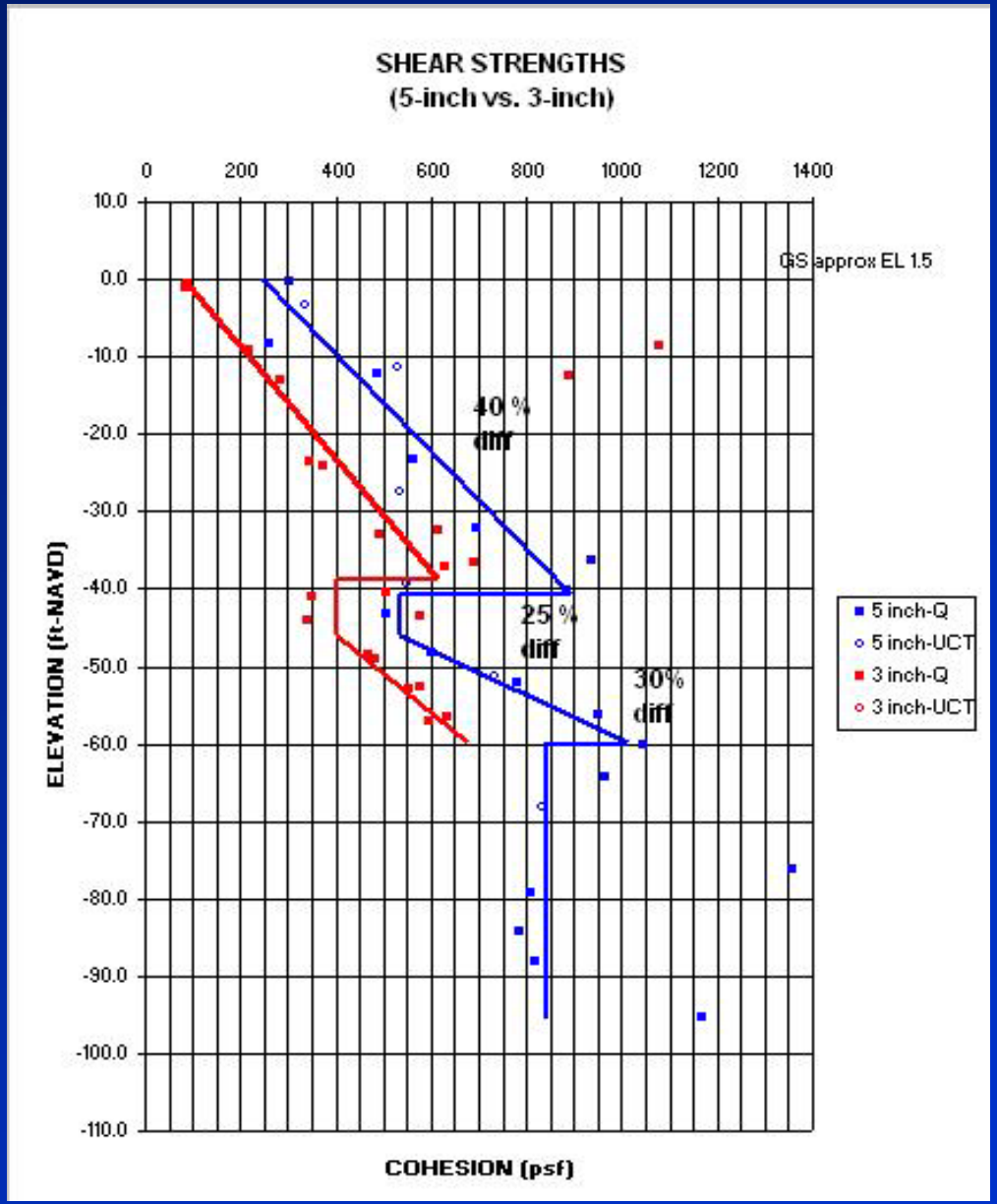
(-)9% - 60%

Organic Clays

Comparing 3" vs 5" Boring Data

RHCUL-1U (5-inch)

RHCUL-1A (3-inch)



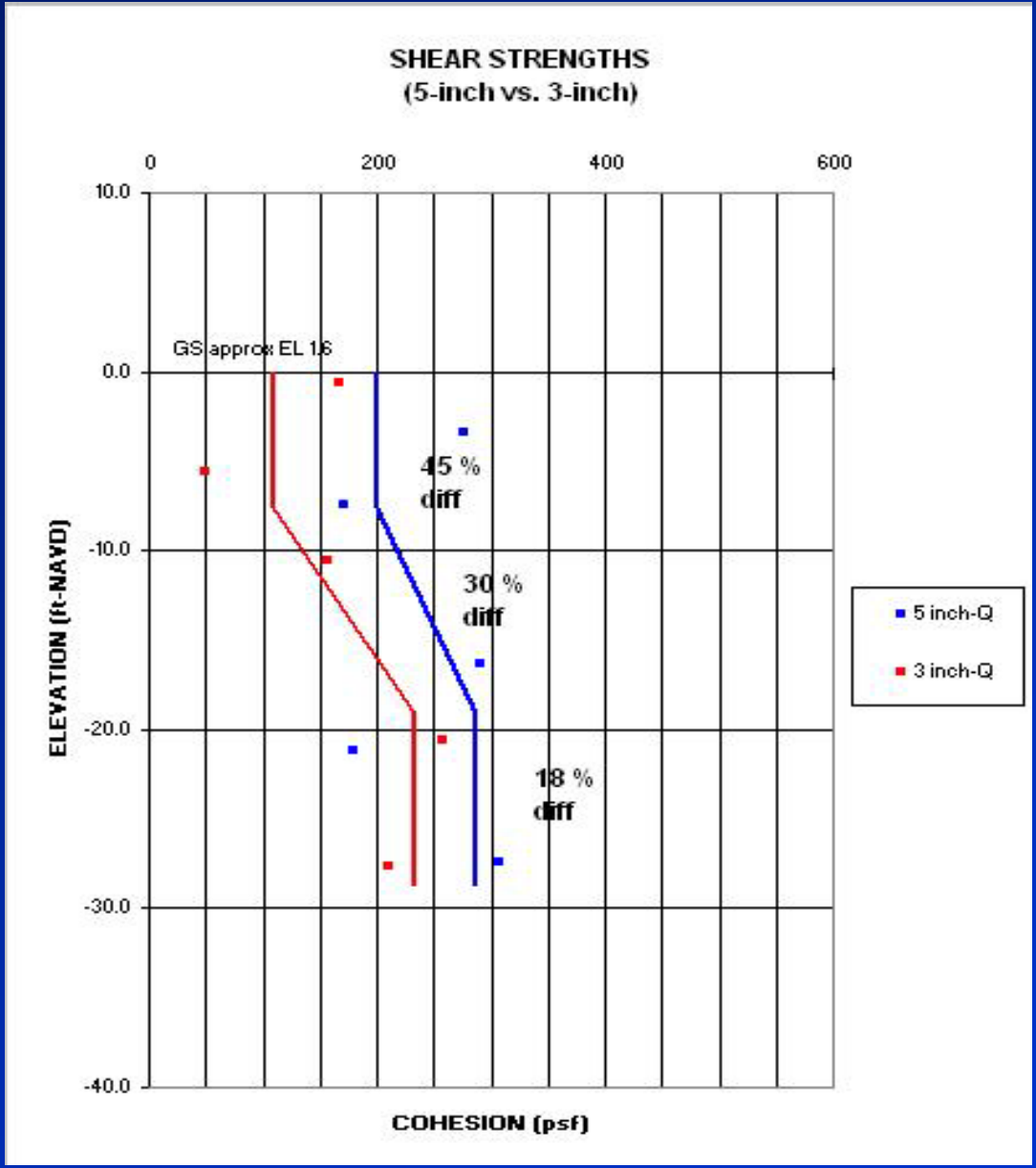
25% - 40%

NOTE: 3" BORING IS NON-CONTINUOUS

Comparing 3" vs 5" Boring Data

RHCUL-2U (5-inch)

RHCUL-2A (3-inch)



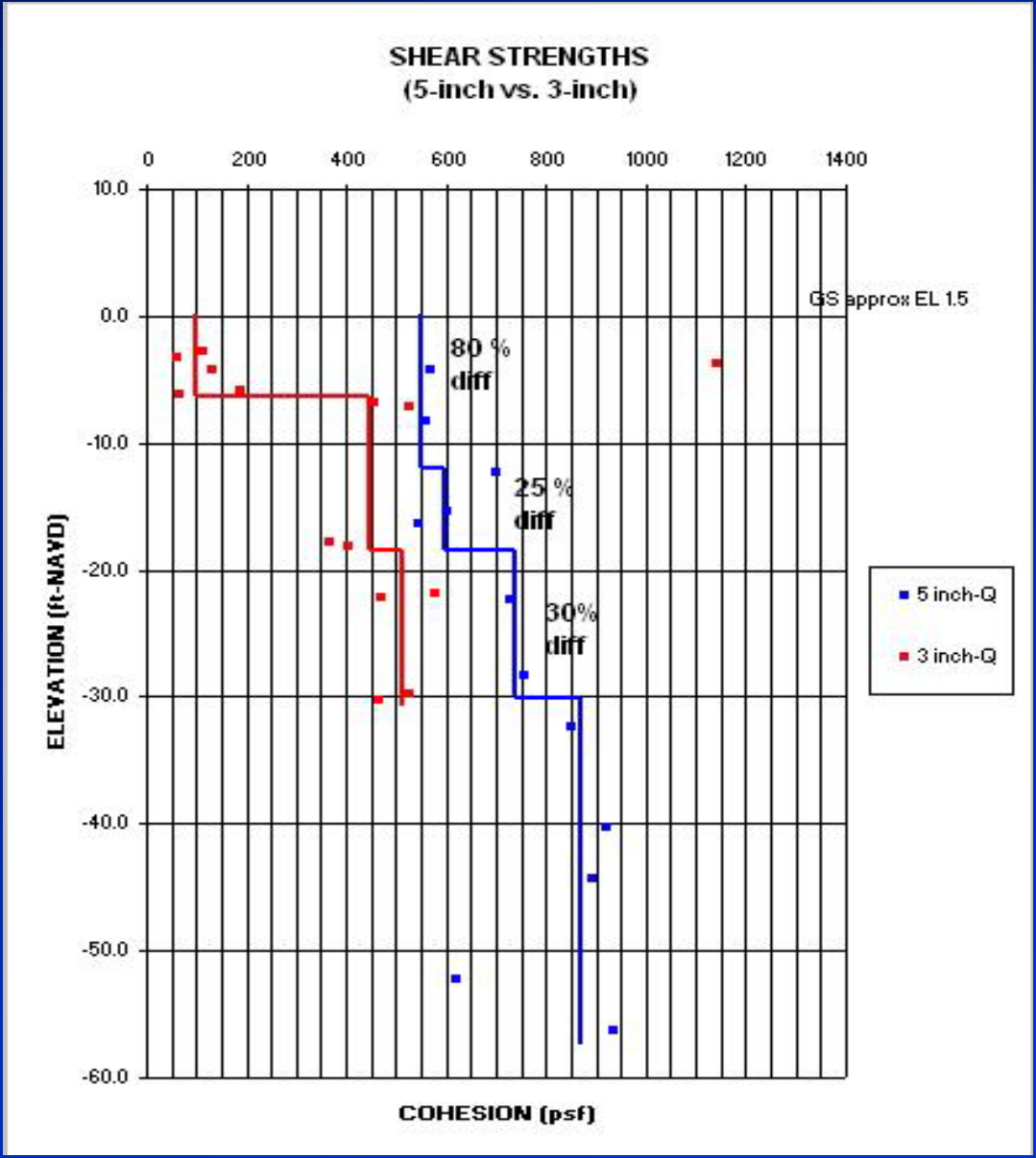
18% - 45%

NOTE: 3" BORING IS NON-CONTINUOUS

Comparing 3" vs 5" Boring Data

MGRH-2U (5-inch)

MGRH-2A (3-inch)



25% - 80%

NOTE: 3" BORING IS CONTINUOUS – EXTRUDED IN THE FIELD

Comparing 3" vs 5" Boring Data

(Preliminary Evaluation)

- Percent difference in strength line ranged from -20% to 80%

- For the soil borings w/natural ground @ 0, average reduced strength was approx 28% (weighted average)

- For the soil borings w/ground above natural ground (Fill), average reduced strength was approximately 11% (weighted average)

Conclusion - 3 inch boring produces lower strength design parameters in soft soils, resulting from sample disturbance

Sensitivity and Cost Analysis

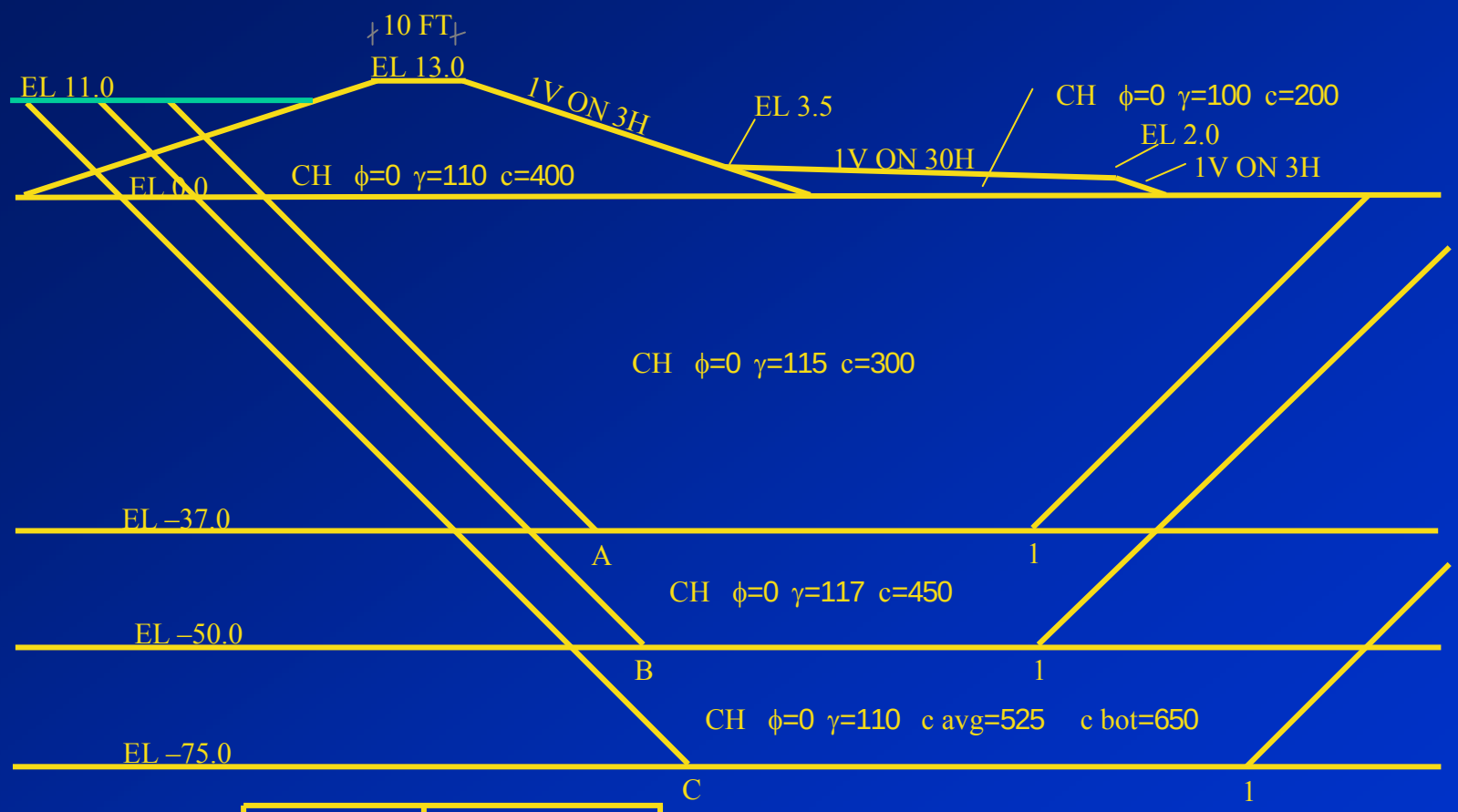
Assumptions

- Levee design
- Soil parameters obtained using 5-inch borings from an existing project
- Use a range of reduction factors to account for the sample disturbance in the soft soils for the 3-inch boring

Assumptions

- Undisturbed soil borings taken every 3000 ft
- 80 ft depth for each boring
- Q test taken every 10 ft

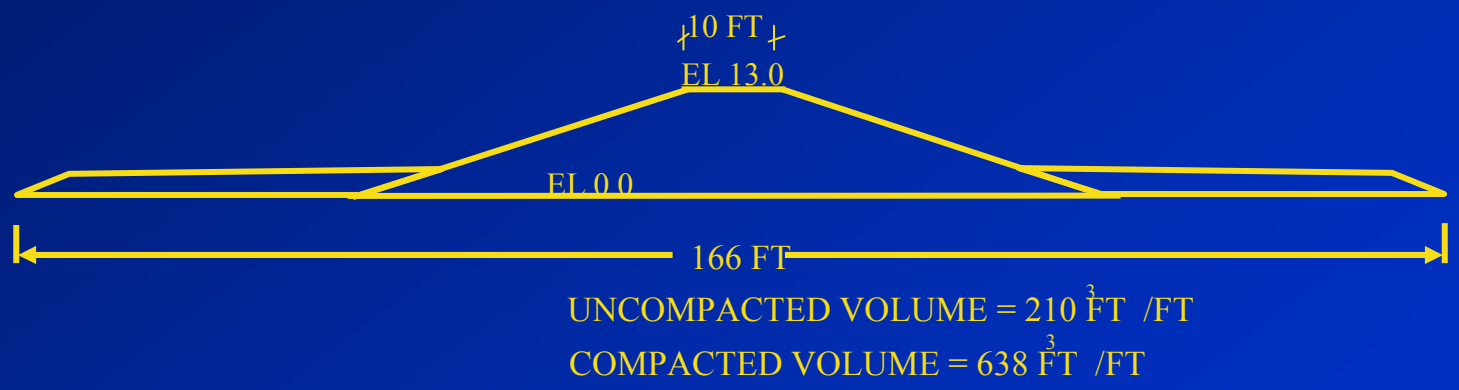
Stability Analysis



WEDGE	FACTOR OF SAFETY
A-1	1. 30
B-1	1. 50
C-1	1. 95

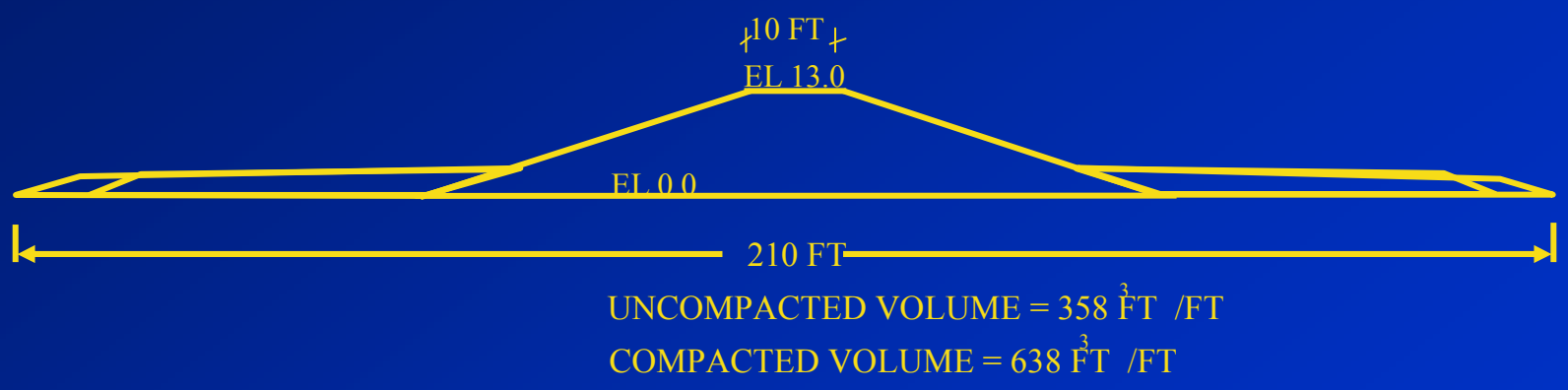
Cross-section based upon 5-inch dia. samples

Typical Section



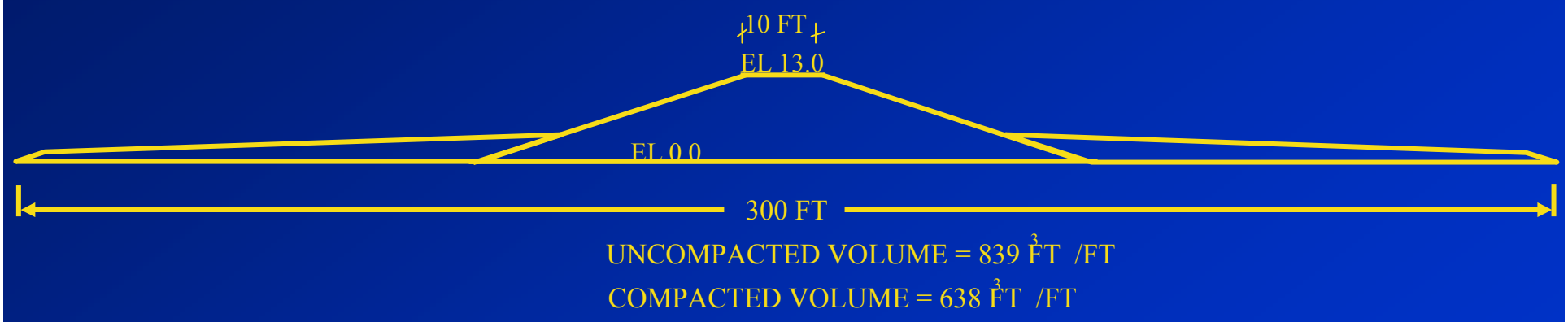
Cross-section based upon 5-inch dia. sample results

Typical Section



Cross-section resulting from using a 10% reduction factor

Typical Section



Cross-section resulting from using a 30% reduction factor

Quantities Based on Berm Fill Only

Options	Uncompacted Volume (ft3/ft)	Uncompacted Volume (yd3/ft)	Embankment Cost ($/ft) based on $5/cu-yd, on-site	Embankment Cost ($) per 1000 ft
0% Reduction	210	7.8	$39	$38,889
10% Reduction	358	13.3	$66	$66,296
20% Reduction	626	23.2	$116	$115,926
30% Reduction	839	31.1	$155	$155,370

This does not consider additional rights-of-way costs nor added borrow pit requirements

Field Sampling and Grouting Costs

Options	Sampling and Grouting Cost ($/ft)	Sampling and Grouting Cost ($/boring)
0% Reduction	$35.02 (1)	$2,801.60
10% Reduction	$16.43 (2)	$1,314.40
20% Reduction	$16.43 (2)	$1,314.40
30% Reduction	$16.43 (2)	$1,314.40

* Based on 80 ft deep borings

(1) 5" Undisturbed boring

(2) General Type boring – Non-continuous

Soil Classifying and Lab Testing Costs

Options	Classifying Cost ($/ft)	Classifying Cost ($/boring)	Testing Cost ($/test)	Testing Cost ($/boring)
0% Reduction	$9.39 (1)	$751.20	$116.36 (3)	$930.88
10% Reduction	$7.16 (2)	$572.80	$38.79 (4)	$310.32
20% Reduction	$7.16 (2)	$572.80	$38.79 (4)	$310.32
30% Reduction	$7.16 (2)	$572.80	$38.79 (4)	$310.32

* Based on 80 ft deep borings and Q tests every 10 ft

(1) 5" Undisturbed boring

(2) General Type boring – Non-continuous

(3) 3-point Q test

(4) 1-point Q test

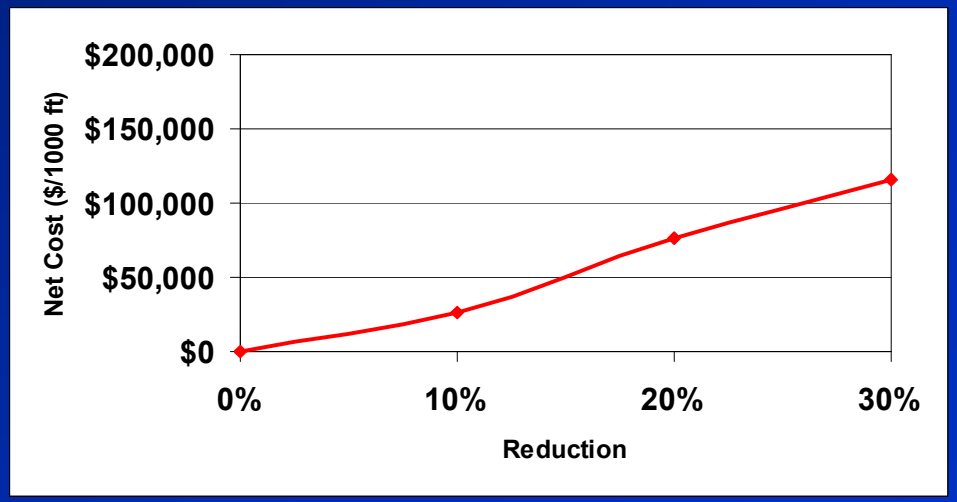
Net Savings/Costs by using a 3-inch Boring
(10% Option only)

Additional Embankment Cost ($/1000ft)	Savings on Sampling and Grouting ($/1000ft)	Savings on Classifying and Testing ($/1000ft)	Net Cost ($/1000ft)
$27,407	$496	$266	$26,645

* Based on one boring every 3000 ft

Net Costs of Uncompacted Material for all Options

Options	Total Cost ($/1000 ft)	Net Cost ($/1000 ft)
0% Reduction	$40,383	$0
10% Reduction	$67,029	$26,645
20% Reduction	$116,658	$76,275
30% Reduction	$156,103	$115,719



* Based on one boring every 1000 ft

These projected savings do not include added cost for Rights-of-Way for increased section and borrow area required.

Conclusion

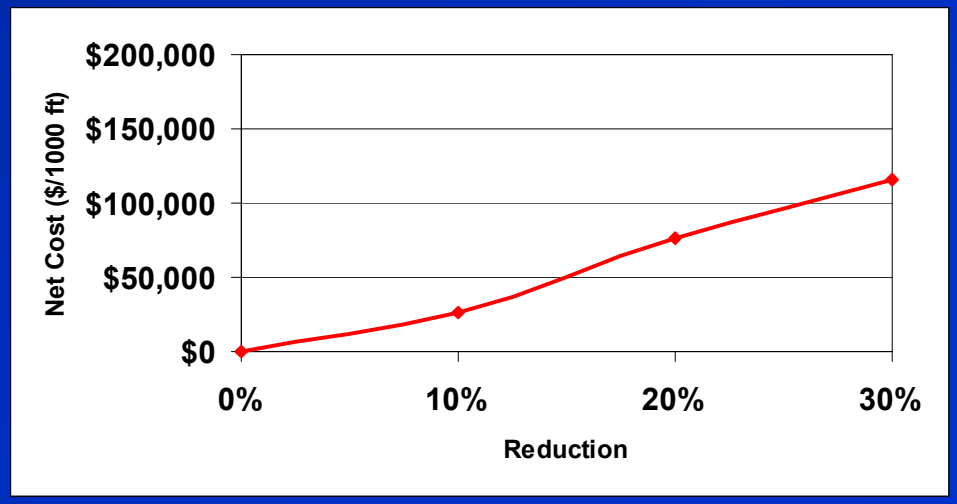
- The 5-inch diameter sampling device was developed to reduce the sample disturbance in soft soils
- It furnishes greater knowledge of the in-situ soil mass
- This knowledge is used to confidently determine the capacity of the foundation

- The designer must have confidence in his field investigation, lab tests, method of analysis, and applied Factor-of-Safety

- There is a massive cost savings in channels,levees, and floodwalls construction to be had by reducing the footprint
  - The impacts are multiplied when real estate values are high, as they are along waterways and urban areas
  - In levee construction, smaller footprints usually result in less wetland usage

The DESIGNER must ask himself:
Does the one time savings at the initiation of a project resulting from a reduced geotechnical investigation(3" vs 5") of the site justify the added expense which will result from the reduced foundation knowledge ?

Options	Total Cost ($/1000 ft)	Net Cost ($/1000 ft)
0% Reduction	$40,383	$0
10% Reduction	$67,029	$26,645
20% Reduction	$116,658	$76,275
30% Reduction	$156,103	$115,719



The New Orleans District

THINKS NOT !

Questions?