2013 Geo^{3}T^2 Conference

Crosshole Sonic Logging: A 10 Year Perspective

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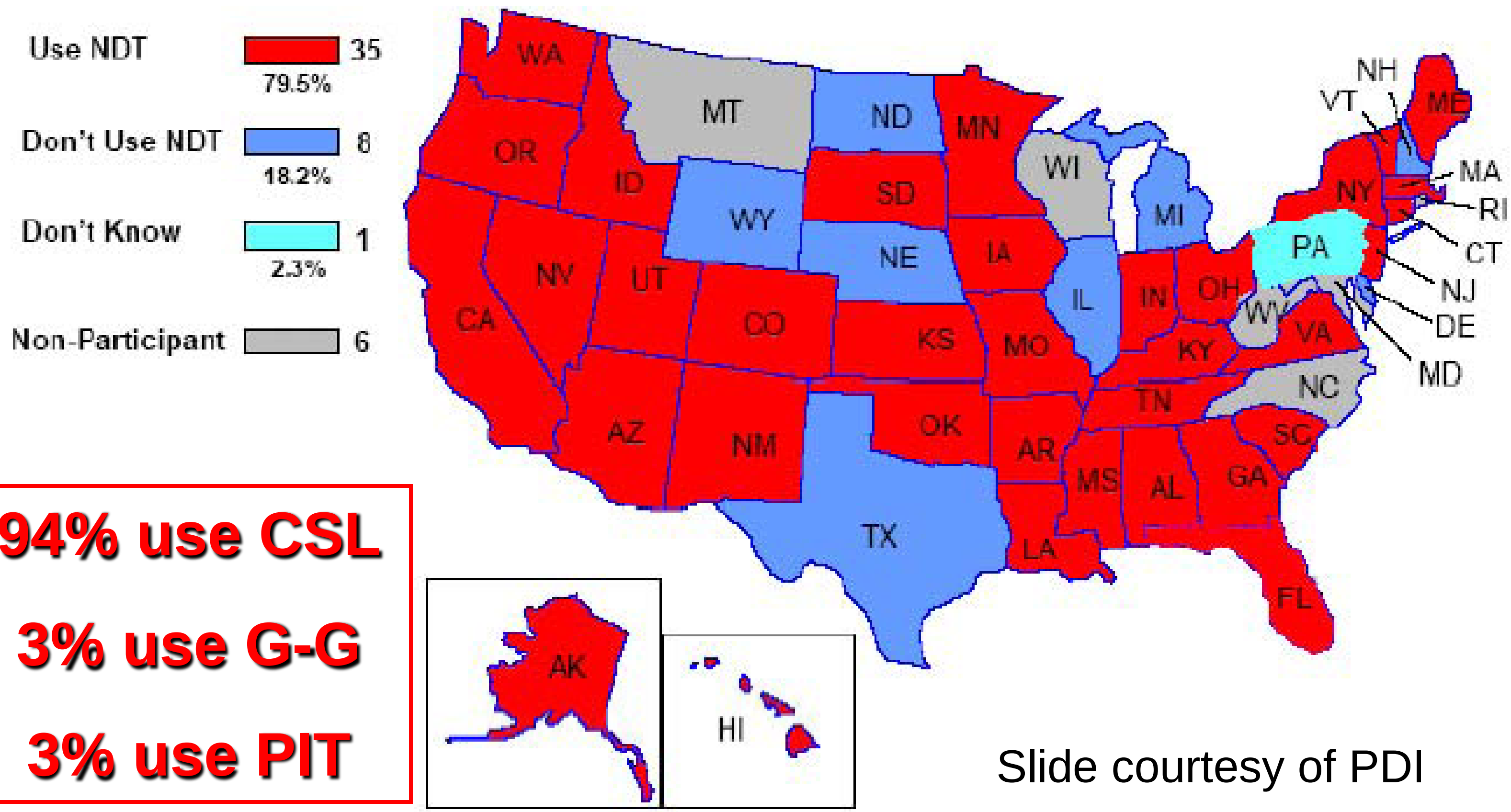
Survey of State DOT Practice: Use of NDE for Drilled Shafts



94% use CSL

3% use G-G

3% use PIT

Slide courtesy of PDI

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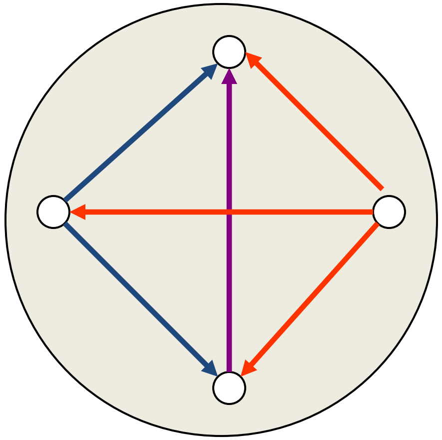
Ref: Khamis Haramy, FHWA Denver 2008

CSL Equipment & Procedure



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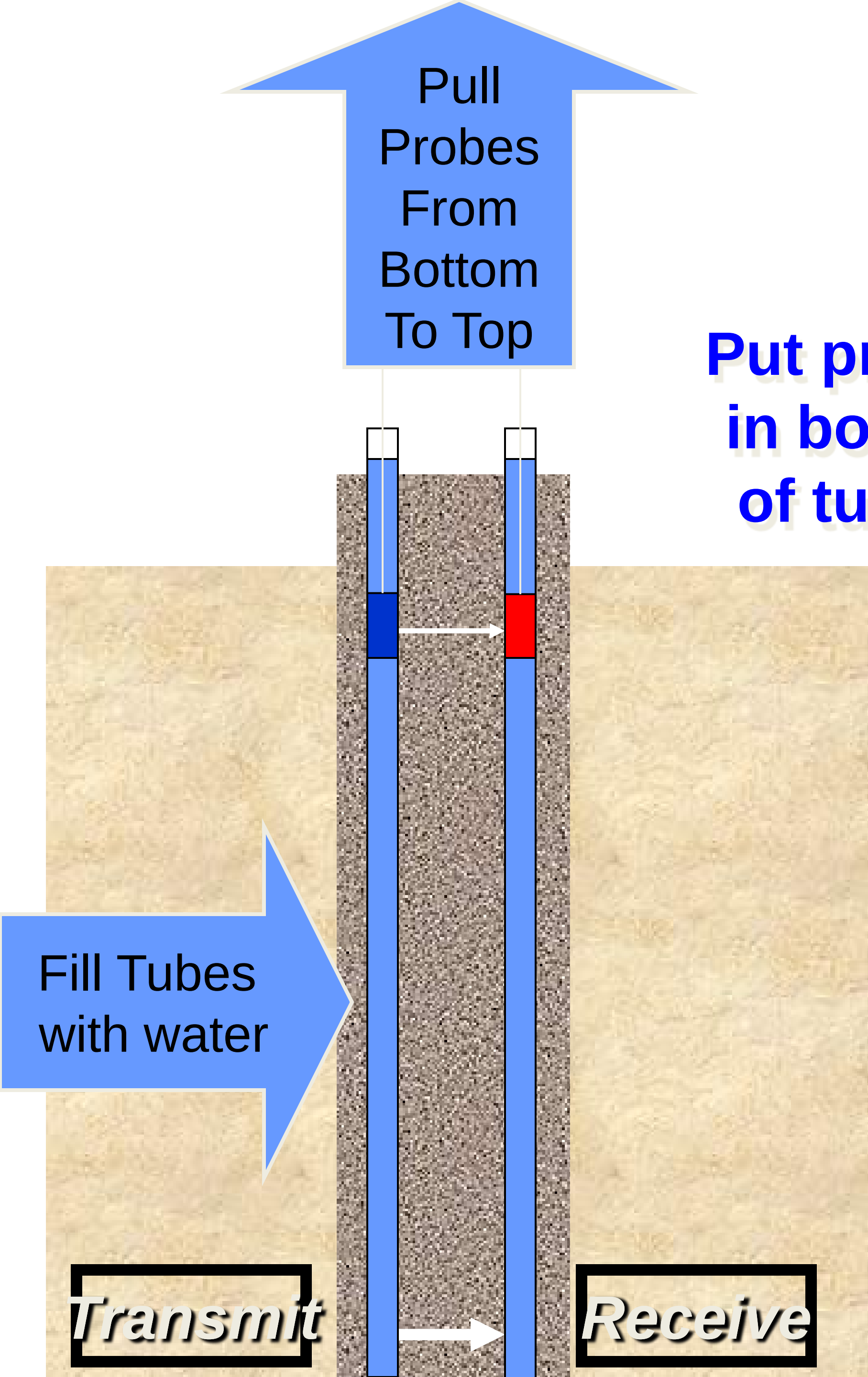
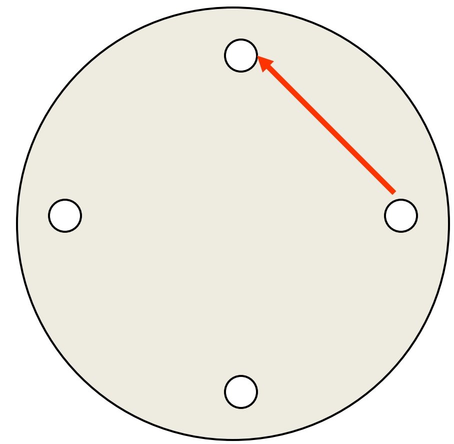
Procedure – cont.



Put probes in bottom of tubes.

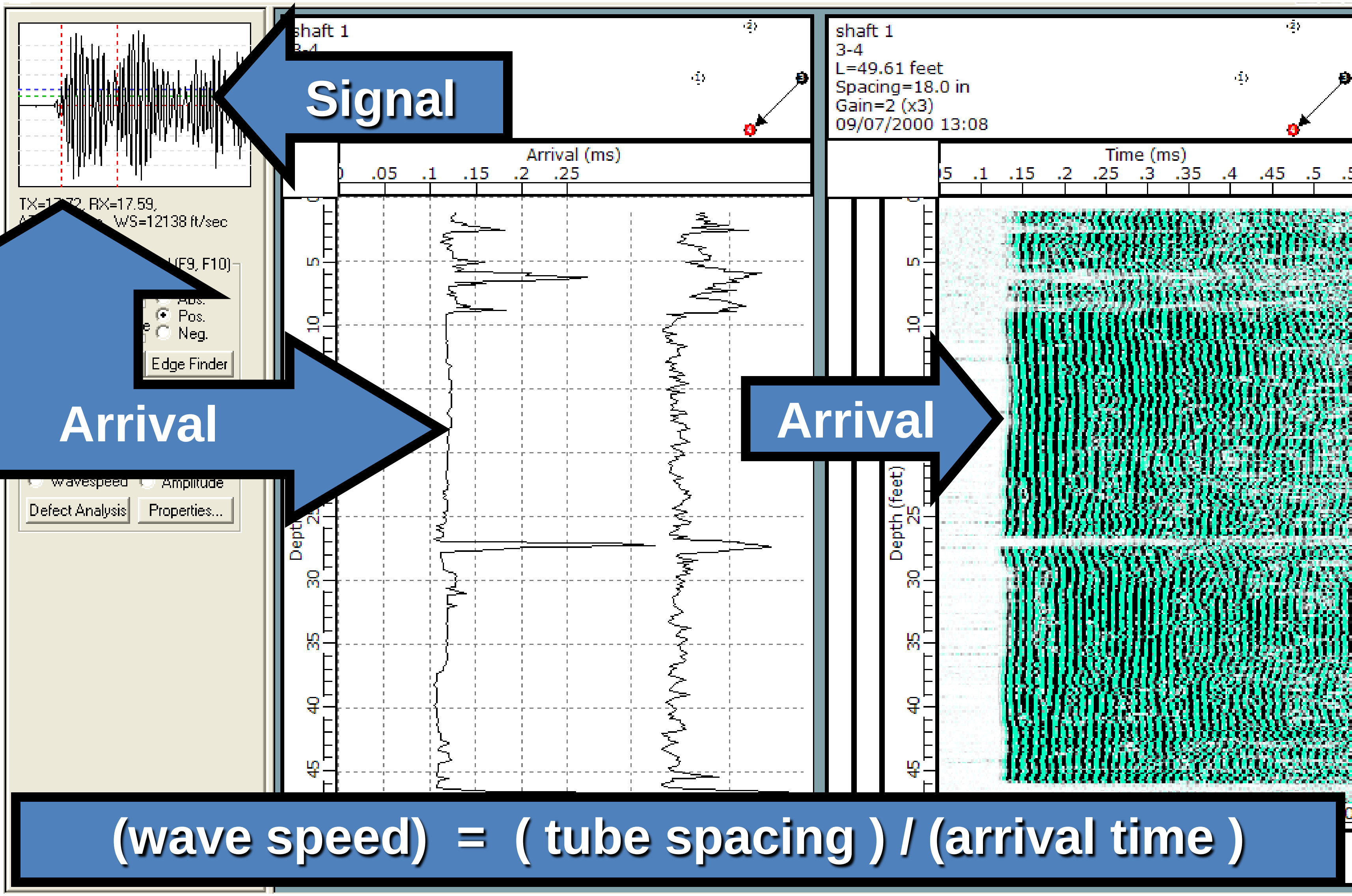
Top view of pile with 4 access tubes



Stress Waves, emitted in one tube are received in another one if concrete quality is satisfactory

Slide courtesy of PDI

Data Processing



Slide courtesy of PDI

Limitations

- Cannot Evaluate Integrity Outside of the Reinforcing Cage
- Cannot be performed soon after concrete placement (typically test no sooner than 3 days)

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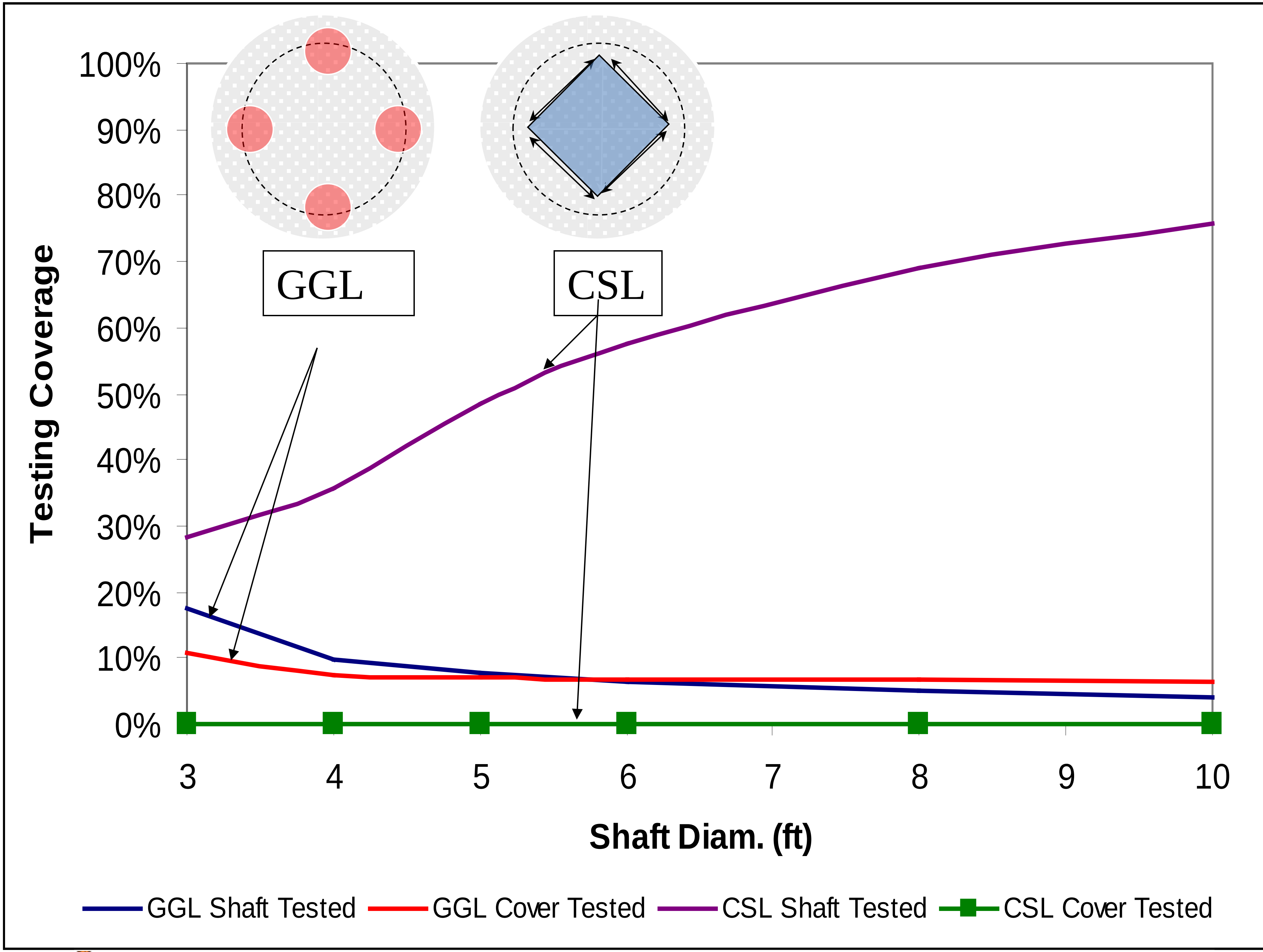
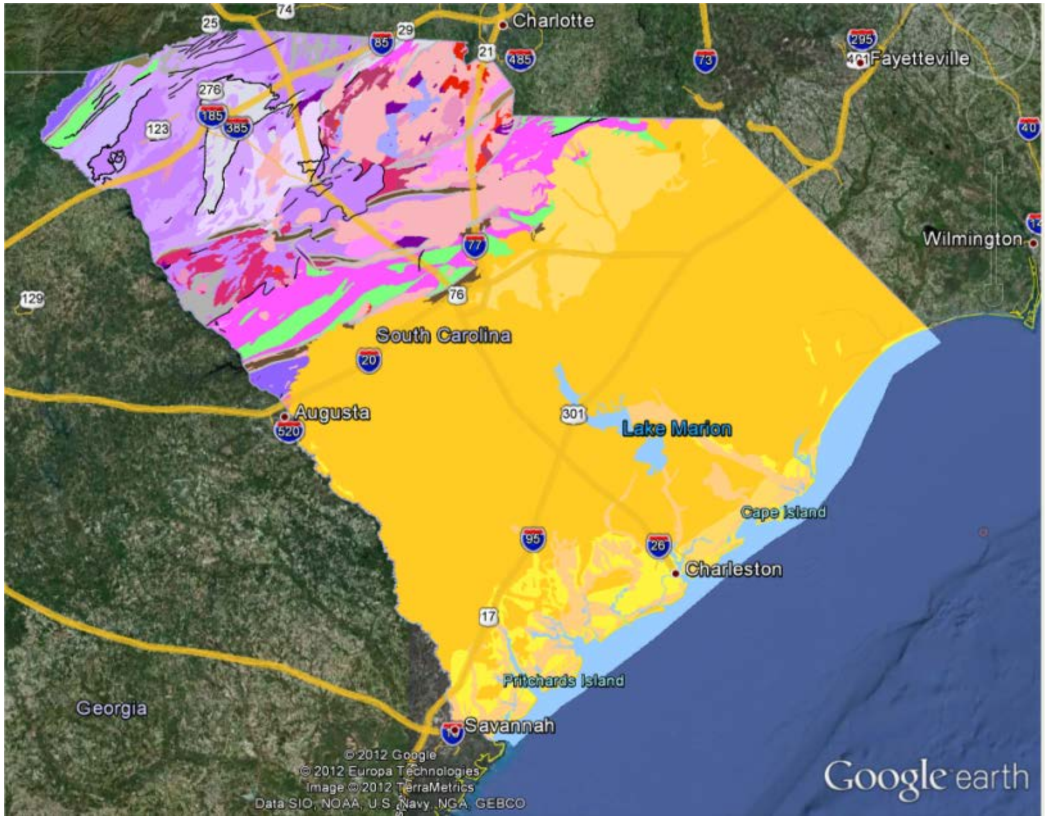


GGL
CSL
Testing Coverage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
3
4
5
6
7
8
9
10
Shaft Diam. (ft)
GGL Shaft Tested
GGL Cover Tested
CSL Shaft Tested
CSL Cover Tested

SCDOT Experience - Background

- SCDOT On-call Foundation Testing Contract
- CSL Since 2000
- Responsible for ≈ ½ testing



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On-Call Consultant Directive

1. Perform CSL on all SCDOT Shafts
2. Identify Anomalies

Anomaly Identification

- **Good:**
  - Velocity decrease of ~~10%~~ 20% or less
  - Constant energy
- ~~**Questionable:**~~
  - ~~Velocity decrease of 10% to 20%~~
- **Poor/Defect:**
  - Velocity decrease >20%
  - Drop in energy or loss of signal

On-Call Consultant Directive – cont.

1. Perform CSL on all SCDOT Shafts
2. Identify Anomalies
3. Review Drilled Shaft Inspection Reports
4. Provide Recommendation
   - “Good” Shaft – Accept
   - “Poor/Defective” Shaft – Additional Evaluation Required

Additional Evaluation

- Re-evaluate design requirements (wrt anomaly size, location, magnitude, etc.)
  - Individual Shaft Loading
  - End Bearing Requirement
  - Lateral Loading/Response
- Chipping/Sounding
- Coring

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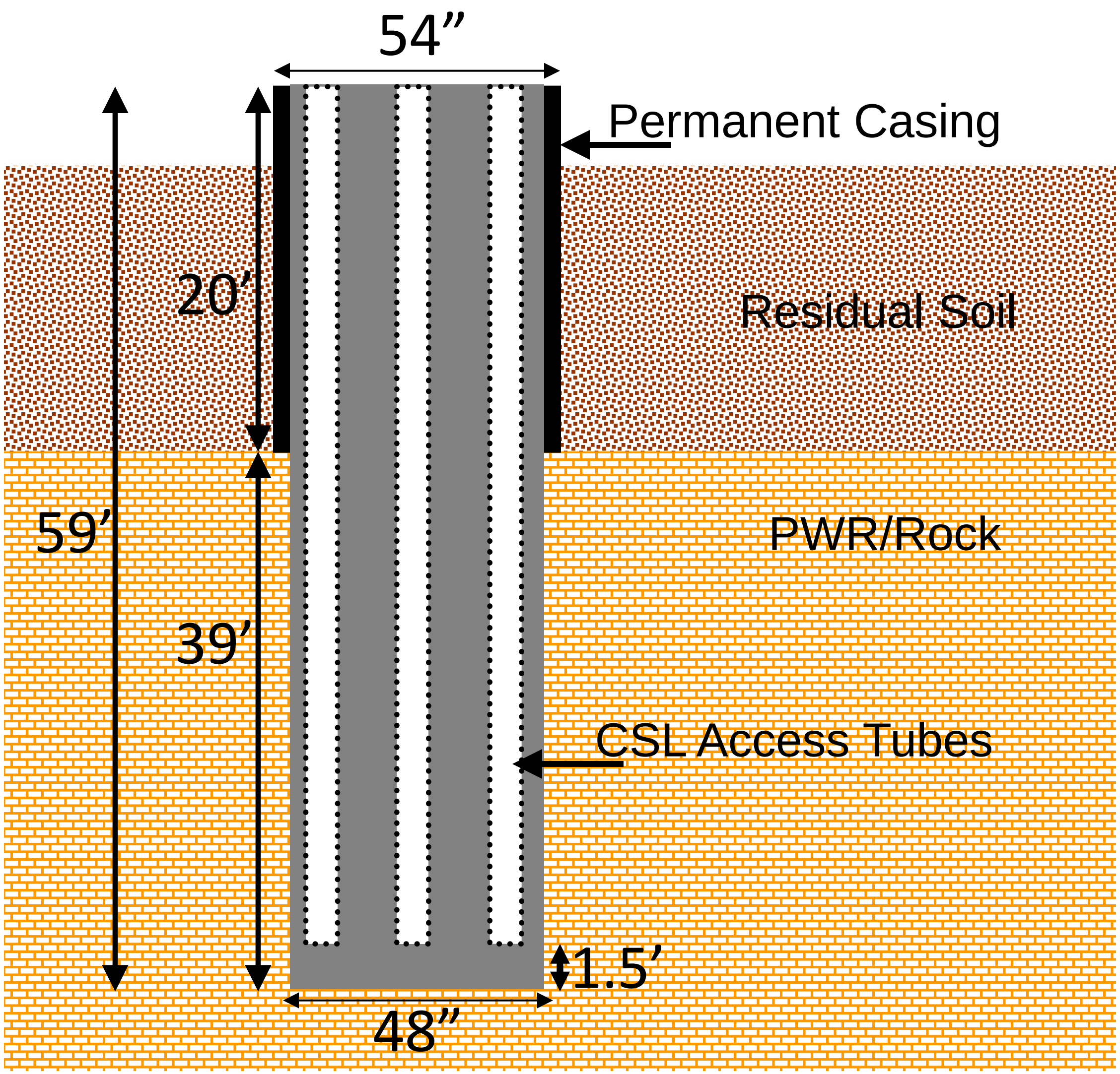
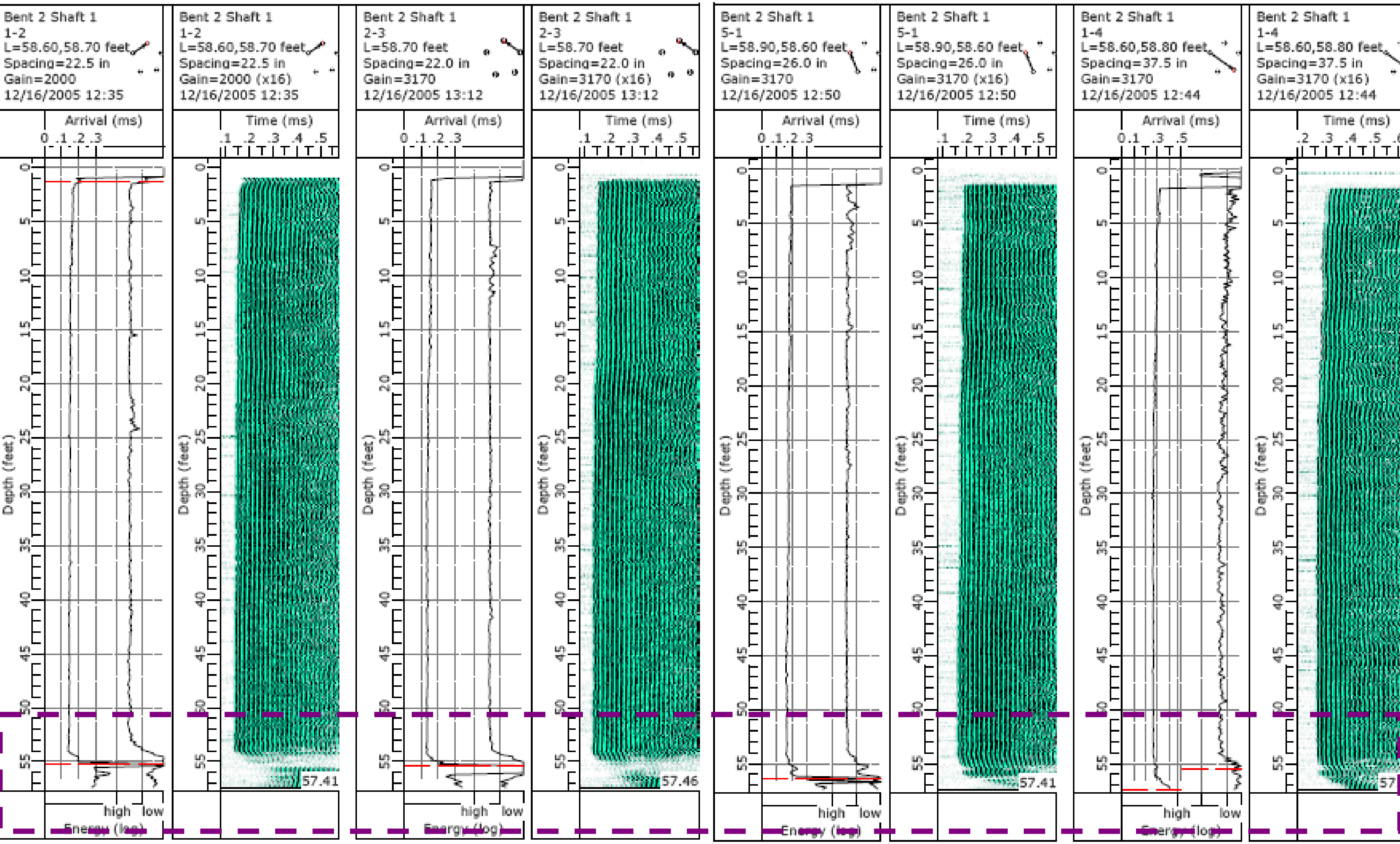
Example – Hellers Creek (2005)



- Dry Construction
- Concrete Placed by Tremie
- CSL Performed 9 Days After Concrete Placement
- First of Four Shafts

Hellers Creek – Cont.



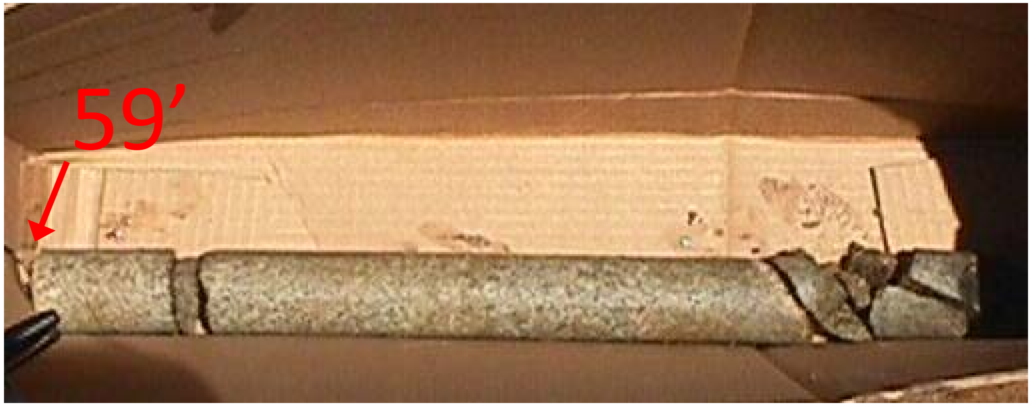
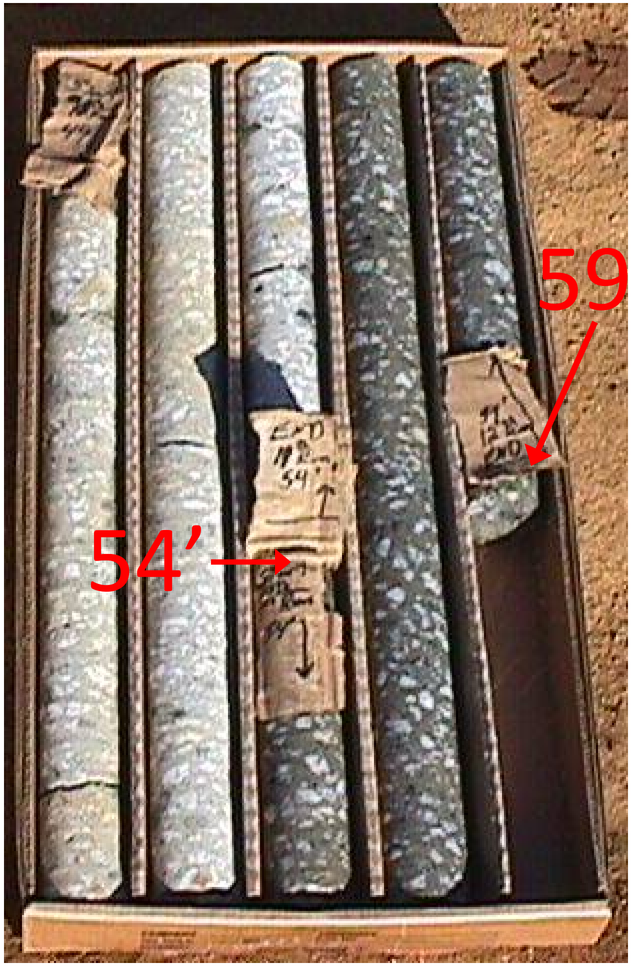
Hellers Creek – Cont.

- Classification – "Poor/Defective"
- Recommendation - Coring

Tube Pair	Presence of Anomalies?	Anomaly Depth (ft)	Maximum First Arrival Time Delay (%)	Increment Rating
1-2	**YES**	54 – 57½	>100	P/D
2-3	**YES**	54 – 57½	>100	P/D
3-4	**YES**	55 – 57½	75	P/D
4-5	**YES**	56 – 57½	>100	P/D
1-5	**YES**	54½ - 57½	>100	P/D
1-4	**YES**	54½ - 57½	41	P/D
1-3	**YES**	54 – 57½	>100	P/D
2-4	**YES**	54½ - 57½	>100	P/D
2-5	**YES**	55 -57½	>100	P/D
3-5	**YES**	55 – 57½	>100	P/D

Hellers Creek – cont.

- Cores from 54’ to 60’ (signal loss from 54’ to 58’ – no CSL below 58’)
- No Irregularities Found



SCDOT CSL Testing Statistics (2000 – 2011)

• Number of Projects	66
• Number of Shafts	850
• Number of Contractors	12
• Number of “Wet” Shafts	658
• Number of “Dry” Shafts	192
• Projects in Soil	24 (469 shafts)
• Projects in Rock	42 (381 shafts)

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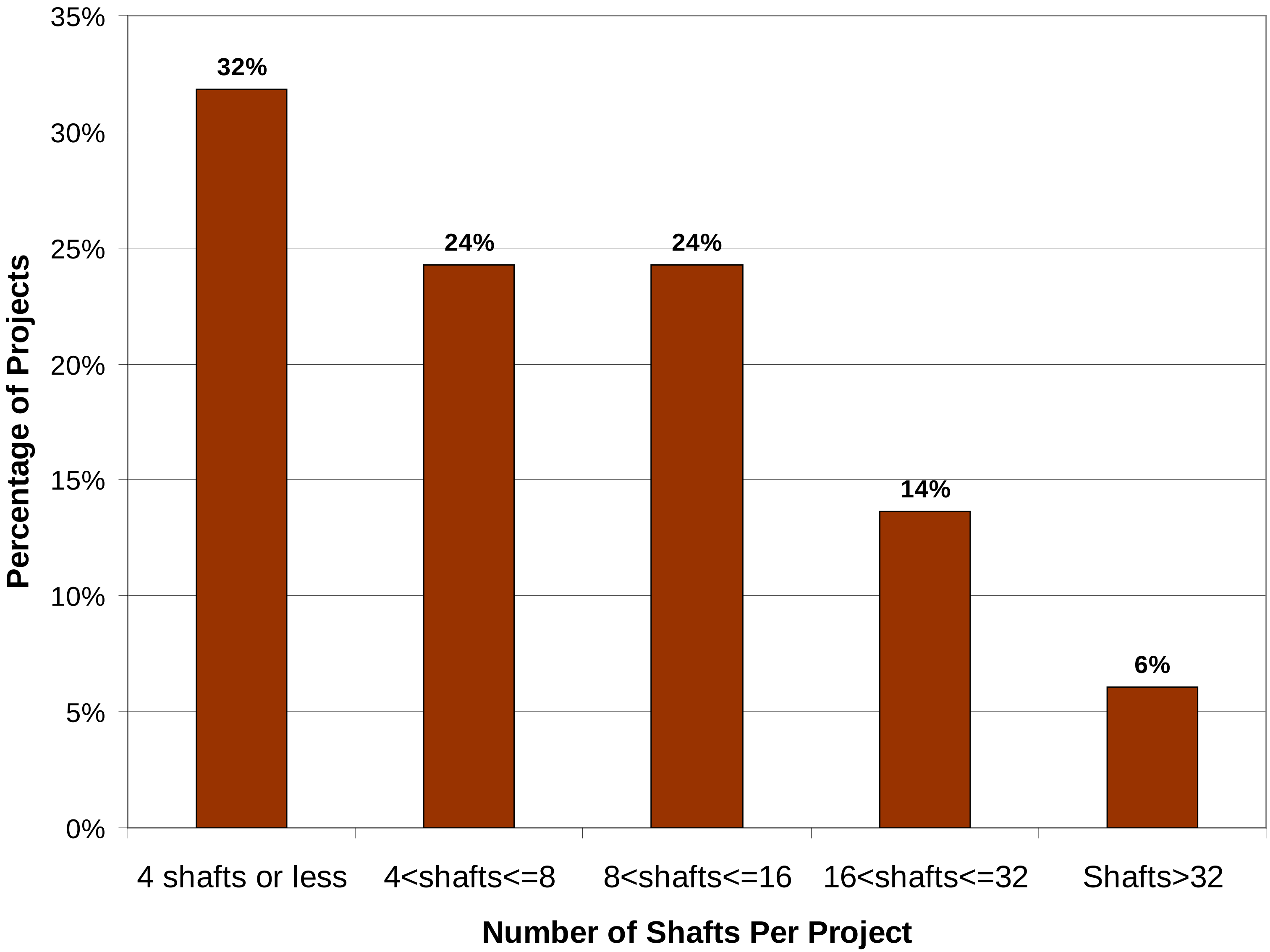
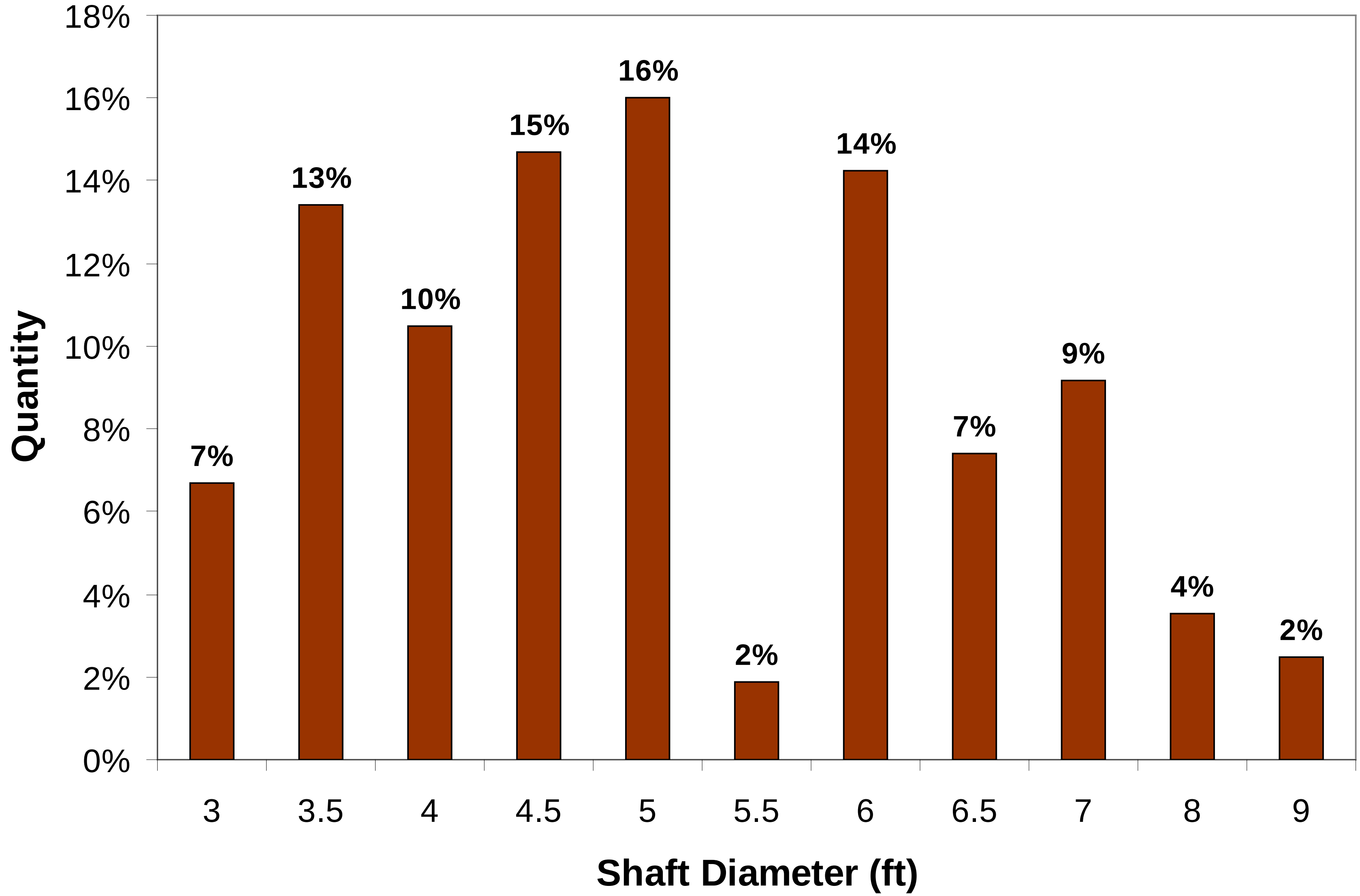
Project Size Distribution



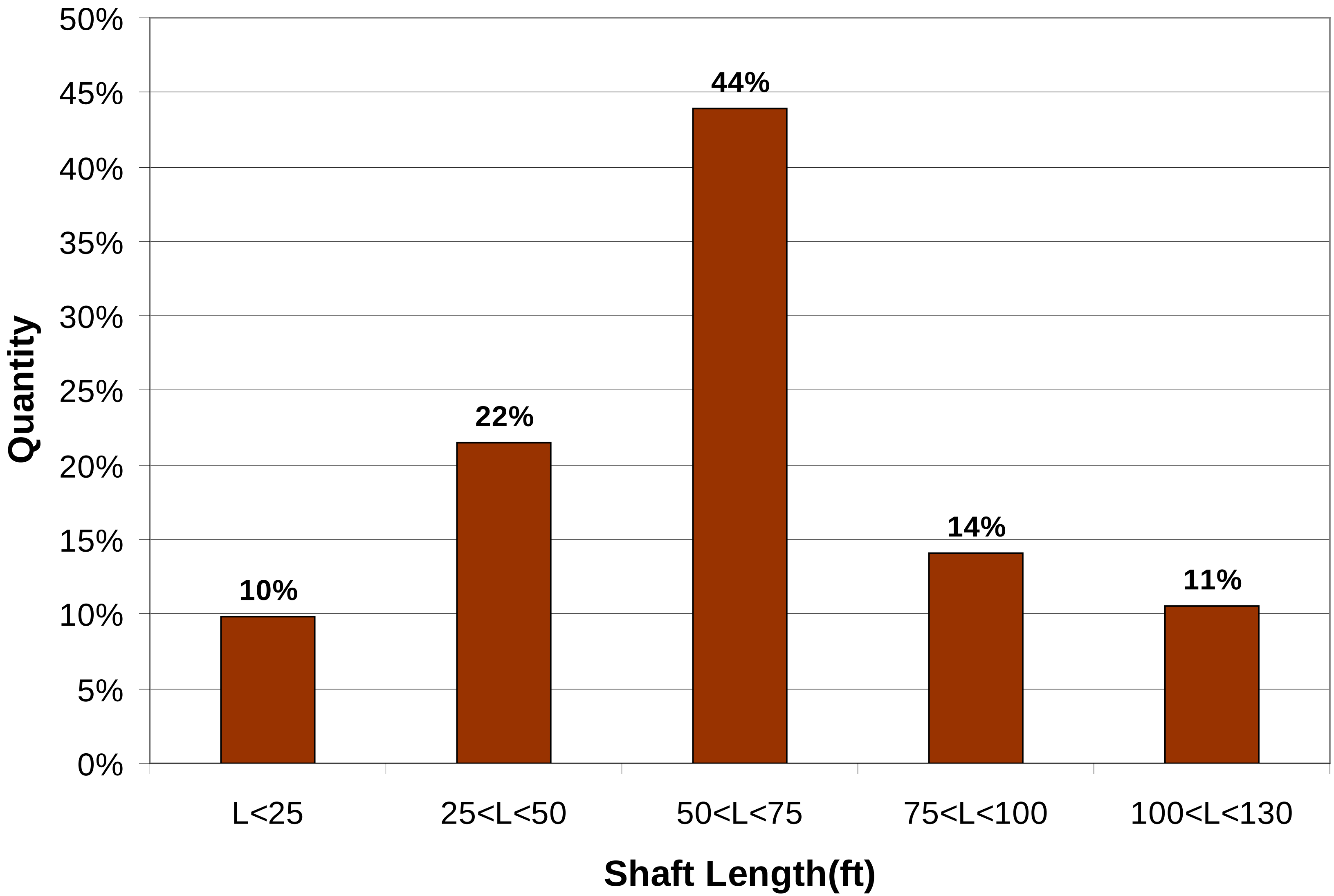
More than ½ have 8 shafts or less

Diameter Distribution



2/3 are < 6 ft

Distribution by Length



CSL Testing Statistics - Anomalies

• Number of Projects	66
• Number of Shafts	850
• Shafts with Anomalies	316 **(37%)**
• Projects with Anomalies	56 **(85%)**
• Projects with No Anomalies	10 **(15%)**
• No. of Shafts on No-Anomaly Projects	43 **(5%)**

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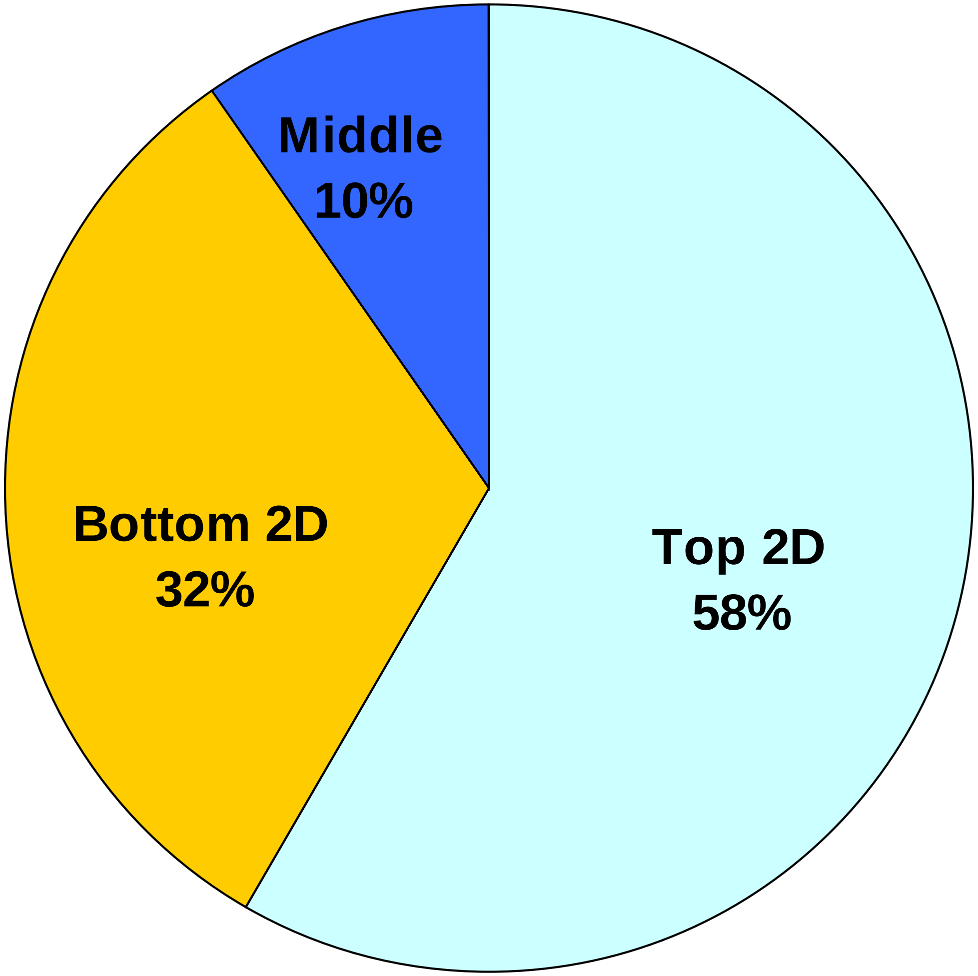
Anomaly Locations

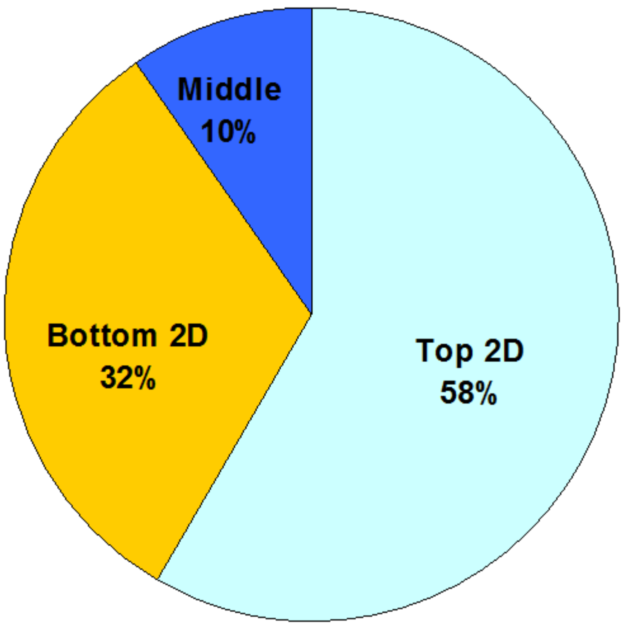


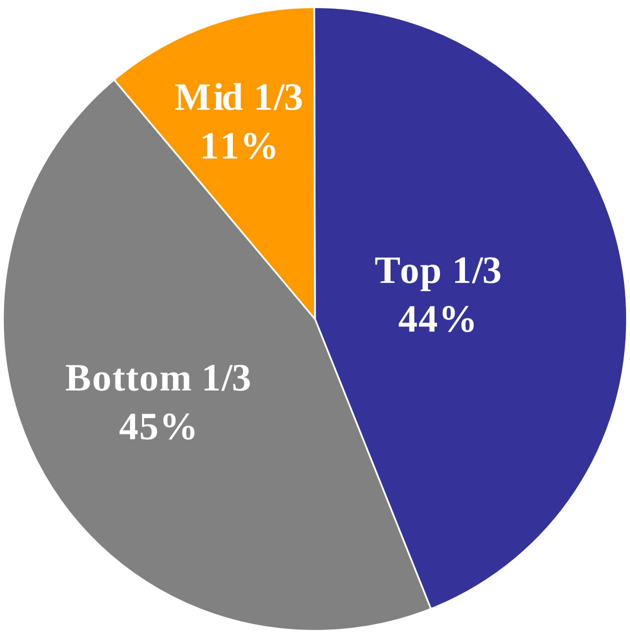
Comparison with Other Studies

Jones & Wu, Geotechnology, Inc. Missouri and Kansas

"Experiences with Cross-hole Sonic Logging and Concrete Coring for Verification of Drilled Shaft Integrity", ADSC GEO^3 Construction Quality Assurance/Quality Control Technical Conference, Dallas Nov 2005

37%





38%

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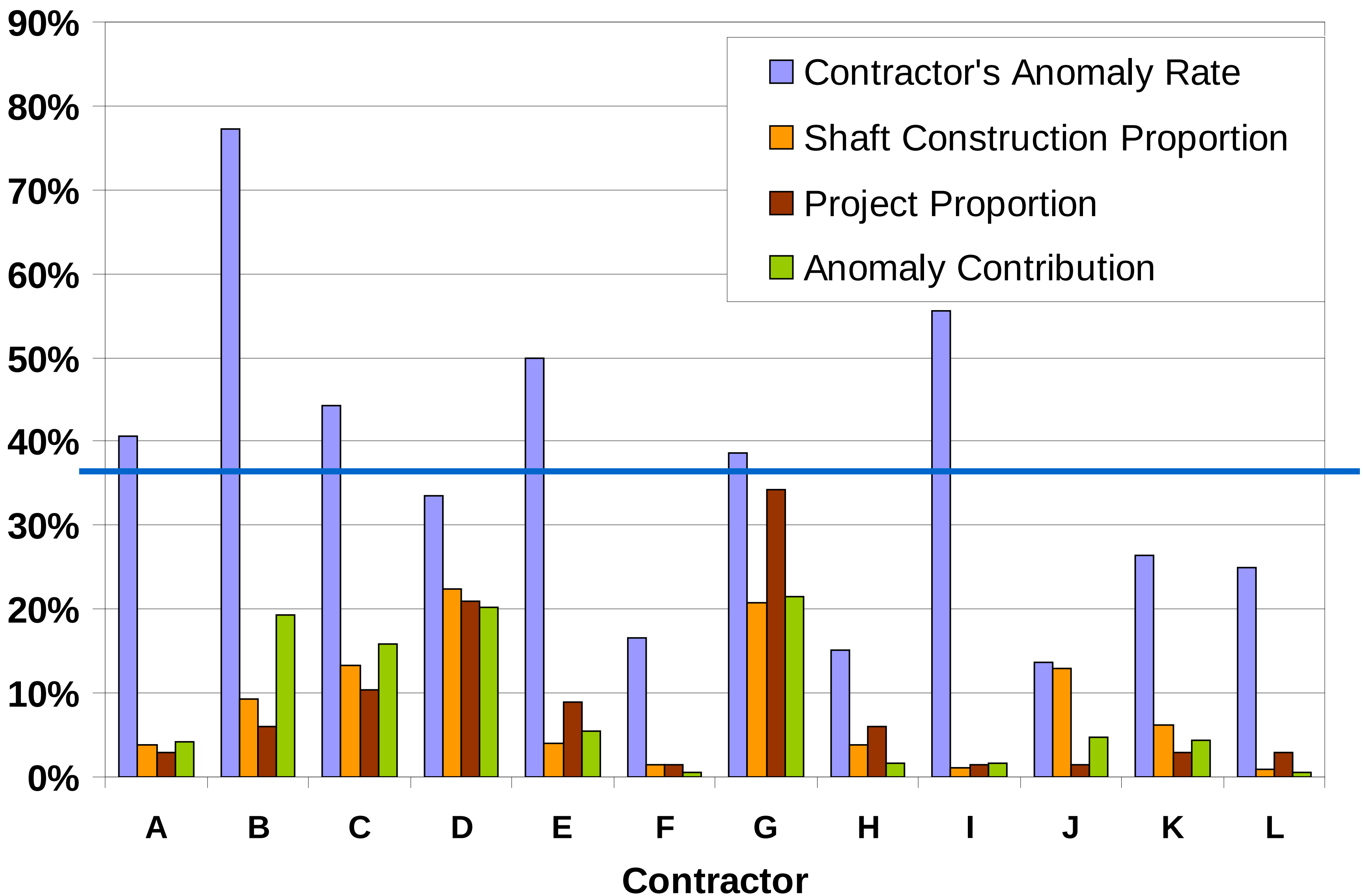
Contractor Performance



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CSL Testing Statistics – Cont.

- Number of "Good" Shafts 730
- Percentage of "Good" Shafts **86%**

- Number of "Poor/Defective Shafts 120
- Percentage of "Poor/Defective" Shafts **14%**
- Projects with coring 12+
  - Core Findings
    - Bleed water features
    - Minor to significant segregation
    - Lumber (missing 4x4)
- **Shafts Requiring Remediation 2**

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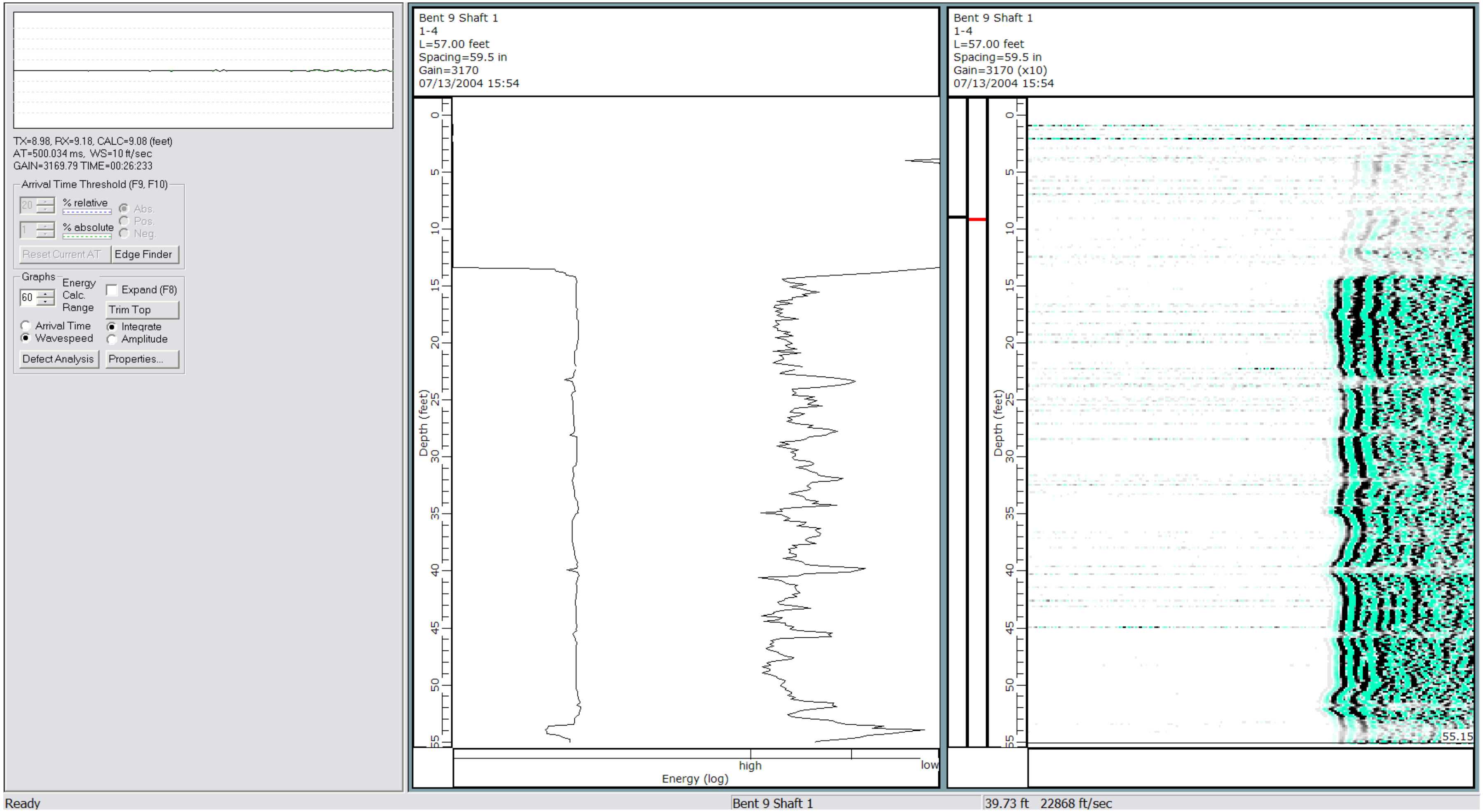
Case Histories & Examples

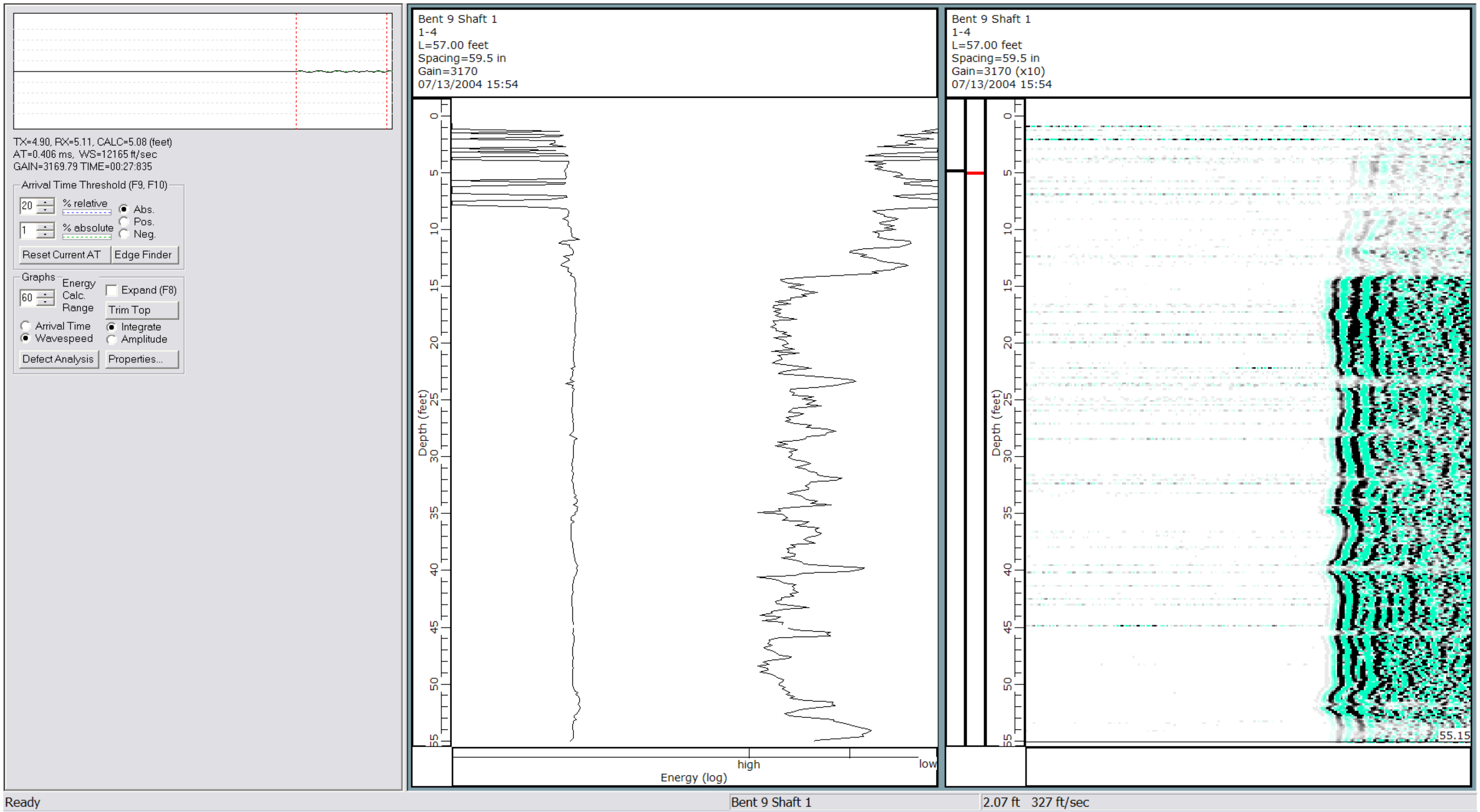
- Top Anomalies
  - 6-ft Diam Shaft in River
  - Mudline is 12 to 18 ft below top of shaft
  - Casing is 30 ft below top of shaft
  - Anomalies in the top of every shaft

Edge Finder



TX=8.98, RX=9.18, CALC=9.08 (feet)
AT=500.034 ms, WS=10 ft/sec
GAIN=3169.79 TIME=00:26:233
Arrival Time Threshold (F9, F10)
% relative
% absolute
Abs.
Pos.
Neg.
Reset Current AT
Edge Finder
Graphs
Energy Calc. Range
Expand (F8)
Trim Top
Arrival Time
Wavespeed
Integrate
Amplitude
Defect Analysis
Properties...
Bent 9 Shaft 1
1-4
L=57.00 feet
Spacing=59.5 in
Gain=3170
07/13/2004 15:54
Depth (feet)
high
low
Energy (log)
Bent 9 Shaft 1
1-4
L=57.00 feet
Spacing=59.5 in
Gain=3170 (x10)
07/13/2004 15:54
Depth (feet)
55.15
Ready
Bent 9 Shaft 1
39.73 ft 22868 ft/sec

Aggressive Manual Picks



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Explanations?

- De-bonding (SCDOT access tubes are steel)
- Flowing water created large thermal gradients leading to micro-cracking during curing
- Bleed water causing flow paths through concrete
  - Supported by coring

Subsequent Information

- Different Project – Same Problem

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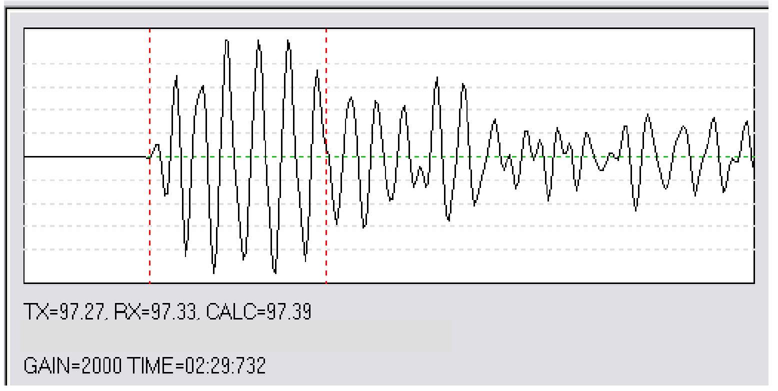
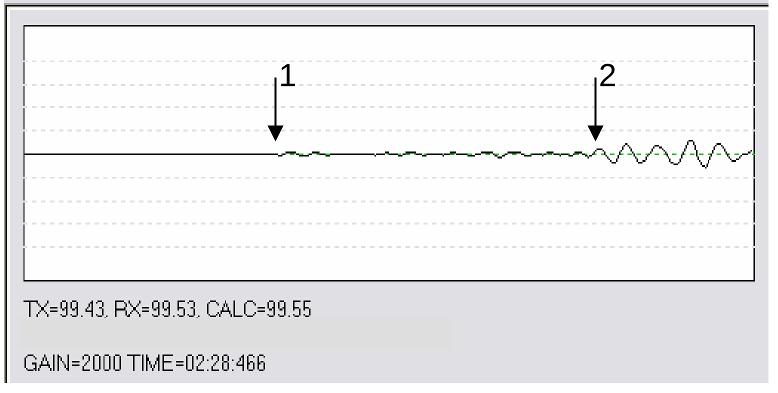
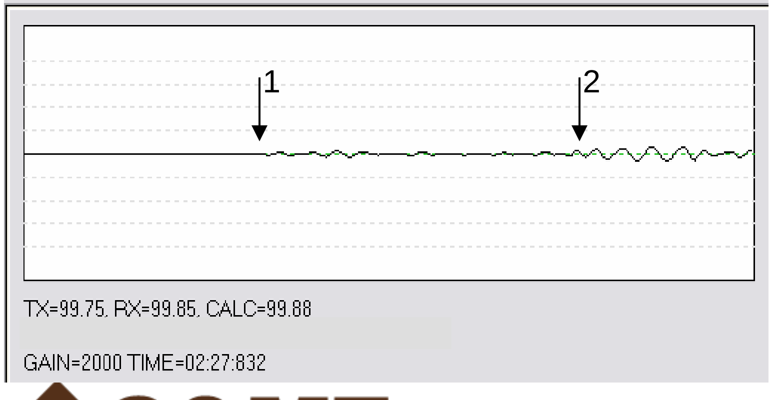
Vertical features
03/02/2005

Consequences of Bleed Water Features



Wavespeed at 97.39 ft = 13,351 fps





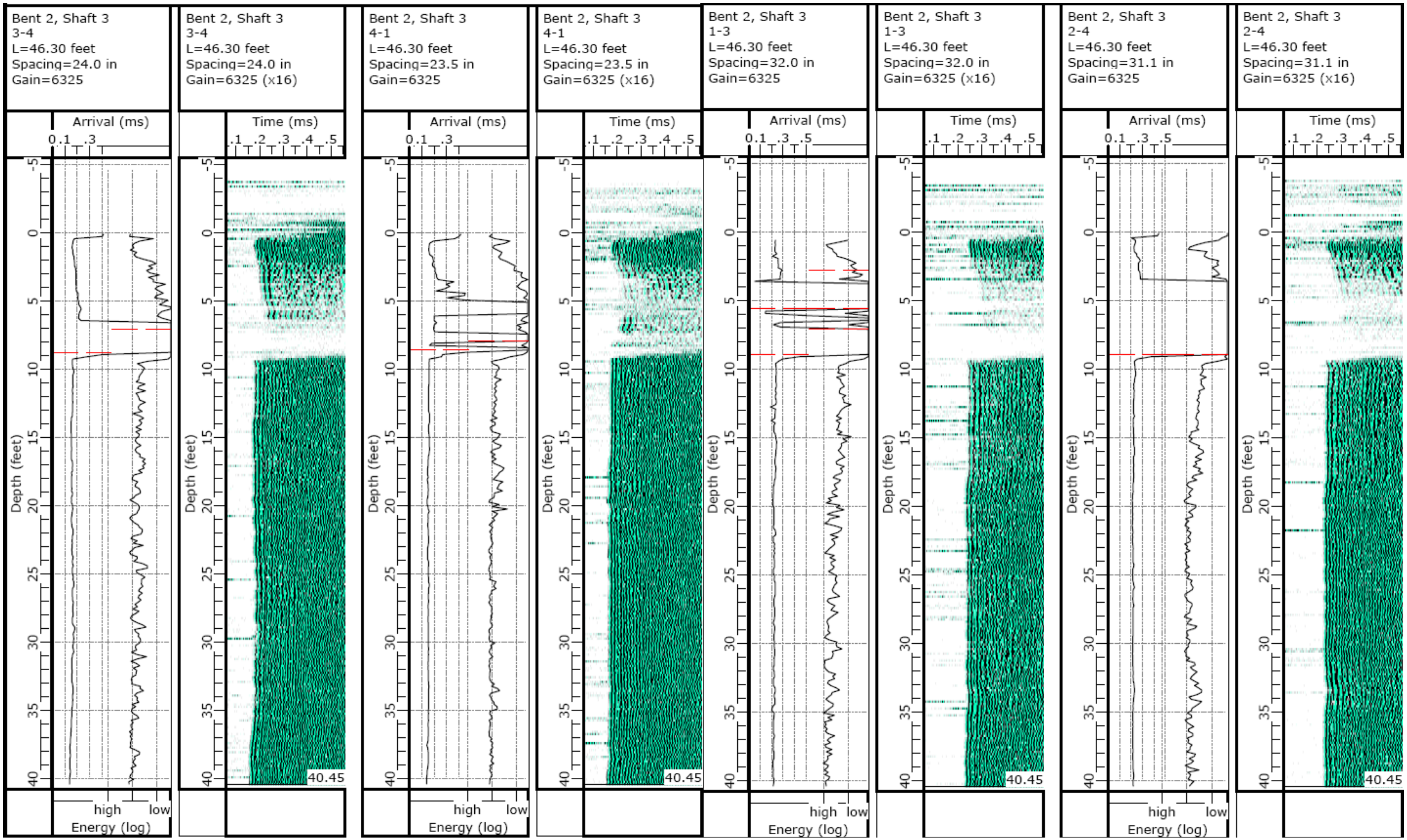
Possible interpretations at 99.55 and 99.88 ft:

No signal or

1) Wavespeed of 8,564 (36% reduction)

2) Wavespeed of 4,647 (65% reduction)

Top Anomaly



Bent 2, Shaft 3
3-4
L=46.30 feet
Spacing=24.0 in
Gain=6325
Arrival (ms)
Depth (feet)
high
low
Energy (log)
Bent 2, Shaft 3
3-4
L=46.30 feet
Spacing=24.0 in
Gain=6325 (x16)
Time (ms)
40.45
Bent 2, Shaft 3
4-1
L=46.30 feet
Spacing=23.5 in
Gain=6325
Bent 2, Shaft 3
4-1
L=46.30 feet
Spacing=23.5 in
Gain=6325 (x16)
Bent 2, Shaft 3
1-3
L=46.30 feet
Spacing=32.0 in
Gain=6325
Bent 2, Shaft 3
1-3
L=46.30 feet
Spacing=32.0 in
Gain=6325 (x16)
Bent 2, Shaft 3
2-4
L=46.30 feet
Spacing=31.1 in
Gain=6325
Bent 2, Shaft 3
2-4
L=46.30 feet
Spacing=31.1 in
Gain=6325 (x16)

Top Anomaly – continued

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Case Histories & Examples

Bottom Anomalies

- From the inspector's logs
  - 4.5 ft diameter, 30 ft long shaft (approx 18 cy vol)
  - Permanent casing with rock socket below
  - No drilling fluid
  - Concrete placed via pump line
  - No problems noted

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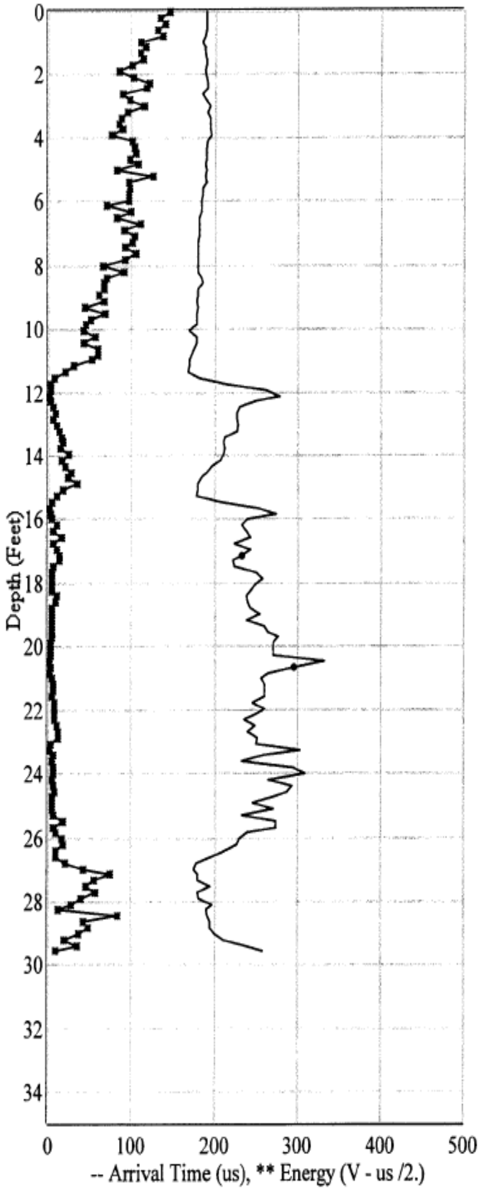
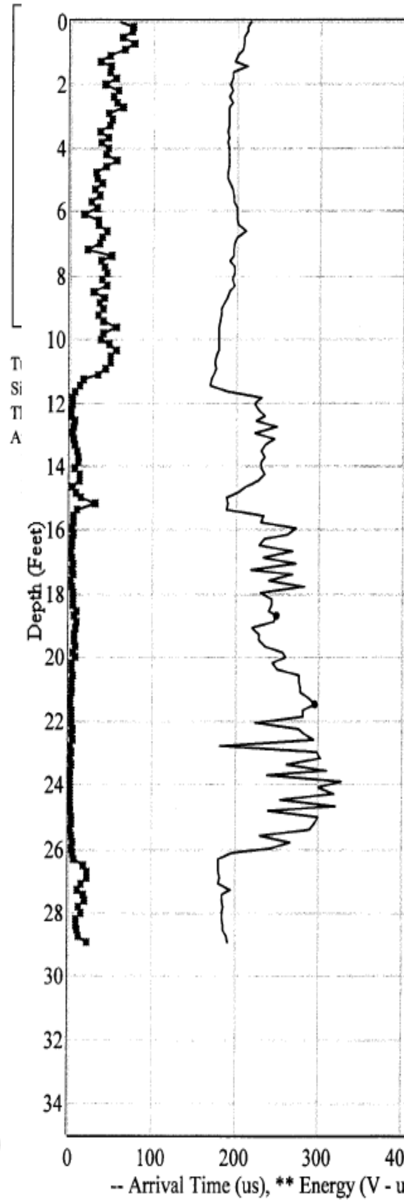
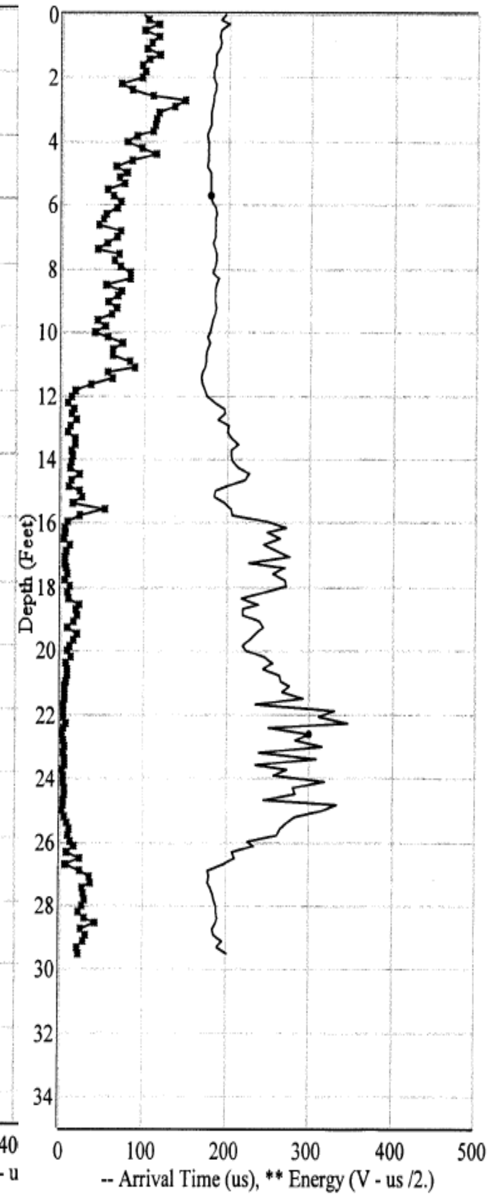
Bent 3 Shaft 2 -- Tubes 1 - 2

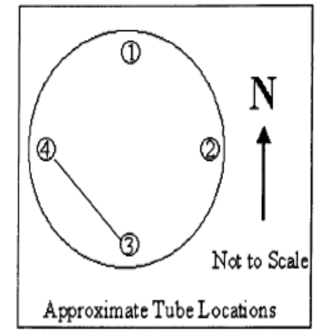


Bent 3 Shaft 2 -- Tubes 2 - 3



Bent 3 Shaft 2 -- Tubes 3 - 4





Tube Spacing :	26.00	inches
Signal Gain :	1	
Threshold :	1.50	
At Depth of	29.48	ft
Velocity	15600	ft/sec
First Arrival Time	202	us
Signal Energy	84.81	V-us

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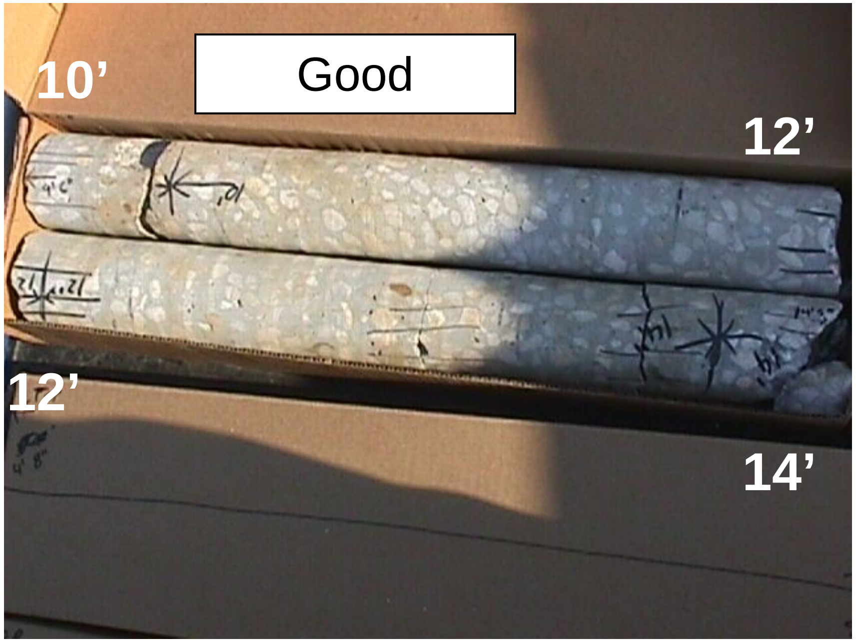

20’ to 25’: Gravel or No Recovery

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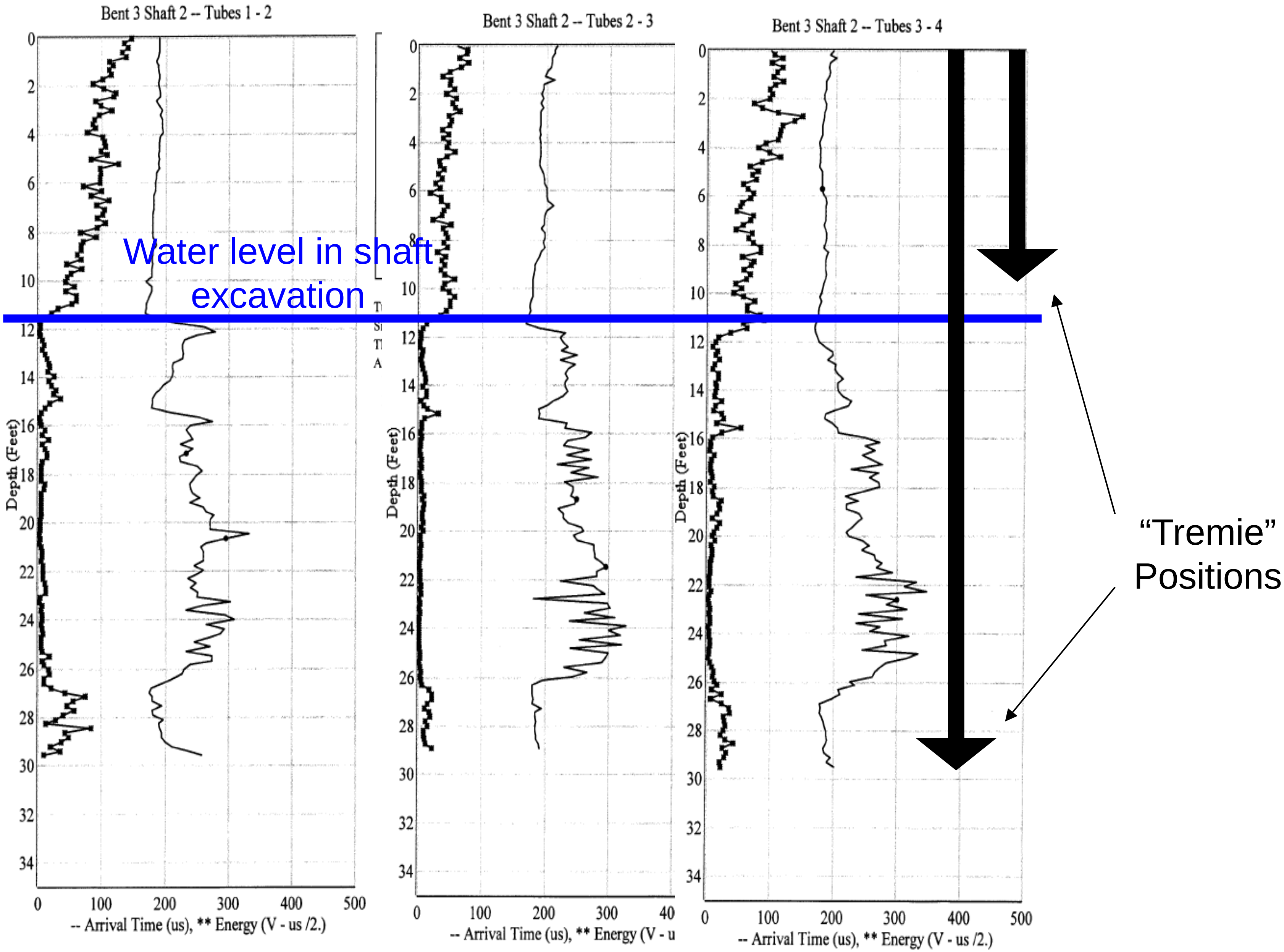
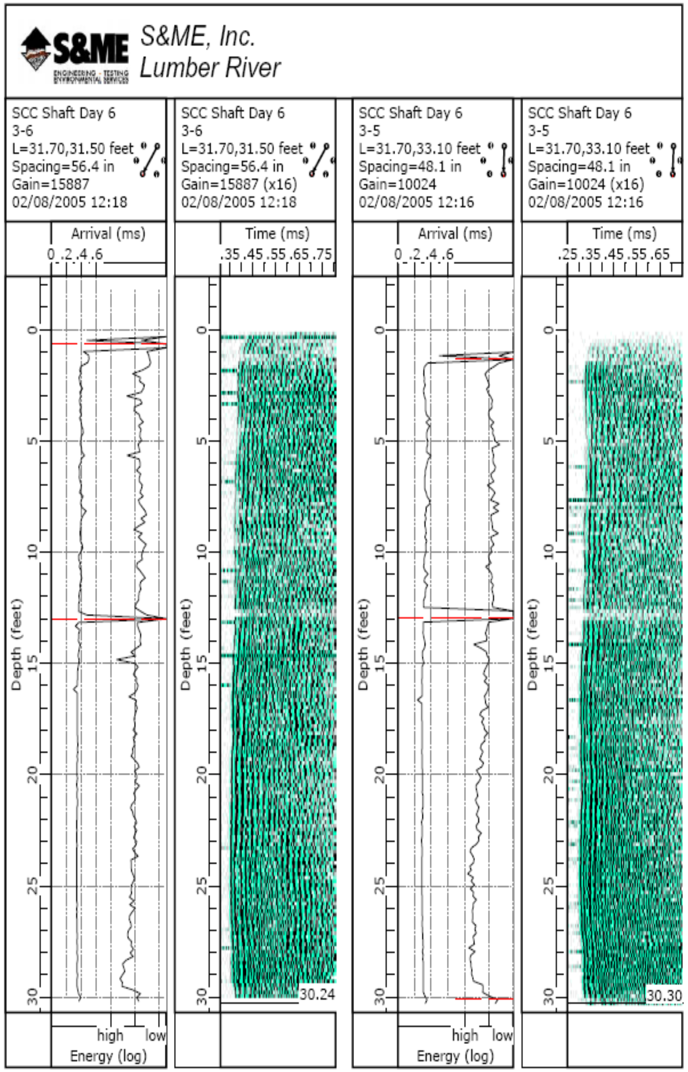
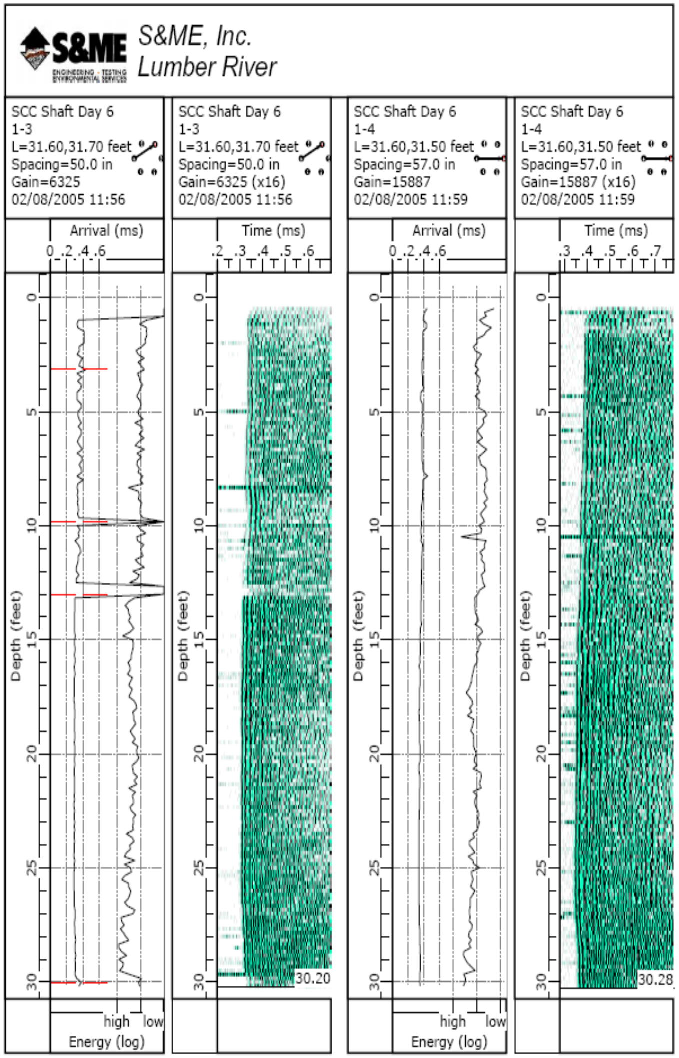

Bent 3 Shaft 2 -- Tubes 1 - 2
Bent 3 Shaft 2 -- Tubes 2 - 3
Bent 3 Shaft 2 -- Tubes 3 - 4
Depth (Feet)
-- Arrival Time (us), ** Energy (V - us /2.)
Water level in shaft excavation
"Tremie" Positions

Middle Anomaly





Middle Anomaly – cont.

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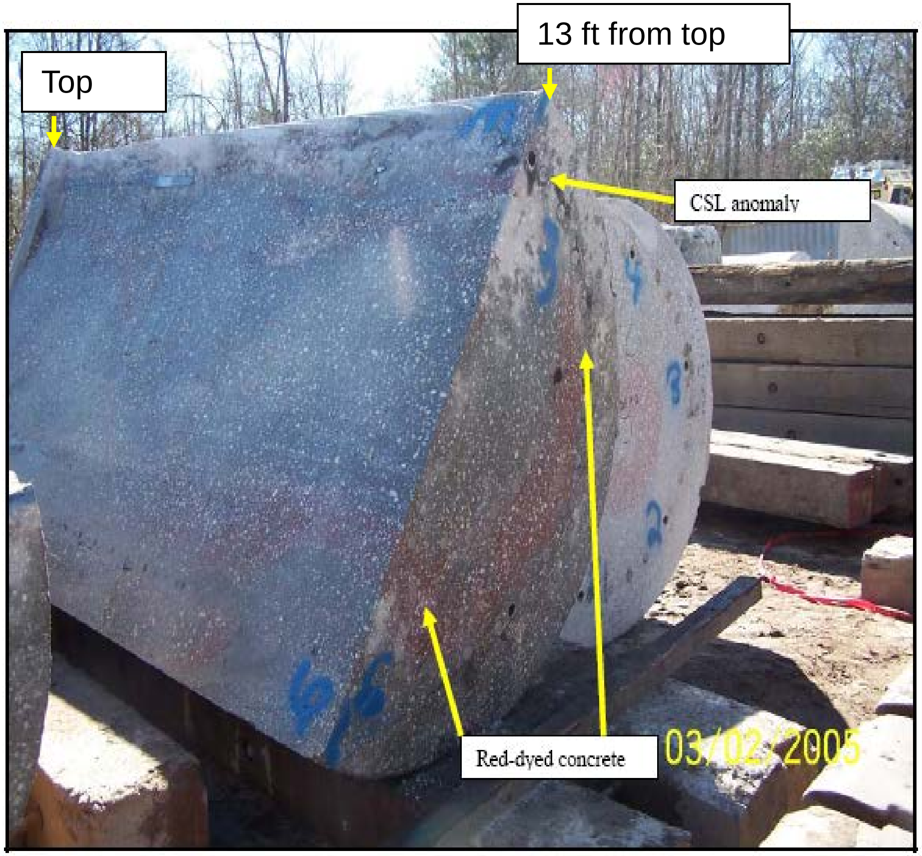
Middle Anomaly – cont.



Summary – Major Delay/No Signal

BAD

OK

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Summary – SCDOT Experience

- Concrete quality, not necking or soil intrusion, is the cause of anomalies
  - Bleed water, segregation, contamination?
- Vast majority of anomalies ≠ defect
- ≈90% of anomalies are found near the top or the bottom
- An anomaly free project is very rare
- Research should address concrete issues