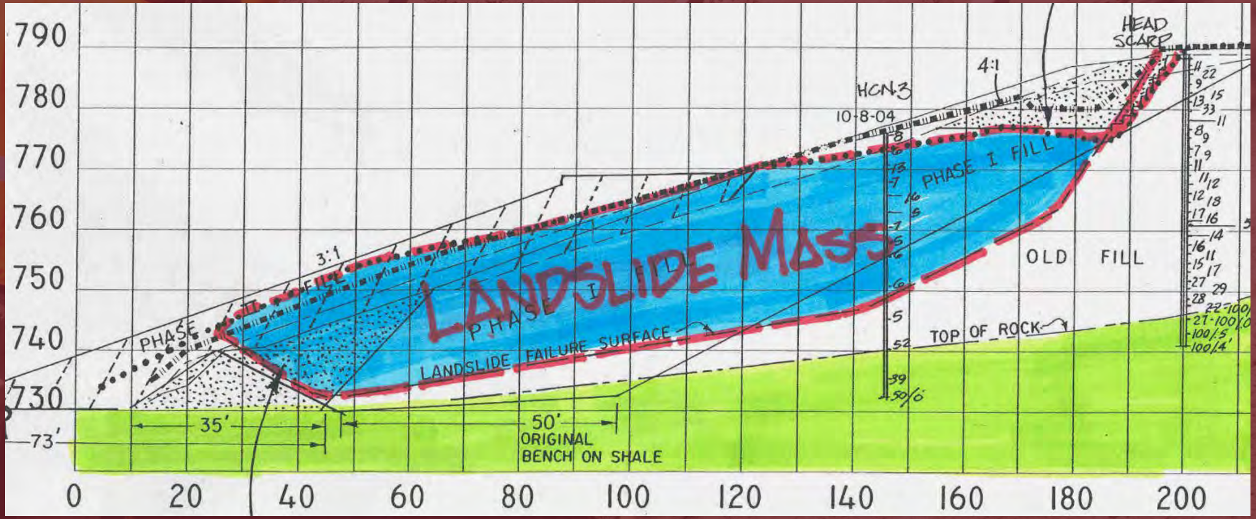
Lessons Learned in Geotechnical Engineering

September 25, 2019

Smithfield, Virginia

1) Excess Pore Water Pressure
2) Pyritic Sulfur

Presented by: George C. Webb, P.E.
Terracon - Cincinnati



Terracon

G-I ASCE GEO-INSTITUTE Virginia Chapter

GEOVIRGINIA 2019

1 Introduction

2 LANDSLIDE Case Study

3 HEAVE Case Study

4 Conclusions

1 Introduction

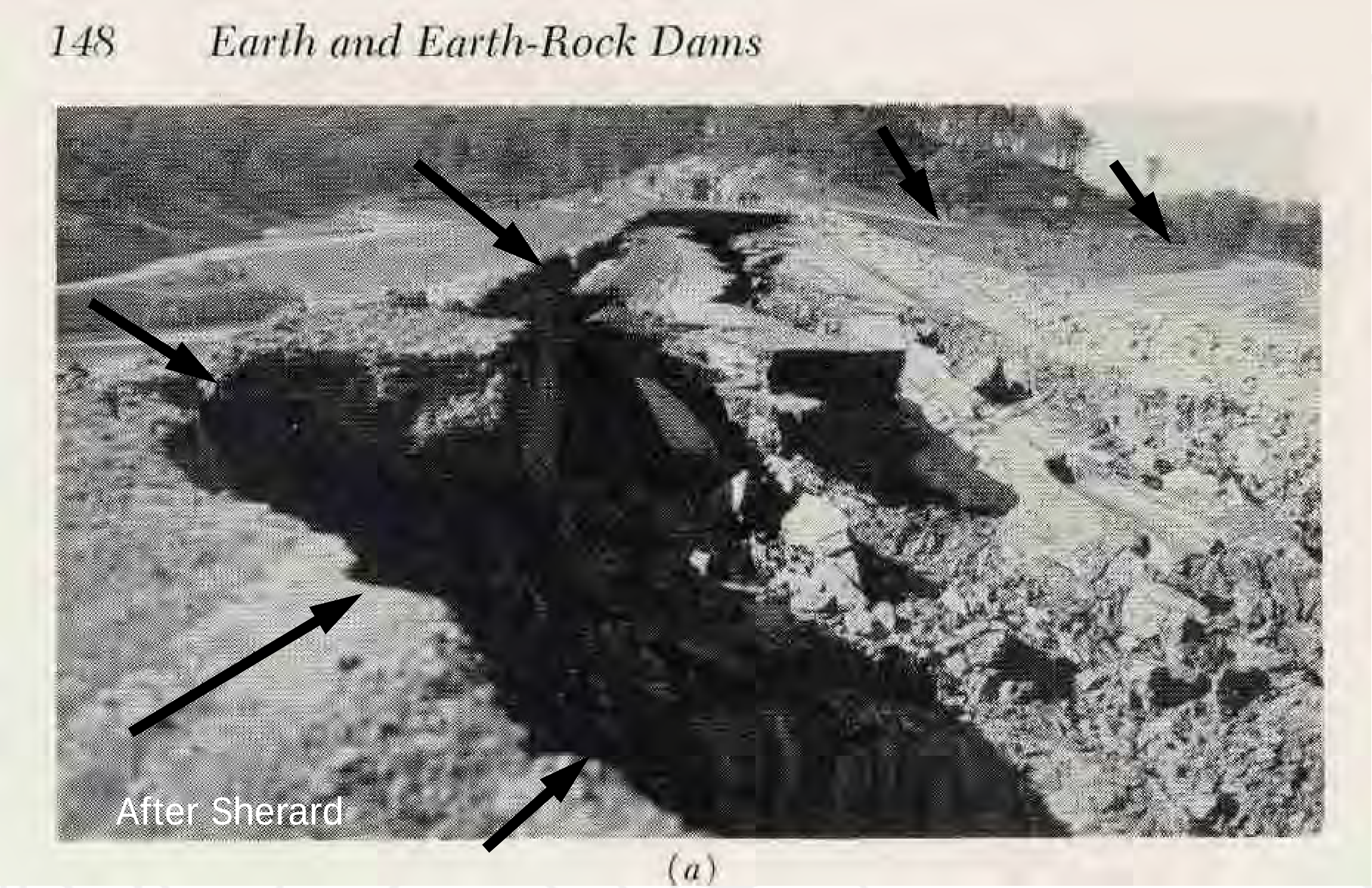
2 Landslide Case Study

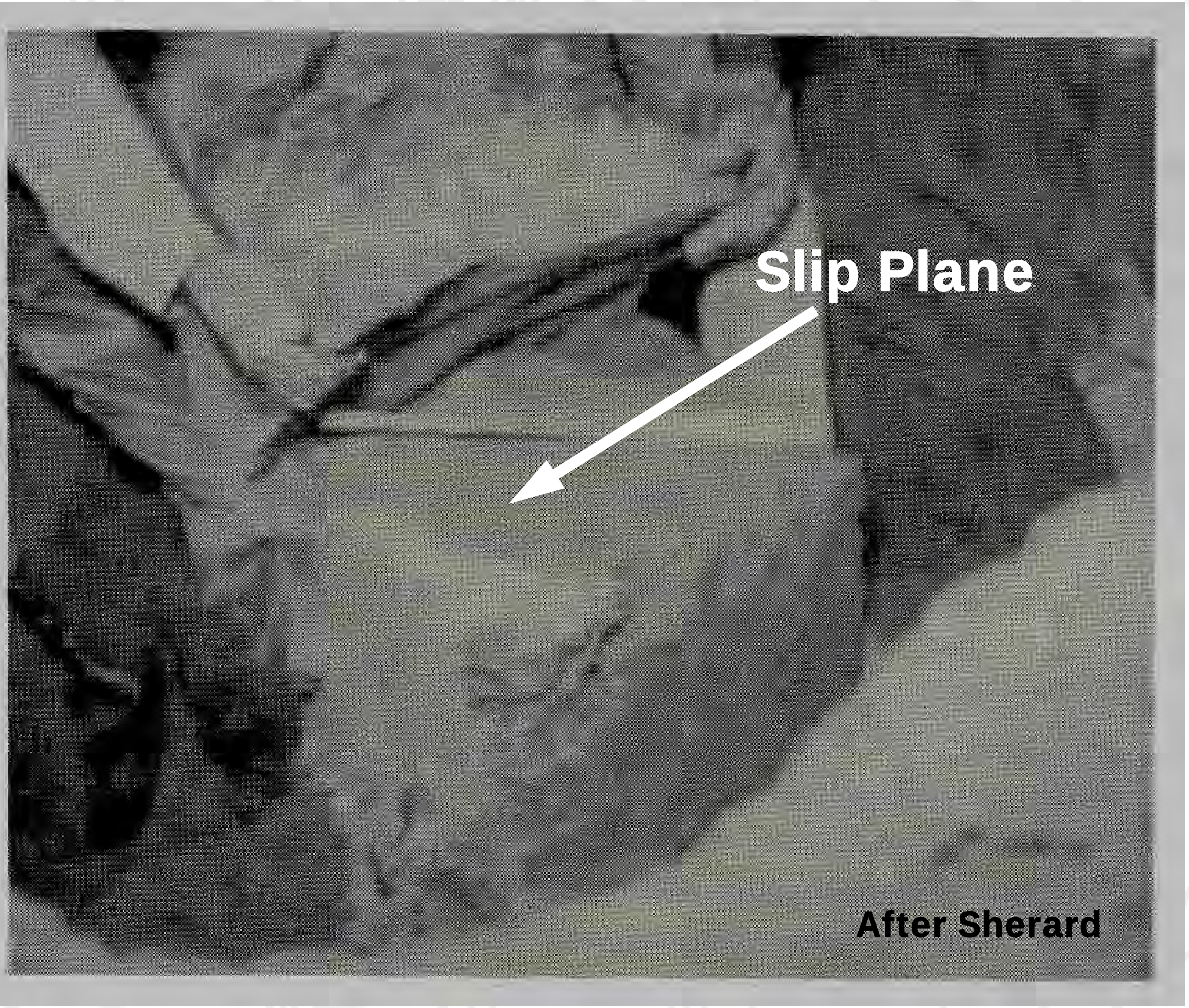
- History
- Remedy
- Lessons Learned

GEOVIRGINIA 2019

Background

Landslide due to Excess Porewater Pressures





So…Can Excess Pore Water Pressures be a Problem in Unsaturated Soils….

Above the Water Table???

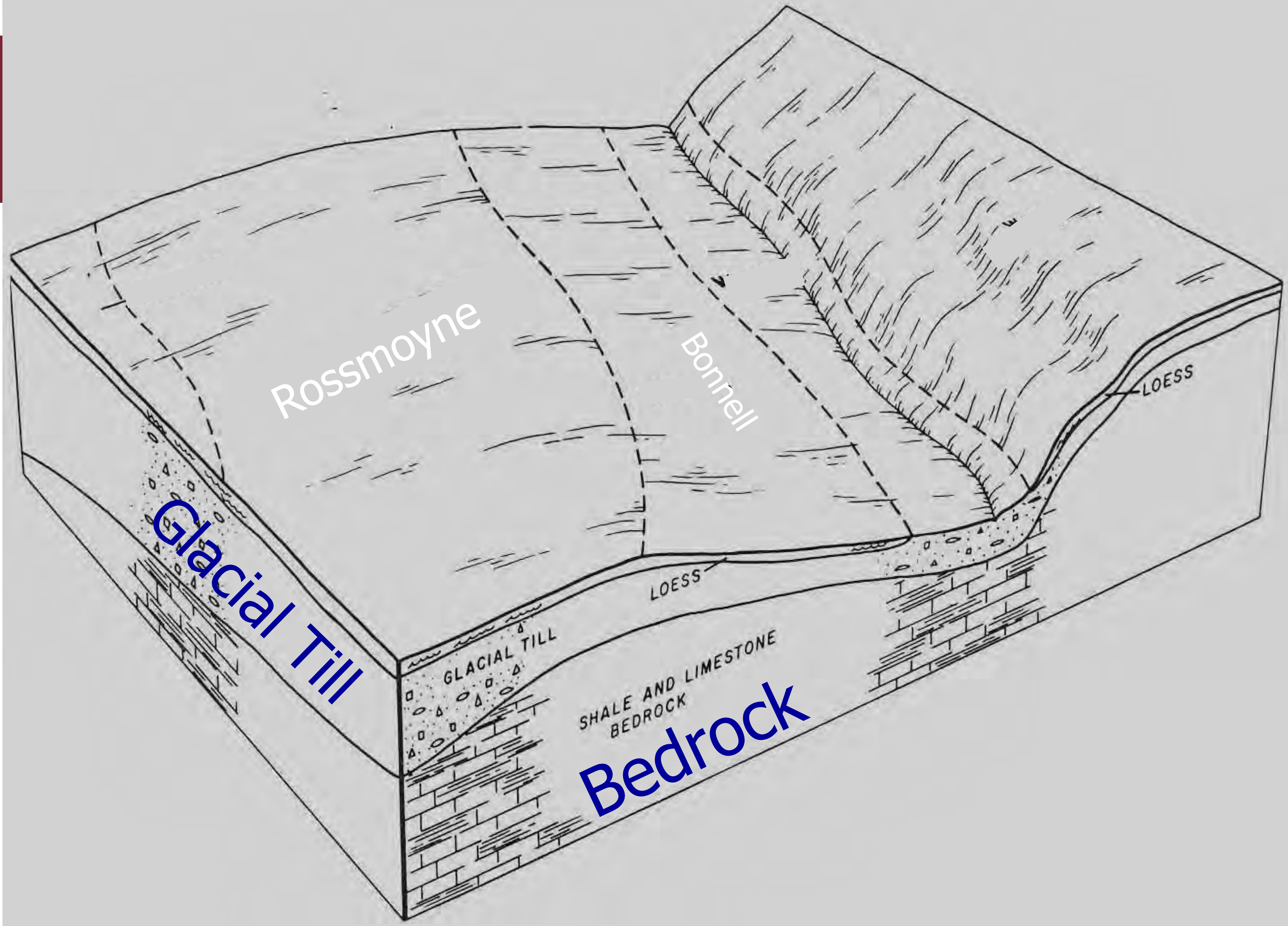
GEOVIRGINIA 2019

Site Locale

Google Local

GEOVIRGINIA 2019

USDA Soil Map Site Geology



Site Fill History

Final Project

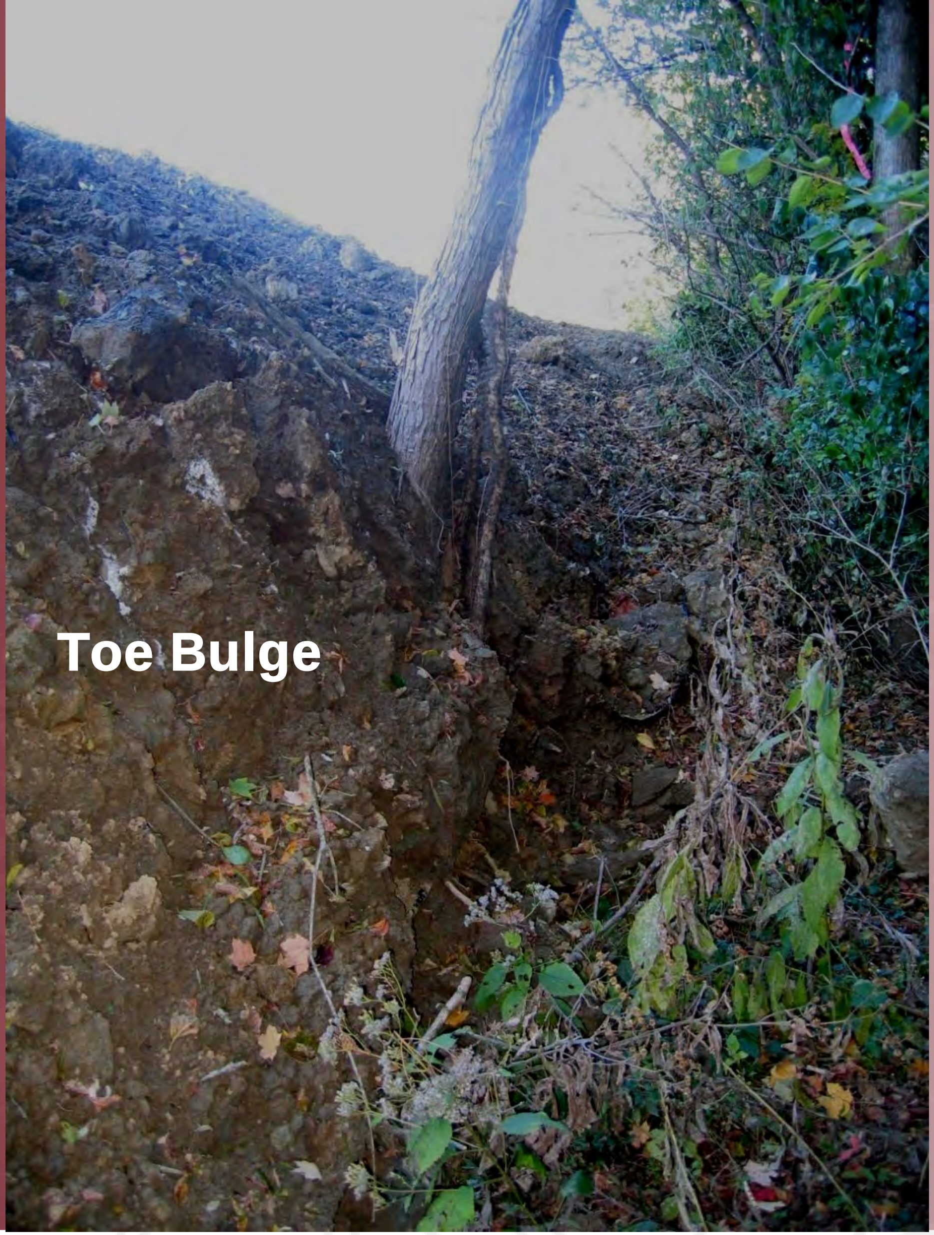
Anderson Town Center
And Park-n-Ride Facility

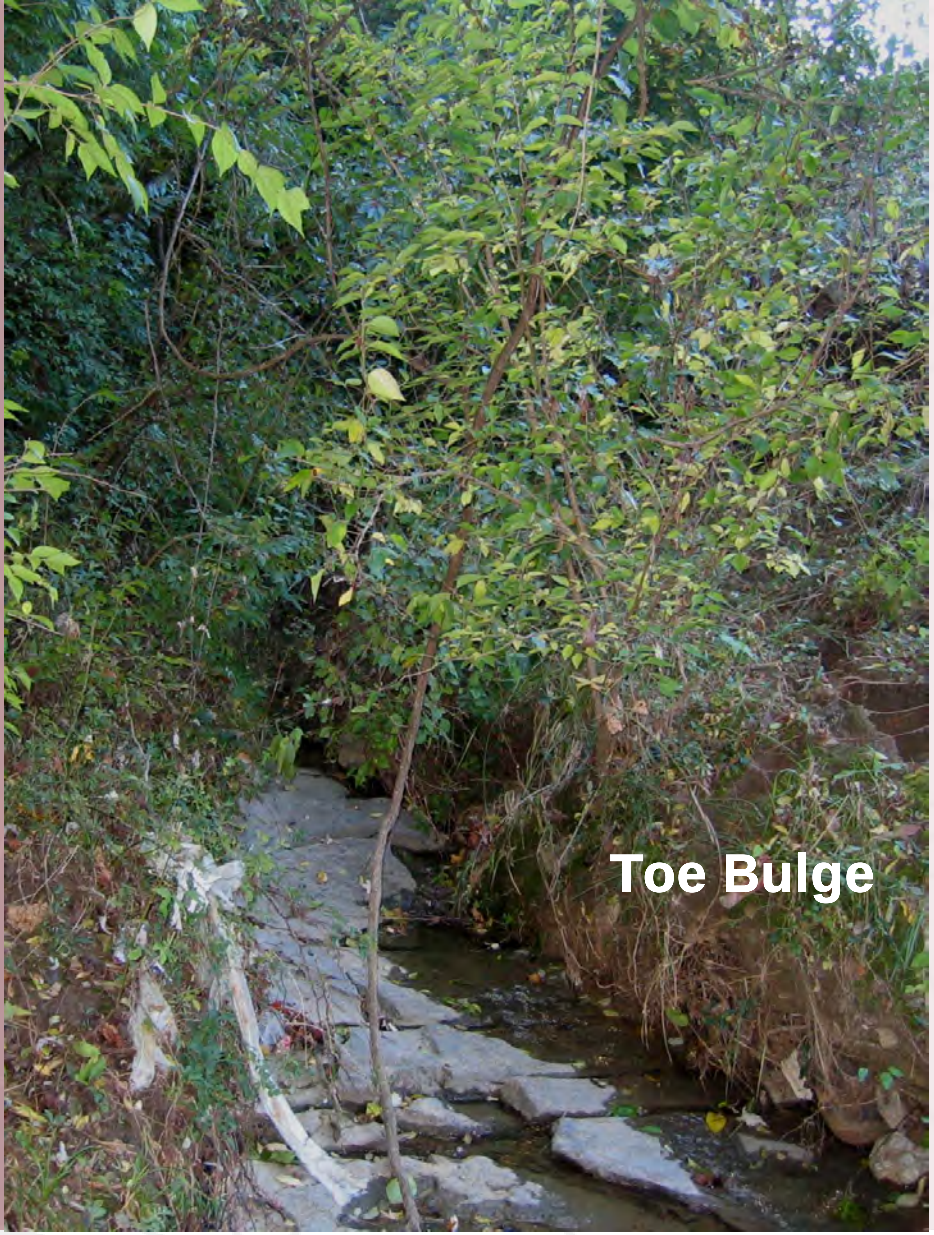
GeoVirginia 2019


N
Beechmont Mall
Landslide
Five Mile Connector

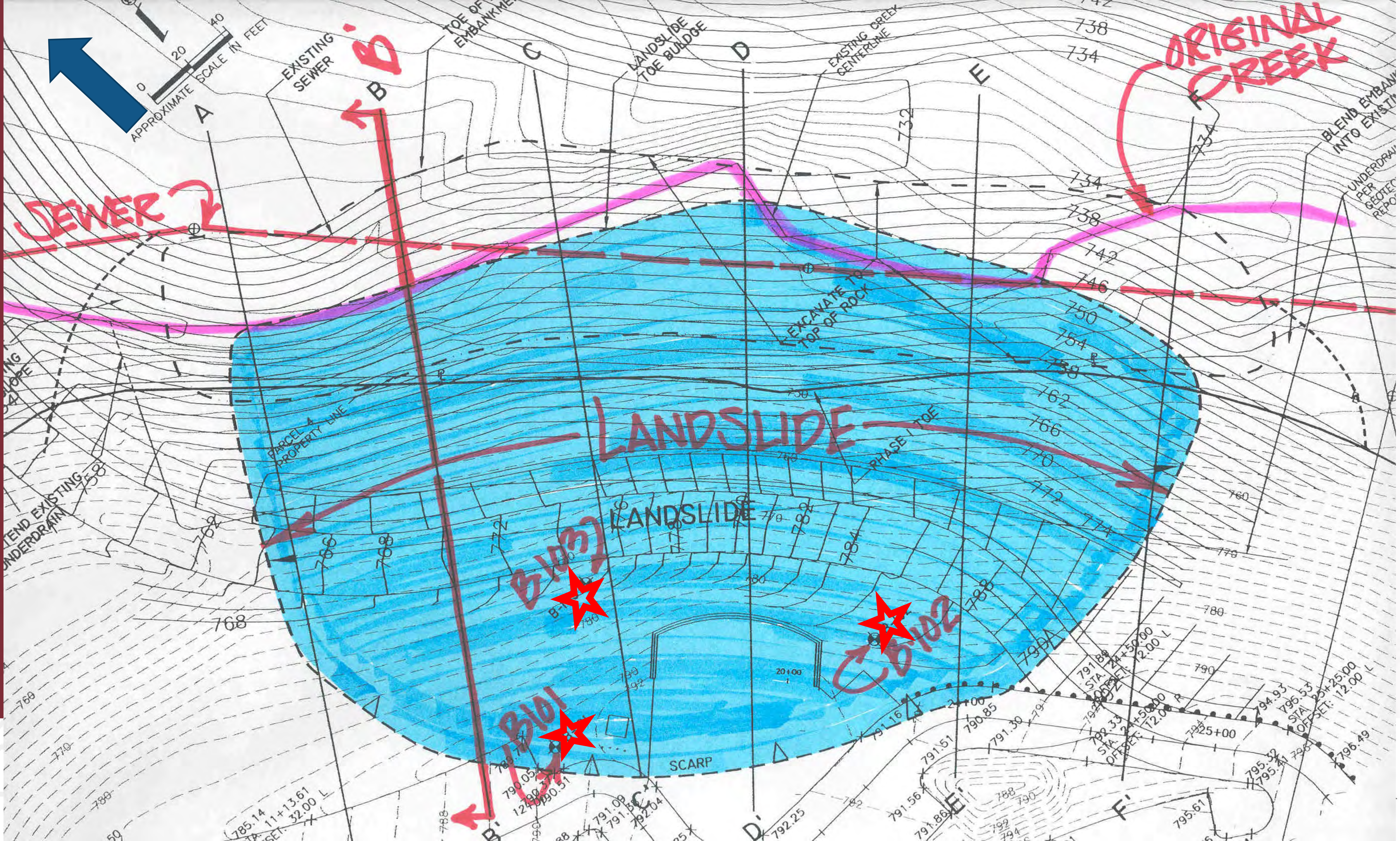
Drilling the day after the landslide occurred

GeoVirginia 2019





The Day After the Landslide Occurred



APPROXIMATE SCALE IN FEET
0
20
40
EXISTING SEWER
TOE OF EMBANKMENT
LANDSLIDE TOE BULDGE
EXISTING CREEK CENTERLINE
BLEND EMBANKMENT INTO EXISTING
ORIGINAL CREEK
SEWER
A
B
B'
C
D
D'
E
E'
F
F'
EXCAVATE TO TOP OF ROCK
PARCEL 4 PROPERTY LINE
PHASE I TOE
LANDSLIDE
LANDSLIDE
EXTEND EXISTING UNDERDRAIN
B-101
B-102
B-103
SCARP
20+00
25+00
734
738
742
746
750
754
758
762
766
770
774
780


HCN-102

Lessons Learned

Test Boring HCN-102

H.C. NUTTING COMPANY
CORPORATE CENTER - 611 LUNKEN PARK DRIVE
CINCINNATI, OH 45226 (513) 321-5816
FAX (513) 321-0294
EMPLOYEE OWNED
GEOTECHNICAL, ENVIRONMENTAL AND TESTING ENGINEERS SINCE 1921

APPALACHIAN REGION, 912 MORRIS STREET, CHARLESTON, WV 25031, (304) 344-0821, FAX (304) 342-4711
CENTRAL OHIO REGION, 790 MORRISON ROAD, COLUMBUS, OH 43230, (614) 863-3113, FAX (614) 863-0475
INDIANA REGION, 349 WALNUT STREET, STE 8, LAWRENCEBURG, IN 47025, (812) 539-4300, FAX (812) 539-4301
BLUEGRASS REGION, 470-B CONWAY CT., STE B-8, LEXINGTON, KY 40511, (859) 455-8530, FAX (859) 455-8630

LOG OF TEST BORING — Page 1 of 2

Client	Hamilton County Engineer's Office	Boring No.	HCN-102
Project	Anderson Lake Park & Ride Landslide Evaluation	Date Started	10/2/2004
Boring Location	As Staked	Date Completed	10/3/2004
Elevation Ref.	Manhole West of Thriftway = Elev. 801.97	Work Order No.	00096.800

ELEV. ft.	DEPTH ft.	DESCRIPTION OF MATERIALS (color, material description, moisture, stiffness/density/hardness)	NO.	TYPE	DEPTH ft.	BLOWS/6" (N Value)	REC. %	RQD %	W %	LL %	PI %	Qu tsf	PPR tsf
789.20	0.0	Dark brown, brown, and gray lean clay and clay (NEW FILL), trace to some sand, gravel and rock fragments, occasional trace organics and wood fragments, moist-stiff to very stiff -occasional clay layers, -noted brick fragments at 10' -noted decayed wood at 26.0'	1	SS	0.0-1.5	3-5-6 (11)	13		10				
			2	SS	2.5-4.0	10-8-6 (14)	67		15				3.5
			3	ST	4.0-6.0	P-U-S-H	60		14	33	15	2.03	
			4	SS	6.0-7.5	2-2-3 (5)	67		19				2.0
			5	SS	7.5-9.0	3-4-4 (8)	100		25	42	23		1.5
			6	SS	10.0-11.5	3-4-5 (9)	100		19				2.75
		New Fill 26.5	7	ST	12.5-14.5	BENT-TUBE	0						
			8	SS	14.5-16.0	4-6-6 (12)	20		19				2.5
			9	SS	17.5-19.0	6-7-7 (14)	100		26	48	26		2.0
			10	SS	20.0-21.5	3-5-6 (11)	67		24				1.25
762.70	26.5		11	SS	25.0-26.5	6-5-7 (12)	67		25	36	18		2.25
		Dark brown, brown, and gray lean clay and clay (OLD FILL), trace sand, gravel, and rock fragments, trace organics, moist to very moist-stiff to very stiff											
		9.5	12	ST	30.0-32.0	P-U-S-H	70		24	41	20		
		Old Fill	13	SS	32.0-33.5	5-8-7 (15)	100		23				3.5

General Notes

Driller	D.M.
Rig No.	18
Rig Type	Truck, M-57
Method	SS/ST
Inspector	

Remarks

3/ST Dry Density=109.0 pcf
13/SS LOI=4.2%
14/ST Dry Density=95.8 pcf

Water Level Observations

Immediate	50.0	ft. ∇
At Completion	NW	ft.
After 0 Hrs.	BF	ft.
Water used in drilling	57.5	ft.

BF = BACKFILLED NW = NO WATER
(Measured from ground surface)

TEST BORING LOGS.GPJ HC NUTTING.GDT 12/3/04

GEOVIRGINIA 2019

Two Days after Landslide Occurred

Ten Days After the Landslide Occurred

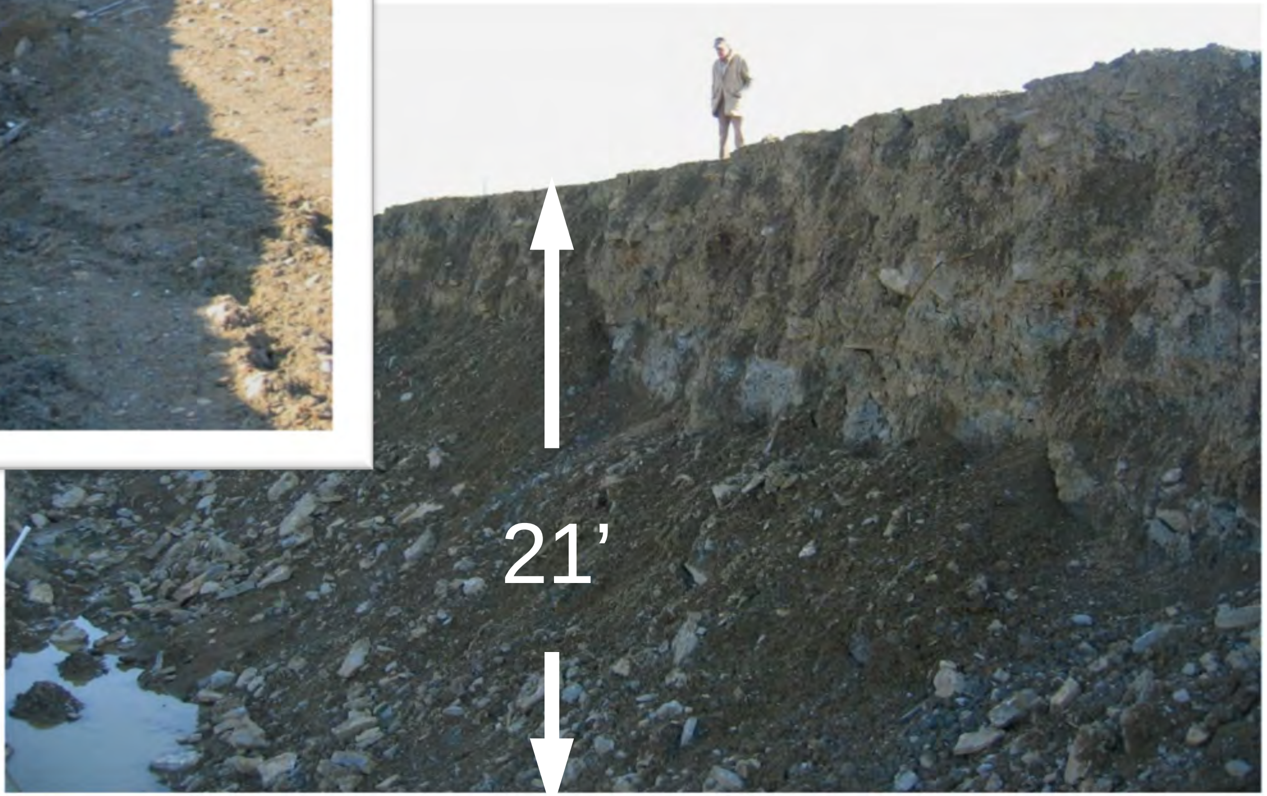
GeoVirginia 2019

12’

GeoVirginia 2019

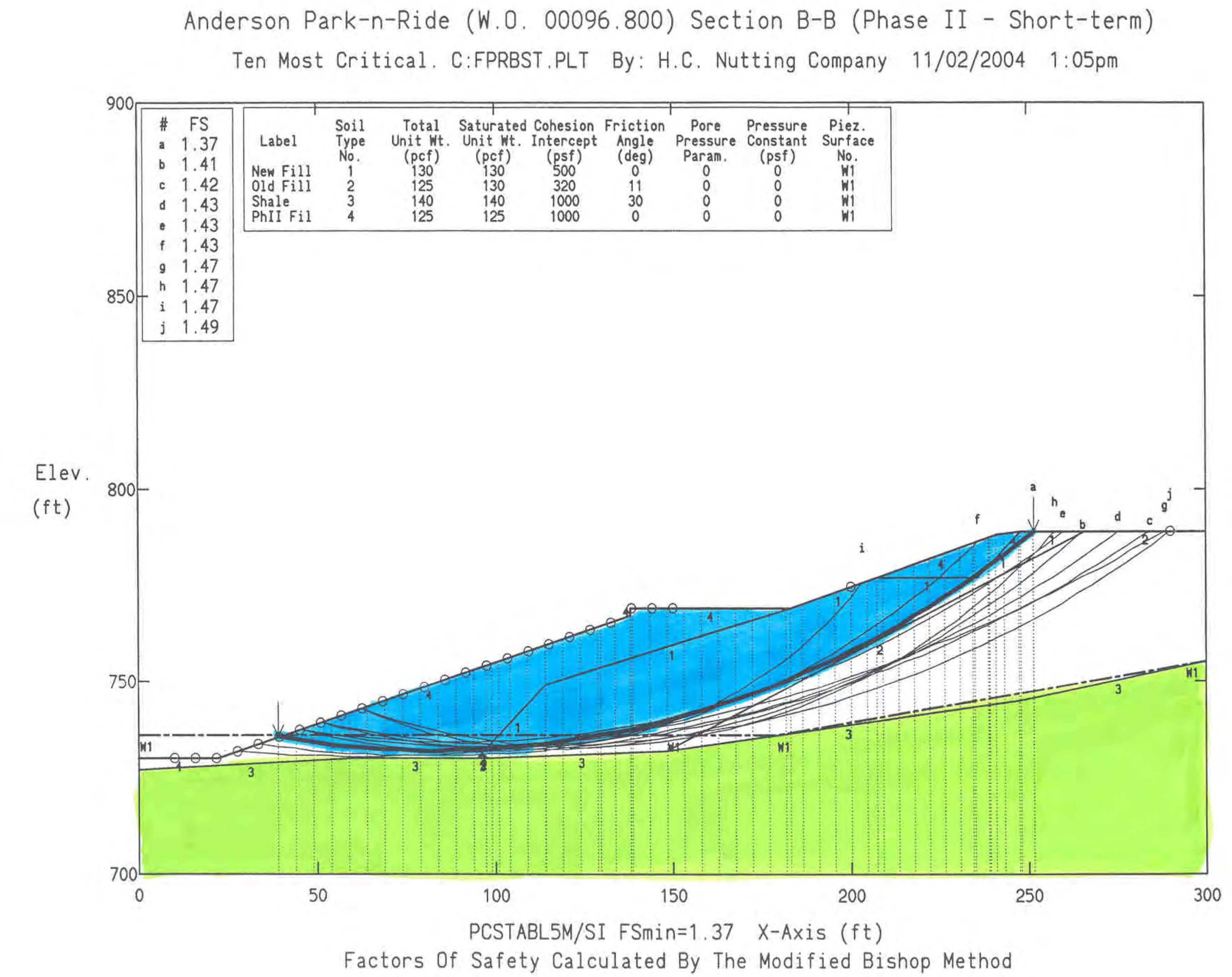
18 Days After the Landslide Occurred

5 Months after the Landslide Occurred



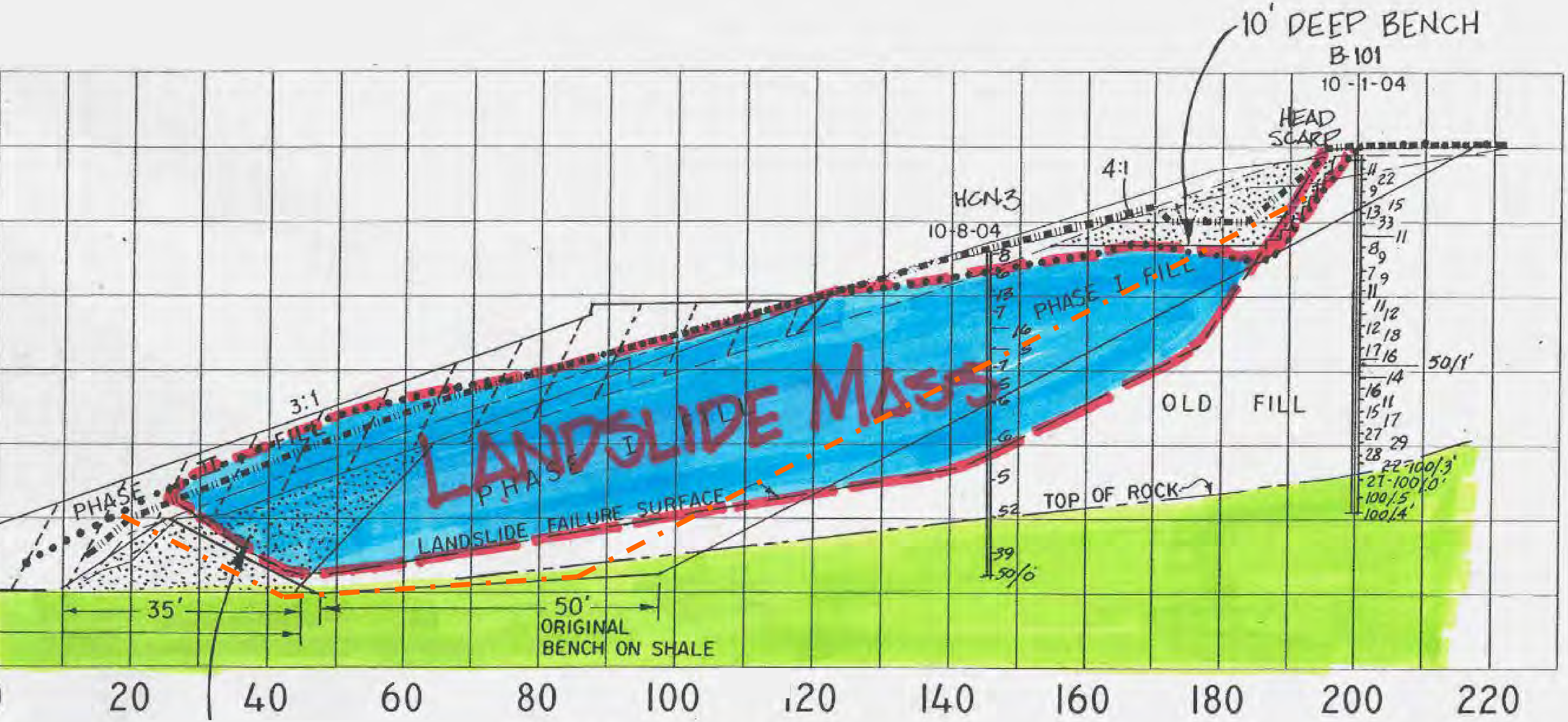
5 Months after the Landslide Occurred

GEOVIRGINIA 2019



Evaluation

GEOVIRGINIA 2019

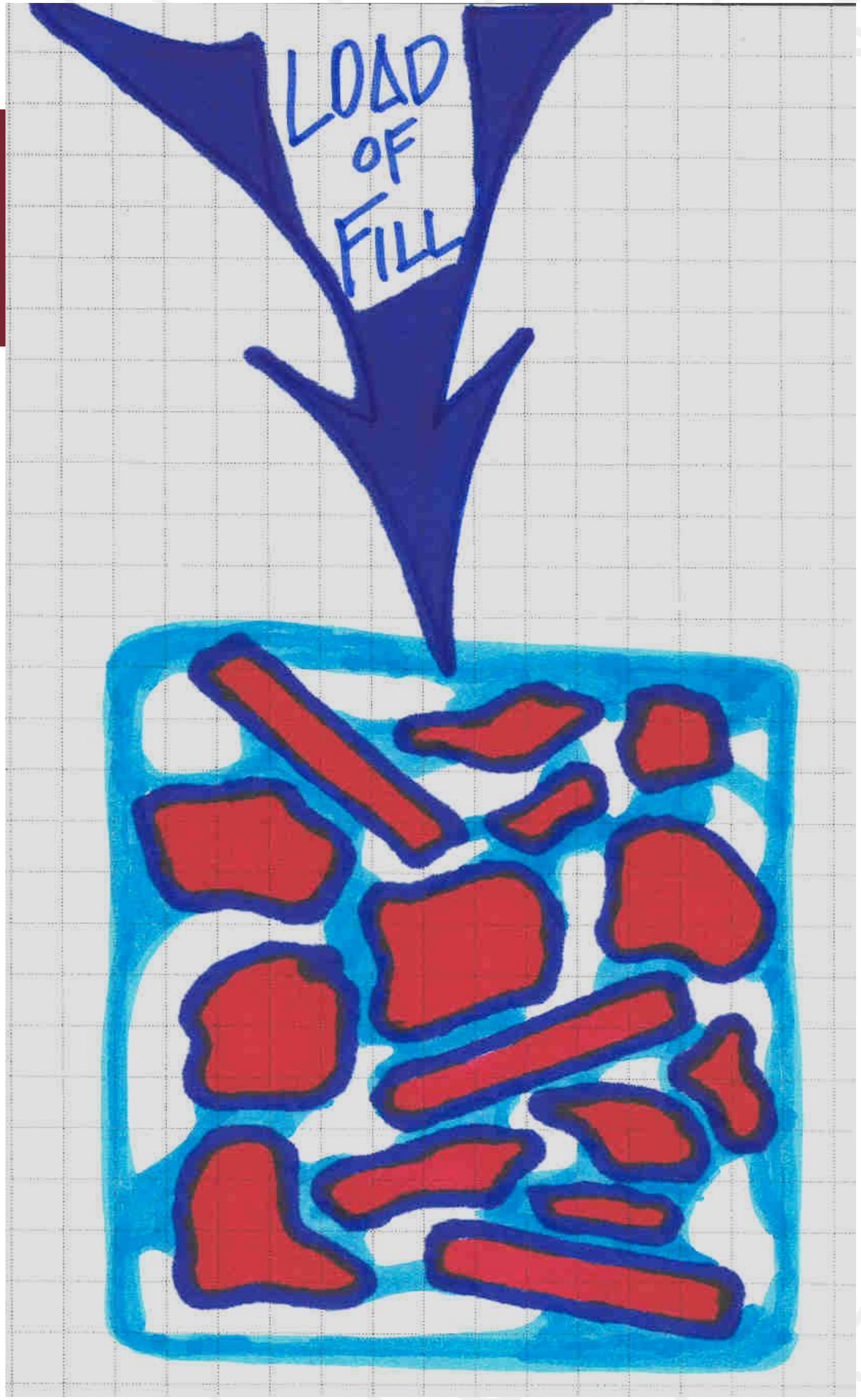


CROSS-SECTION B-B'

SCALE: 1"=20'

Background

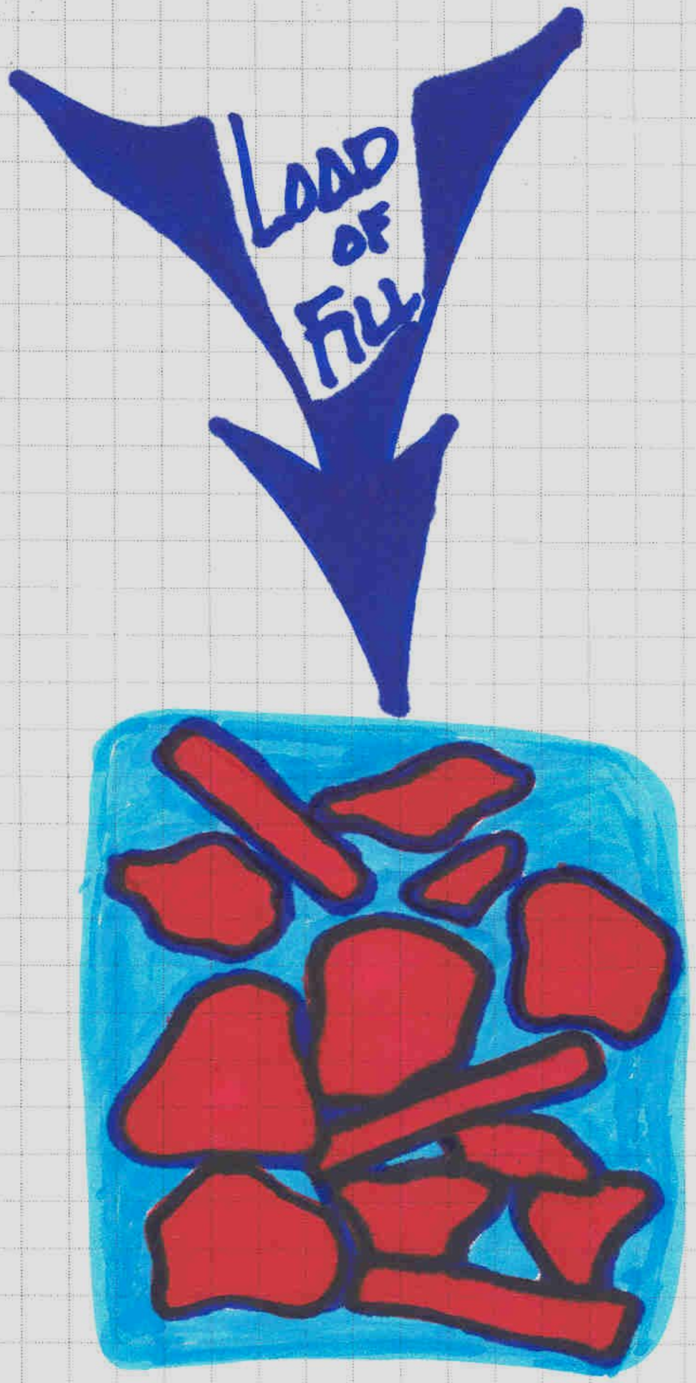
Just How Important
is
Soil Moisture
In a Controlled Fill?



Unsaturated Soil

Background

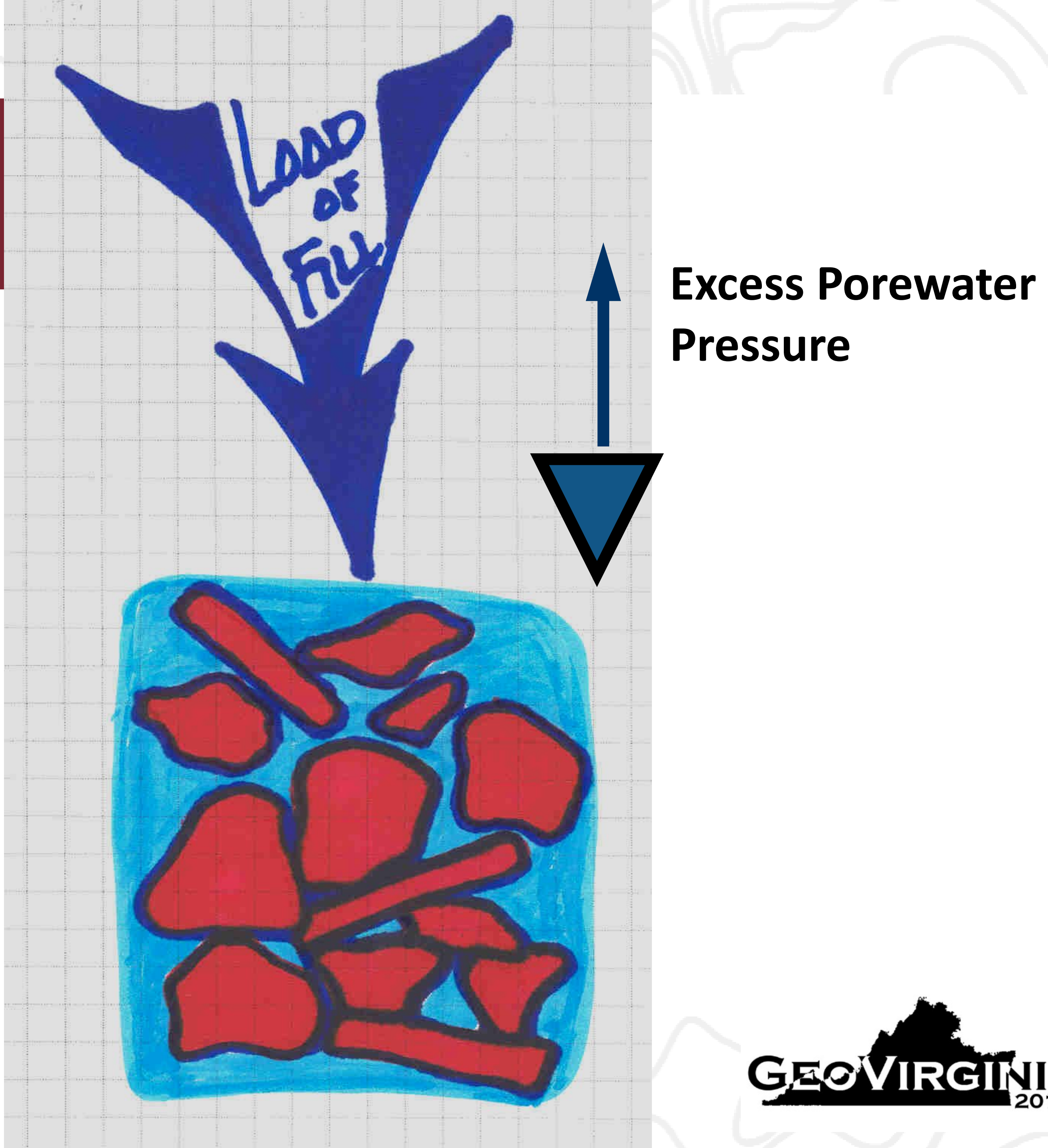
Just How Important
is
Soil Moisture
In a Controlled Fill?



Saturated Soil

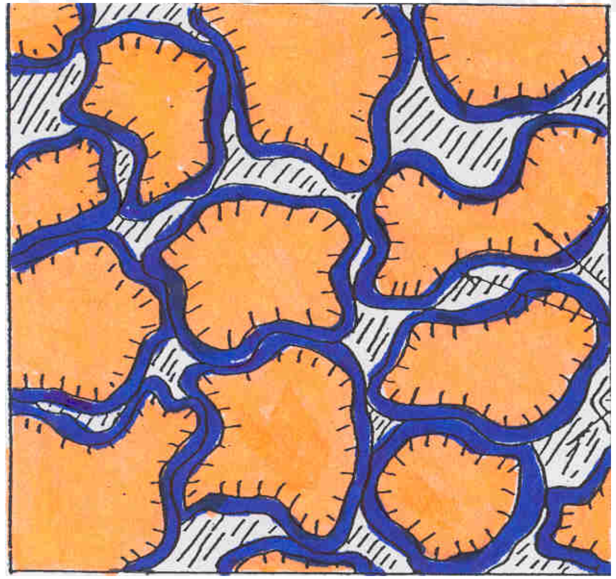
Background

Just How Important
is
Soil Moisture
In a Controlled Fill?

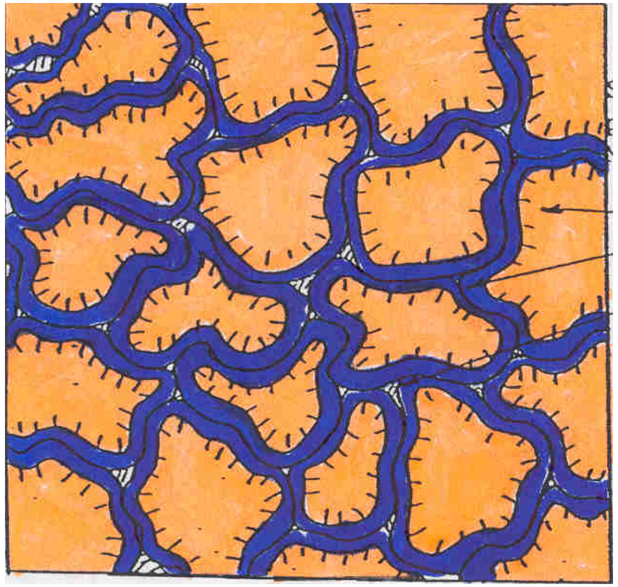


GEOVIRGINIA 2019

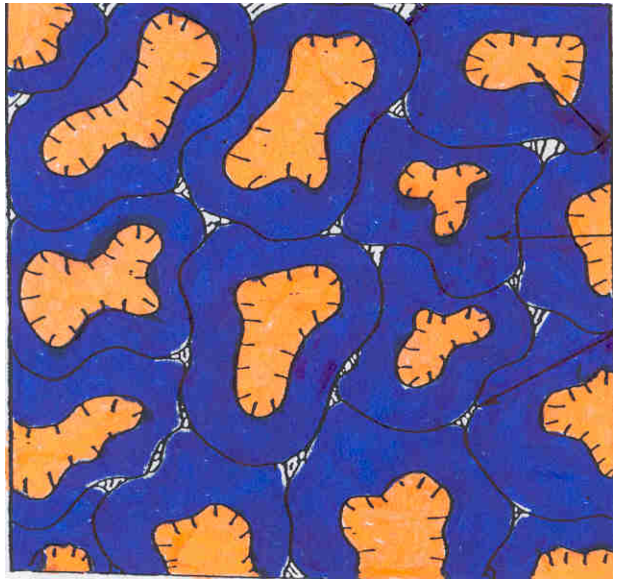
Nuclear Density Testing



Too Dry



Optimum

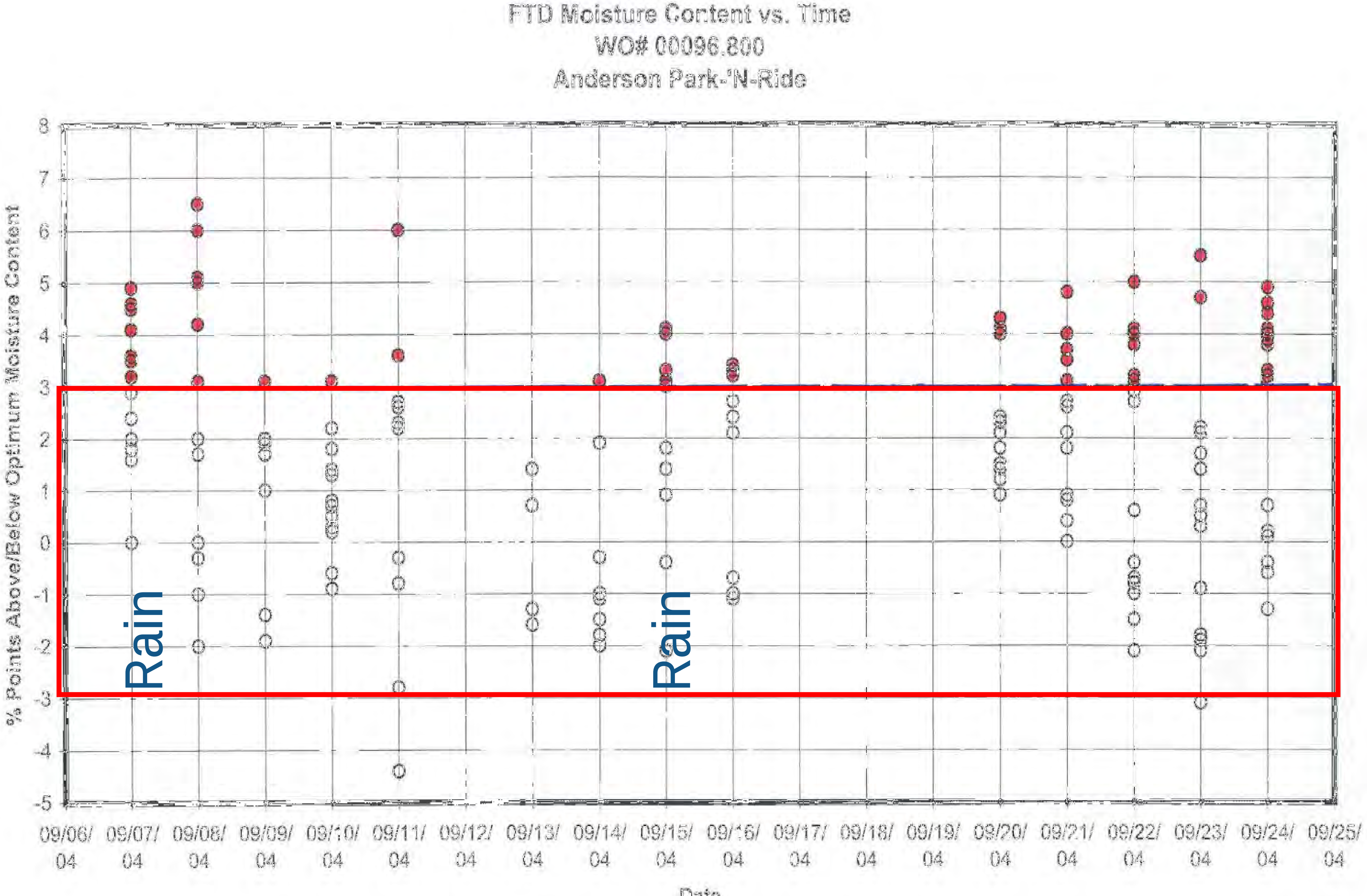


Too Wet

September 2004

<table>
<tr><td>« Previous Month</td><td>« 2003</td><td colspan="3">September 2004</td><td>2005 »</td><td>Next Month »</td></tr>
<tr><th>Sunday</th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th><th>Saturday</th></tr>
<tr><td></td><td></td><td></td>
<td>1
Actual: 81 | 60
Precip: 0.00
Average: 82 | 61
Precip: 0.11</td>
<td>2
Actual: 83 | 62
Precip: 0.00
Average: 82 | 61
Precip: 0.11</td>
<td>3
Actual: 78 | 68
Precip: 1.29
Average: 82 | 61
Precip: 0.10</td>
<td>4
Actual: 84 | 64
Precip: 0.00
Average: 81 | 61
Precip: 0.10</td></tr>
<tr><td>5
Actual: 85 | 65
Precip: 0.00
Average: 81 | 60
Precip: 0.10</td>
<td>6
Actual: 86 | 65
Precip: 0.00
Average: 81 | 60
Precip: 0.10</td>
<td>7
Actual: 74 | 68
Precip: T
Average: 81 | 60
Precip: 0.10</td>
<td>8
Actual: 68 | 64
Precip: 0.01
Average: 80 | 59
Precip: 0.10</td>
<td>9
Actual: 73 | 58
Precip: 0.00
Average: 80 | 59
Precip: 0.10</td>
<td>10
Actual: 80 | 54
Precip: 0.00
Average: 80 | 59
Precip: 0.10</td>
<td>11
Actual: 81 | 59
Precip: 0.00
Average: 80 | 59
Precip: 0.09</td></tr>
<tr><td>12
Actual: 82 | 61
Precip: 0.00
Average: 79 | 58
Precip: 0.09</td>
<td>13
Actual: 84 | 65
Precip: 0.00
Average: 79 | 58
Precip: 0.09</td>
<td>14
Actual: 84 | 61
Precip: 0.00
Average: 79 | 58
Precip: 0.09</td>
<td>15
Actual: 84 | 62
Precip: 0.00
Average: 78 | 57
Precip: 0.09</td>
<td>16
Actual: 82 | 64
Precip: T
Average: 78 | 57
Precip: 0.09</td>
<td>17
Actual: 72 | 55
Precip: 0.23
Average: 78 | 57
Precip: 0.09</td>
<td>18
Actual: 77 | 50
Precip: 0.00
Average: 77 | 56
Precip: 0.09</td></tr>
<tr><td>19
Actual: 75 | 51
Precip: 0.00
Average: 77 | 56
Precip: 0.09</td>
<td>20
Actual: 80 | 50
Precip: 0.00
Average: 77 | 55
Precip: 0.09</td>
<td>21
Actual: 82 | 48
Precip: 0.00
Average: 76 | 55
Precip: 0.09</td>
<td>22
Actual: 85 | 52
Precip: 0.00
Average: 76 | 55
Precip: 0.09</td>
<td>23
Actual: 88 | 56
Precip: 0.00
Average: 76 | 54
Precip: 0.09</td>
<td>24
Actual: 84 | 59
Precip: 0.00
Average: 75 | 54
Precip: 0.09</td>
<td>25
Actual: 76 | 59
Precip: 0.00
Average: 75 | 53
Precip: 0.09</td></tr>
<tr><td>26
Actual: 74 | 54
Precip: 0.00
Average: 75 | 53
Precip: 0.09</td>
<td>27
Actual: 77 | 55
Precip: 0.00
Average: 74 | 53
Precip: 0.09</td>
<td>28
Actual: 78 | 56
Precip: 0.00
Average: 74 | 52
Precip: 0.09</td>
<td>29
Actual: 63 | 52
Precip: 0.00
Average: 74 | 52
Precip: 0.09</td>
<td>30
Actual: 70 | 44
Precip: 0.00
Average: 73 | 51
Precip: 0.09</td>
<td></td><td></td></tr>
<tr><td colspan="7">Month Precipitation - Actual month total: 1.53 Normal month total: 2.82</td></tr>
</table>

Fill Moisture Contents



SOIL STRENGTH

$$S = C' + \left[(\sigma_n) - u\right] Tan(\phi')$$

Where:
S = soil strength
C = cohesion
σ_n = normal principal stress
u = pore water pressure

$(\sigma_n) - u$ = mean normal effective stress

GEOVIRGINIA 2019

Lesson Learned

Undrained Shear Strength

Not for evaluating controlled fill

(false sense of security)

GEOVIRGINIA 2019

GEOVIRGINIA 2019

Anderson Town Center
And Park-n-Ride Facility

Lessons Learned:

1. Recognize importance of proper control of moisture content of fill soil
2. Do NOT use undrained shear strength to control fill placement
3. Consider excess PWP for all embankments greater than 30 feet high

GEOVIRGINIA 2019

1 Introduction

2 Landslide Case Study

- History
- Lessons Learned
- Remedy

3 HEAVE Case Study

- History
- Monitoring
- Lessons Learned
- Remedy

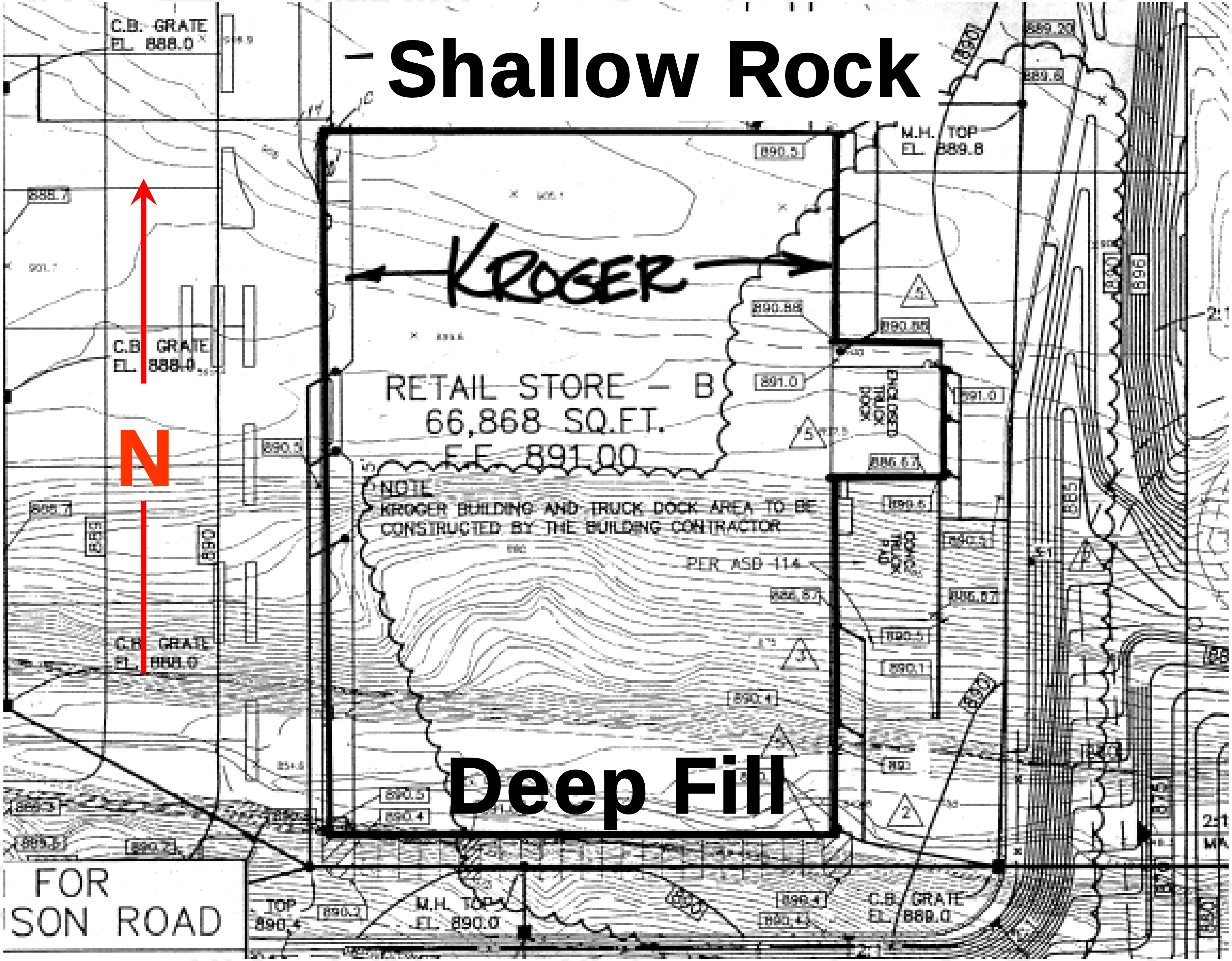
GEOVIRGINIA 2019

Background

CASE STUDY 2:

Overview Pyritic Sulfur

- Store completed in 1996
- Cracks first noticed in 2001 (5 years later)
- Heave is along buried utility corridors
- One Test Pit completed on June 13, 2006
- Laboratory Tests performed
- Monitored Heave with Dial Gauge
- Discuss methods to prevent in future



Site Grading Plan

Floor Slab Heave in 'Back Room'

2 $^{1}/_{8}$" Heave
In 2006

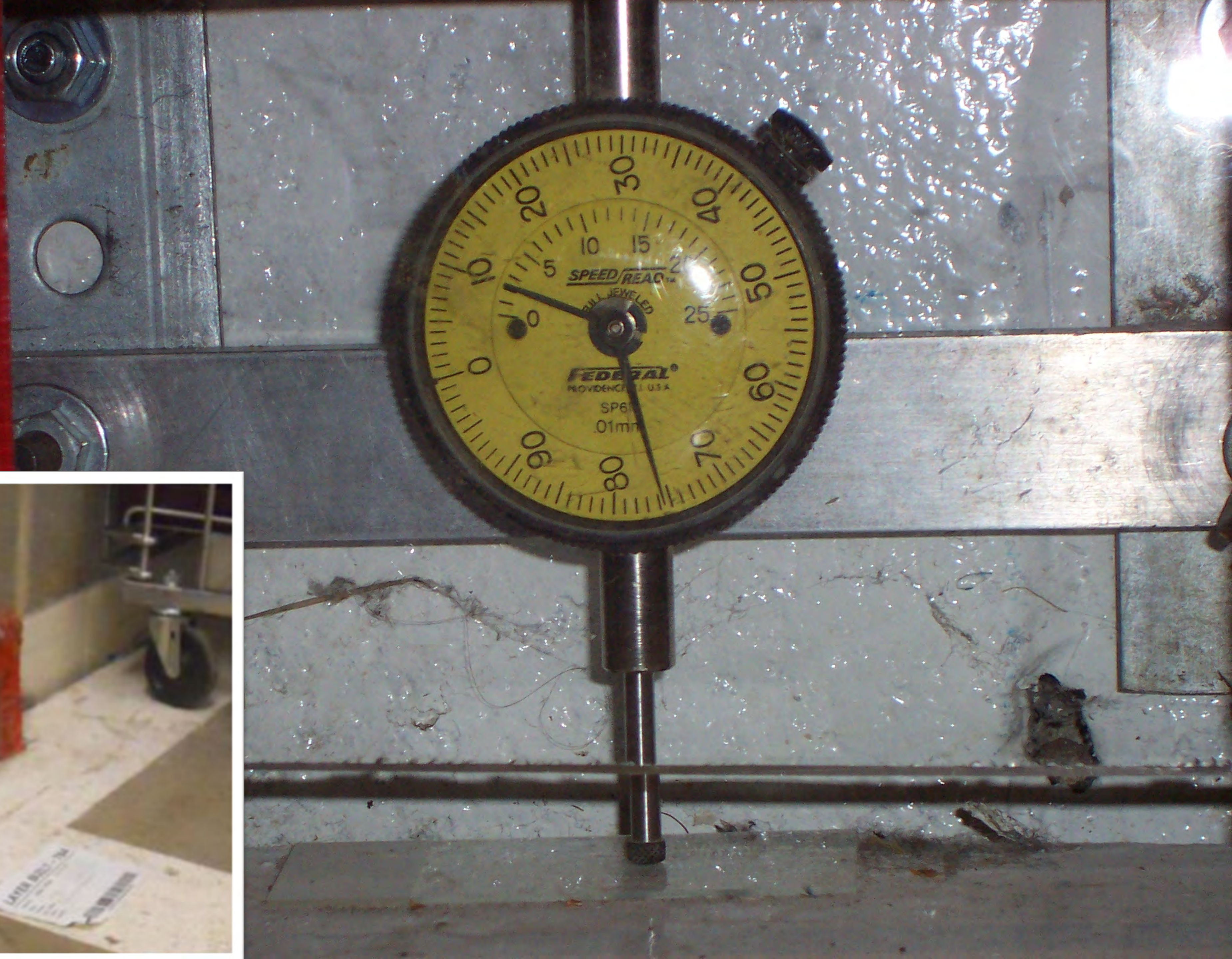
Test Pit
Bag 4

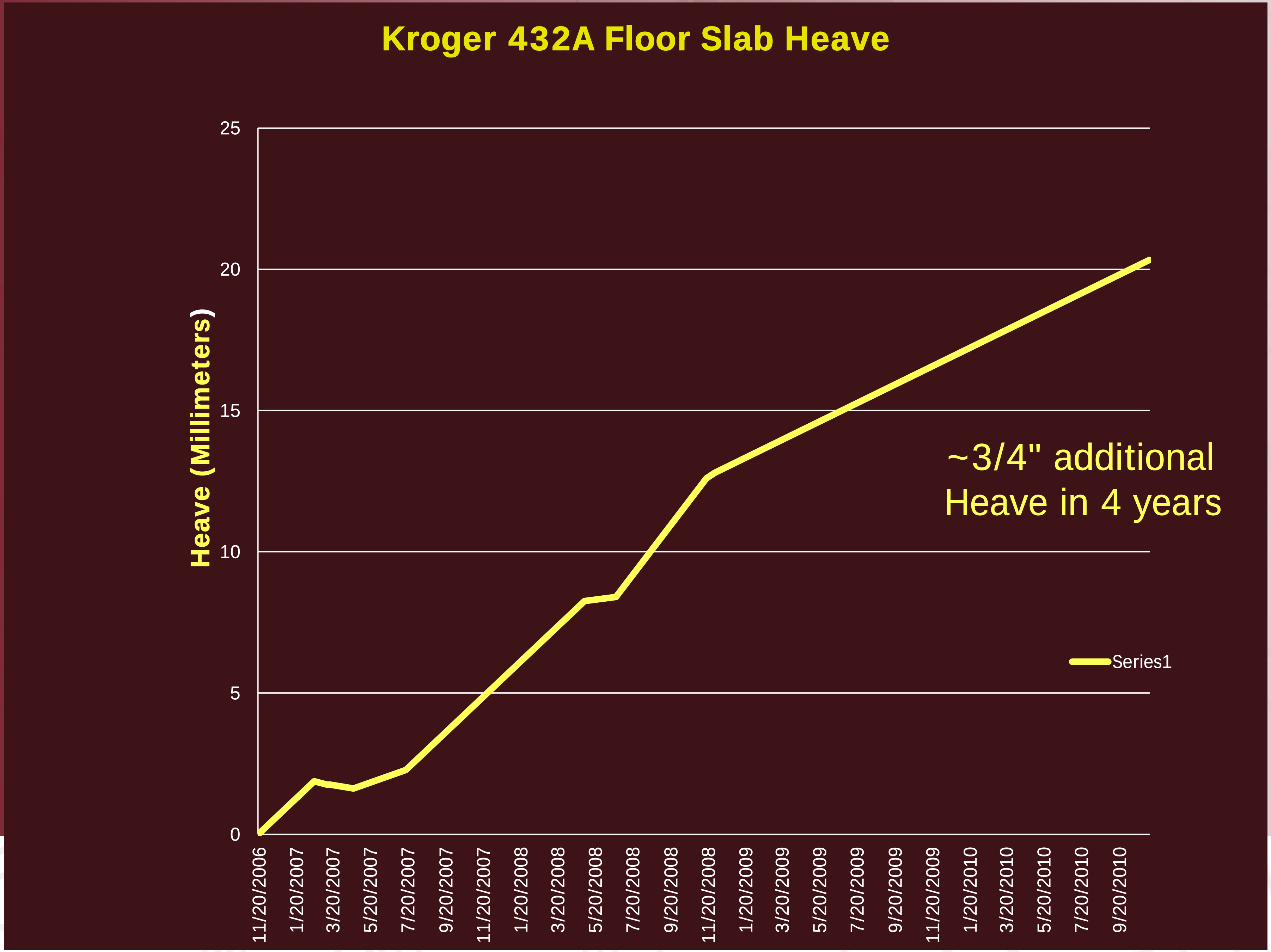
Very Densely Compacted Trench Backfill

Lab Results

- **Five Samples Tested for Pyritic Sulfur.**
- **Results varied from 0.17 to 0.21% Pyritic Sulfur (Sulfide Sulfur).**
- **Tests confirmed presence of Pyritic Sulfur below the slab.**
- **Performed X-Ray Diffraction tests which showed the presence of Basaluminite ($Al_4(SO_4)(OH)_{10}\ 5H_2O$) from the oxidation of Pyrite (H_2S).**

Monitoring over ~4 years

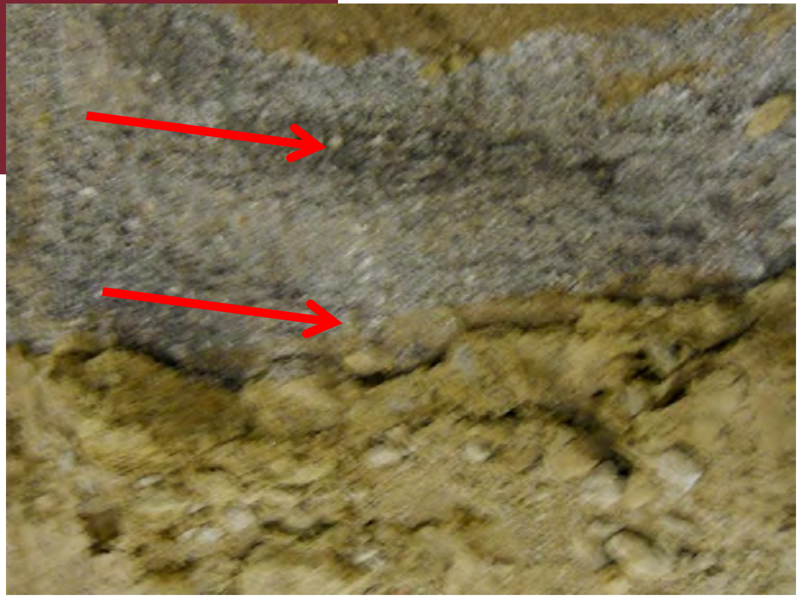




Kept Growing

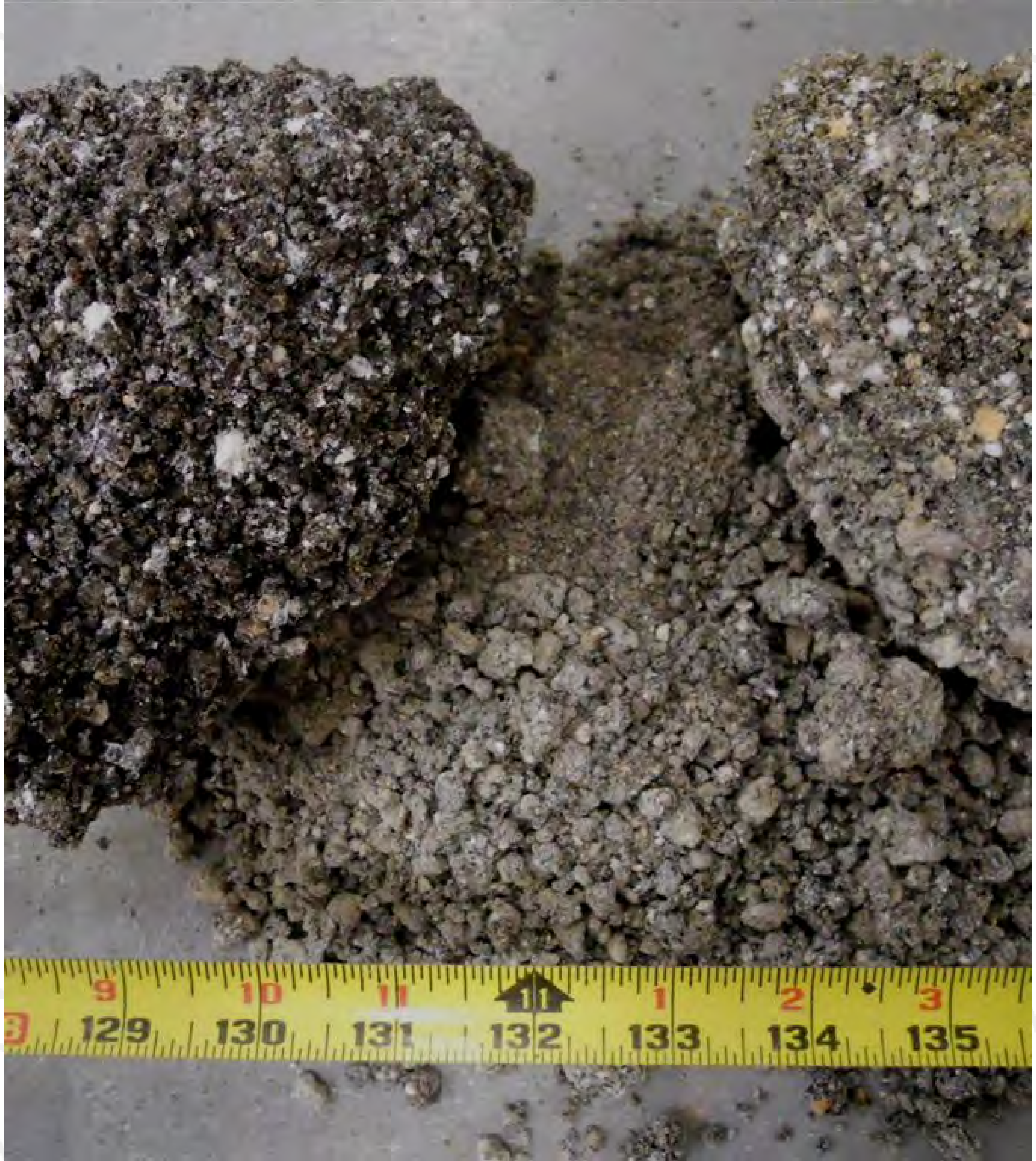
Lesson Learned

Never use slag inside a building



Contaminated Materials

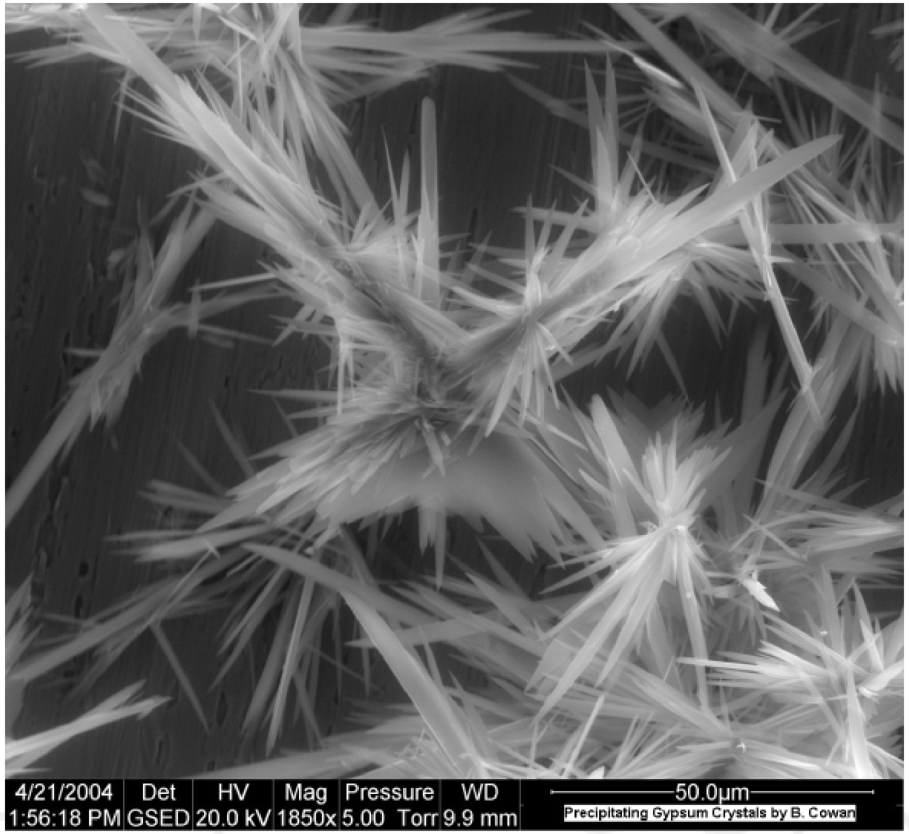
- **Gypsum and Ettringite Crystal Growth**



Ettringite Crystals

GeoVirginia 2019

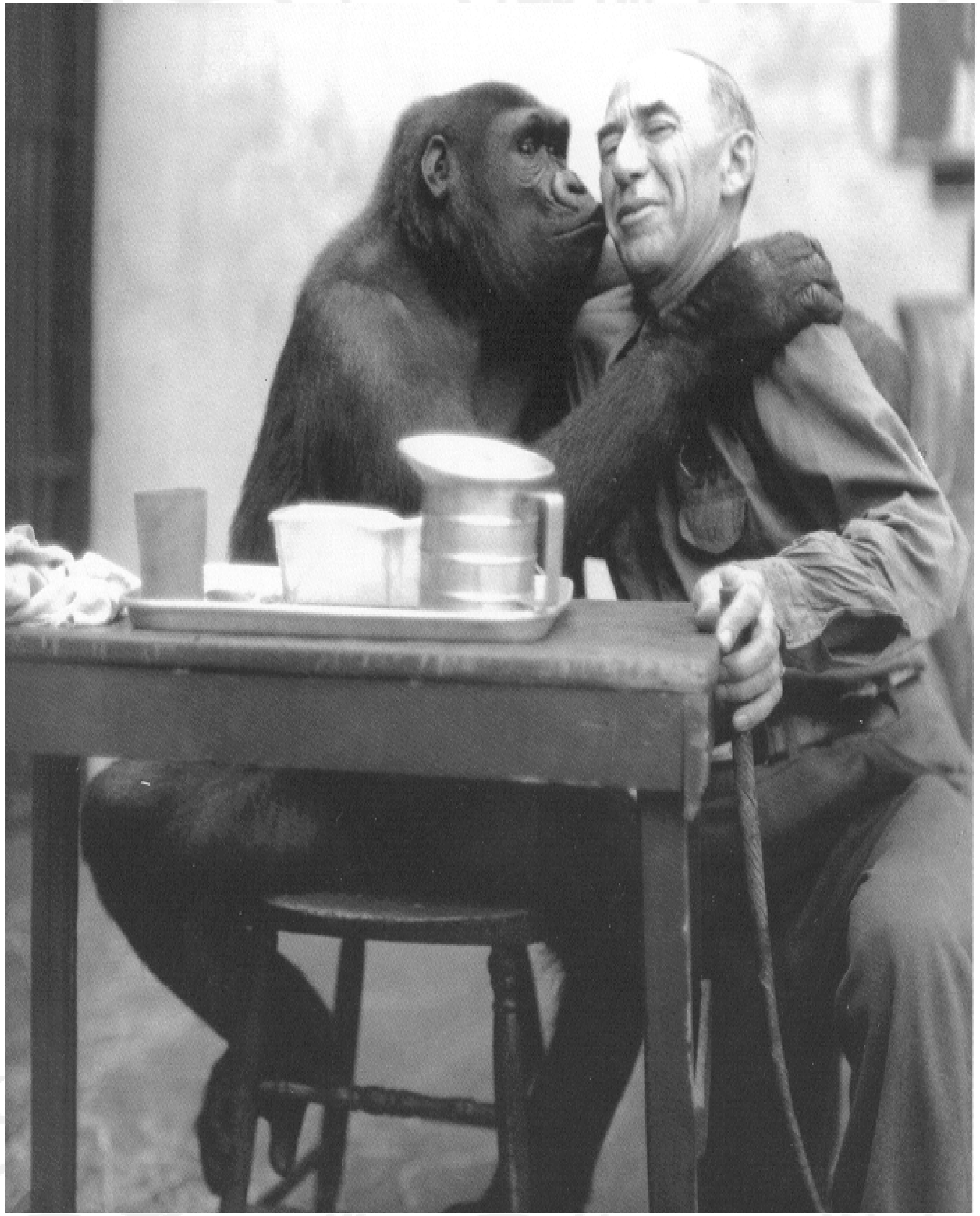
Gypsum Crystals



GEOVIRGINIA 2019

Conclusions

1. **Know the materials you are recycling.**
2. **Never use slag or cinder materials inside of a building.**
3. **Heave pressures from secondary mineral growth are significant.**



Thank You For Your Attention

Questions?

GEO-INSTITUTE

Virginia Chapter

GEOVIRGINIA 2019