PTS Laboratories
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PTS File No.: 37769

9.0

Each Interval Equals One Tenth of a Foot

10.0

Project: North Lake Union   Boring ID: GP-04
Project No.: 37769

PTS Laboratories
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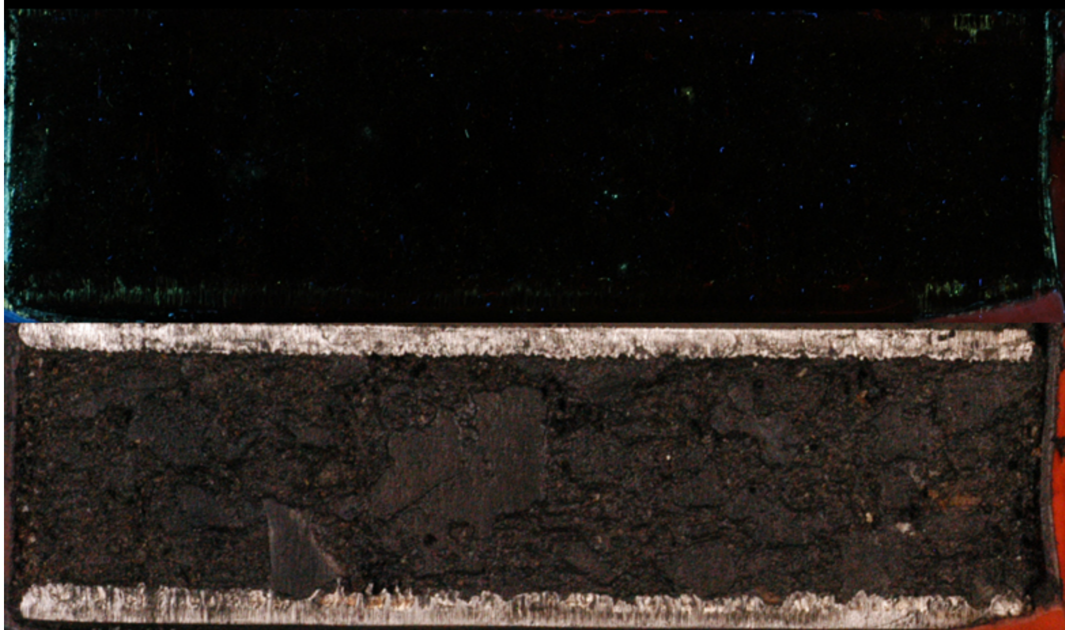
PTS File No.: 37769

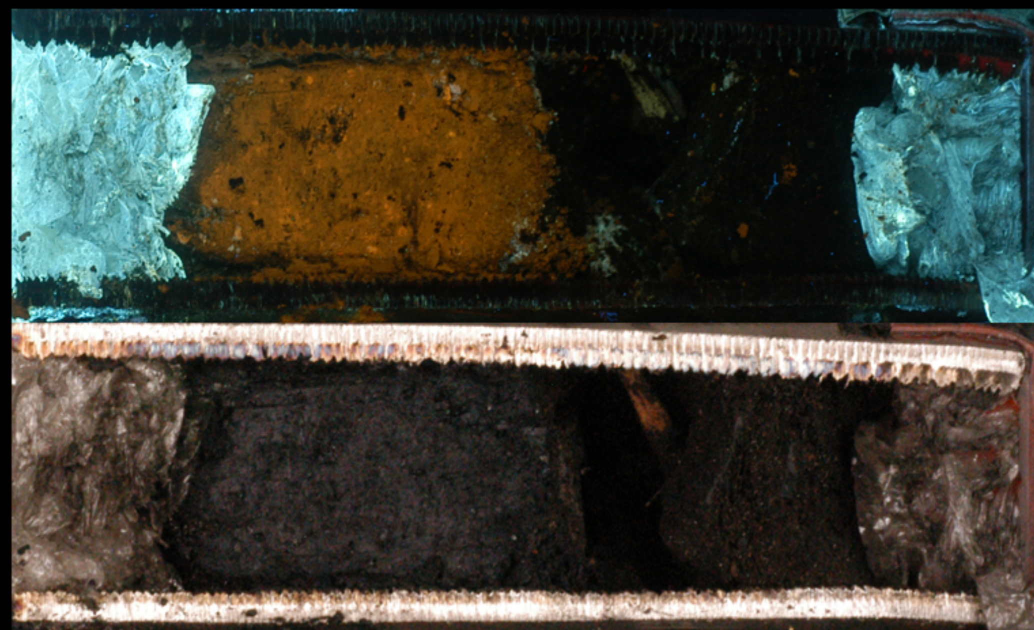


10.0

11.0

Each Interval Equals One Tenth of a Foot

Project: North Lake Union   Boring ID: GP-04
Project No.: 37769



7.0

8.0

Each Interval Equals One Tenth of a Foot

Project: North Lake Union Boring ID: GP-05
Project No.: 37769

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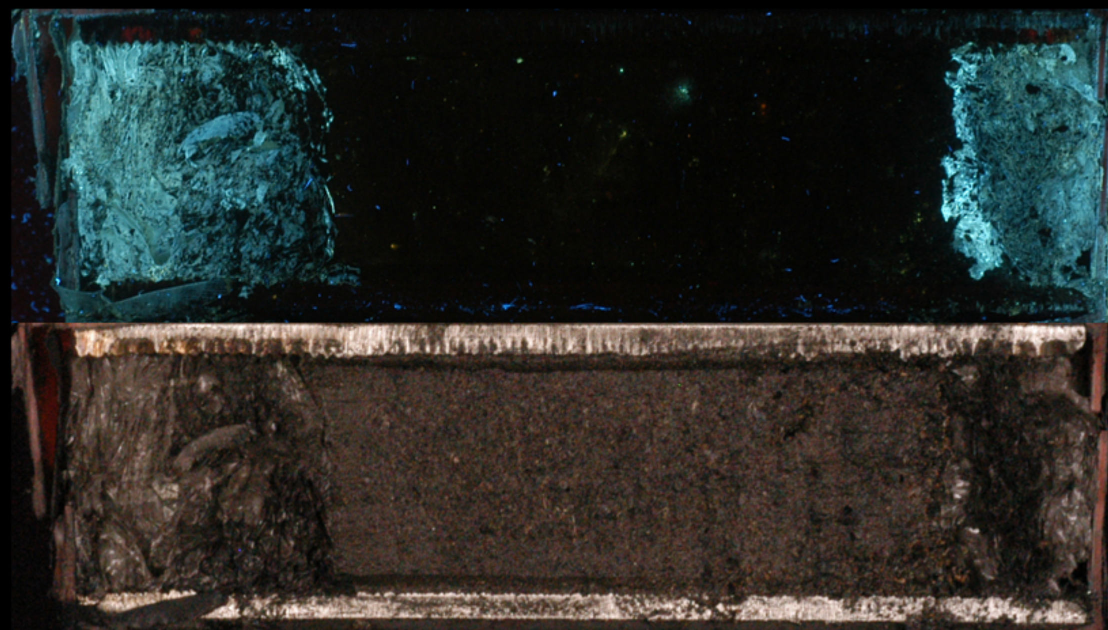
PTS File No.: 37769



14.0
15.0
Each Interval Equals One Tenth of a Foot

Project: North Lake Union Boring ID: GP-05
Project No.: 37769

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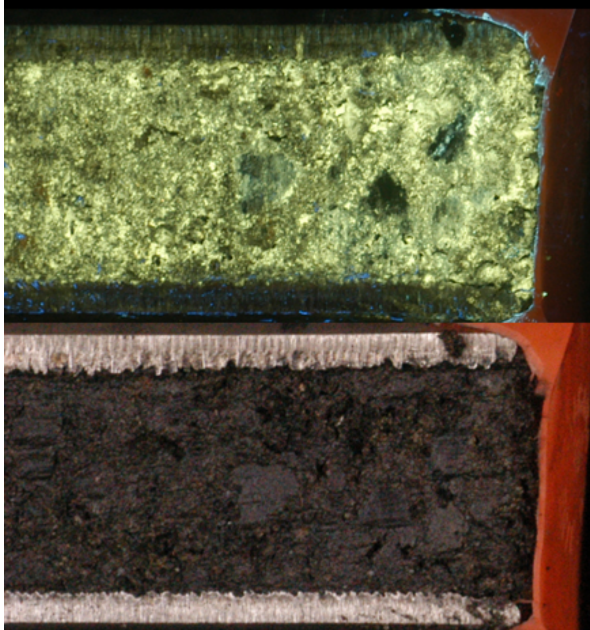
PTS File No.: 37769



9.0

10.0

Each Interval Equals One Tenth of a Foot

Project: North Lake Union   Boring ID: GP-09R1
Project No.: 37769

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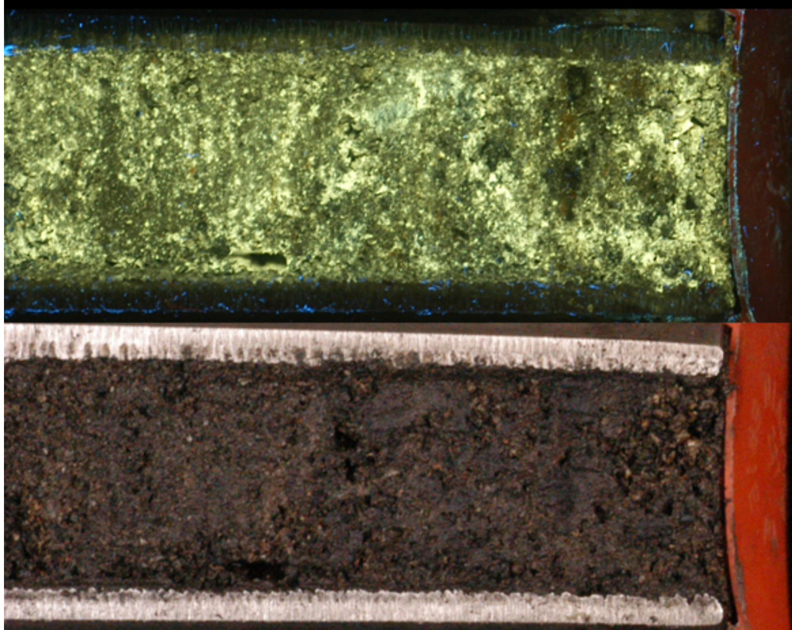
PTS File No.: 37769



11.0 — 12.0

Each Interval Equals One Tenth of a Foot

Project: North Lake Union Boring ID: GP-09R1

Project No.: 37769

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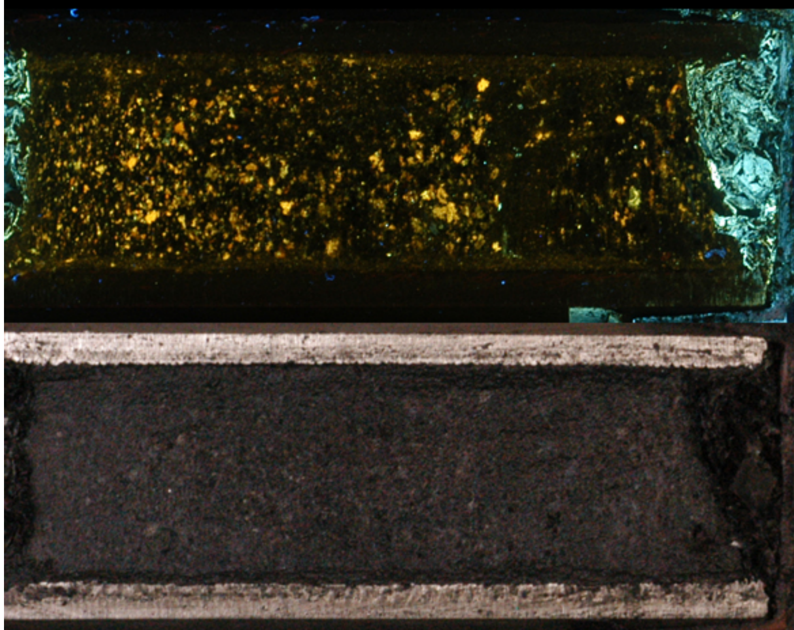
PTS File No.: 37769

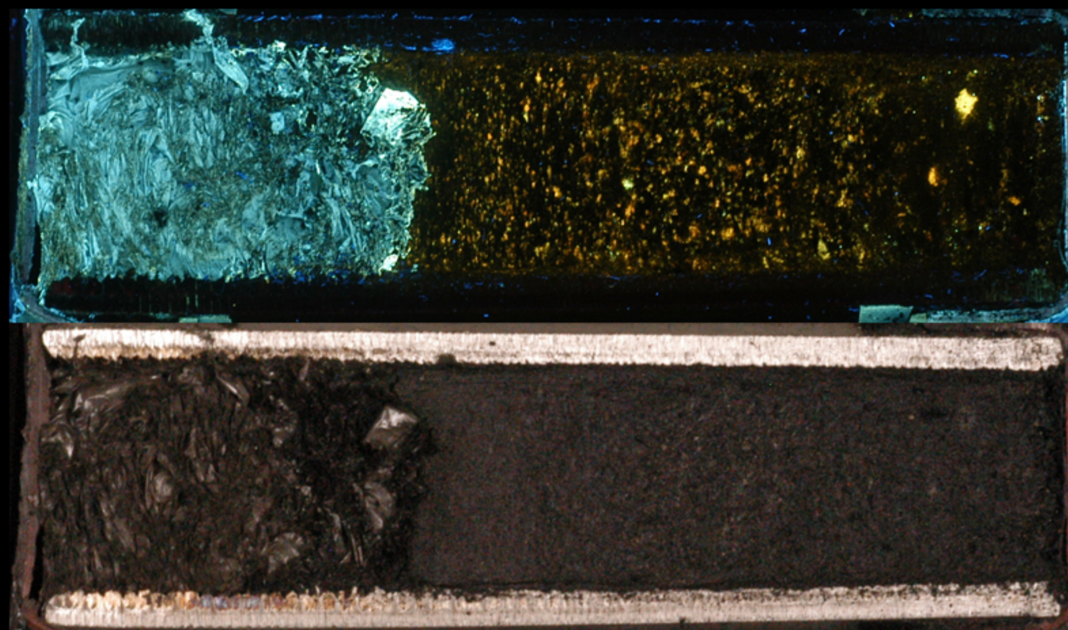


21.0

22.0

Each Interval Equals One Tenth of a Foot

Project: North Lake Union   Boring ID: GP-11
Project No.: 37769



22.0

23.0

Each Interval Equals One Tenth of a Foot

Project: North Lake Union Boring ID: GP-11
Project No.: 37769

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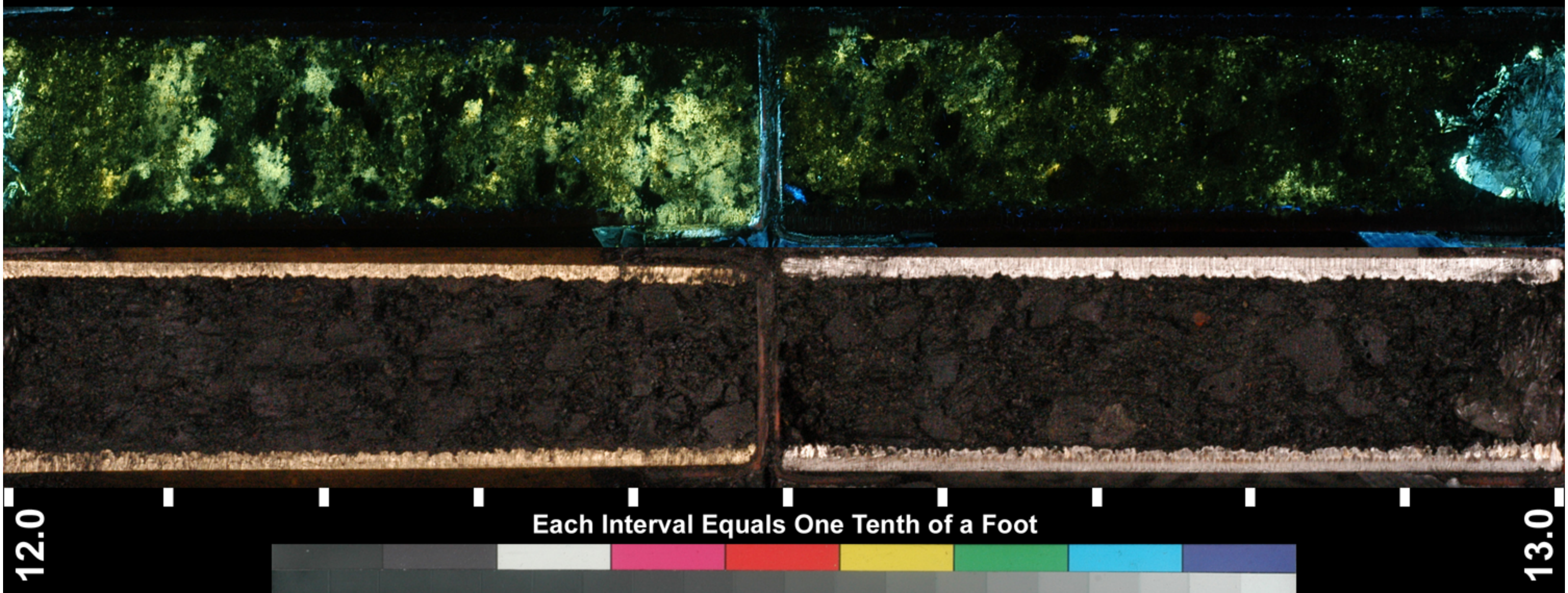
PTS File No.: 37769



Project: North Lake Union Boring ID: GP-11R3
Project No.: 37769

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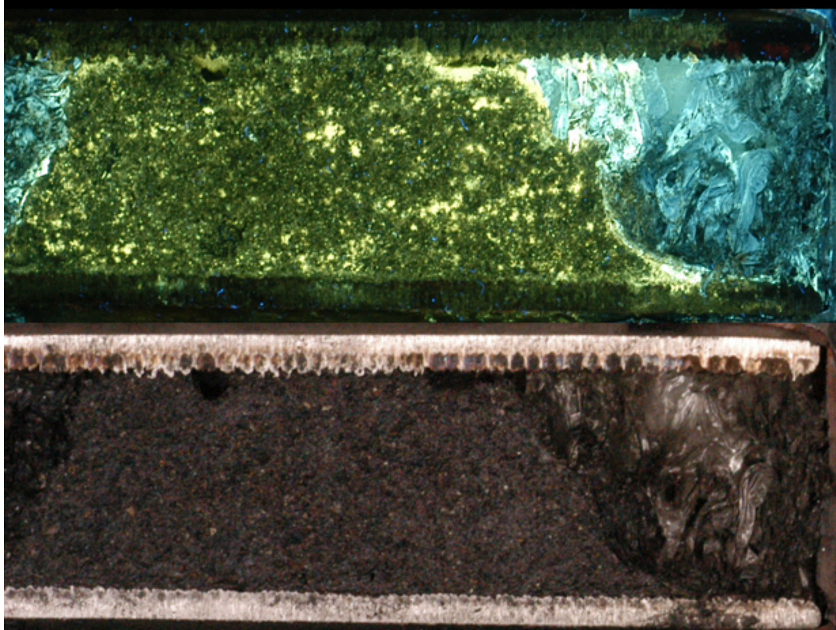
PTS File No.: 37769



11.0

12.0

Each Interval Equals One Tenth of a Foot

Project: North Lake Union Boring ID: GP-12R1
Project No.: 37769

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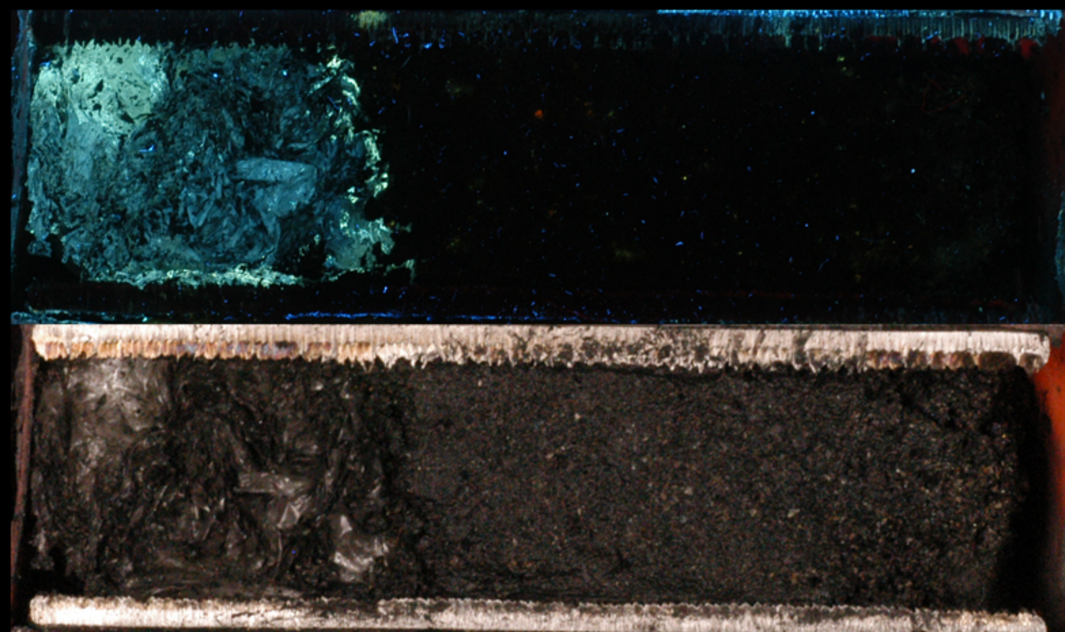
PTS File No.: 37769



23.0

24.0

Each Interval Equals One Tenth of a Foot

Project: North Lake Union   Boring ID: GP-12R1
Project No.: 37769

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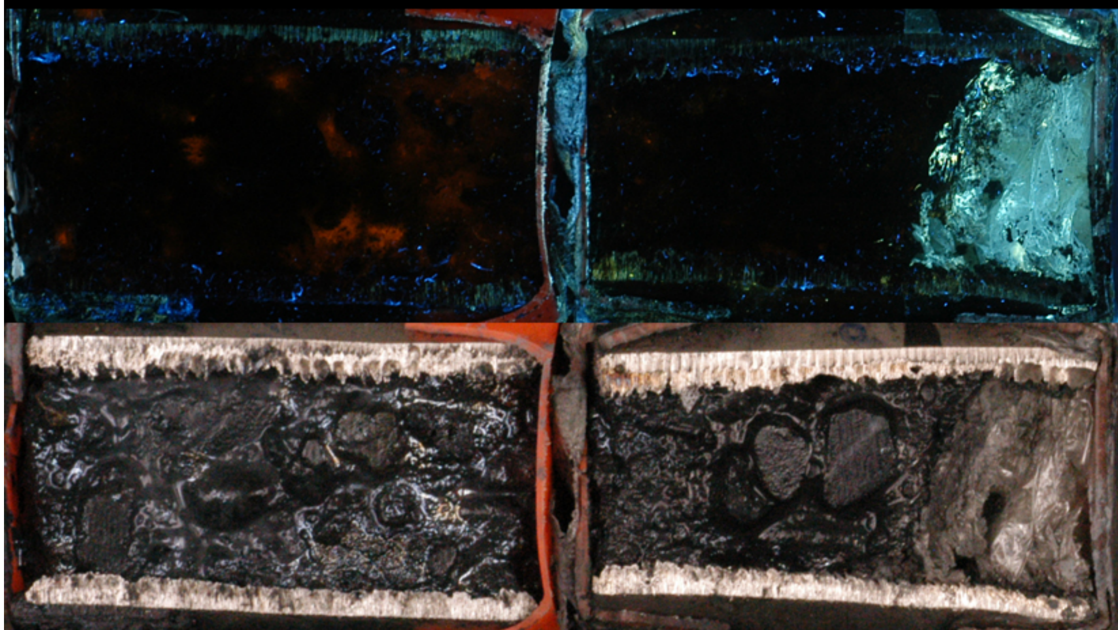
ENVIRONMENTAL SERVICES
PTS File No.: 37769



25.0

Each Interval Equals One Tenth of a Foot

26.0

Project: North Lake Union Boring ID: GP-12R1
Project No.: 37769

Petrophysical Data

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PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL/WATER CAPILLARY PRESSURE

(ASTM D6836; Drainage Centrifugal Method: native sample, air displacing NAPL and water)

Final (Post-Test) Saturations

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

		METHODS:	API RP 40 / ASTM D2216	API RP 40		API RP 40		API RP 40	
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	MOISTURE CONTENT, % weight	DENSITY		POROSITY, %Vb (2)		PORE FLUID SATURATIONS, % Pv (3)	
				BULK, g/cc	GRAIN, g/cc	TOTAL	AIR FILLED	WATER	NAPL
GP-05-7.5-8.0	7.6	H	49.6	0.75	1.80	58.3	21.1	25.1	38.8
GP-09RI-9.0-9.5	9.15	H	25.3	0.90	2.25	60.2	37.6	21.4	16.2
GP-11R3-12.0-12.5	12.45	H	26.9	0.97	2.25	57.1	40.9	8.7	19.5
GP-12R1-11.0-11.5	11.2	H	14.9	0.85	2.25	62.1	49.0	18.6	2.4

(1) Sample Orientation: H = horizontal; V = vertical (2) Total Porosity = no pore fluids in place; all interconnected pore channels; Air Filled = pore channels not occupied by pore fluids (3) Water = 0.9996 g/cc, Hydrocarbon = 1.000 g/cc; Vb = Bulk Volume, cc; Pv = Pore Volume, cc; ND = Not Detected

PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL-WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: native sample, air displacing NAPL and water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

Capillary Pressure			Height Above Water Table,	Sample ID GP-05-7.5-8.0 at 7.6 ft.	
psi	bar	cm water	ft	Water Saturation, % pore volume	NAPL Saturation, % pore volume
0.000	0.000	0.00	0.000	48.9	38.8
0.091	0.006	6.37	0.210	48.9	38.8
0.363	0.025	25.50	0.839	48.9	38.8
0.816	0.056	57.37	1.89	48.9	38.8
1.450	0.100	101.98	3.36	48.4	38.8
2.27	0.156	159.35	5.25	46.7	38.8
3.26	0.225	229.46	7.55	43.6	38.8
4.75	0.328	334.11	11.0	40.1	38.8
5.80	0.400	407.94	13.4	37.4	38.8
7.34	0.506	516.29	17.0	33.9	38.8
9.07	0.625	637.40	21.0	30.8	38.8
20.4	1.41	1434.15	47.2	26.8	38.8
56.7	3.91	3983.75	131	25.1	38.8

Note: No NAPL produced by sample GP-05-7.5-8.0 at 7.6 ft.

PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL-WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: native sample, air displacing NAPL and water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

Capillary Pressure			Height Above Water Table, ft	Sample ID: **GP-09RI-9.0-9.5 at 9.15 ft.**	
psi	bar	cm water		Water Saturation, % pore volume	NAPL Saturation, % pore volume
0.000	0.000	0.00	0.000	70.7	16.2
0.090	0.006	6.32	0.208	70.7	16.2
0.359	0.025	25.27	0.832	70.7	16.2
0.809	0.056	56.86	1.87	53.0	16.2
1.438	0.099	101.08	3.33	40.4	16.2
2.25	0.155	157.94	5.20	34.1	16.2
3.23	0.223	227.43	7.49	30.3	16.2
4.71	0.325	331.16	10.9	26.9	16.2
5.75	0.396	404.33	13.3	25.2	16.2
7.28	0.502	511.73	16.8	24.4	16.2
8.99	0.620	631.76	20.8	23.4	16.2
20.2	1.39	1421.47	46.8	22.3	16.2
56.2	3.87	3948.52	130	21.4	16.2

Note: No NAPL produced by sample GP-09RI-9.0-9.5 at 9.15 ft.

PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL-WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: native sample, air displacing NAPL and water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

Capillary Pressure			Height Above Water Table, ft	Sample ID GP-11R3-12.0-12.5 at 12.45 ft.	
psi	bar	cm water		Water Saturation, % pore volume	NAPL Saturation, % pore volume
0.000	0.000	0.00	0.000	70.2	19.5
0.093	0.006	6.53	0.215	70.2	19.5
0.371	0.026	26.11	0.859	68.4	19.5
0.836	0.058	58.75	1.93	43.9	19.5
1.486	0.102	104.45	3.44	34.2	19.5
2.32	0.160	163.20	5.37	28.1	19.5
3.34	0.230	235.01	7.74	23.7	19.5
4.87	0.336	342.19	11.3	19.7	19.5
5.94	0.410	417.80	13.8	17.5	19.5
7.52	0.519	528.78	17.4	15.8	19.5
9.28	0.640	652.81	21.5	14.0	19.5
20.9	1.44	1468.82	48.3	9.6	19.5
58.0	4.00	4080.06	134	8.7	19.5

Note: No NAPL produced by sample GP-11R3-12.0-12.5 at 12.45 ft.

PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL-WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: native sample, air displacing NAPL and water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

Capillary Pressure			Height Above Water Table, ft	Sample ID: **GP-12R1-11.0-11.5 at 11.2 ft.**	
psi	bar	cm water		Water Saturation, % pore volume	NAPL Saturation, % pore volume
0.000	0.000	0.00	0.000	87.8	2.4
0.090	0.006	6.30	0.207	84.1	2.4
0.359	0.025	25.21	0.830	82.3	2.4
0.807	0.056	56.73	1.87	55.9	2.4
1.434	0.099	100.86	3.32	44.1	2.4
2.24	0.155	157.59	5.19	36.8	2.4
3.23	0.223	226.93	7.47	32.2	2.4
4.70	0.324	330.41	10.9	28.2	2.4
5.74	0.396	403.42	13.3	25.9	2.4
7.26	0.501	510.58	16.8	23.9	2.4
8.97	0.618	630.35	20.7	22.2	2.4
20.2	1.39	1418.29	46.7	19.5	2.4
56.0	3.86	3939.69	130	18.6	2.4

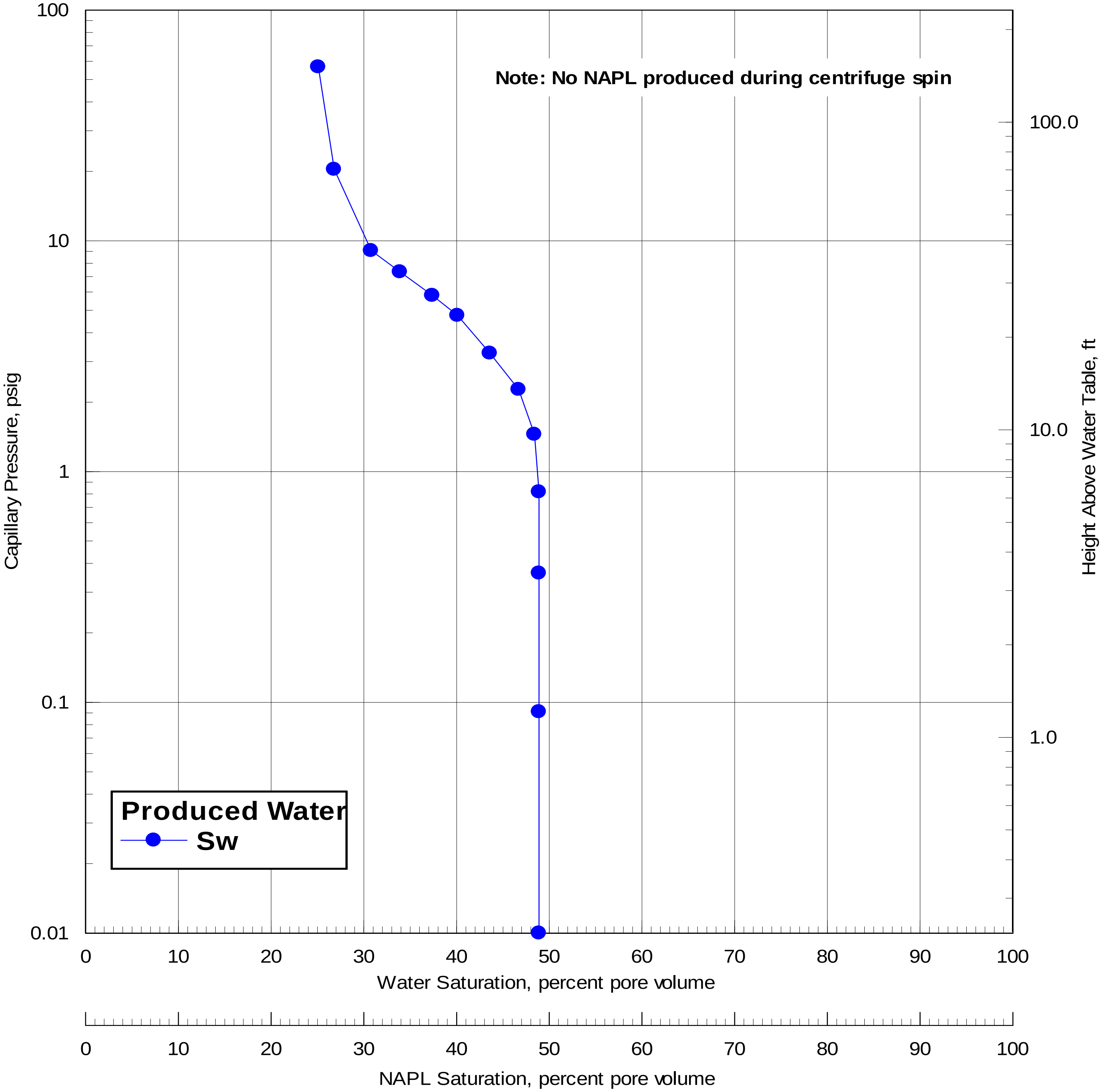
Note: No NAPL produced by sample GP-12R1-11.0-11.5 at 11.2 ft.

RETEC/ENSR
File No.: 37769

CAPILLARY PRESSURE
Centrifugal Method
Air Displacing Oil and Water System - ASTM D6836

Project Name: North Lake Union
Project No: 05570028-360

Sample ID: GP-05-7.5-8.0
Depth, ft: 7.6

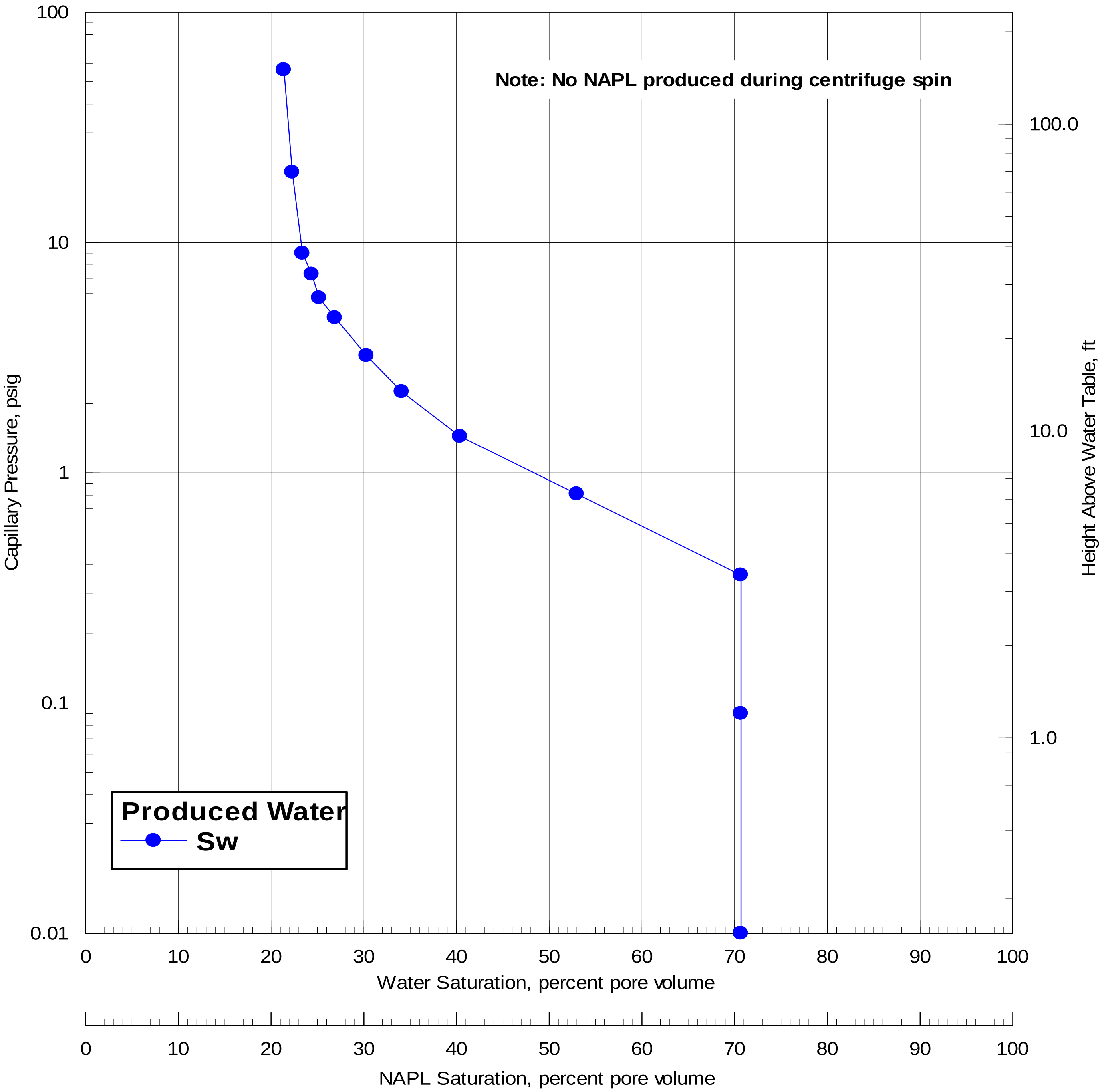


RETEC/ENSR
File No.: 37769

CAPILLARY PRESSURE
Centrifugal Method
Air Displacing Oil and Water System - ASTM D6836

Project Name: North Lake Union
Project No: 05570028-360

Sample ID: GP-09RI-9.0-9.5
Depth, ft: 9.15



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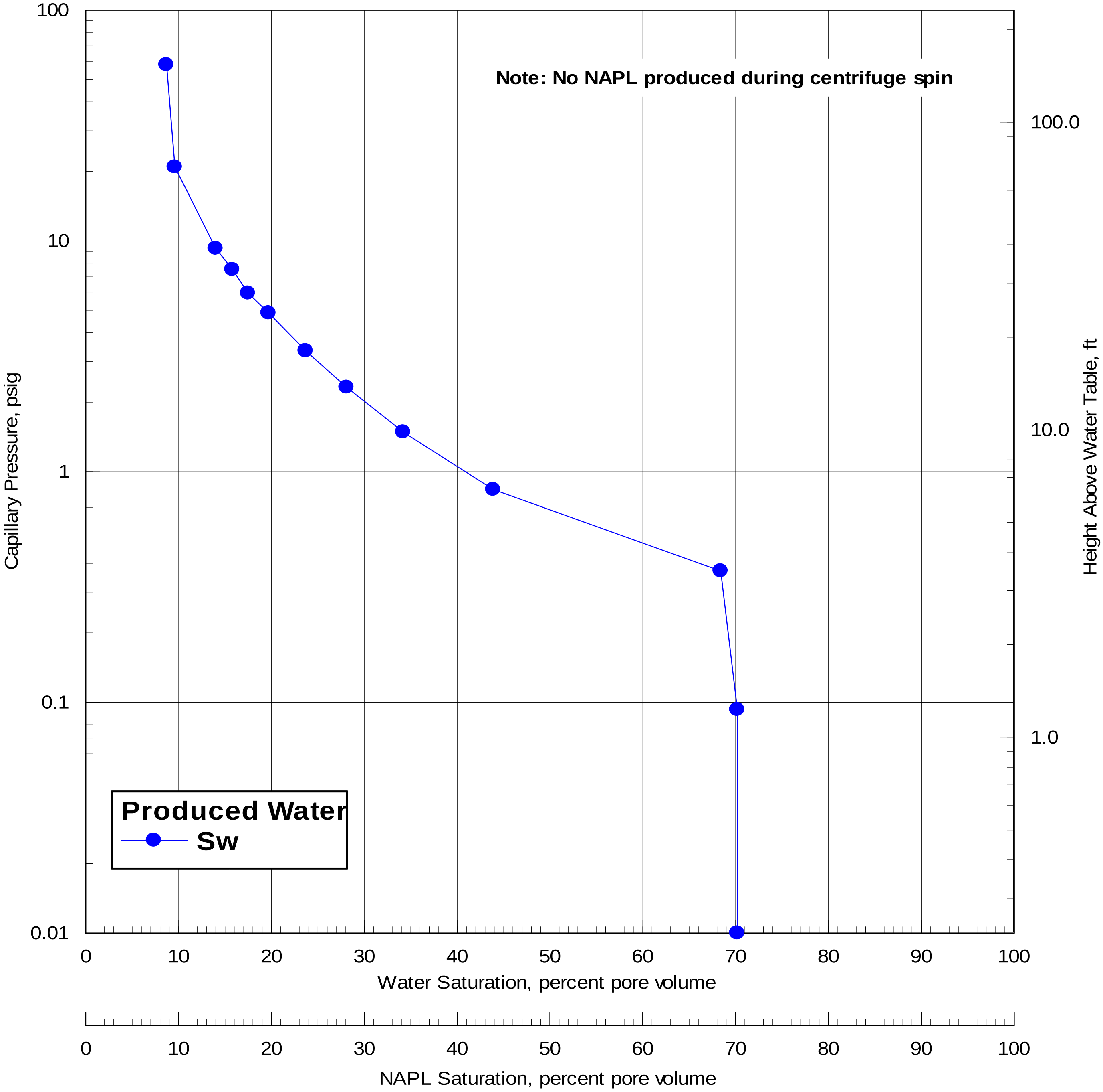
File No.: 37769

CAPILLARY PRESSURE
Centrifugal Method

Air Displacing Oil and Water System - ASTM D6836

Project Name: North Lake Union
Project No: 05570028-360

Sample ID: GP-11R3-12.0-12.5
Depth, ft: 12.45



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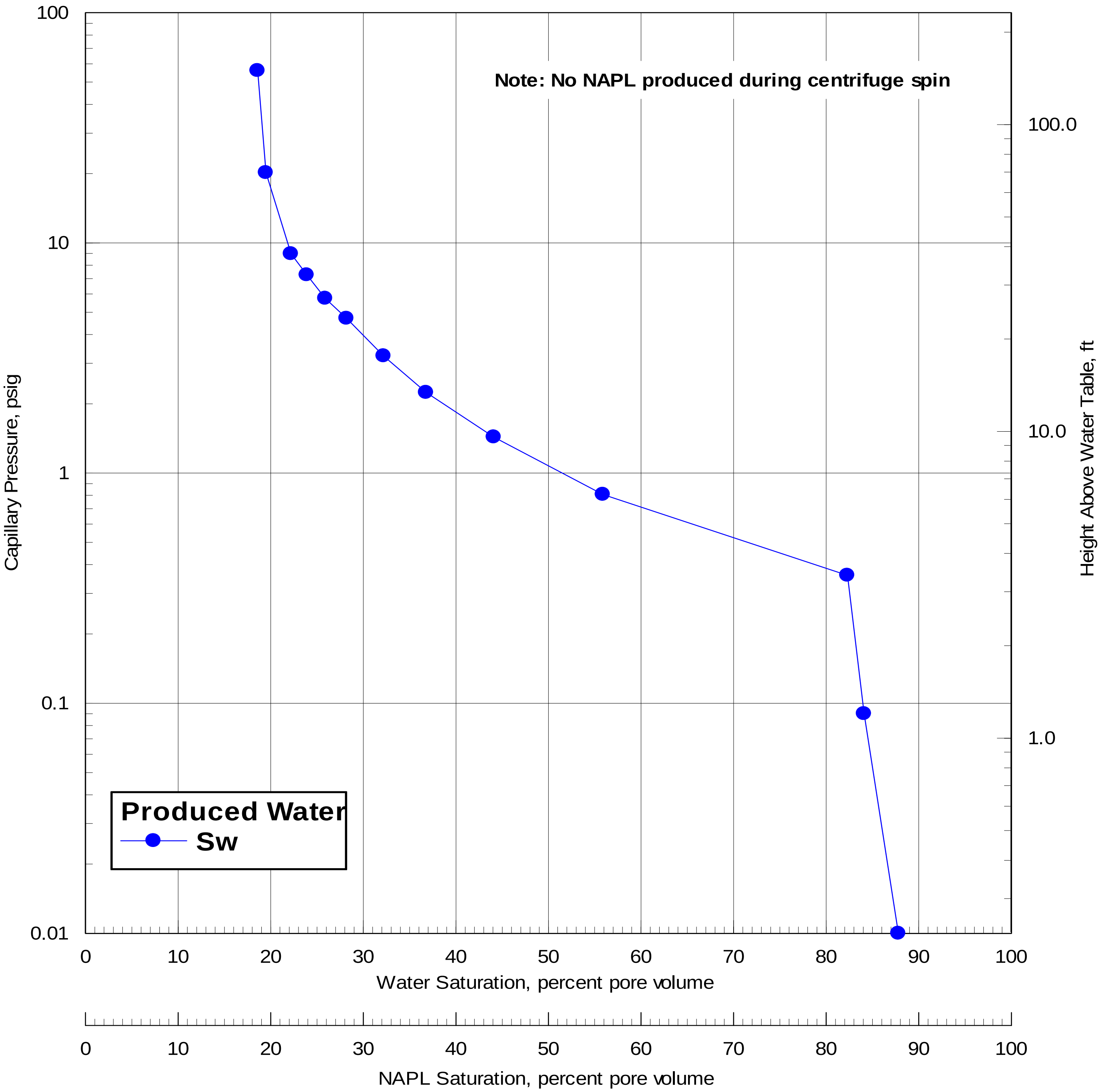
File No.: 37769

CAPILLARY PRESSURE
Centrifugal Method
Air Displacing Oil and Water System - ASTM D6836

Project Name: North Lake Union
Project No: 05570028-360

Sample ID: GP-12R1-11.0-11.5
Depth, ft: 11.2



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PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL/WATER CAPILLARY PRESSURE

(ASTM D6836; Imbibition Centrifugal Method: native sample, water displacing air and NAPL)

Final (Post-Test) Saturations

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

		METHODS:	**API RP 40 / ASTM D2216**	**API RP 40**		**API RP 40**		**API RP 40**	
		SAMPLE	MOISTURE	DENSITY		POROSITY, %Vb (2)		PORE FLUID SATURATIONS, % Pv (3)	
SAMPLE ID.	DEPTH, ft.	ORIENTATION (1)	CONTENT, % weight	BULK, g/cc	GRAIN, g/cc	TOTAL	AIR FILLED	WATER	NAPL
GP-02-12.5-13.0	12.55	H	15.6	1.72	2.62	34.6	7.8	73.3	4.0
GP-09R1-11.0-11.5	11.25	H	77.1	0.71	2.15	66.8	12.1	77.0	4.8
GP-11-21.0-21.5	21.05	H	106.6	0.64	2.05	68.6	0.5	82.9	16.4
GP-11-22.5-23.0	22.7	H	74.9	0.74	2.03	63.4	7.8	80.0	7.7
GP-11R3-12.0-12.5	12.3	H	68.2	0.88	2.12	58.5	0.3	92.7	6.8
GP-12R1-25.0-25.25	25.15	H	18.2	1.71	2.59	34.1	3.3	85.8	4.6

(1) Sample Orientation: H = horizontal; V = vertical (2) Total Porosity = no pore fluids in place; all interconnected pore channels; Air Filled = pore channels not occupied by pore fluids (3) Water = 0.9996 g/cc, Hydrocarbon = 1.000 g/cc; Vb = Bulk Volume, cc; Pv = Pore Volume, cc; ND = Not Detected

PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL/WATER CAPILLARY PRESSURE

(ASTM D6836; Imbibition Centrifugal Method: native sample, water displacing air and NAPL)

PROJECT NAME North Lake Union
PROJECT NO: 05570028-360

Capillary Pressure		Height Above Water Table, ft	Sample ID: **GP-02-12.5-13.0 at 12.55.0 ft.**		
psi	cm water		Water Saturation, % pore volume	Oil Saturation, % pore volume	Air Saturation, % pore volume
0.000	0.00	0.000	N/A	4.0	N/A
0.092	6.47	0.213	N/A	4.0	N/A
0.368	25.9	0.852	N/A	4.0	N/A
0.828	58.2	1.92	N/A	4.0	N/A
1.47	104	3.41	N/A	4.0	N/A
2.30	162	5.33	N/A	4.0	N/A
4.51	317	10.4	N/A	4.0	N/A
7.46	524	17.3	N/A	4.0	N/A
20.7	1456	47.9	N/A	4.0	N/A
56.8	3997	132	73.4	4.0	22.6

No visible free product produced.

Note: No NAPL produced by spontaneous imbibition.

N/A: Air-Water-DNAPL system uses standard drainage centrifuge cups - unable to measure imbibed water.

PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL/WATER CAPILLARY PRESSURE

(ASTM D6836; Imbibition Centrifugal Method: native sample, water displacing air and NAPL)

PROJECT NAME North Lake Union
PROJECT NO: 05570028-360

Capillary Pressure		Height Above Water Table, ft	Sample ID		
			GP-09R1-11.0-11.5 at 11.25.0 ft.		
psi	cm water		Water Saturation, % pore volume	Oil Saturation, % pore volume	Air Saturation, % pore volume
0.000	0.00	0.000	N/A	4.8	N/A
0.088	6.20	0.204	N/A	4.8	N/A
0.353	24.8	0.817	N/A	4.8	N/A
0.794	55.8	1.84	N/A	4.8	N/A
1.41	99	3.27	N/A	4.8	N/A
2.21	155	5.11	N/A	4.8	N/A
4.32	304	10.0	N/A	4.8	N/A
7.15	503	16.5	N/A	4.8	N/A
19.9	1396	45.9	N/A	4.8	N/A
54.5	3831	126	77.0	4.8	18.1

No visible free product produced.

Note: No NAPL produced by spontaneous imbibition.

N/A: Air-Water-DNAPL system uses standard drainage centrifuge cups - unable to measure imbibed water.

PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL/WATER CAPILLARY PRESSURE

(ASTM D6836; Imbibition Centrifugal Method: native sample, water displacing air and NAPL)

PROJECT NAME North Lake Union
PROJECT NO: 05570028-360

Capillary Pressure		Height Above Water Table,	Sample ID		
			GP-11-21.0-21.5 at 21.05 ft.		
psi	cm water	ft	Water Saturation, % pore volume	Oil Saturation, % pore volume	Air Saturation, % pore volume
0.000	0.00	0.000	N/A	16.7	N/A
0.089	6.26	0.206	N/A	16.7	N/A
0.356	25.0	0.824	N/A	16.7	N/A
0.801	56.3	1.85	N/A	16.7	N/A
1.42	100	3.30	N/A	16.7	N/A
2.23	157	5.15	N/A	16.6	N/A
4.36	307	10.1	N/A	16.6	N/A
7.21	507	16.7	N/A	16.5	N/A
20.0	1409	46.4	N/A	16.5	N/A
55.0	3866	127	82.9	16.3	0.7

Trace of NAPL produced during final five points.

Note: No NAPL produced by spontaneous imbibition.

N/A: Air-Water-DNAPL system uses standard drainage centrifuge cups - unable to measure imbibed water.

PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL/WATER CAPILLARY PRESSURE

(ASTM D6836; Imbibition Centrifugal Method: native sample, water displacing air and NAPL)

PROJECT NAME North Lake Union
PROJECT NO: 05570028-360

Capillary Pressure		Height Above Water Table,	Sample ID GP-11-22.5-23.0 at 22.7 ft.		
psi	cm water	ft	Water Saturation, % pore volume	Oil Saturation, % pore volume	Air Saturation, % pore volume
0.000	0.00	0.000	N/A	7.9	N/A
0.089	6.25	0.206	N/A	7.9	N/A
0.355	25.0	0.822	N/A	7.9	N/A
0.800	56.2	1.85	N/A	7.9	N/A
1.42	100	3.29	N/A	7.9	N/A
2.22	156	5.14	N/A	7.9	N/A
4.35	306	10.1	N/A	7.9	N/A
7.20	506	16.7	N/A	7.8	N/A
20.0	1406	46.3	N/A	7.8	N/A
54.9	3858	127	79.9	7.7	12.3

Trace of NAPL produced during final three points.

Note: No NAPL produced by spontaneous imbibition.

N/A: Air-Water-DNAPL system uses standard drainage centrifuge cups - unable to measure imbibed water.

PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL/WATER CAPILLARY PRESSURE

(ASTM D6836; Imbibition Centrifugal Method: native sample, water displacing air and NAPL)

PROJECT NAME North Lake Union
PROJECT NO: 05570028-360

Capillary Pressure		Height Above Water Table, ft	Sample ID: **GP-11R3-12.0-12.5 at 12.3 ft.**		
psi	cm water		Water Saturation, % pore volume	Oil Saturation, % pore volume	Air Saturation, % pore volume
0.000	0.00	0.000	89.0	6.7	4.3
0.088	6.19	0.204	89.1	6.7	4.2
0.352	24.8	0.815	89.3	6.7	4.0
0.792	55.7	1.83	89.6	6.7	3.7
1.41	99	3.26	89.7	6.7	3.5
2.20	155	5.09	90.2	6.7	3.0
4.31	303	10.0	91.1	6.7	2.2
7.13	501	16.5	91.6	6.7	1.6
19.8	1393	45.8	92.3	6.7	0.9
54.4	3823	126	92.7	6.7	0.6

No visible free product produced.

Note: No NAPL produced by spontaneous imbibition.

Air-Water-LNAPL system uses standard imbibition centrifuge cups.

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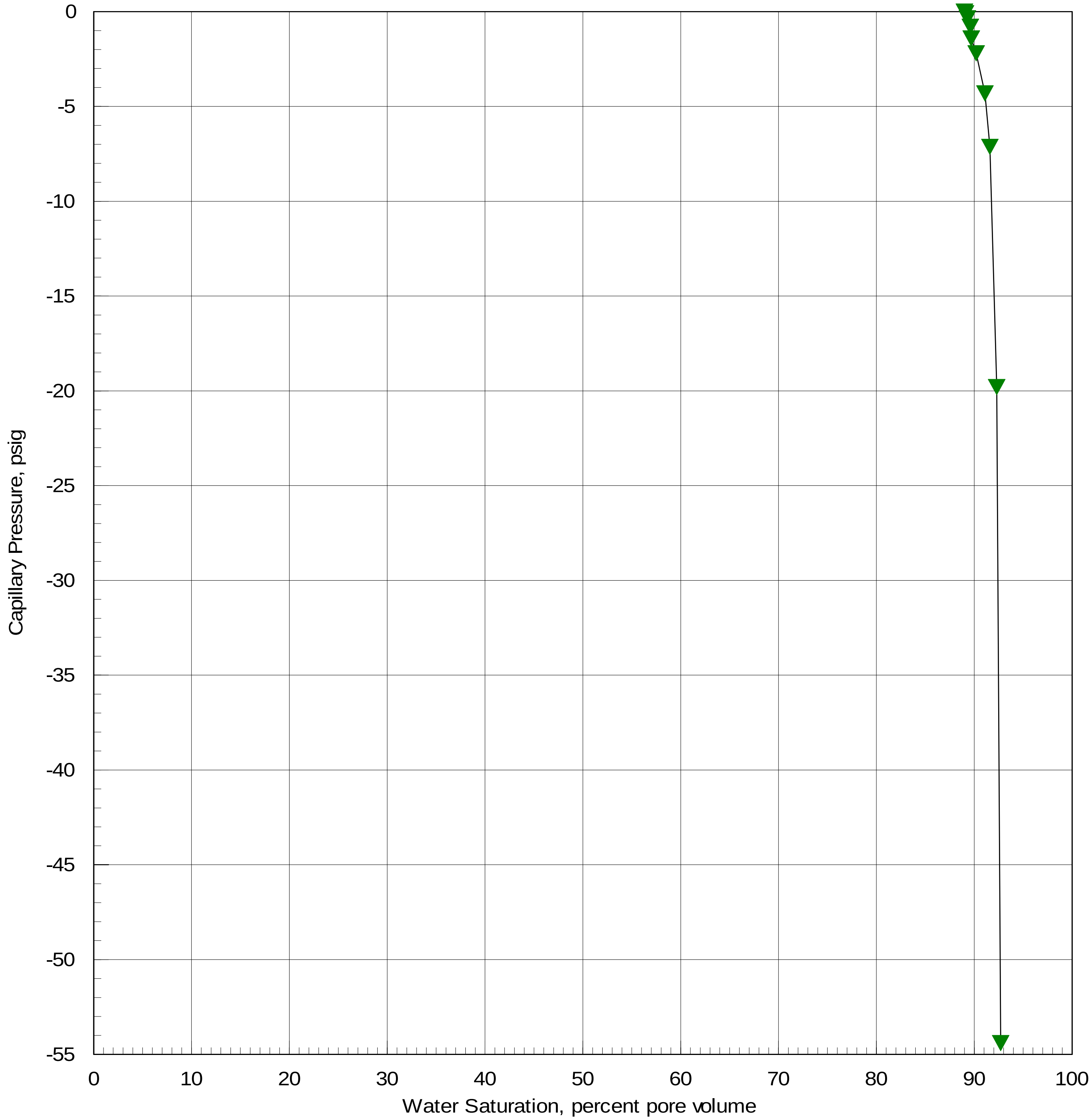
RETEC/ENSR
File No.: 37769

CAPILLARY PRESSURE
Native Sample - Centrifugal Method
Air/Water Imbibition - ASTM D6836

Project Name: North Lake Union
Project Number: 05570028-360

Sample ID: GP-11R3-12.0-12.5
Depth, ft.: 12.3



PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/OIL/WATER CAPILLARY PRESSURE

(ASTM D6836; Imbibition Centrifugal Method: native sample, water displacing air and NAPL)

PROJECT NAME North Lake Union
PROJECT NO: 05570028-360

Capillary Pressure		Height Above Water Table, ft	Sample ID: **GP-12R1-25.0-25.25 at 25.15 ft.**		
psi	cm water		Water Saturation, % pore volume	Oil Saturation, % pore volume	Air Saturation, % pore volume
0.000	0.00	0.000	N/A	5.0	N/A
0.092	6.49	0.213	N/A	5.0	N/A
0.369	25.9	0.854	N/A	5.0	N/A
0.830	58.4	1.92	N/A	5.0	N/A
1.48	104	3.42	N/A	5.0	N/A
2.31	162	5.34	N/A	4.8	N/A
4.52	318	10.5	N/A	4.8	N/A
7.47	525	17.3	N/A	4.7	N/A
20.8	1459	48.0	N/A	4.7	N/A
57.0	4005	132	85.8	4.5	9.7

Trace of NAPL produced during final five points.

Note: No NAPL produced by spontaneous imbibition.

N/A: Air-Water-DNAPL system uses standard drainage centrifuge cups - unable to measure imbibed water.

PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

		METHODS:	API RP 40 / ASTM D2216	API RP 40		API RP 40		API RP 40
		SAMPLE	MOISTURE	DENSITY		POROSITY, %Vb (2)		TOTAL PORE FLUID
SAMPLE ID.	DEPTH, ft.	ORIENTATION (1)	CONTENT, % weight	BULK, g/cc	GRAIN, g/cc	TOTAL	AIR FILLED	SATURATIONS (3), % Pv
GP-02-12.0-12.5	12.1	V	51.6	0.87	2.15	59.8	13.6	77.2
GP-04-9.25-9.5	9.35	V	88.6	0.73	2.23	67.2	1.3	98.1
GP-05-7.5-8.0	7.6	H	49.6	0.75	1.80	58.3	21.1	63.9
GP-05-14.5-15.0	14.65	V	103	0.66	2.21	70.2	2.3	96.8
GP-09RI-9.0-9.5	9.15	V	67.2	0.81	2.24	64.0	4.3	93.3
GP-11-21.0-21.5	21.2	V	99.3	0.65	2.11	69.1	2.3	96.7
GP-11R3-12.5-13.0	12.7	V	43.8	1.10	2.38	53.8	4.7	91.3
GP-12R1-25.0-25.25	25.15	H	18.2	1.71	2.59	34.1	3.3	90.4

(1) Sample Orientation: H = horizontal; V = vertical (2) Total Porosity = no pore fluids in place; all interconnected pore channels; Air Filled = pore channels not occupied by pore fluids (3) Water = 0.9996 g/cc; Vb = Bulk Volume, cc; Pv = Pore Volume, cc; ND = Not Detect

PTS File No: 37769
Client: RETEC/ENSR

PERMEABILITY DATA - AIR/WATER CAPILLARY PRESSURE

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

		METHODS:	API RP 40; ASTM D5084; EPA 910(		
			25 PSI CONFINING STRESS		
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	SPECIFIC (2) PERMEABILITY TO AIR millidarcy	EFFECTIVE (3,4) PERMEABILITY TO WATER, millidarcy	HYDRAULIC CONDUCTIVITY (3,4), cm/s
GP-02-12.0-12.5	12.1	V	8110	5959	5.48E-03
GP-04-9.25-9.5	9.35	V	5881	3946	3.59E-03
GP-05-7.5-8.0	7.6	V	606	85.3	7.66E-05
GP-05-14.5-15.0	14.65	V	5766	1181	1.07E-03
GP-09RI-9.0-9.5	9.15	V	5439	4261	3.91E-03
GP-11-21.0-21.5	21.2	V	3220	2217	2.00E-03
GP-11R3-12.5-13.0	12.7	V	3563	2784	2.56E-03
GP-12R1-25.0-25.25	25.15	V	1011	92.6	8.44E-05

(1) Sample Orientation: H = horizontal; V = vertical (2) Specific = No pore fluids in place (3) Native State or Effective = With as-received pore fluids in place (4) Permeability to water and hydraulic conductivity measured at saturated conditions

PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-02-12.0-12.5
DEPTH, ft: 12.10

Capillary Pressure		Height Above Water Table,	Water Saturation,	Moisture Content,
psi	cm water	ft	% pore volume	% dry weight
0.000	0.00	0.000	100.0	71.4
0.096	6.73	0.221	100.0	71.4
0.215	15.1	0.498	83.6	59.7
0.383	26.9	0.886	66.7	47.6
0.598	42.0	1.38	55.7	39.8
0.861	60.5	1.99	49.8	35.6
1.17	82.4	2.71	44.3	31.7
1.53	108	3.54	39.8	28.5
2.39	168	5.54	34.3	24.6
3.44	242	7.97	30.2	21.6
4.69	330	10.9	26.1	18.7
6.12	431	14.2	23.4	16.8
7.75	545	17.9	21.5	15.5
9.57	673	22.1	20.2	14.5
21.5	1514	49.8	17.4	12.5

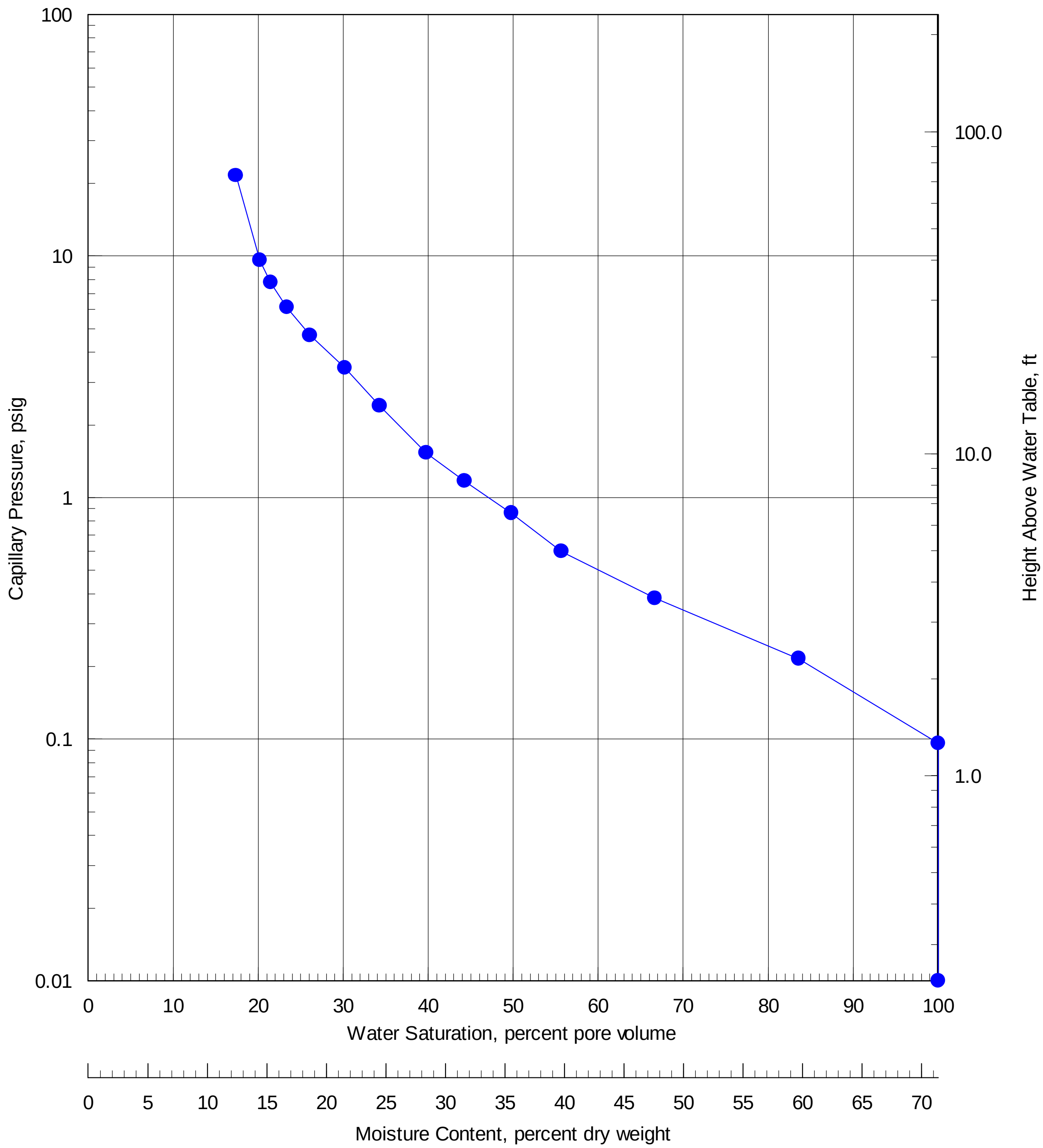
PTS File No: 37769
Client: RETEC/ENSR

AIR/WATER CAPILLARY PRESSURE PLOT

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-02-12.0-12.5
DEPTH, ft: 12.10



PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-04-9.25-9.50
DEPTH, ft: 9.35

Capillary Pressure		Height Above Water Table,	Water Saturation,	Moisture Content,
psi	cm water	ft	% pore volume	% dry weight
0.000	0.00	0.000	100.0	80.6
0.091	6.39	0.210	100.0	80.6
0.205	14.4	0.474	100.0	80.6
0.364	25.6	0.842	97.3	78.4
0.568	40.0	1.32	85.6	69.0
0.818	57.5	1.89	72.5	58.5
1.11	78.3	2.58	60.5	48.8
1.45	102	3.37	53.3	43.0
2.27	160	5.26	42.5	34.3
3.27	230	7.58	36.7	29.6
4.46	313	10.3	32.2	26.0
5.82	409	13.5	29.5	23.8
7.37	518	17.0	26.3	21.3
9.09	639	21.0	24.5	19.9
20.5	1439	47.4	20.0	16.3

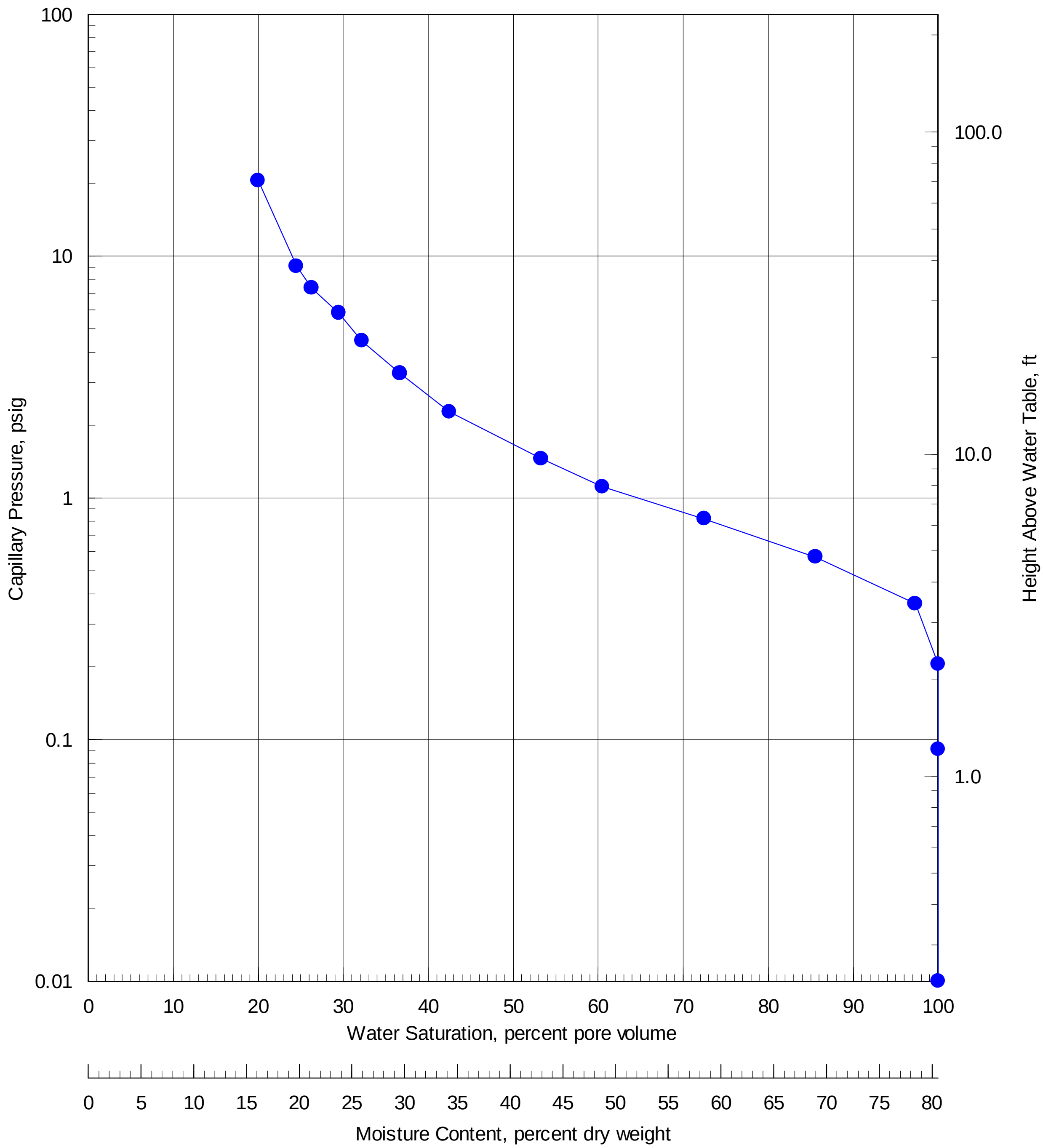
PTS File No: 37769
Client: RETEC/ENSR

AIR/WATER CAPILLARY PRESSURE PLOT

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-04-9.25-9.50
DEPTH, ft: 9.35



PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-05-7.5-8.0
DEPTH, ft: 7.60

Capillary Pressure		Height Above Water Table, ft	Water Saturation, % pore volume	Moisture Content, % dry weight
psi	cm water			
0.000	0.00	0.000	100.0	58.4
0.091	6.41	0.211	100.0	58.4
0.205	14.4	0.475	100.0	58.4
0.365	25.6	0.844	98.8	57.7
0.570	40.0	1.32	96.5	56.3
0.820	57.7	1.90	95.3	55.7
1.12	78.5	2.58	93.0	54.3
1.46	103	3.37	90.6	52.9
2.28	160	5.27	88.3	51.6
3.28	231	7.59	84.7	49.5
4.47	314	10.3	81.2	47.4
5.83	410	13.5	77.1	45.1
7.38	519	17.1	74.2	43.3
9.11	641	21.1	70.1	40.9
20.5	1442	47.5	51.9	30.3

PTS Laboratories

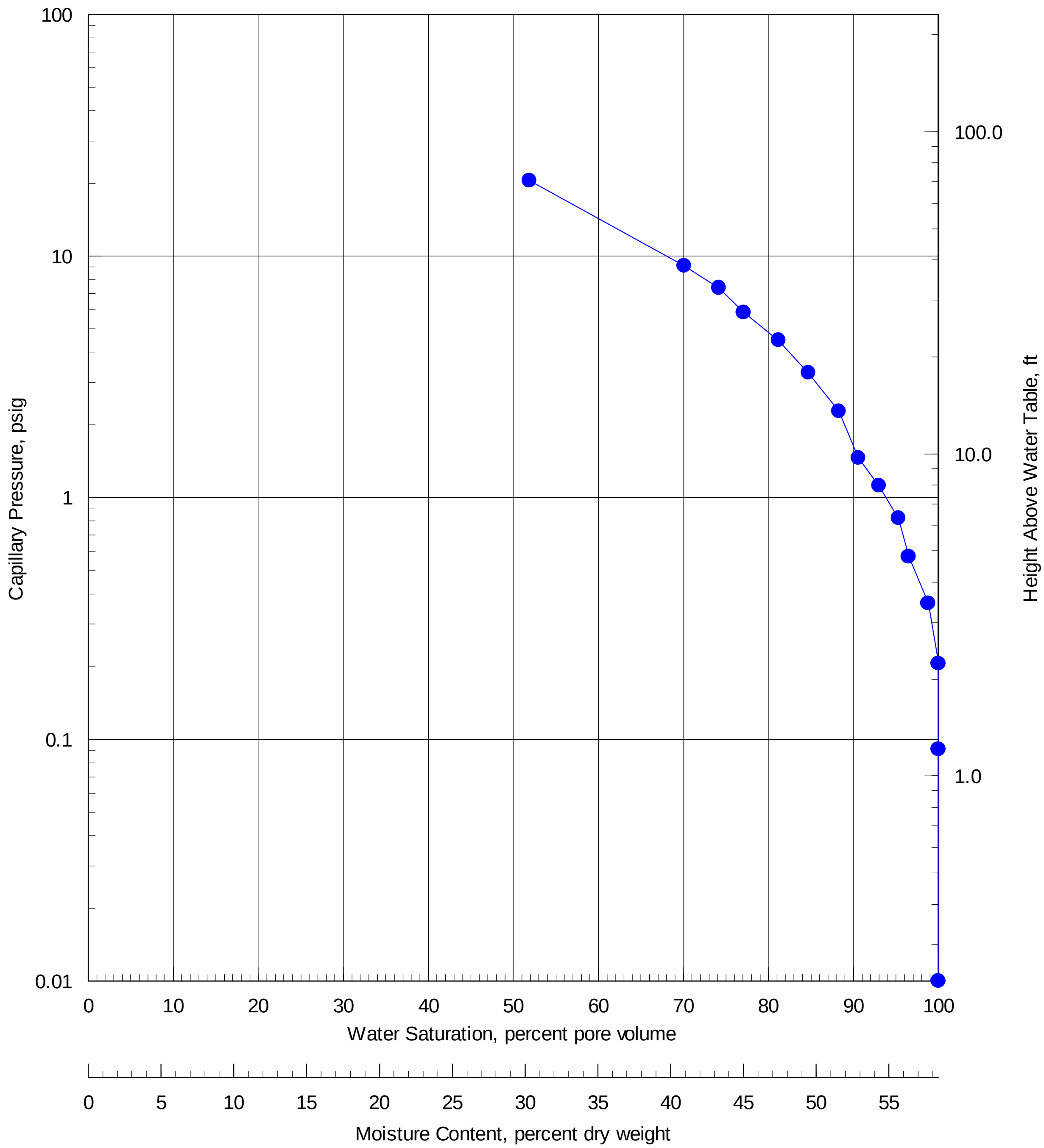
PTS File No: 37769
Client: RETEC/ENSR

AIR/WATER CAPILLARY PRESSURE PLOT

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-05-7.5-8.0
DEPTH, ft: 7.60



PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-05-14.5-15.0
DEPTH, ft: 14.65

Capillary Pressure		Height Above Water Table,	Water Saturation,	Moisture Content,
psi	cm water	ft	% pore volume	% dry weight
0.000	0.00	0.000	100.0	95.1
0.083	5.87	0.193	100.0	95.1
0.188	13.2	0.435	100.0	95.1
0.334	23.5	0.772	95.6	90.9
0.522	36.7	1.21	91.1	86.7
0.751	52.8	1.74	78.3	74.5
1.02	71.9	2.37	59.5	56.6
1.34	93.9	3.09	43.7	41.6
2.09	147	4.83	35.3	33.7
3.00	211	6.95	30.3	29.0
4.09	287	9.46	26.9	25.7
5.34	375	12.4	24.9	23.8
6.76	475	15.6	22.4	21.5
8.34	587	19.3	20.9	20.1
18.8	1320	43.5	17.5	16.8

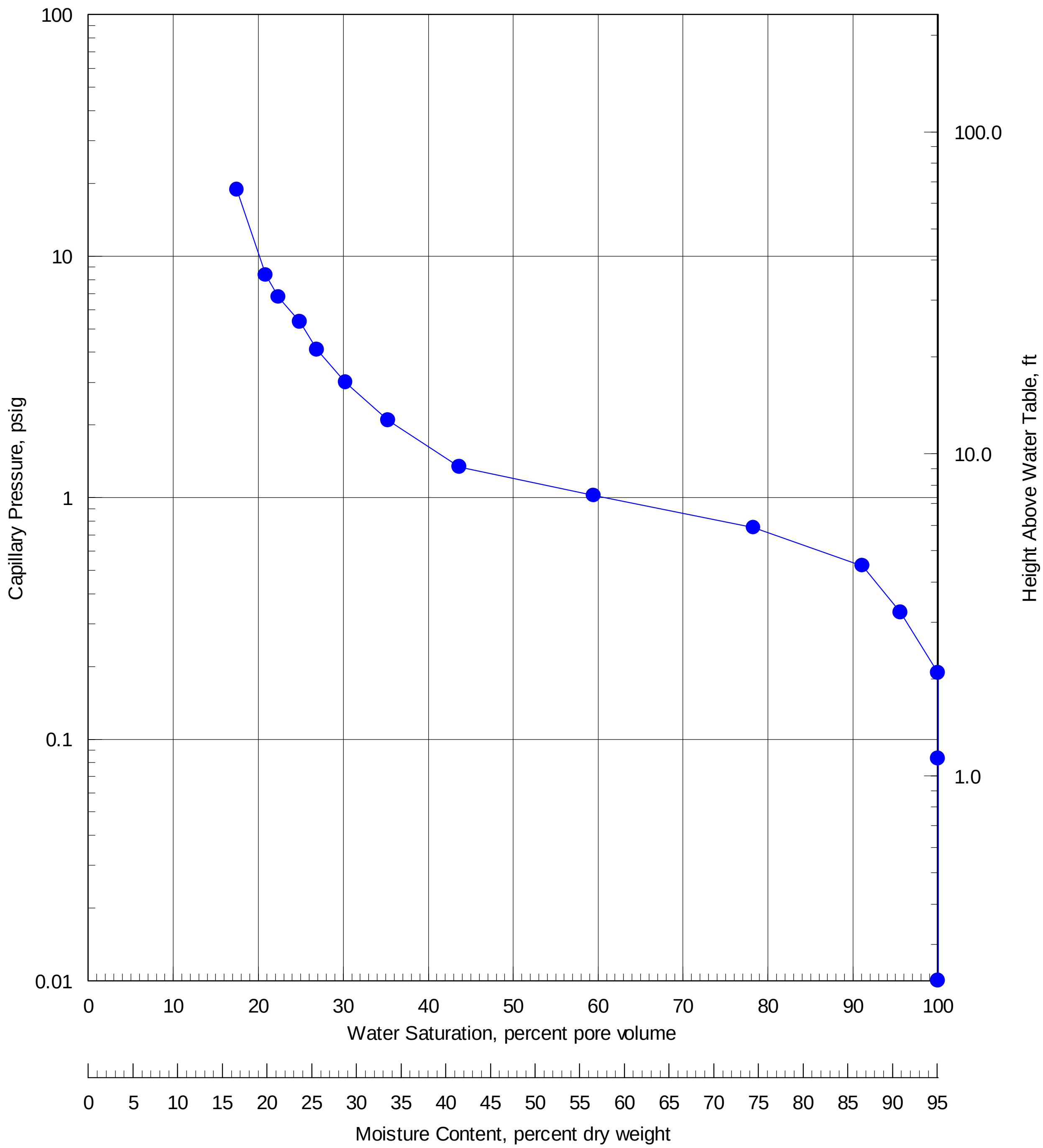
PTS File No: 37769
Client: RETEC/ENSR

AIR/WATER CAPILLARY PRESSURE PLOT

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-05-14.5-15.0
DEPTH, ft: 14.65



PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-09RI-9.0-9.5
DEPTH, ft: 9.15

Capillary Pressure		Height Above Water Table,	Water Saturation,	Moisture Content,
psi	cm water	ft	% pore volume	% dry weight
0.000	0.00	0.000	100.0	70.3
0.093	6.53	0.215	100.0	70.3
0.209	14.7	0.484	100.0	70.3
0.372	26.1	0.860	92.6	65.1
0.581	40.8	1.34	82.0	57.7
0.836	58.8	1.94	67.5	47.5
1.14	80.0	2.63	57.2	40.3
1.49	105	3.44	49.8	35.1
2.32	163	5.38	42.8	30.2
3.35	235	7.74	36.8	26.0
4.55	320	10.54	31.7	22.4
5.95	418	13.8	28.4	20.1
7.53	529	17.4	25.7	18.1
9.29	653	21.5	22.9	16.2
20.9	1470	48.4	17.8	12.6

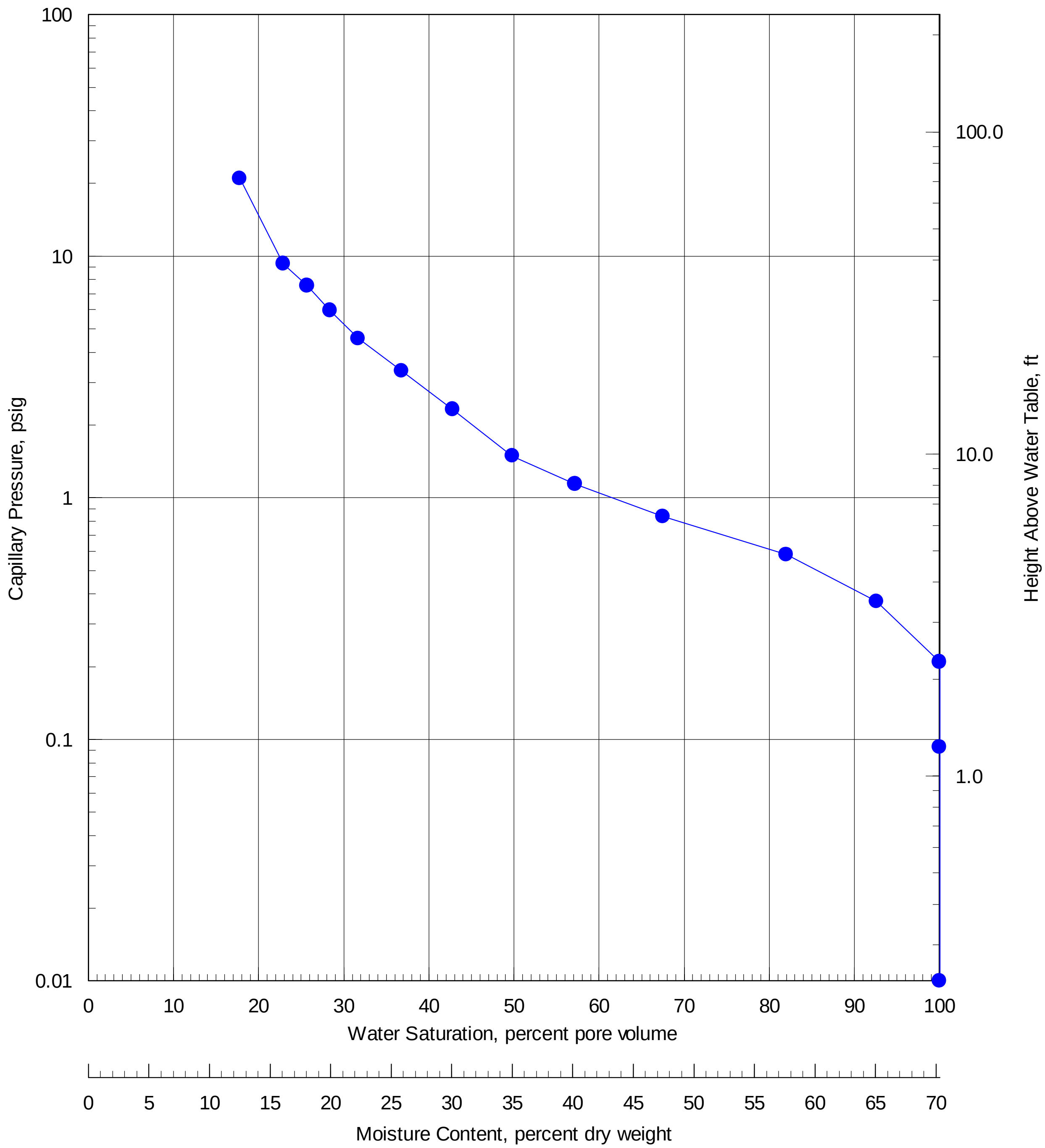
PTS File No: 37769
Client: RETEC/ENSR

AIR/WATER CAPILLARY PRESSURE PLOT

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-09RI-9.0-9.5
DEPTH, ft: 9.15



PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-11-21.0-24.5
DEPTH, ft: 21.20

Capillary Pressure		Height Above Water Table, ft	Water Saturation, % pore volume	Moisture Content, % dry weight
psi	cm water			
0.000	0.00	0.000	100.0	93.5
0.085	5.95	0.196	100.0	93.5
0.191	13.4	0.441	100.0	93.5
0.339	23.8	0.784	96.0	89.8
0.529	37.2	1.22	88.2	82.5
0.762	53.6	1.76	81.0	75.8
1.04	72.9	2.40	73.5	68.7
1.35	95.3	3.14	64.0	59.9
2.12	149	4.90	52.0	48.7
3.05	214	7.05	43.1	40.4
4.15	292	9.60	35.5	33.3
5.42	381	12.5	31.8	29.8
6.86	482	15.9	28.4	26.7
8.47	595	19.6	26.1	24.5
19.1	1340	44.1	19.4	18.3

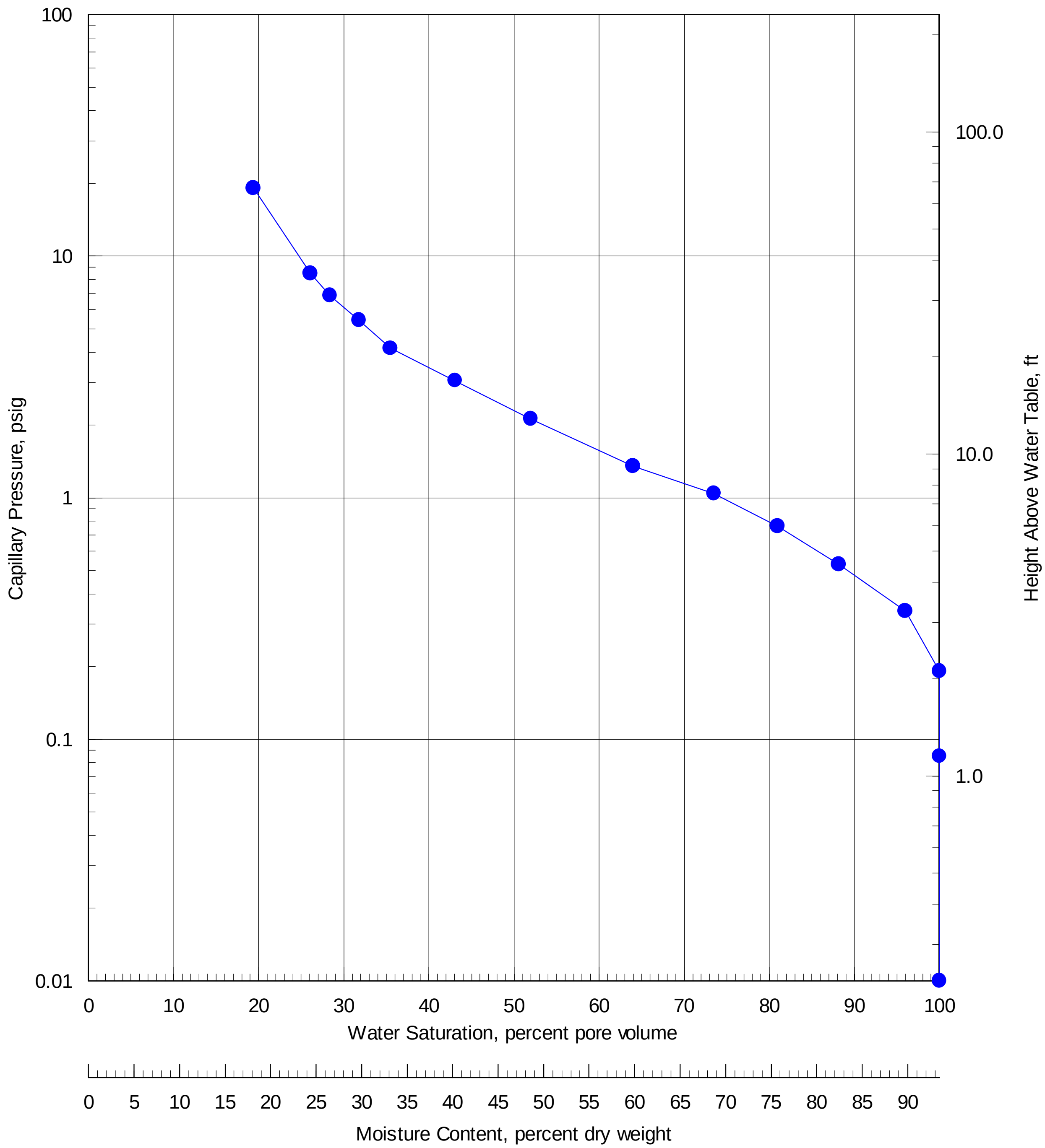
PTS File No: 37769
Client: RETEC/ENSR

AIR/WATER CAPILLARY PRESSURE PLOT

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-11-21.0-24.5
DEPTH, ft: 21.20



PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-11R3-12.5-13
DEPTH, ft: 12.70

Capillary Pressure		Height Above Water Table,	Water Saturation,	Moisture Content,
psi	cm water	ft	% pore volume	% dry weight
0.000	0.00	0.000	100.0	45.6
0.093	6.53	0.215	100.0	45.6
0.209	14.7	0.484	100.0	45.6
0.372	26.1	0.860	84.8	38.7
0.581	40.8	1.34	75.6	34.5
0.836	58.8	1.94	69.0	31.5
1.14	80.0	2.63	63.5	29.0
1.49	105	3.44	56.3	25.8
2.32	163	5.38	47.2	21.6
3.35	235	7.74	41.1	18.8
4.55	320	10.5	35.0	16.0
5.95	418	13.8	31.0	14.2
7.53	529	17.4	27.9	12.8
9.29	653	21.5	25.4	11.6
20.9	1470	48.4	20.3	9.3

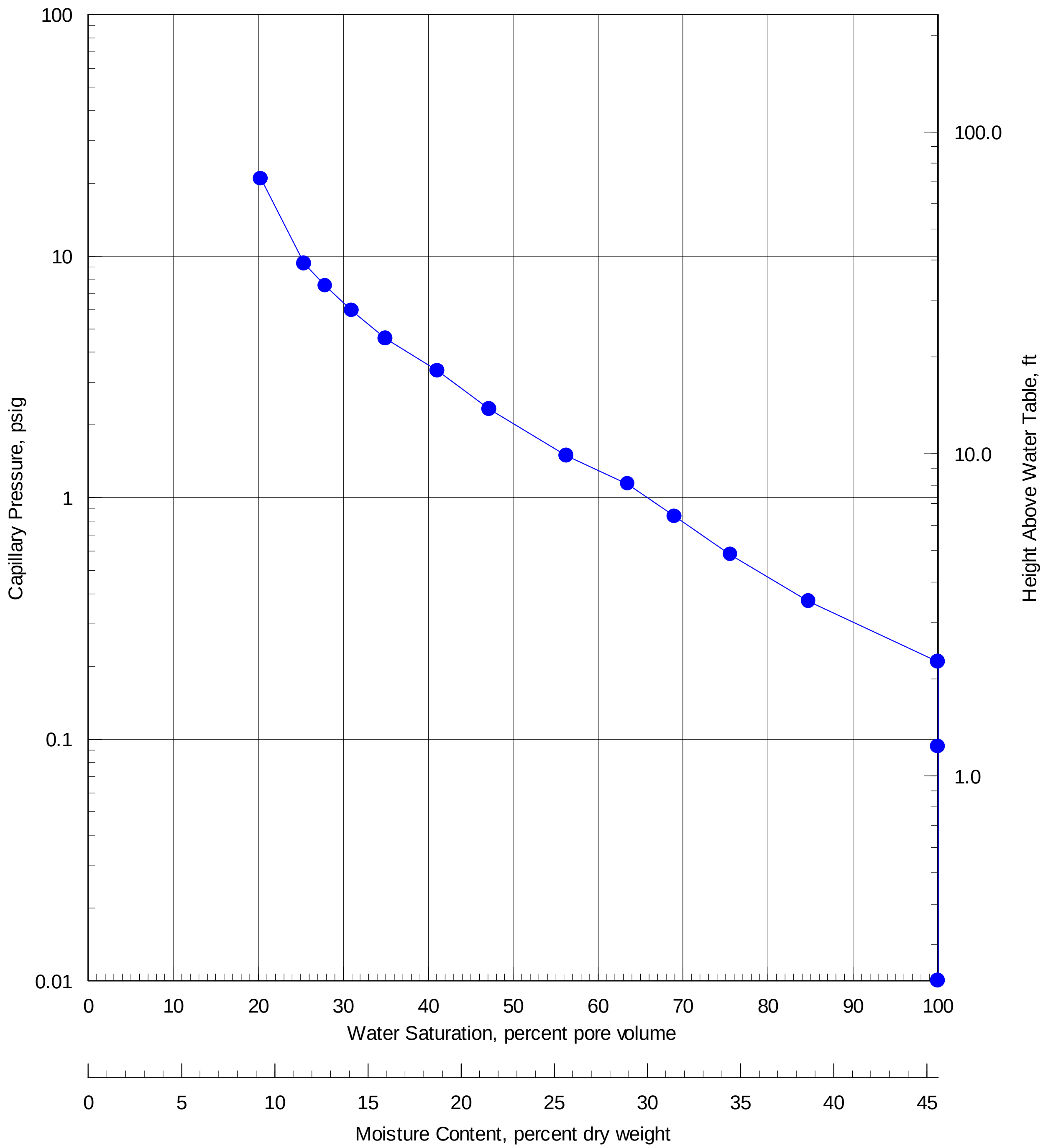
PTS File No: 37769
Client: RETEC/ENSR

AIR/WATER CAPILLARY PRESSURE PLOT

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-11R3-12.5-13
DEPTH, ft: 12.70



PTS File No: 37769
Client: RETEC/ENSR

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-12R1-25.0-25.25
DEPTH, ft: 25.15

Capillary Pressure		Height Above Water Table,	Water Saturation,	Moisture Content,
psi	cm water	ft	% pore volume	% dry weight
0.000	0.00	0.000	100.0	18.3
0.093	6.55	0.216	100.0	18.3
0.210	14.7	0.485	100.0	18.3
0.372	26.2	0.862	97.6	17.8
0.582	40.9	1.35	94.2	17.2
0.838	58.9	1.94	90.0	16.5
1.14	80.2	2.64	81.8	14.9
1.49	105	3.45	76.0	13.9
2.33	164	5.39	68.5	12.5
3.35	236	7.76	62.7	11.5
4.56	321	10.6	58.5	10.7
5.96	419	13.8	55.2	10.1
7.54	530	17.5	51.9	9.5
9.31	655	21.6	50.2	9.2
21.0	1473	48.5	43.6	8.0

PTS Laboratories

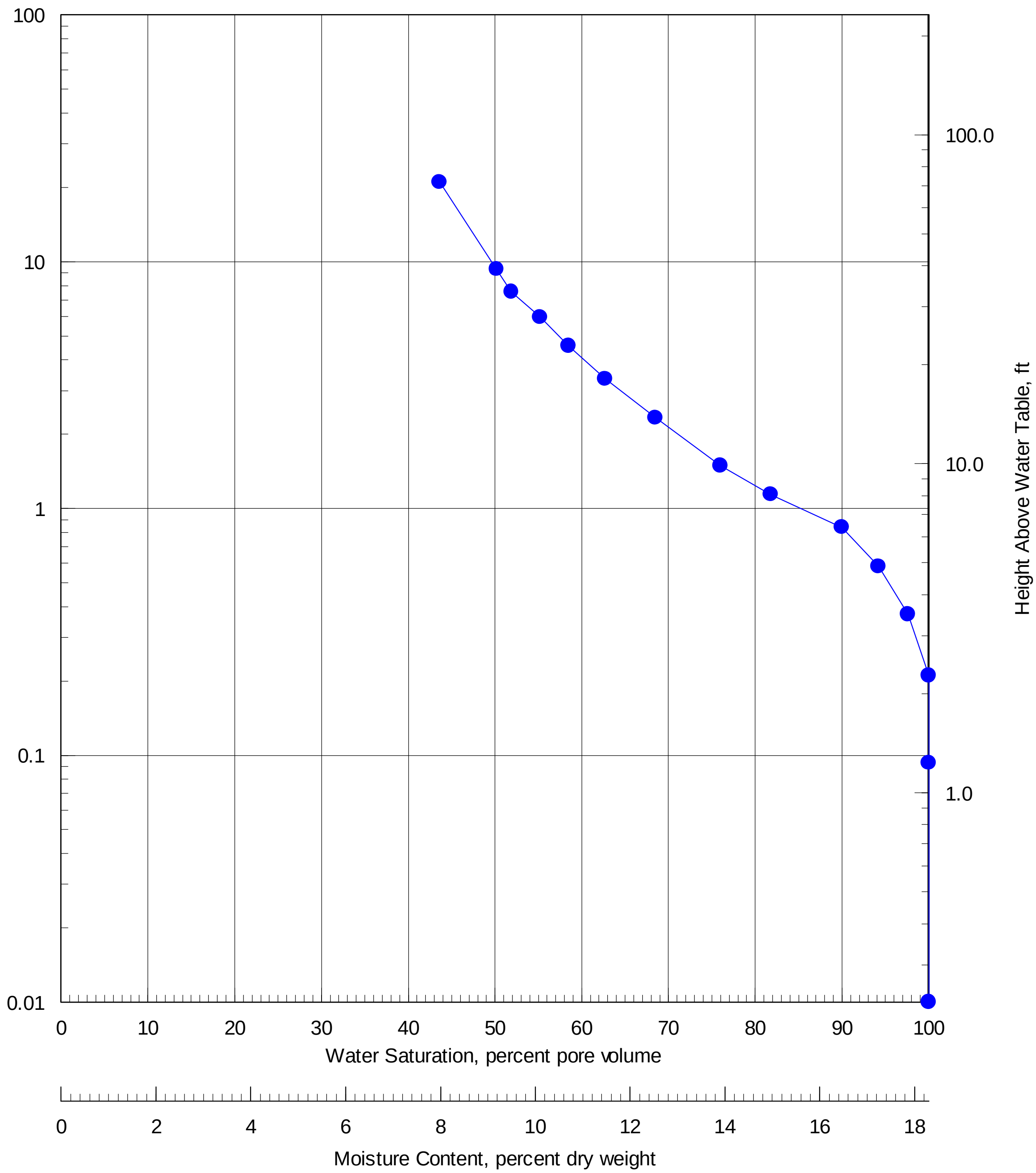
PTS File No: 37769
Client: RETEC/ENSR

AIR/WATER CAPILLARY PRESSURE PLOT

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: North Lake Union
PROJECT NO: 05570028-360

SAMPLE ID: GP-12R1-25.0-25.25
DEPTH, ft: 25.15

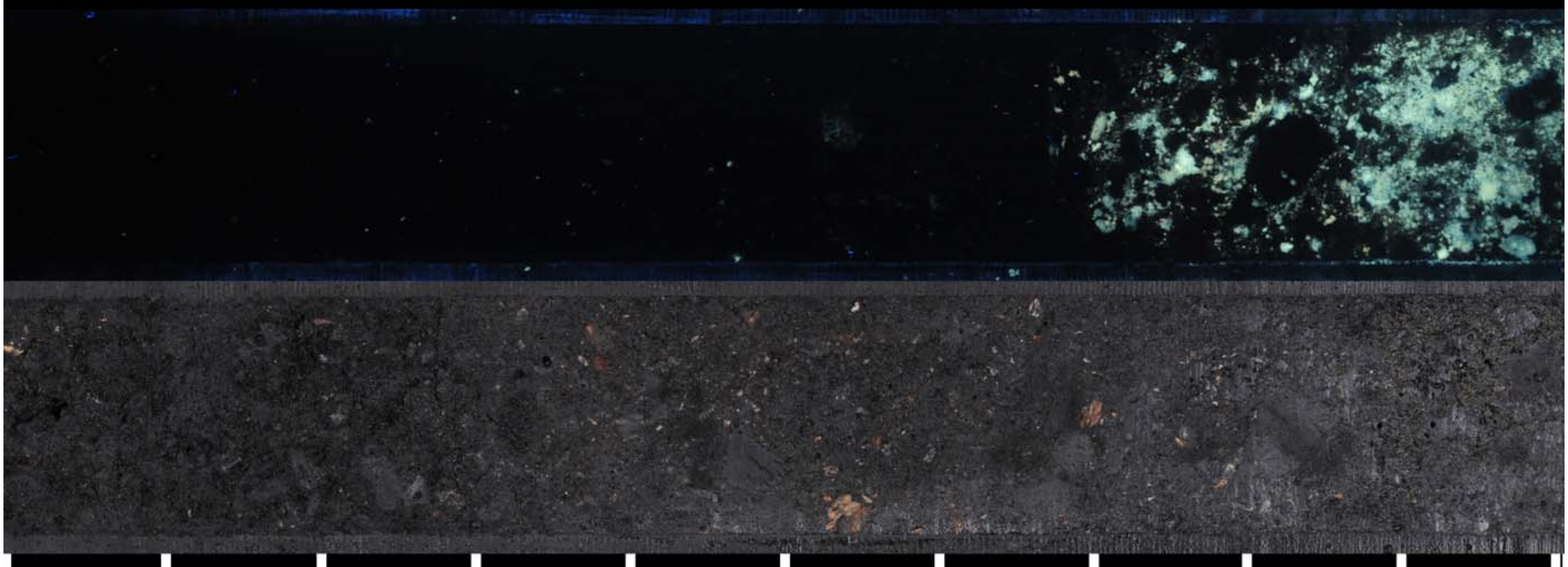


SUB-ATTACHMENT 5F-1.4

Supplemental Investigation UV Photographs and Petrophysical Data 2013

UV Photographs

PTS Laboratories
PTS File No.: 43238



11.2

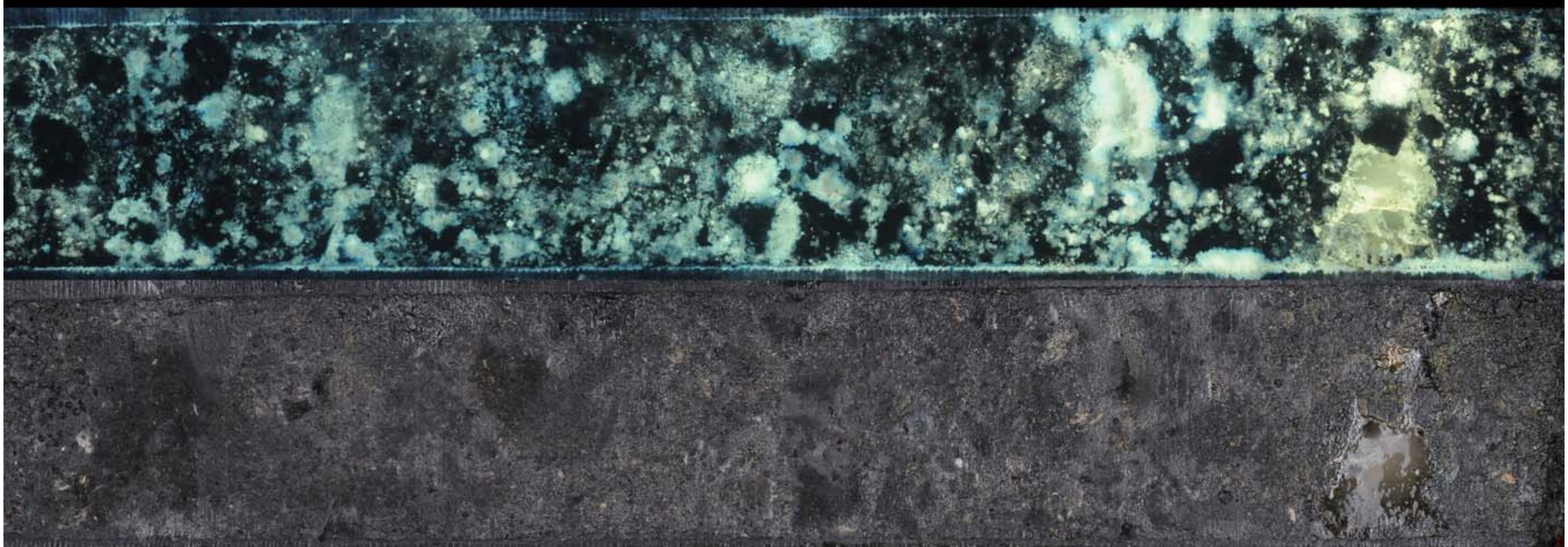
Each Interval Equals One Tenth of a Foot

12.2

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT01B

PTS Laboratories
PTS File No.: 43238



12.2

Each Interval Equals One Tenth of a Foot

13.2

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT01B

PTS Laboratories
PTS File No.: 43238

20.0

Each Interval Equals One Tenth of a Foot

21.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01 Boring ID: PT01

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PTS File No.: 43238

21.0

Each Interval Equals One Tenth of a Foot

22.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT01

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01 Boring ID: PT01

PTS Laboratories
PTS File No.: 43238

23.0

Each Interval Equals One Tenth of a Foot

24.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT01

PTS Laboratories
PTS File No.: 43238

24.0

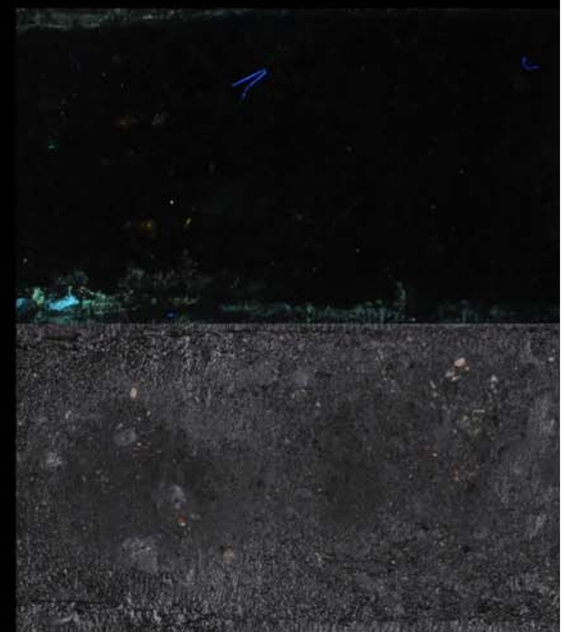
Each Interval Equals One Tenth of a Foot

25.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01 Boring ID: PT01

PTS Laboratories
PTS File No.: 43238



8.0

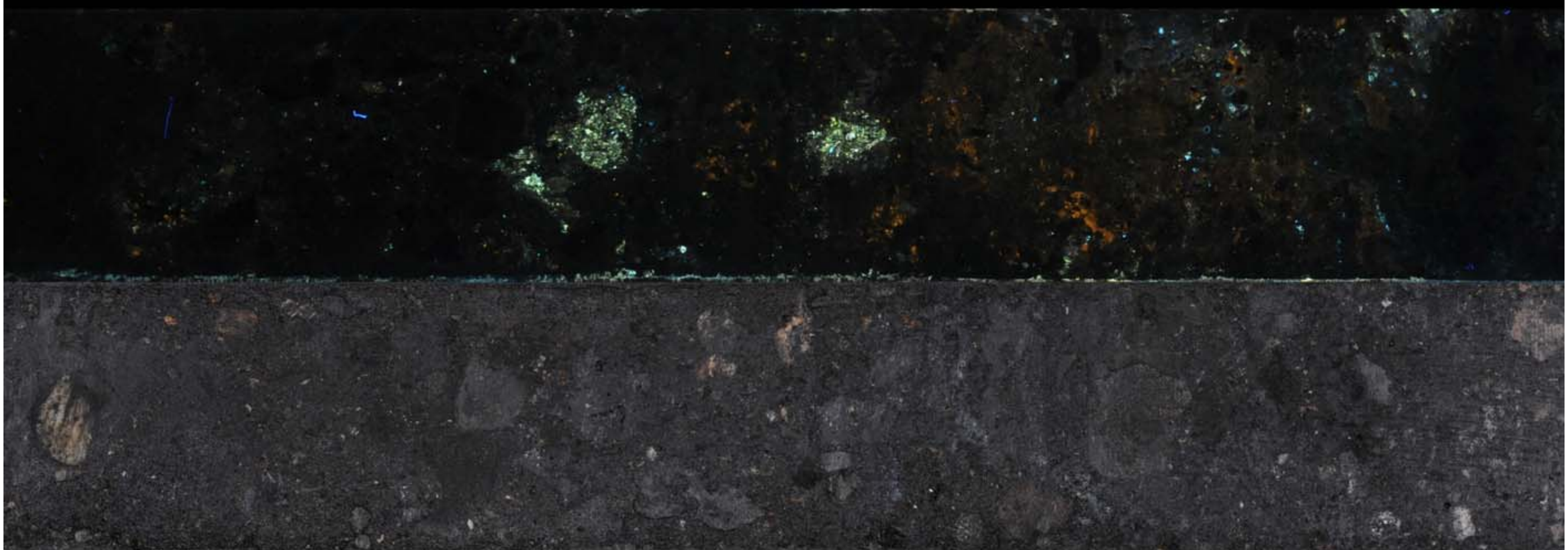
Each Interval Equals One Tenth of a Foot

9.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT02

PTS Laboratories
PTS File No.: 43238



9.0

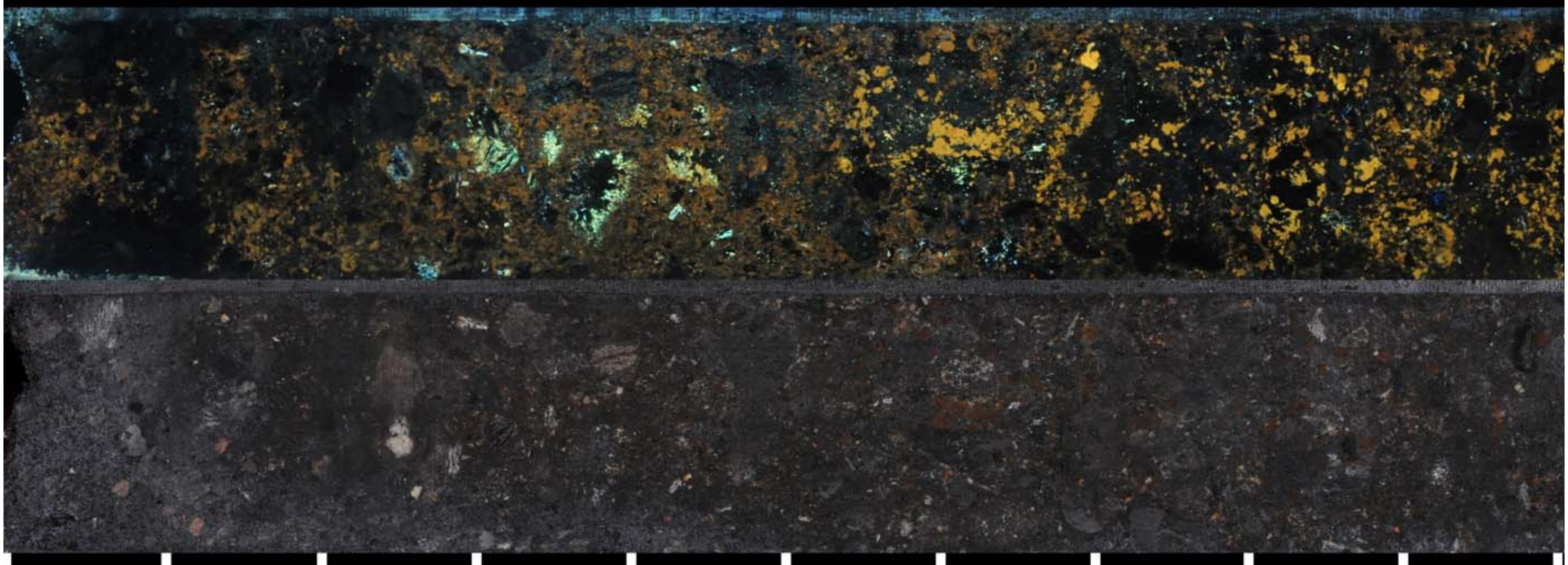
Each Interval Equals One Tenth of a Foot

10.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT02

PTS Laboratories
PTS File No.: 43238



10.0

Each Interval Equals One Tenth of a Foot

11.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01 Boring ID: PT02

PTS Laboratories
PTS File No.: 43238

11.0

Each Interval Equals One Tenth of a Foot

12.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT02

PTS Laboratories
PTS File No.: 43238

12.0

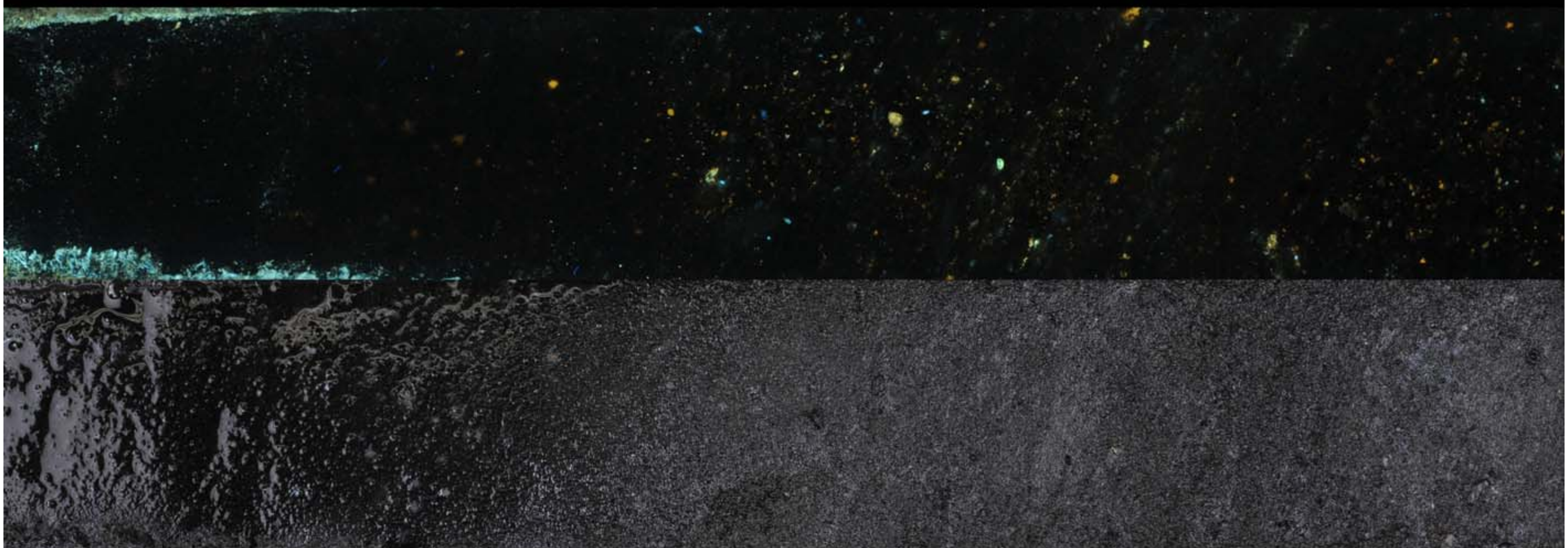
Each Interval Equals One Tenth of a Foot

13.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT02

PTS Laboratories
PTS File No.: 43238



20.0

Each Interval Equals One Tenth of a Foot

21.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT02

PTS Laboratories
PTS File No.: 43238

22.0

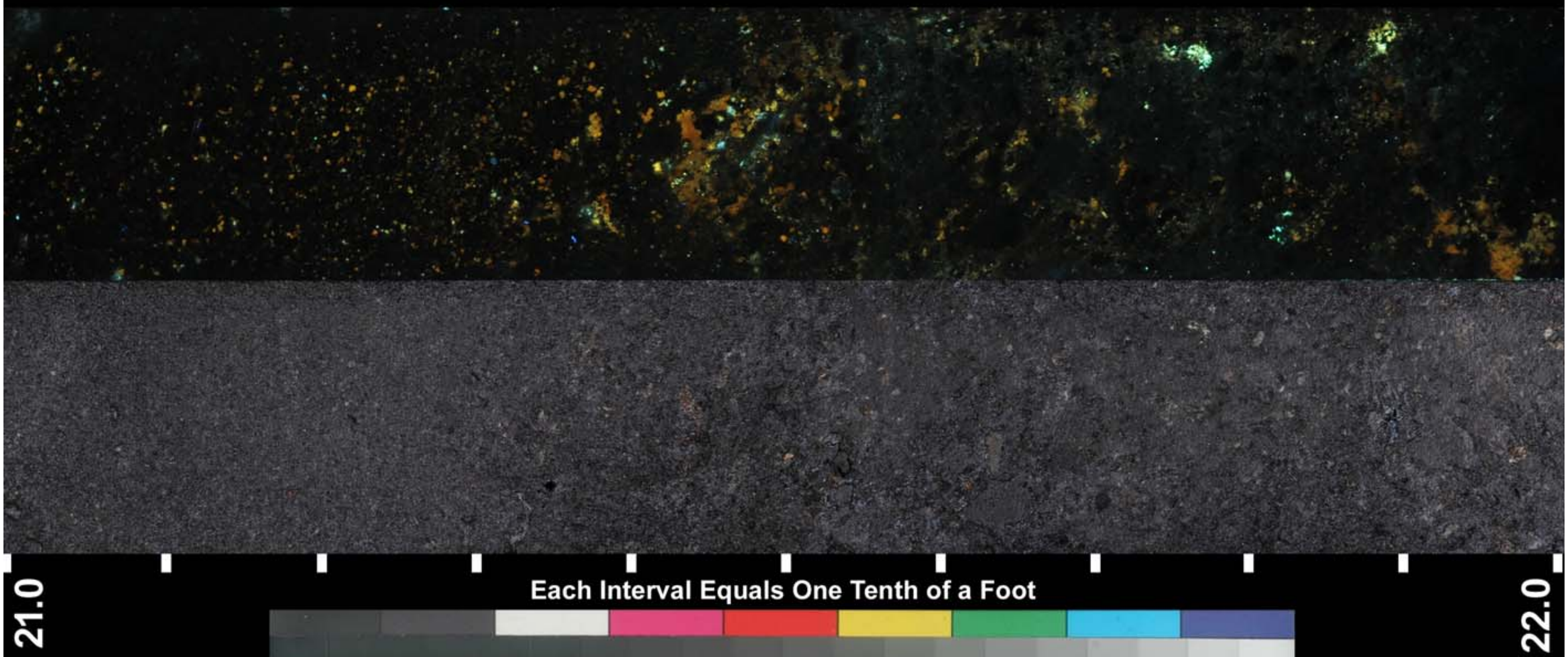
Each Interval Equals One Tenth of a Foot

23.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01 Boring ID: PT02

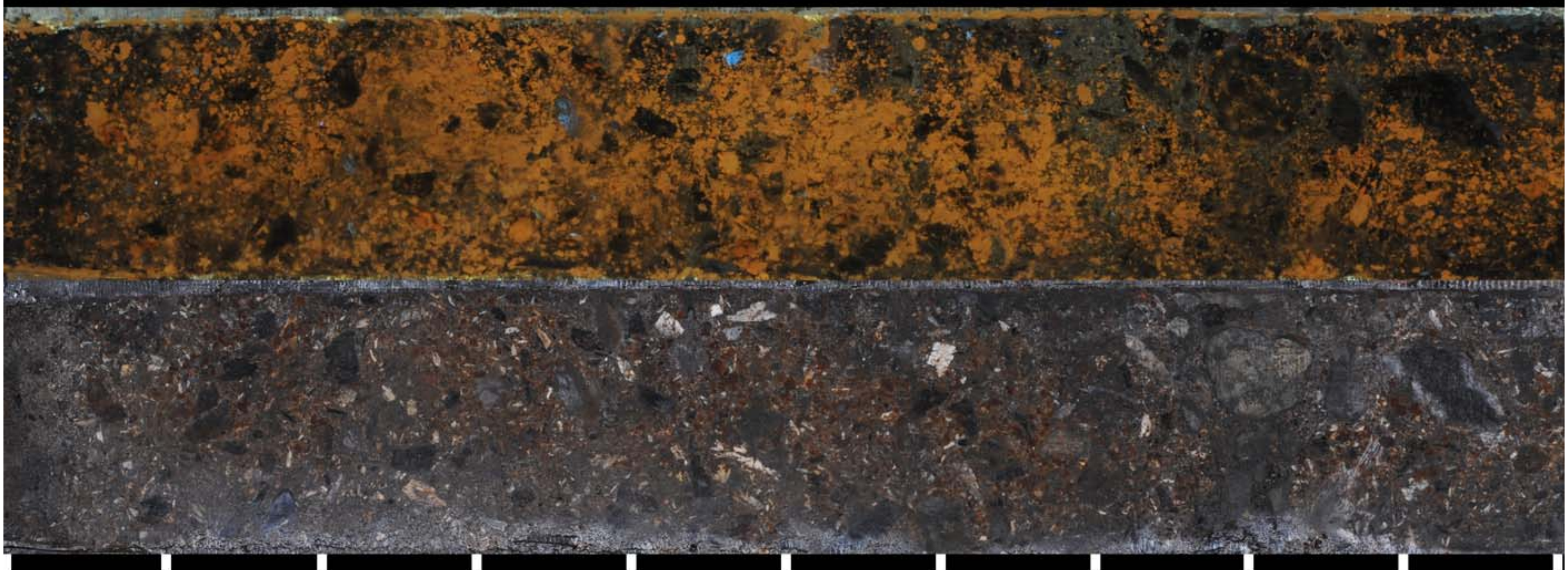
PTS Laboratories
PTS File No.: 43238



Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT02

PTS Laboratories
PTS File No.: 43238

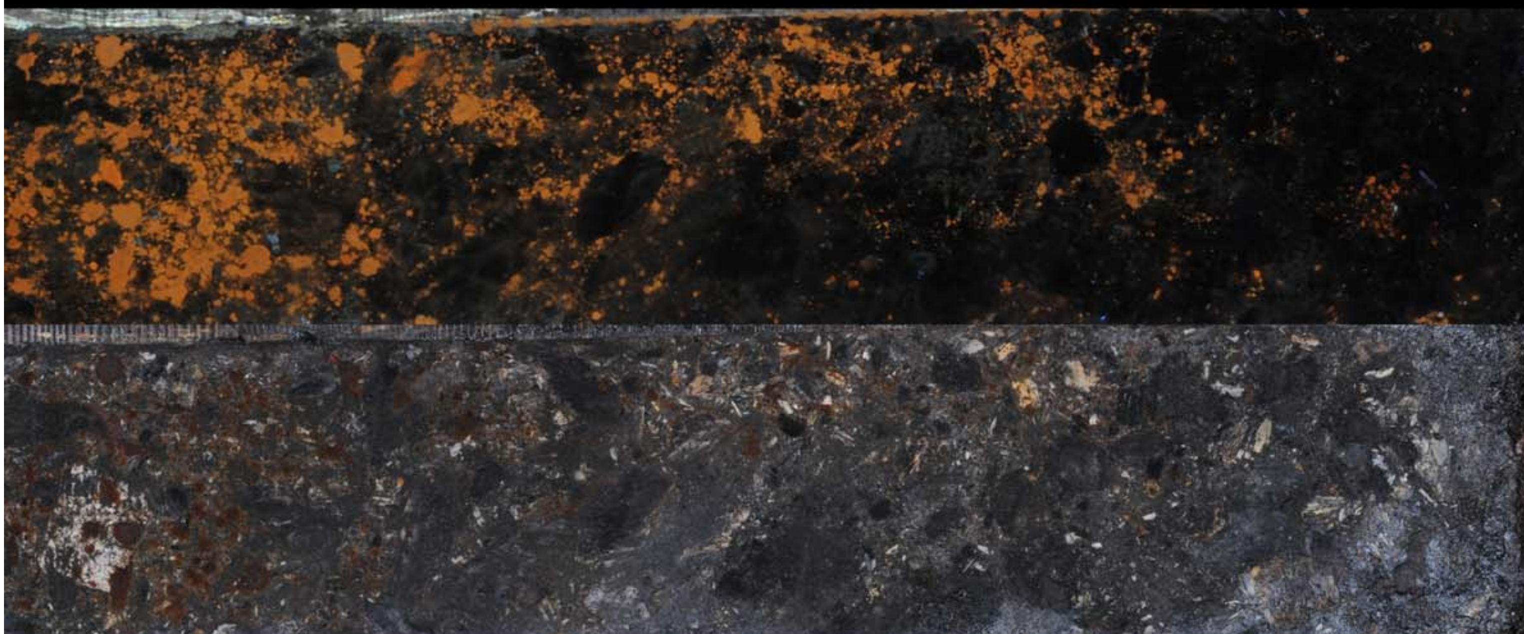


Each Interval Equals One Tenth of a Foot

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT03

PTS Laboratories
PTS File No.: 43238



9.0

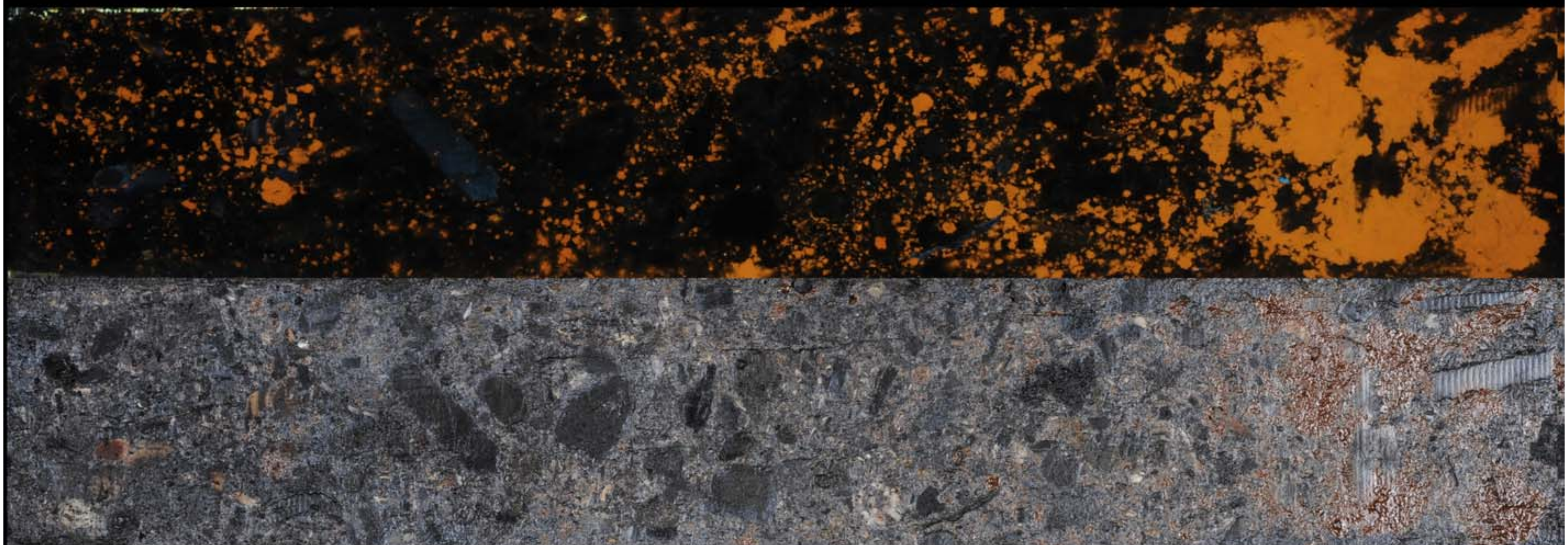
Each Interval Equals One Tenth of a Foot

10.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT03

PTS Laboratories
PTS File No.: 43238



10.0

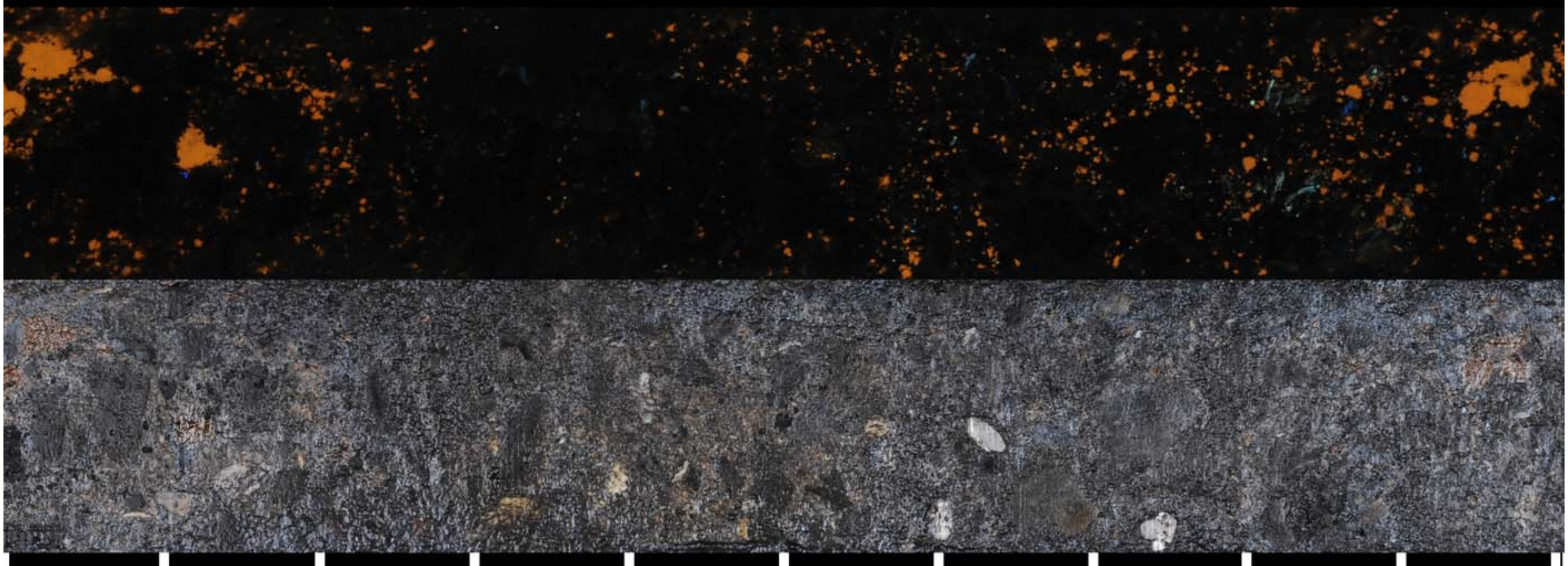
Each Interval Equals One Tenth of a Foot

11.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01 Boring ID: PT03

PTS Laboratories
PTS File No.: 43238



11.0 Each Interval Equals One Tenth of a Foot 12.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01 Boring ID: PT03

PTS Laboratories
PTS File No.: 43238

12.0

Each Interval Equals One Tenth of a Foot

13.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01 Boring ID: PT03

PTS Laboratories
PTS File No.: 43238

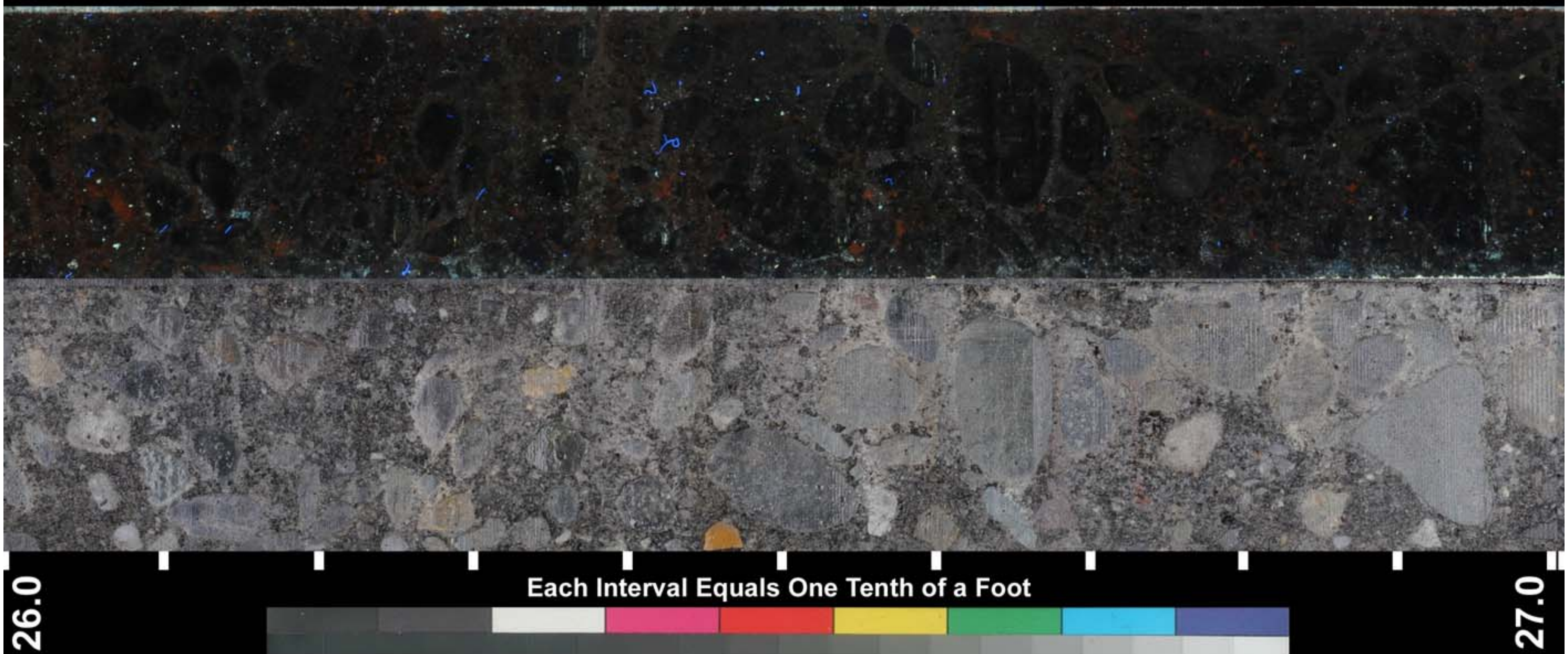
25.0

Each Interval Equals One Tenth of a Foot

26.0

Project: North Lake Union-Gas Works Park

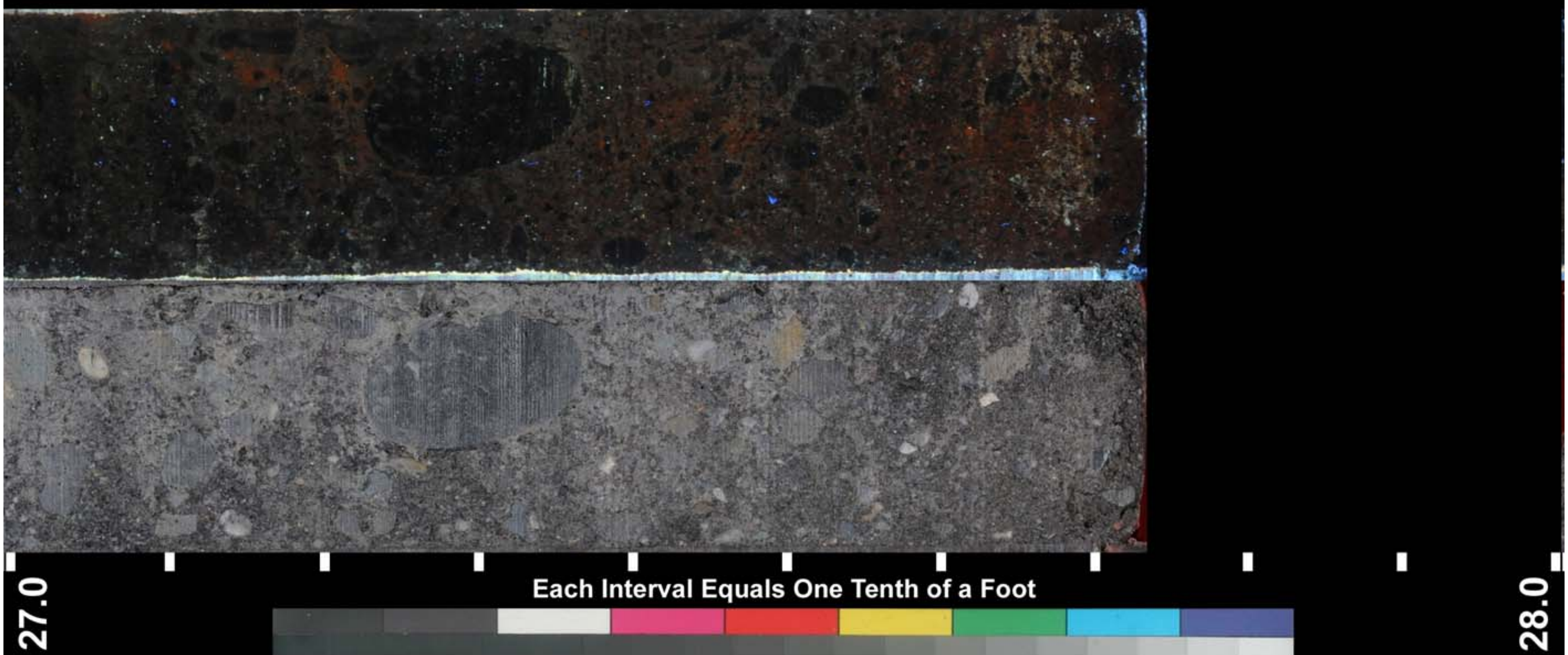
Project No.: 0186-846-01   Boring ID: PT03



Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT03

PTS Laboratories
PTS File No.: 43238



27.0

Each Interval Equals One Tenth of a Foot

28.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT03

PTS Laboratories
PTS File No.: 43238

28.0

Each Interval Equals One Tenth of a Foot

29.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01 Boring ID: PT03

PTS Laboratories
PTS File No.: 43238

29.0

Each Interval Equals One Tenth of a Foot

30.0

Project: North Lake Union-Gas Works Park

Project No.: 0186-846-01   Boring ID: PT03

Petrophysical Data

PTS Laboratories, Inc.

8100 Secura Way • Santa Fe Springs, CA 90670
Telephone (562) 347-2500 • Fax (562) 907-3610

June 28, 2013

Zanna A. Satterwhite
GeoEngineers, Inc.
600 Stewart Street, Suite 1700
Seattle, WA 98101

Re: PTS File No: 43238
Physical Properties Data
North Lake Union-Gas Works Park; 0186-846-01

Dear Ms. Satterwhite:

Please find enclosed report for Physical Properties analyses conducted upon samples received from your North Lake Union-Gas Works Park; 0186-846-01 project. All analyses were performed by applicable ASTM, EPA, or API methodologies. Electronic versions of the core images and physical properties report have been uploaded to PTS Laboratories website, www.ptslabs.com. The cores remain in frozen storage and will be held indefinitely. Please note that core storage will be billed quarterly beginning September 1, 2013.

PTS Laboratories appreciates the opportunity to be of service. If you have any questions or require additional information, please contact Rachel Spitz at (562) 347-2504.

Sincerely,
PTS Laboratories

for Rachel Sz

~~Michael~~ Mark Brady, P.G.
District Manager

Encl.

PTS Laboratories

Project Name: North Lake Union-Gas Works Park
Project Number: 0186-846-01

PTS File No: 43238
Client: GeoEngineers, Inc.

TEST PROGRAM - 20130530

CORE ID	Depth ft.	Core Recovery ft.	Slab and Core Photo	*Free Product Mobility	*Free Product Mobility Under Water	Modified Free Product Mobility	Viscosity/ Density at 70ºF	Viscosity/ Density at 70ºF	Notes
Method:		**Plugs:**	1/4:3/4	Hor. 1.5"	Hor. 1.5"	Hor. 1.5"	ASTM D1481, D445	ASTM D1481, D445	Keep core frozen
Date Received: 20130424									
MW09-130415-LNAPL	N/A	N/A					X		200 mL LNAPL
MW09-130415-DNAPL	N/A	N/A						X	200 mL DNAPL
DW07-130415-DNAPL	N/A	N/A						X	200 mL DNAPL
DW04-130415-DNAPL	N/A	N/A							200 mL DNAPL HOLD
DW05-130415-DNAPL	N/A	N/A							200 mL DNAPL HOLD
PZ03-130417-DNAPL	N/A	N/A						X	200 mL DNAPL
MW18-130422-DNAPL	N/A	N/A						X	200 mL DNAPL
MW03-130419	N/A	N/A							2400 mL Water for FPM
PT01B-11-13.2A	11-13.2	2.25	2	12.9				Photograph 2 feet that appear most impacted	
PT02-8-10A	8.7-10	1.30	2						
PT02-10-13B	10-13	2.85	3		11.8				
PT02-20-23	20-23	2.85	3		21.45				
PT01-20-21.1A	20-21.1	0.85	1						Photograph lower foot
PT01-21.1-22B	21.1-22	0.75	1		21.2				
PT03-8-10A	8-10	1.85	2	8.55					Only photograph 8-10'
PT03-10-13B	10-13	2.80	3		10.85				No top or bottom labeled
PT03-25-28A	25-28	2.70	3						
PT03-28-30B	28-30	2.00	2		29.7				Photograph upper 2 feet
PT01-22-25C	22-25	2.70	3						
TOTALS:	13 jars 11 cores	22.90	25	2	5	0	1	5	25

Laboratory Test Program Notes

Contaminant identification: **Possible BTEX, PAH, & Arsenic**

Sample locations to be selected by GeoEngineers, Inc. personnel from core photography.

Standard TAT for basic analysis is 10 business days. Advanced tests require additional time.

*Free Product Mobility (Stepped): 250RPM, 500RPM, and 1000RPM.

Modified Free Product Mobility: Apply centrifugal force at 1000xG for one hour. Submit centrifuged sample to analytical laboratory selected by GeoEngineers, Inc.

Shipping not included.

Please contact laboratory if you would like the "HOLD" samples retained longer than 30 days.

PTS File No: 43238
Client: GeoEngineers, Inc.

PTS Laboratories

STEPPED FREE PRODUCT MOBILITY: INITIAL AND RESIDUAL SATURATIONS

(Centrifugal method: samples spun under air, stepped pressures.)

PROJECT NAME: North Lake Union-Gas Works Park
PROJECT NO: 0186-846-01

		METHODS:	API RP 40		API RP 40		ASTM D425M, DEAN-STARK			
							PORE FLUID SATURATIONS, % Pv			
		SAMPLE	DENSITY		TOTAL	APPLIED	Initial Fluid Saturations		After Centrifuging	
SAMPLE ID.	DEPTH, ft.	ORIENTATION (1)	DRY BULK, g/cc	GRAIN, g/cc	POROSITY, %Vb	FORCE, RPM or xG	WATER (Swi) SATURATION	NAPL (Soi) SATURATION	WATER (Srw) SATURATION	NAPL (Sor) SATURATION
PT01B-11-13.2A	12.9	H	0.65	1.87	65.1	250 RPM	80.6	6.8	75.5	6.8
	NOTE: No visible NAPL produced. Produced water cloudy with strong hydrocarbon odor.									
						500 RPM	75.5	6.8	30.9	6.8
	NOTE: No visible NAPL produced. Produced water slightly cloudy with strong hydrocarbon odor.									
						1000 RPM	30.9	6.8	23.2	6.7
	NOTE: Trace NAPL produced. Produced water slightly cloudy.									
PT03-8-10A	8.55	H	0.85	2.46	65.4	250 RPM	78.2	8.4	76.8	8.4
	NOTE: No visible NAPL produced. Produced water clear with moderate hydrocarbon odor.									
						500 RPM	76.8	8.4	57.1	8.4
	NOTE: No visible NAPL produced. Produced water slightly cloudy, yellow tint, and moderate hydrocarbon odor.									
						1000 RPM	57.1	8.4	43.3	8.4
	NOTE: No visible NAPL produced. Produced water slightly cloudy, yellow tint, and moderate hydrocarbon odor.									

N/A = Not Analyzed. Vb = Bulk Volume, Pv = Pore Volume. (1) H = horizontal, V = vertical, R = remold
Soi = Initial NAPL Saturation as received prior to centrifuging at 1000xG, Swi = Initial Water Saturation as received prior to centrifuging at 1000xG
Sor = Residual NAPL Saturation after centrifuging at 1000xG, Srw = Residual Water Saturation after centrifuging at 1000xG
Water =0.9996 g/cc, NAPL = 0.9193 g/cc.

PTS File No: 43238
Client: GeoEngineers, Inc.

PTS Laboratories

FREE PRODUCT MOBILITY: INITIAL AND RESIDUAL SATURATIONS

(Samples spun under water, stepped pressures.)

PROJECT NAME: North Lake Union-Gas Works Park
PROJECT NO: 0186-846-01

		METHODS:	API RP 40		API RP 40		ASTM D425M, DEAN-STARK			
							PORE FLUID SATURATIONS, % Pv			
		SAMPLE	DENSITY		TOTAL	APPLIED	Initial Fluid Saturations		After Centrifuging	
SAMPLE ID.	DEPTH, ft.	ORIENTATION (1)	DRY BULK, g/cc	GRAIN, g/cc	POROSITY, %Vb	FORCE, RPM or xG	WATER (Swi) SATURATION	NAPL (Soi) SATURATION	WATER (Srw) SATURATION	NAPL (Sor) SATURATION
PT02-10-13B	11.8	H	0.44	2.00	77.8	250 RPM	47.6	46.6	49.5	46.6
NOTE: No visible NAPL produced. Produced water clear with strong hydrocarbon odor.										
						500 RPM	49.5	46.6	50.0	46.6
NOTE: No visible NAPL produced. Produced water clear with strong hydrocarbon odor.										
						1000 RPM	50.0	46.6	50.6	46.6
NOTE: No visible NAPL produced. Produced water clear with strong hydrocarbon odor.										
PT02-20-23	21.45	H	0.75	2.10	64.4	250 RPM	69.6	19.6	73.8	19.6
NOTE: No visible NAPL produced. Produced water clear with moderate hydrocarbon odor. Fines produced.										
						500 RPM	73.8	19.6	74.0	19.6
NOTE: No visible NAPL produced. Produced water clear with moderate hydrocarbon odor. Fines produced.										
						1000 RPM	74.0	19.6	74.4	19.6
NOTE: No visible NAPL produced. Produced water clear with moderate hydrocarbon odor. Fines produced.										
PT01-21.1-22B	21.2	H	1.69	2.70	37.2	250 RPM	70.9	10.3	75.3	10.3
NOTE: No visible NAPL produced. Produced water cloudy with moderate hydrocarbon odor. Fines produced.										
						500 RPM	75.3	10.3	75.3	10.3
NOTE: No visible NAPL produced. Produced water cloudy with moderate hydrocarbon odor. Fines produced.										
						1000 RPM	75.3	10.3	75.3	10.3
NOTE: No visible NAPL produced. Produced water cloudy with moderate hydrocarbon odor. Fines produced.										

N/A = Not Analyzed. Vb = Bulk Volume, Pv = Pore Volume. (1) H = horizontal, V = vertical, R = remold
Soi = Initial NAPL Saturation as received prior to centrifuging, Swi = Initial Water Saturation as received prior to centrifuging
Sor = Residual NAPL Saturation after centrifuging, Srw = Residual Water Saturation after centrifuging
Water =0.9996 g/cc, NAPL = 0.9193 g/cc.

PTS File No:	43238	**PTS** Laboratories
Client:	GeoEngineers, Inc.	

FREE PRODUCT MOBILITY: INITIAL AND RESIDUAL SATURATIONS

(Samples spun under water, stepped pressures.)

PROJECT NAME: North Lake Union-Gas Works Park
PROJECT NO: 0186-846-01

		METHODS:	API RP 40		API RP 40		ASTM D425M, DEAN-STARK			
							PORE FLUID SATURATIONS, % Pv			
		SAMPLE	DENSITY		TOTAL	APPLIED	Initial Fluid Saturations		After Centrifuging	
SAMPLE ID.	DEPTH, ft.	ORIENTATION (1)	DRY BULK, g/cc	GRAIN, g/cc	POROSITY, %Vb	FORCE, RPM or xG	WATER (Swi) SATURATION	NAPL (Soi) SATURATION	WATER (Srw) SATURATION	NAPL (Sor) SATURATION
PT03-10-13B	10.85	H	0.65	2.43	73.2	250 RPM	66.3	14.5	66.3	14.5
	NOTE: No visible NAPL produced. Produced water clear with strong hydrocarbon odor. Fines produced.									
						500 RPM	66.3	14.5	66.3	14.5
	NOTE: No visible NAPL produced. Produced water clear with moderate hydrocarbon odor. Fines produced.									
						1000 RPM	66.3	14.5	66.3	14.5
	NOTE: No visible NAPL produced. Produced water clear with faint-moderate hydrocarbon odor. Fines produced. Sample compressed slightly from confining pressure.									
PT03-28-30B	29.7	H	1.90	2.73	30.1	250 RPM	57.3	13.8	65.0	13.8
	NOTE: No visible NAPL produced. Produced water clear with strong hydrocarbon odor. Fines produced.									
						500 RPM	65.0	13.8	65.0	13.8
	NOTE: No visible NAPL produced. Produced water clear with moderate hydrocarbon odor. Fines produced.									
						1000 RPM	65.0	13.8	65.0	13.8
	NOTE: No visible NAPL produced. Produced water clear with moderate hydrocarbon odor. Fines produced.									

N/A = Not Analyzed. Vb = Bulk Volume, Pv = Pore Volume. (1) H = horizontal, V = vertical, R = remold
Soi = Initial NAPL Saturation as received prior to centrifuging, Swi = Initial Water Saturation as received prior to centrifuging
Sor = Residual NAPL Saturation after centrifuging, Srw = Residual Water Saturation after centrifuging
Water =0.9996 g/cc, NAPL = 0.9193 g/cc.

PTS File No: 43238
Client: GeoEngineers, Inc.

PTS Laboratories

VISCOSITY, DENSITY, and SPECIFIC GRAVITY DATA

(METHODOLOGY: ASTM D445, ASTM D1481, API RP40)

PROJECT NAME: North Lake Union-Gas Works Park
PROJECT NO: 0186-846-01

SAMPLE ID	MATRIX	TEMPERATURE, °F	SPECIFIC GRAVITY	DENSITY, g/cc	VISCOSITY	
					centistokes	centipoise
MW09-130415-LNAPL	NAPL	70	0.9212	0.9193	14.6	13.4

PTS File No: 43238
Client: GeoEngineers, Inc.

PTS Laboratories

VISCOSITY, DENSITY, and SPECIFIC GRAVITY DATA

(METHODOLOGY: ASTM D445, ASTM D1481, API RP40)

PROJECT NAME: North Lake Union-Gas Works Park
PROJECT NO: 0186-846-01

SAMPLE ID	MATRIX	TEMPERATURE, °F	SPECIFIC GRAVITY	DENSITY, g/cc	VISCOSITY	
					centistokes	centipoise
MW09-130415-DNAPL	NAPL	70	1.019	1.017	22.2	22.6
DW07-130415-DNAPL	NAPL	70	1.081	1.079	46.0	49.6
PZ03-130417-DNAPL	NAPL	70	1.082	1.080	685	740
MW18-130422-DNAPL	NAPL	70	1.109	1.107	1129	1250

PTS Laboratories, Inc.

CHAIN OF CUSTODY RECORD

COMPANY: GeoEngineers

ADDRESS: 600 Stewart St Suite 1700 CITY: Seattle ZIP CODE: 98101

PROJECT MANAGER: Zanna Satterwhite

PROJECT NAME: GWP PHONE NUMBER: 2067282674

PROJECT NUMBER: 0186-846-01 FAX NUMBER: 2067282732

SITE LOCATION: GWP-Seattle

SAMPLER SIGNATURE:

PO#:

TURNAROUND TIME: 24 HOURS ☐ 48 HOURS ☐ 72 HOURS ☐ 5 DAYS ☐ NORMAL ☒

OTHER: ____

SAMPLE INTEGRITY (CHECK): INTACT ____ ON ICE ____

PTS QUOTE NO.: Q13-063

PTS FILE: 43238

ANALYSIS REQUEST

SAMPLE ID NUMBER	DATE	TIME	DEPTH, FT	NUMBER OF SAMPLES	SOIL PROPERTIES PACKAGE	HYDRAULIC CONDUCTIVITY PACKAGE	PORE FLUID SATURATIONS PACKAGE	TCEQ/TNRCC PROPERTIES PACKAGE	CAPILLARITY PACKAGE	FLUID PROPERTIES PACKAGE	PHOTOLOG: CORE PHOTOGRAPHY	MOISTURE CONTENT, ASTM D2216	POROSITY: TOTAL, API RP40	POROSITY: EFFECTIVE, ASTM D425M	SPECIFIC GRAVITY, ASTM D854	BULK DENSITY (DRY), API RP40 or ASTM D2937	AIR PERMEABILITY, API RP40	HYDRAULIC CONDUCTIVITY, EPA9100, API RP40, D5084	GRAIN SIZE DISTRIBUTION, ASTM D422/4464M	TOC: WALKLEY-BLACK	ATTERBERG LIMITS, ASTM D4318	VISCOSITY/DENSITY ASTM D445				COMMENTS
MW09-130415-LNAPL	4/15	845		1																		X				
MW09-130415-DNAPL	4/15	910		1																		X				
DW07-130415-DNAPL	4/15	1240		1																		X				
DW04-130415-DNAPL	4/15	1325		1																						*HOLD
DW05-130415-DNAPL	4/15	1340		1																						*HOLD
PZ03-130417-DNAPL	4/17	1537		1																		X				
MW18-130422-DNAPL	4/22	930		1																		X				
MW03-130419	4/19	940		6																						For Free Product mobility
			65.5°																							

1. RELINQUISHED BY	2. RECEIVED BY	3. RELINQUISHED BY	4. RECEIVED BY
COMPANY: GeoEngineers	COMPANY: PTS LABS	COMPANY:	COMPANY:
DATE: 4/22 TIME: 1250	DATE: 4/24/13 TIME: 10:35	DATE: TIME:	DATE: TIME:

PTS Laboratories, Inc.

CHAIN OF CUSTODY RECORD

COMPANY: GeoEngineers

ADDRESS: 600 Stewart Suite 1700 | CITY: Seattle | ZIP CODE: 98101

PROJECT MANAGER: Zanna Satterwhite

PROJECT NAME: GWP | PHONE NUMBER: (206) 7282674

PROJECT NUMBER: 0186-846-01 | FAX NUMBER: (206) 7282732

SITE LOCATION: GWP-Seattle

SAMPLER SIGNATURE: [signature]

PO#:

TURNAROUND TIME: 24 HOURS ☐ 48 HOURS ☐ 72 HOURS ☐ 5 DAYS ☐ NORMAL ☒

OTHER: ______

SAMPLE INTEGRITY (CHECK): INTACT ____ ON ICE ____

PTS QUOTE NO.: Q13-063

PTS FILE: 43238

ANALYSIS REQUEST: NUMBER OF SAMPLES; SOIL PROPERTIES PACKAGE; HYDRAULIC CONDUCTIVITY PACKAGE; PORE FLUID SATURATIONS PACKAGE; TCEQ/TNRCC PROPERTIES PACKAGE; CAPILLARITY PACKAGE; FLUID PROPERTIES PACKAGE; PHOTOLOG: CORE PHOTOGRAPHY; MOISTURE CONTENT, ASTM D2216; POROSITY: TOTAL, API RP40; POROSITY: EFFECTIVE, ASTM D425M; SPECIFIC GRAVITY, ASTM D854; BULK DENSITY (DRY), API RP40 or ASTM D2937; AIR PERMEABILITY, API RP40; HYDRAULIC CONDUCTIVITY, EPA9100, API RP40, D5084; GRAIN SIZE DISTRIBUTION, ASTM D422/4464M; TOC: WALKLEY-BLACK; ATTERBERG LIMITS, ASTM D4318; UV Photography

SAMPLE ID NUMBER	DATE	TIME	DEPTH, FT	NUMBER OF SAMPLES	COMMENTS
PT01B-11-13.2A	4/17	1122	11-13.2	1	
PT02-8~~7~~10A	4/17	1348	8~~7~~-10	1	
PT02-10-13B	4/17	1348	10-13	1	
~~PT02-18-20A~~	~~4/17~~	~~1420~~	~~18-20~~	~~1~~	
PT02-20-23 ~~B~~	4/17	1420	20-23	1	
PT01-20-21.1A	4/17	1028	20-21.1	1	
PT01-21.1-22B	4/17	1028	21.1-22	1	
PT03-8-10 A	4/18	1015	8-10	1	
PT03-10-13 B	4/18	1015	10-13	1	
PT03-25-28 A	4/18	1100	25-28	1	
PT03-28-30B	4/18	1100	28-30	1	

1. RELINQUISHED BY	2. RECEIVED BY	3. RELINQUISHED BY	4. RECEIVED BY
[signature]	[signature] -14.3 °F		
COMPANY: GeoEngineers	COMPANY: PTS LABS	COMPANY:	COMPANY:
DATE: 4/22 TIME: 1250	DATE: 4/24/13 TIME: 10:35	DATE: TIME:	DATE: TIME:

PTS Laboratories, Inc.

CHAIN OF CUSTODY RECORD

COMPANY	GeoEngineers
ADDRESS / CITY / ZIP CODE	
PROJECT MANAGER	
PROJECT NAME / PHONE NUMBER	
PROJECT NUMBER / FAX NUMBER	
SITE LOCATION	
SAMPLER SIGNATURE	

ANALYSIS REQUEST

SAMPLE ID NUMBER	DATE	TIME	DEPTH, FT	NUMBER OF SAMPLES	SOIL PROPERTIES PACKAGE	HYDRAULIC CONDUCTIVITY PACKAGE	PORE FLUID SATURATIONS PACKAGE	TCEQ/TNRCC PROPERTIES PACKAGE	CAPILLARITY PACKAGE	FLUID PROPERTIES PACKAGE	PHOTOLOG: CORE PHOTOGRAPHY	MOISTURE CONTENT, ASTM D2216	POROSITY: TOTAL, API RP40	POROSITY: EFFECTIVE, ASTM D425M	SPECIFIC GRAVITY, ASTM D854	BULK DENSITY (DRY), API RP40 or ASTM D2937	AIR PERMEABILITY, API RP40	HYDRAULIC CONDUCTIVITY, EPA9100, API RP40, D5084	GRAIN SIZE DISTRIBUTION, ASTM D422/4464M	TOC: WALKLEY-BLACK	ATTERBERG LIMITS, ASTM D4318	UV Photography				COMMENTS
PT01-22-25C	4/17	1028	22-25																							

PO#

TURNAROUND TIME
24 HOURS ☐ 48 HOURS ☐ 72 HOURS ☐ 5 DAYS ☐ NORMAL ☐
OTHER: ______

SAMPLE INTEGRITY (CHECK): INTACT ____ ON ICE ____

PTS QUOTE NO.

PTS FILE: 43238

1. RELINQUISHED BY	2. RECEIVED BY	3. RELINQUISHED BY	4. RECEIVED BY
[signature]	[signature] -14.3°F		
COMPANY: GeoEngineers	COMPANY: PTS LABS	COMPANY	COMPANY
DATE 4/22 TIME 1250	DATE 4/24/13 TIME 10:35	DATE TIME	DATE TIME

SUB-ATTACHMENT 5F-2.2
TarGOST Responses of Various Products with Sand

Attachment 5F-2
TarGOST®

SUB-ATTACHMENT 5F-2.1
TarGOST Reference Log

Dakota Technologies
TarGOST® Reference Log

Main Plot:

Signal (total fluorescence) versus depth where signal is relative to the Reference Emitter (RE). The total area of the waveform is divided by the total area of the Reference Emitter yielding the %RE. This %RE scales with the NAPL fluorescence. The fill color is based on relative contribution of each channel's area to the total waveform area (see callout waveform). The channel-to-color relationship and corresponding wavelengths are given in the upper right corner of the main plot.

Callouts:

Waveforms from selected depths or depth ranges showing the multi-wavelength waveform for that depth. The four peaks are due to fluorescence at four wavelengths and referred to as "channels." Each channel is assigned a color.

Various NAPLs will have a unique waveform "fingerprint" due to the relative amplitude of the four channels and/or broadening of one or more channels. Basic waveform statistics and any operator notes are given below the callout.

Conductivity Plot:

The Electrical Conductivity (EC) of the soil can be logged simultaneously with the TarGOST data. EC often provides insight into the stratigraphy.

Scatter Plot:

Scatter versus depth where intensity is relative to the scatter level of the Reference Emitter.

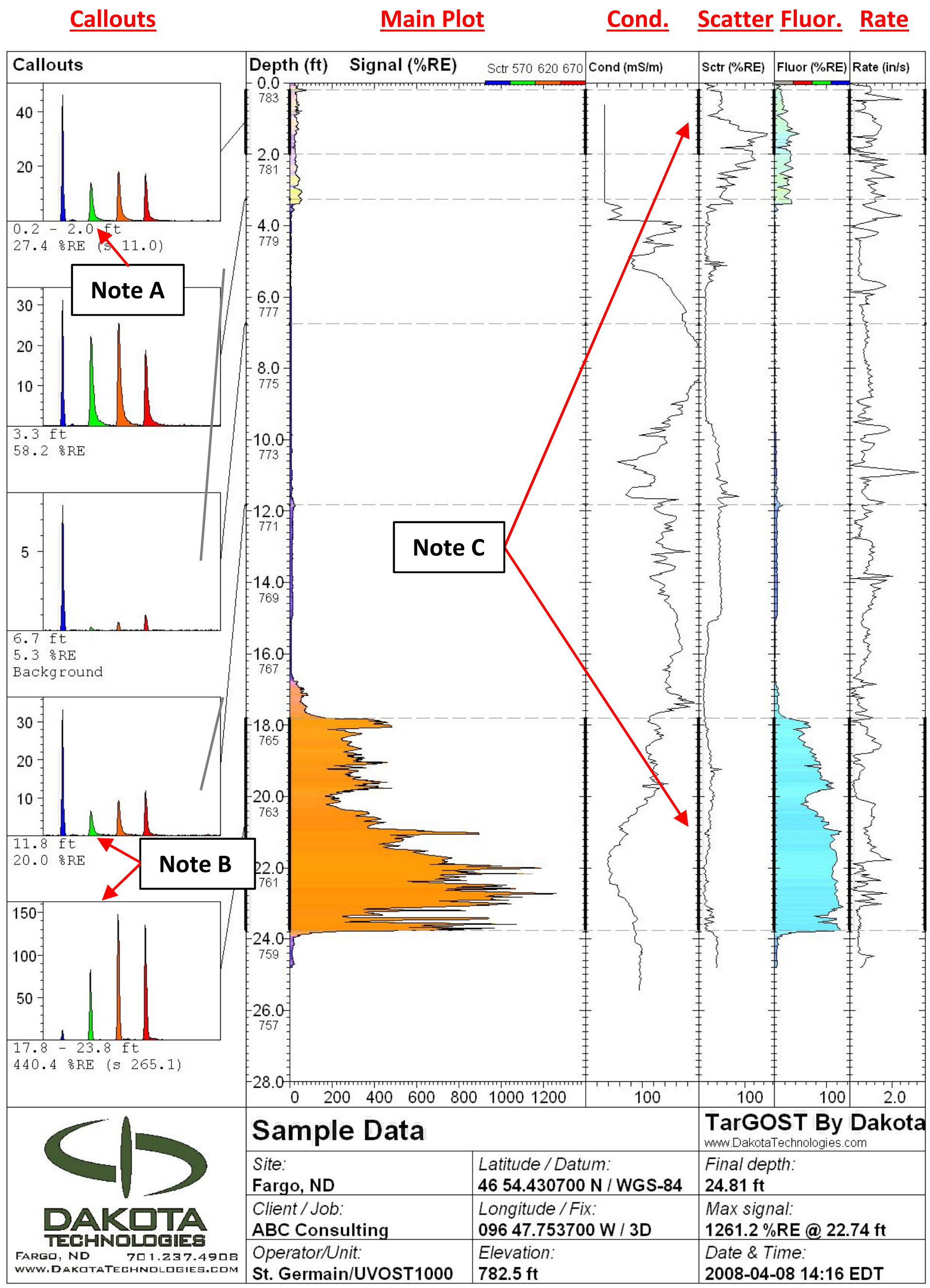
Fluorescence Plot:

A plot of the fluorescence signal alone versus depth. The scatter channel is not used in the calculation of signal intensity or coloring. Note the coloring key at the top of the plot. Intensity unit is percent of Reference Emitter fluorescence.

Varying soil or product can often be visually pulled-out from the background based on the fill color of this plot if scatter dominates the color of the main plot.

Rate Plot:

The rate of probe advancement. Approx. 0.8 inches (2cm) per second is preferred. A noticeable decrease in the rate of advancement may be indicative of difficult probing conditions (gravel, angular sands, etc.) such as that seen here at approx. 5 ft.



Note A:

Time is along the x axis. No scale is given on callouts, but it is constant and is 250ns wide. The y axis is in mV and directly corresponds to the amount of light striking the photodetector.

Note B:

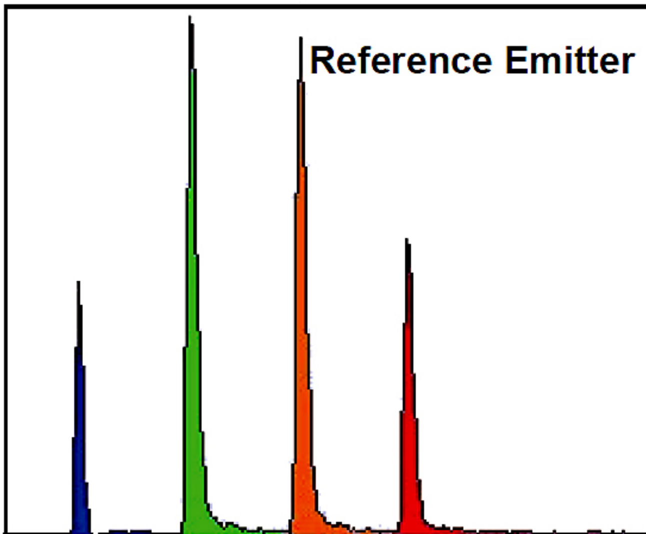
These two waveforms show two different products, each with a unique waveform.

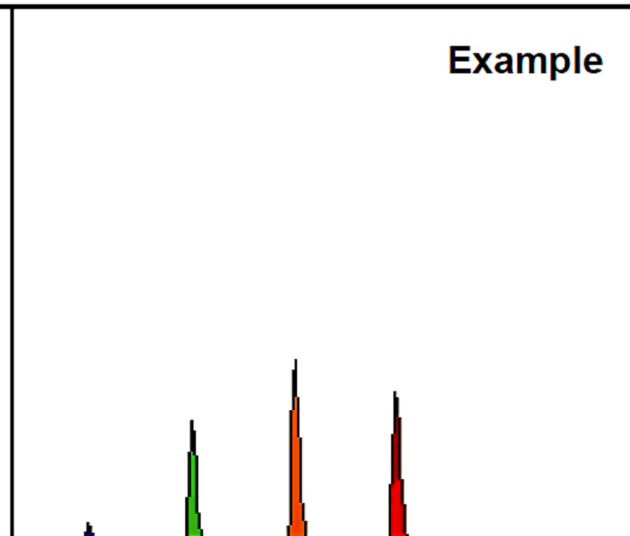
Note C:

The top zone has moderate fluorescence, but high scatter while the bottom zone has high fluorescence and low scatter. Note how this impacts the main signal plot.

Dakota Technologies TarGOST® Reference Log

Waveform Signal Calculation





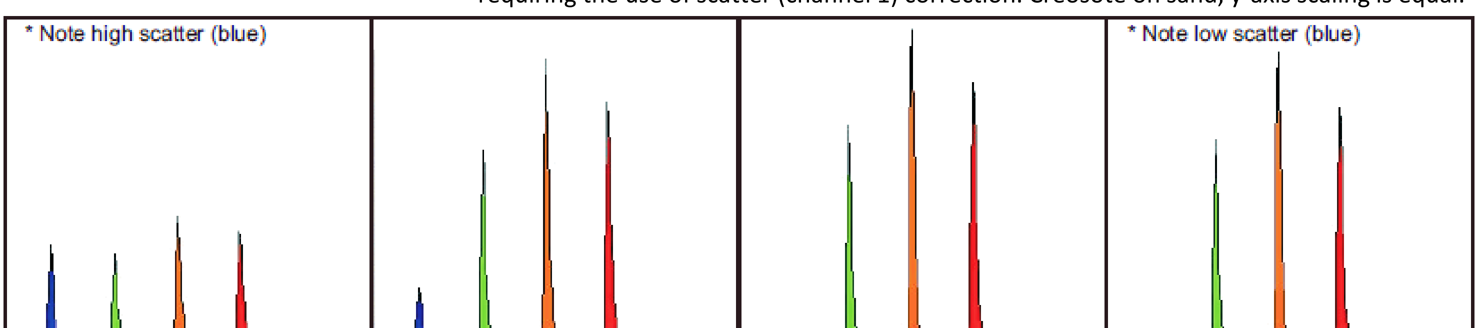
Channel	Sctr		CH2	+	CH3	+	CH4	=	Fluor	»	Total%
Reference Emitter – *Area (pVs)*	255	¦	785	+	772	+	462	=	2019	»	100/100
Reference Emitter – *Percent RE*	100	¦	38.9	+	38.2	+	22.9	=	100	»	100%
Example – *Area (pVs)*	36	¦	153	+	244	+	226	=	623	»	31/14
Example – *Percent RE*	14.1	¦	7.6	+	11.1	+	11.2	=	31	»	219%

Data Files

***.lif.raw.bin**	Raw data file. Header is ASCII format and contains information stored when the file was initially written (e.g. date, total depth, max signal, GPS, etc., and any information entered by the operator). All Raw waveforms are appended to the bottom of the file in a binary format.
***.lif.plt**	Stores the plot scheme history (e.g. callout depths) for associated Raw file. Transfer along with the Raw file in order to recall previous plots.
***.lif.jpg**	A .jpg image of the OST log including the main signal vs. depth plot, callouts, information, etc.
***.lif.dat.txt**	Data export of a single Raw file. Tab delimited format. No string header is provided for the columns to make importing into some programs easier. Each row is a unique depth reading. The columns are: 1-Depth; 2-Total Signal (%RE); 3-CH1%; 4-Ch2%; 5-CH3%; 6-Ch4%; 7-Rate; 8-EC Depth; 9-EC Signal; 10-Hammer Rate Depth; 11-Hammer Rate; 12-Color (RRGGBB). Summing channels 1 to 4 yields the Total Signal.
***.lif.sum.txt**	A summary file for a number of Raw files. ASCII tab delimited format. The file contains a string header. The summary includes one row for each Raw file and contains information for each filed including: the file name, GPS coordinates, max depth, max signal, and depth at which the max signal occurred.
***.lif.log.txt**	An activity log generated automatically is located in the OST application directory in the 'log' subfolder. Each OST unit the computer operates will generate a separate log file per month. A log file contains much of the header information contained within each separate Raw file, including: data rate, total depth, max signal, etc.

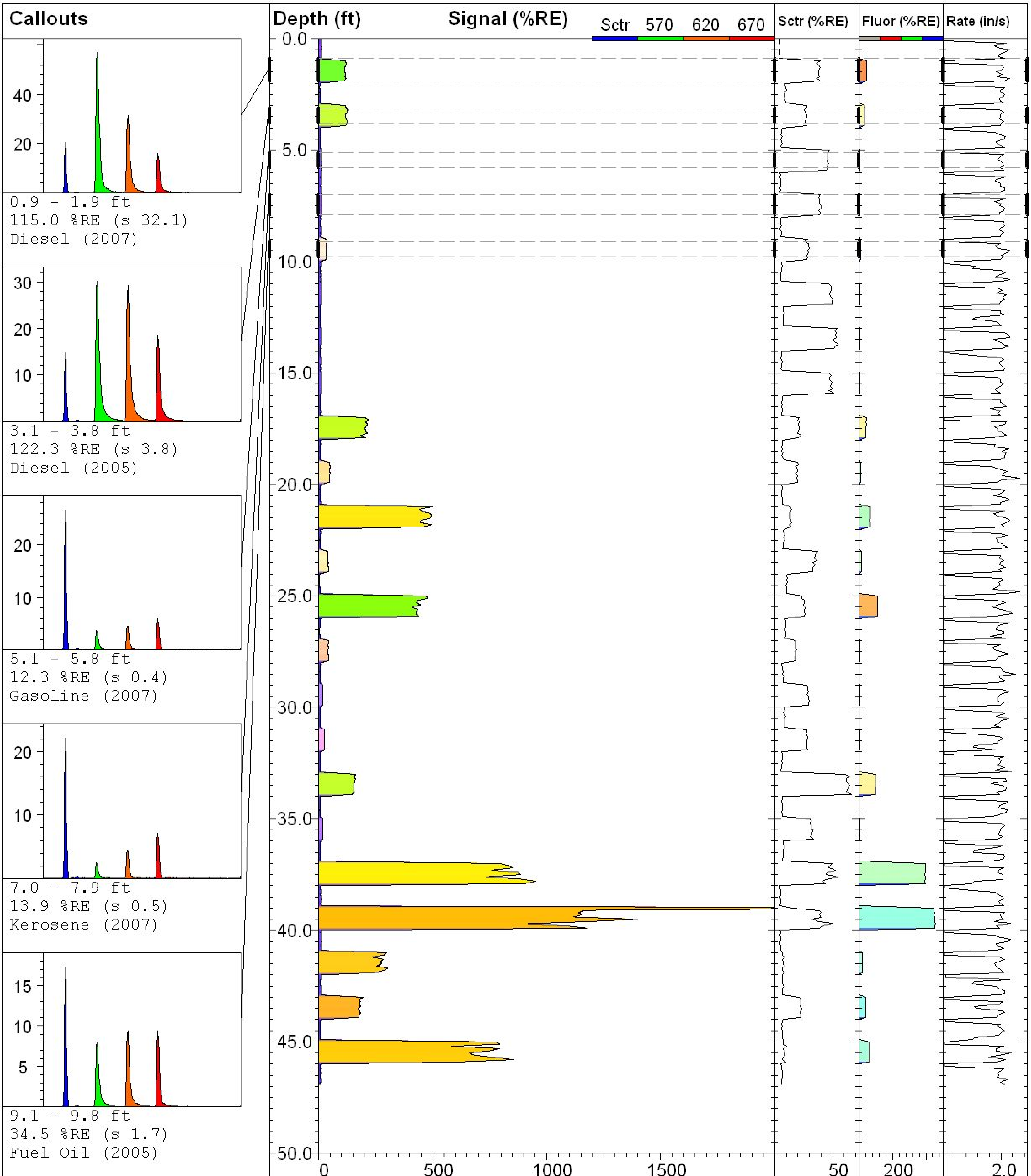
Non Linear Fluorescence

Due to self-absorption, fluorescence levels (channels 2-4) are not linear with concentration, requiring the use of scatter (channel 1) correction. Creosote on sand, y-axis scaling is equal.



1,000ppm (60%RE) | 10,000ppm (215%RE) | 100,000ppm (935%RE) | Neat (1925%RE)

SUB-ATTACHMENT 5F-2.2
TarGOST Responses of Various Products with Sand



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TG_various products on sand

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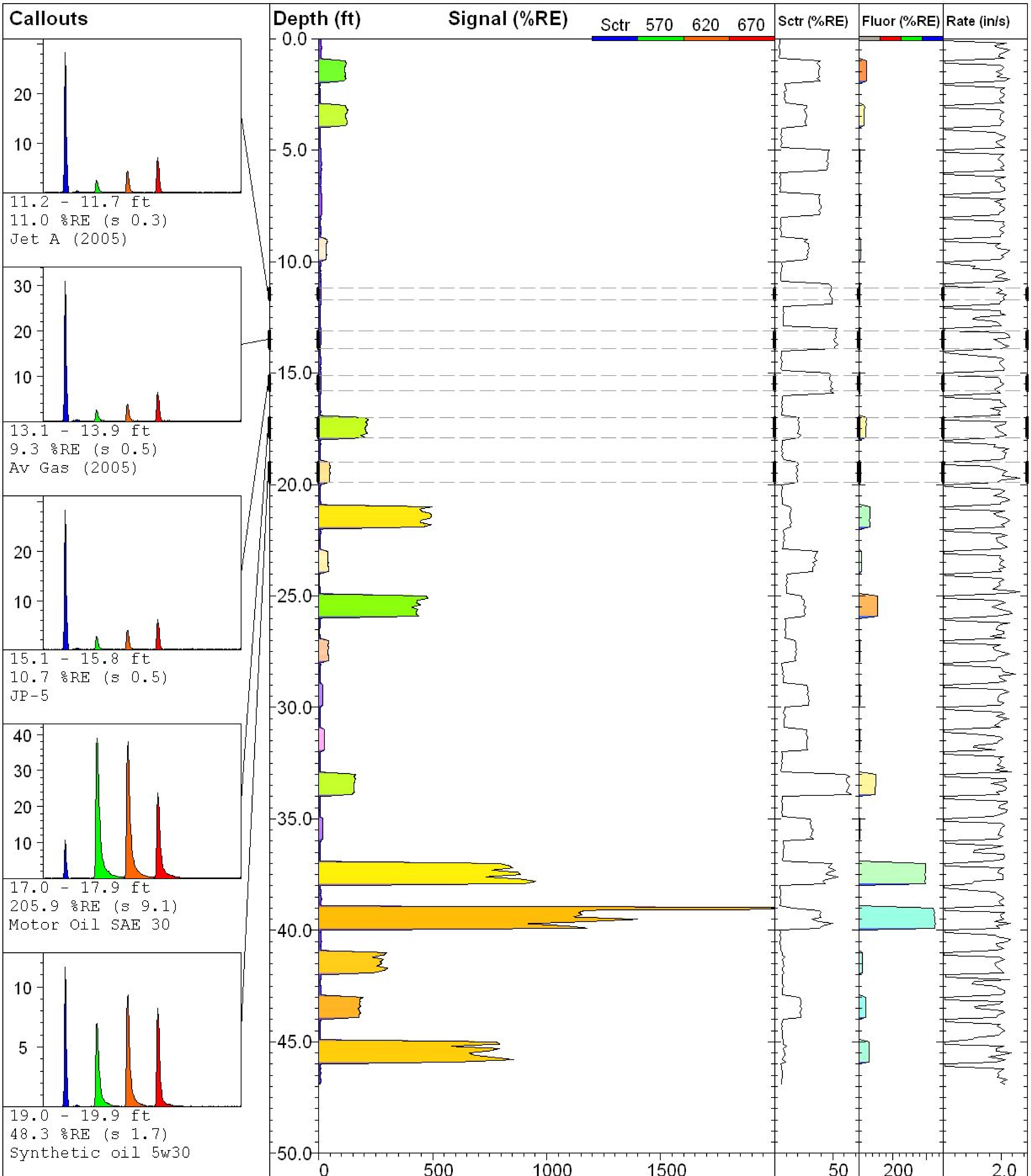
Site:	*Latitude / Datum:* **Unavailable / NA**	*Final depth:* **46.90 ft**
Client:	*Longitude / Fix:* **Unavailable / NA**	*Max signal:* **2964.7 % @ 39.00 ft**
Job:	*Operator/Unit:* **TJR/TG1001**	*Date & Time:* **2008-06-04 15:42 CDT**



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TarGOST By Dakota
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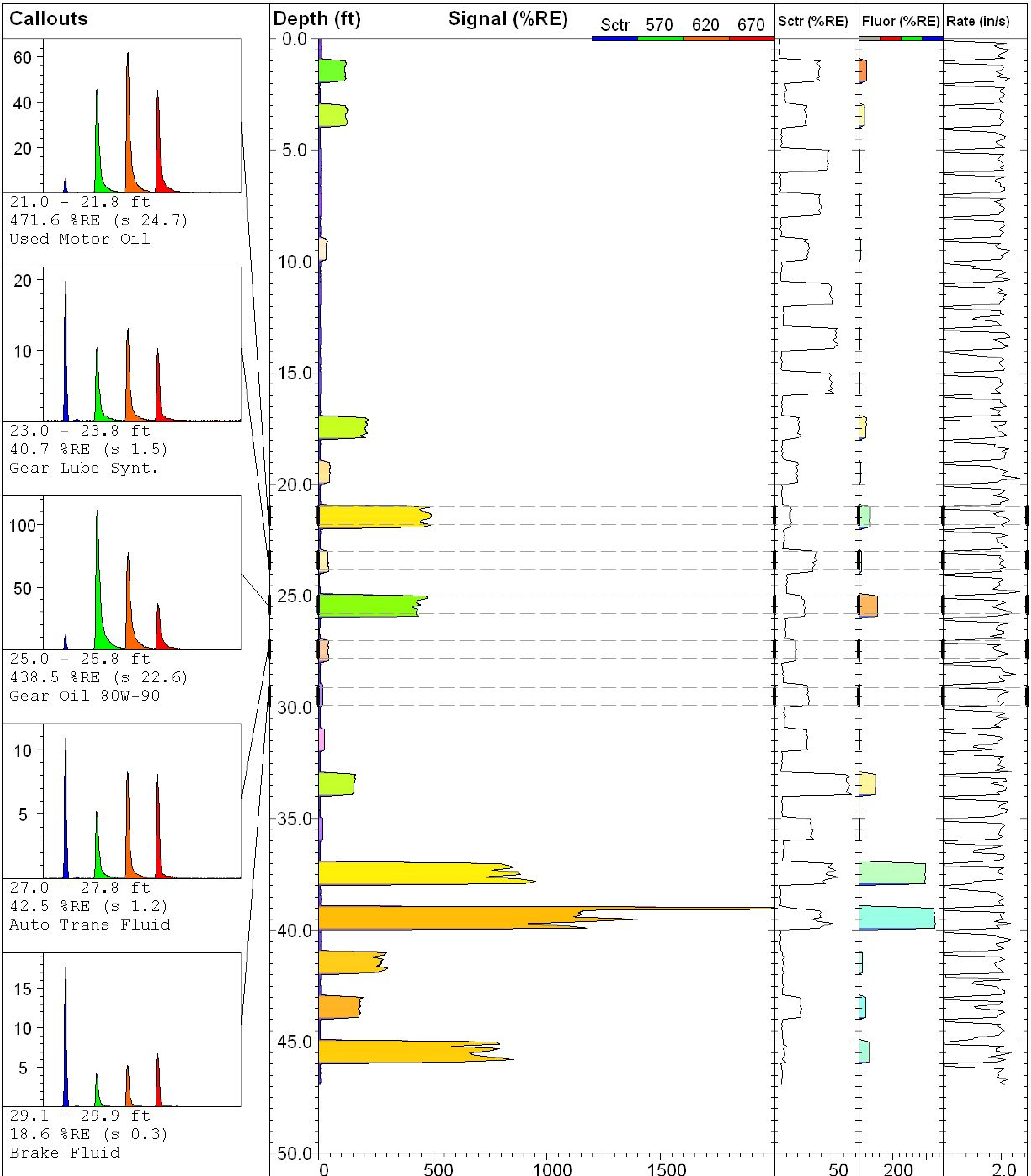
Site:	*Latitude / Datum:* **Unavailable / NA**	*Final depth:* **46.90 ft**
Client:	*Longitude / Fix:* **Unavailable / NA**	*Max signal:* **2964.7 % @ 39.00 ft**
Job:	*Operator/Unit:* **TJR/TG1001**	*Date & Time:* **2008-06-04 15:42 CDT**



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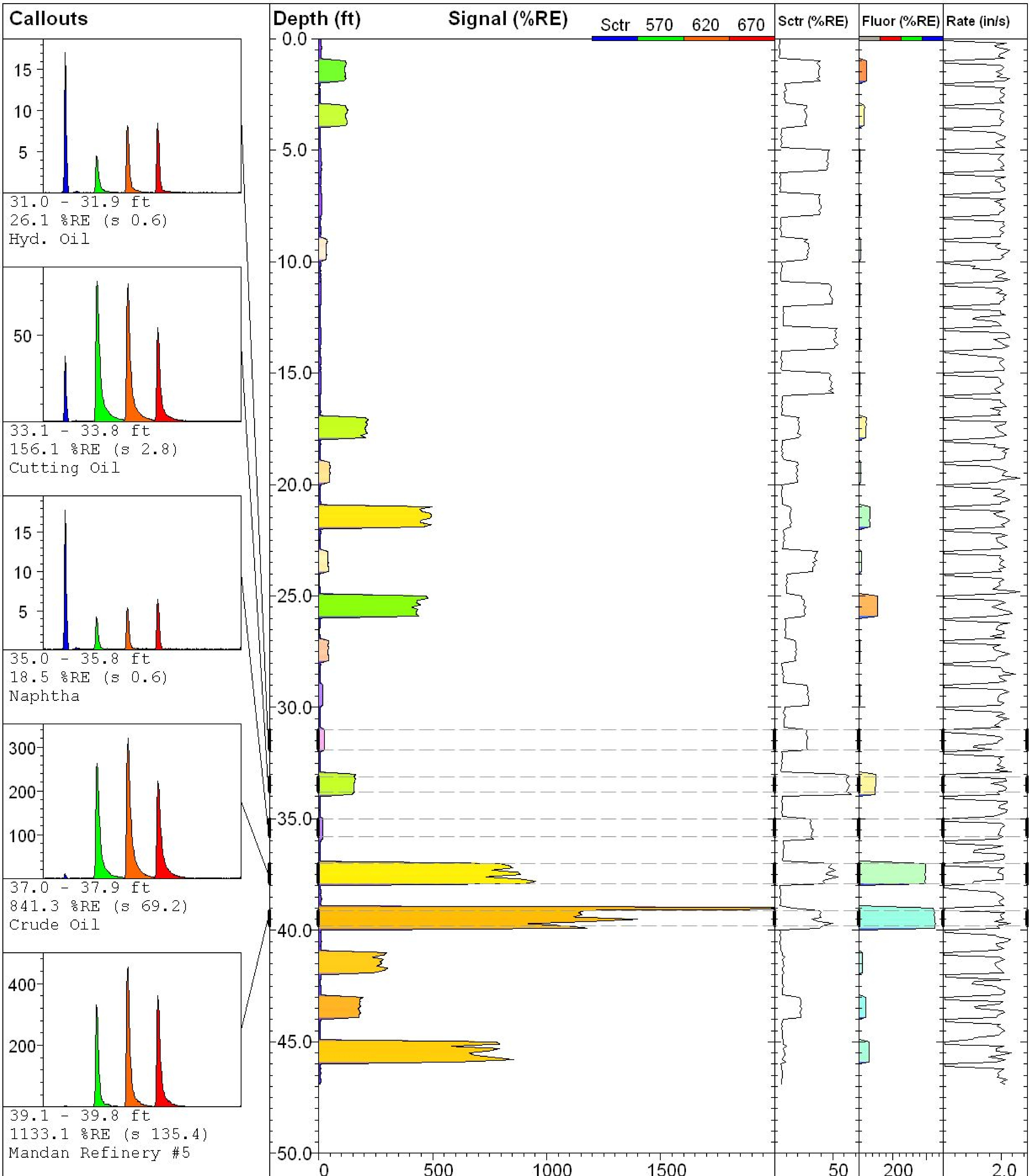
Site:	*Latitude / Datum:* **Unavailable / NA**	*Final depth:* **46.90 ft**
Client:	*Longitude / Fix:* **Unavailable / NA**	*Max signal:* **2964.7 % @ 39.00 ft**
Job:	*Operator/Unit:* **TJR/TG1001**	*Date & Time:* **2008-06-04 15:42 CDT**



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TG_various products on sand

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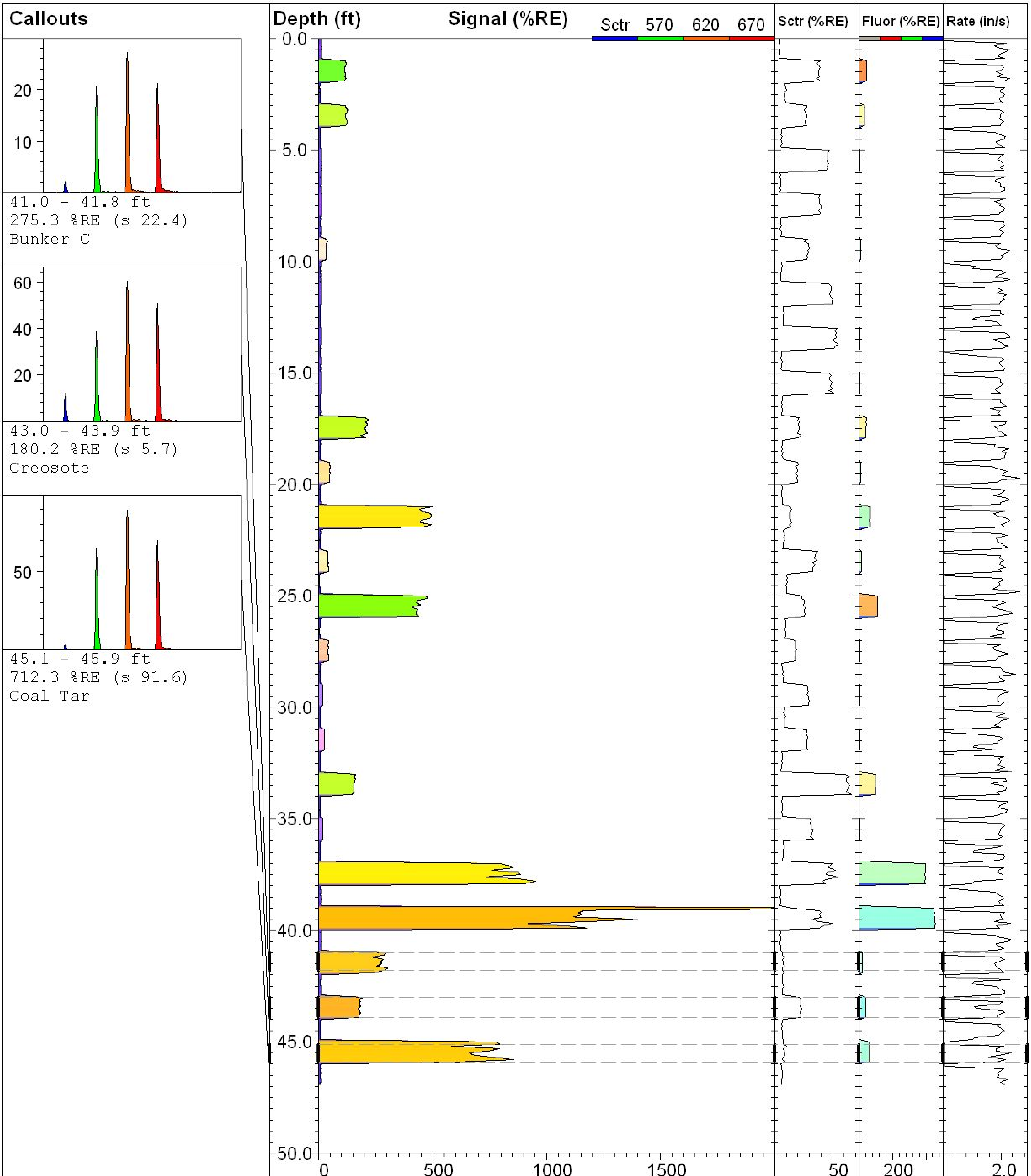
Site:	*Latitude / Datum:* **Unavailable / NA**	*Final depth:* **46.90 ft**
Client:	*Longitude / Fix:* **Unavailable / NA**	*Max signal:* **2964.7 % @ 39.00 ft**
Job:	*Operator/Unit:* **TJR/TG1001**	*Date & Time:* **2008-06-04 15:42 CDT**



TG_various products on sand		TarGOST By Dakota www.DakotaTechnologies.com
Site:	*Latitude / Datum:* **Unavailable / NA**	*Final depth:* **46.90 ft**
Client:	*Longitude / Fix:* **Unavailable / NA**	*Max signal:* **2964.7 % @ 39.00 ft**
Job:	*Operator/Unit:* **TJR/TG1001**	*Date & Time:* **2008-06-04 15:42 CDT**

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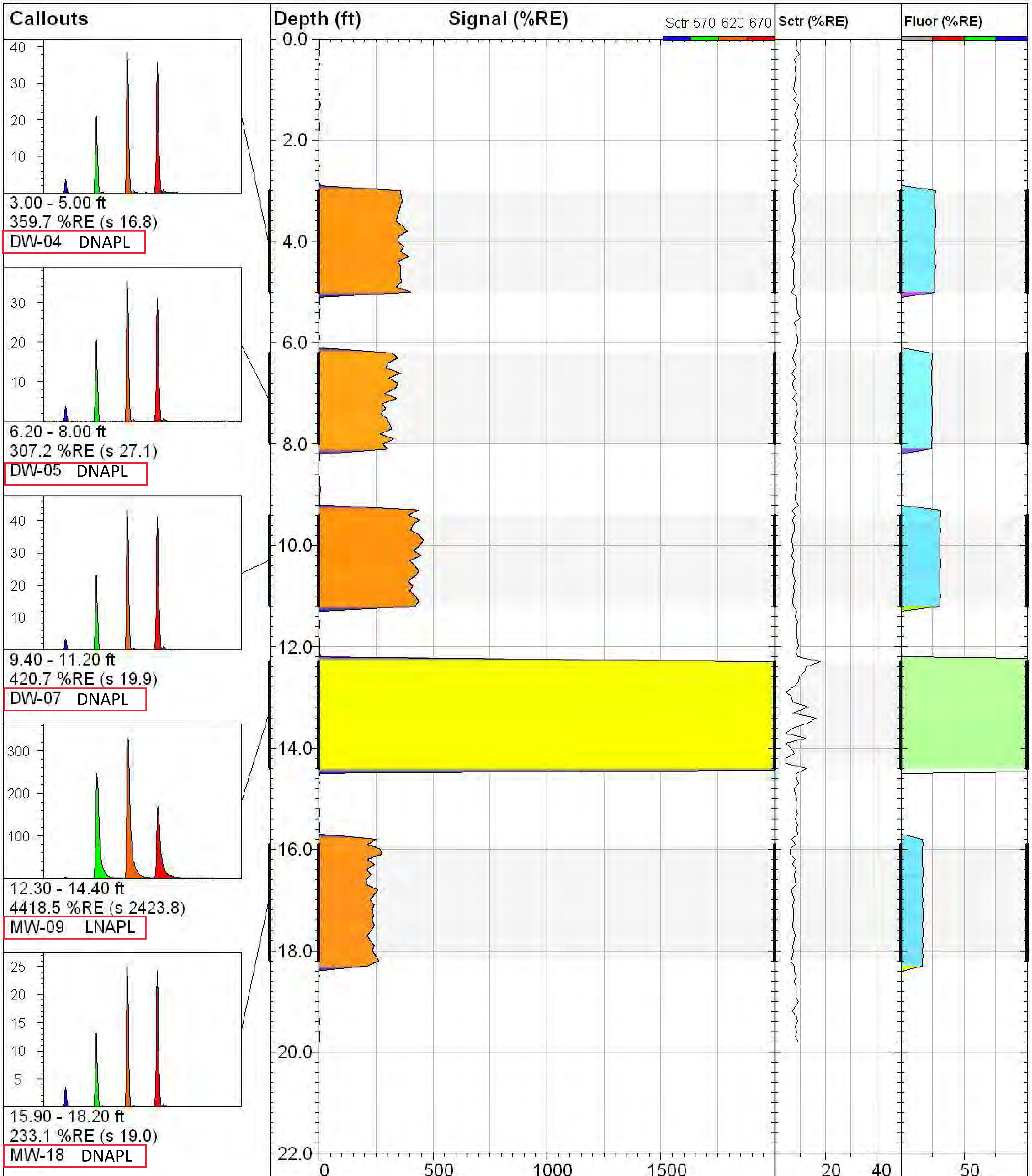
SUB-ATTACHMENT 5F-2.3
TarGOST Responses to Upland AOI NAPL

Ex-Situ Upland AOI NAPL Samples (disregard depths)



Gas Works Park		**TarGOST By Dakota** www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **19.80 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **9144.9 %RE @ 13.70 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-03-05 15:46 CST**

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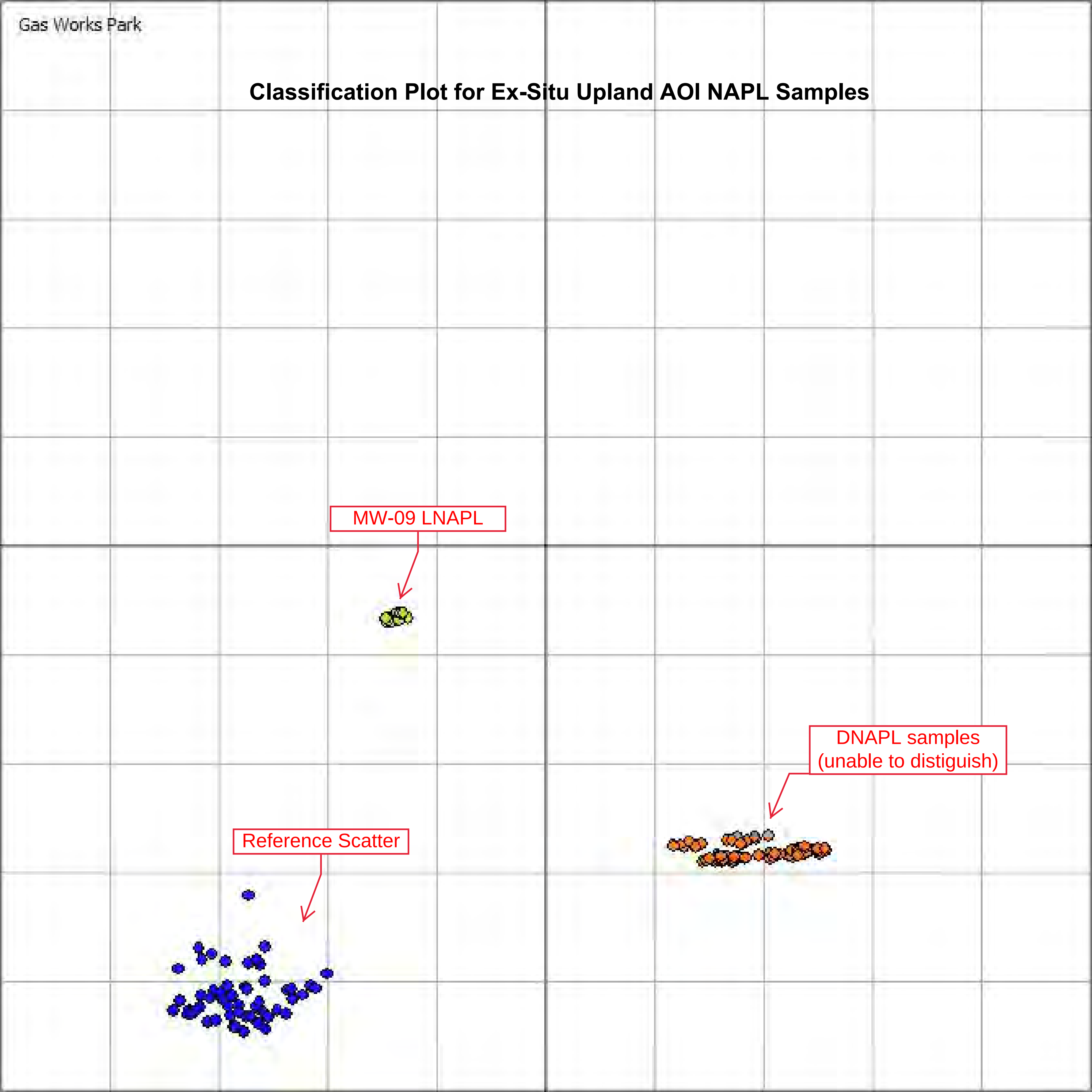
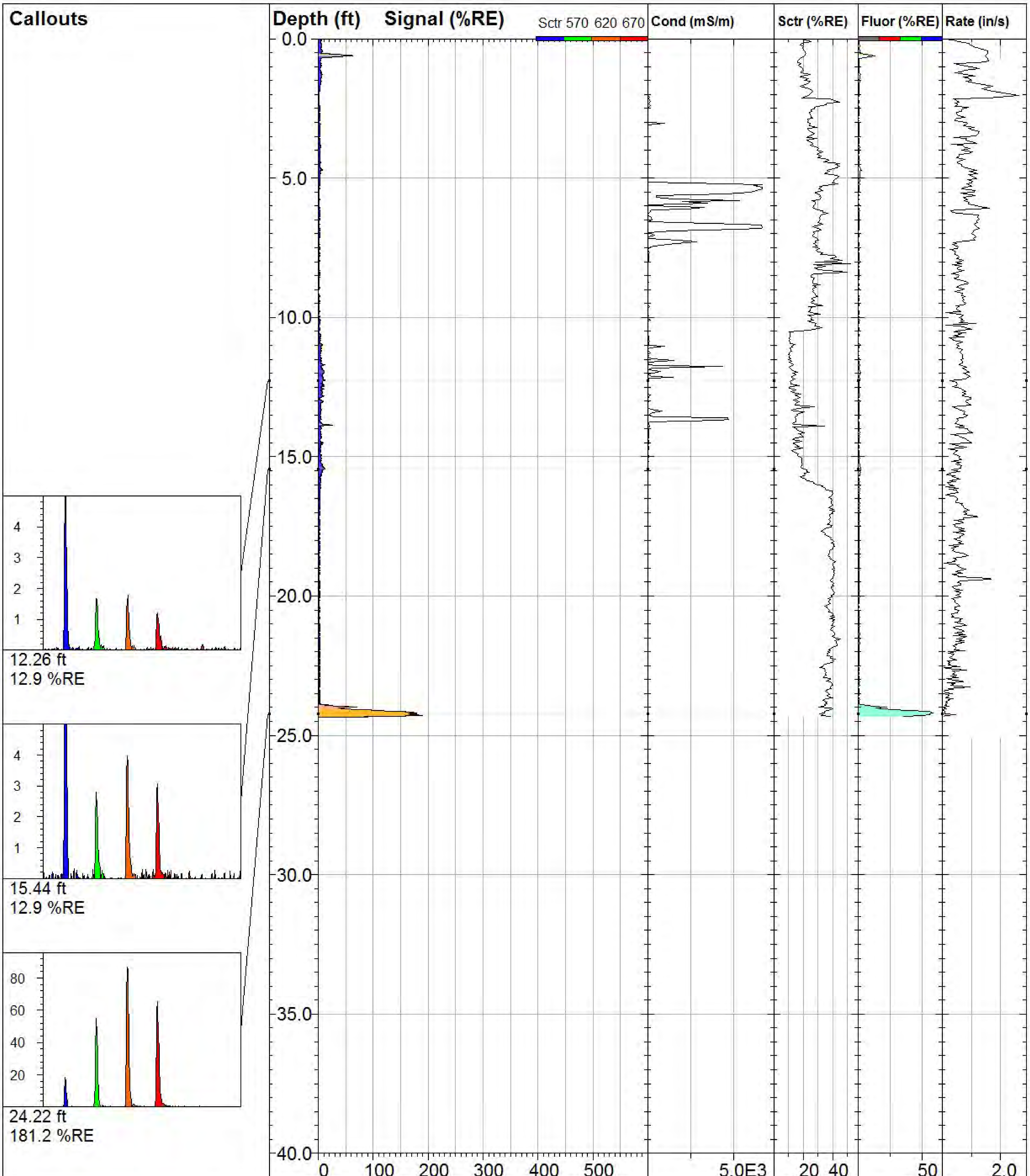

Gas Works Park
Classification Plot for Ex-Situ Upland AOI NAPL Samples
MW-09 LNAPL
DNAPL samples
(unable to distiguish)
Reference Scatter

SUB-ATTACHMENT 5F-2.4
Select TarGOST Upland AOI Results

Select TarGOST Upland AOI Logs



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GWP_TG-05

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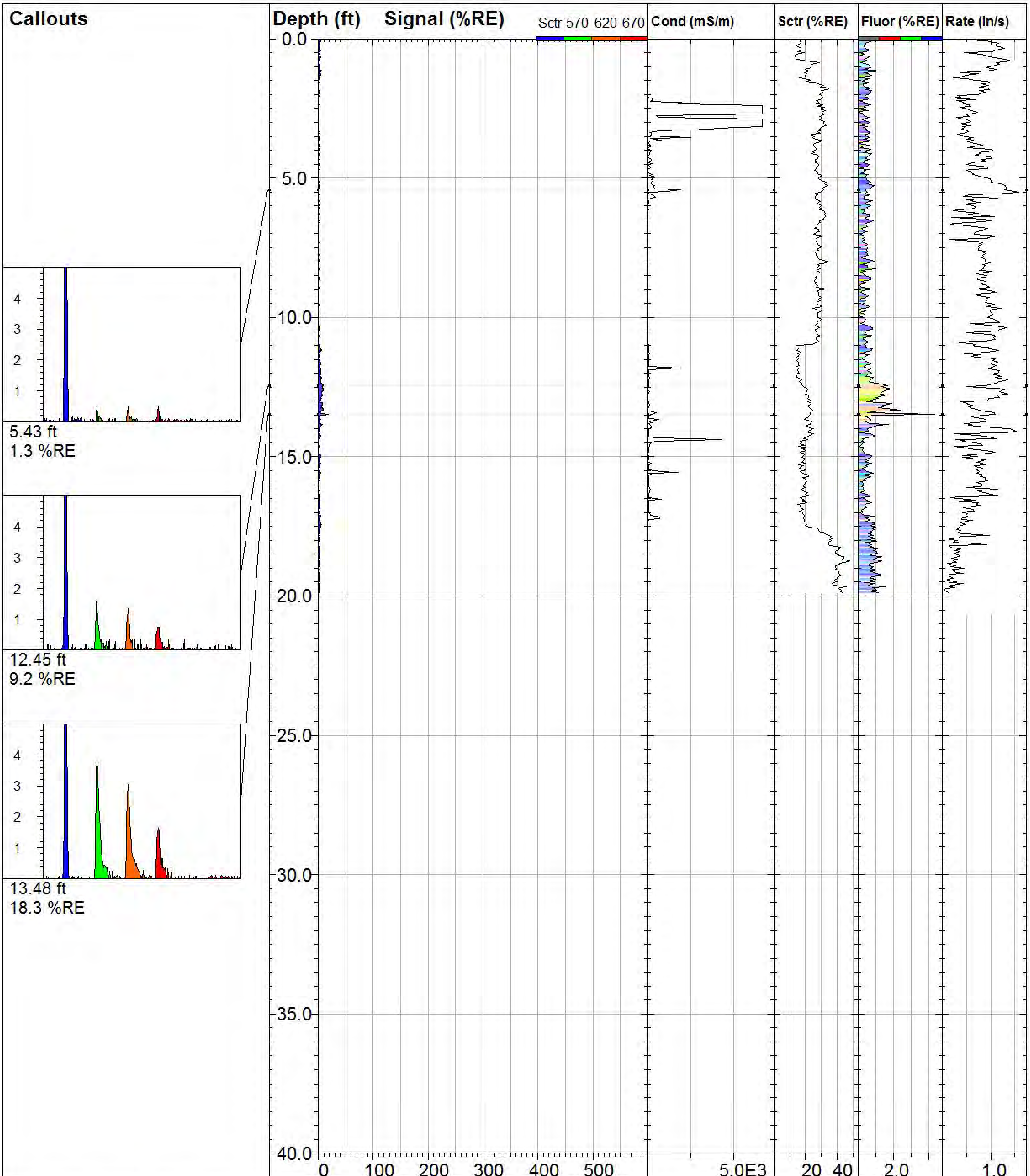
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239494.1244 /**	*Final depth:* **24.35 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270751.378 /**	*Max signal:* **196.5 %RE @ 24.29 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **31.8 ft**	*Date & Time:* **2013-03-19 10:10 PDT**



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GWP_TG-09

TarGOST By Dakota
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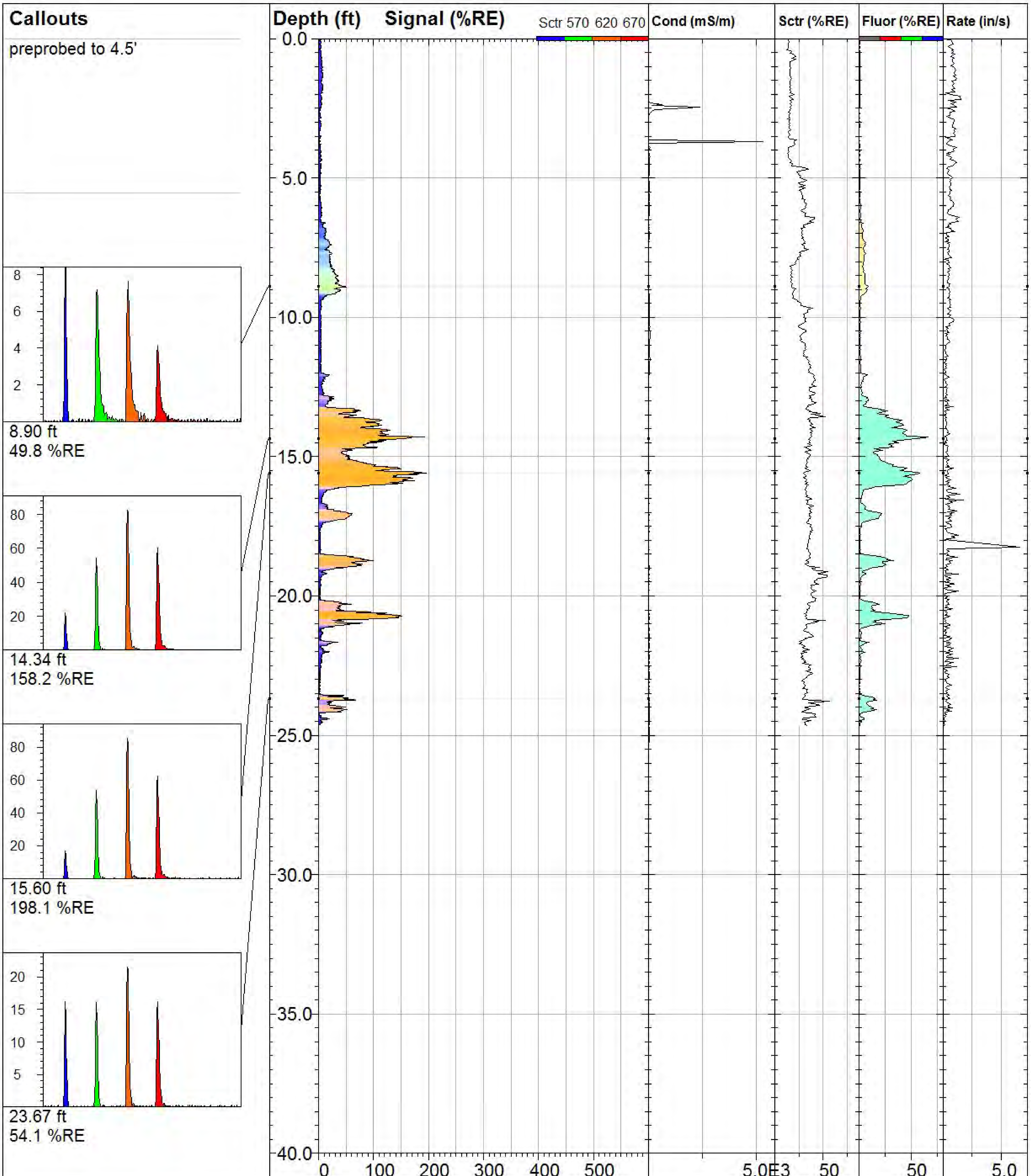
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239330.837 /**	*Final depth:* **19.89 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270782.064 /**	*Max signal:* **18.3 %RE @ 13.48 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **32.1 ft**	*Date & Time:* **2013-03-19 15:26 PDT**



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GWP_TG-11

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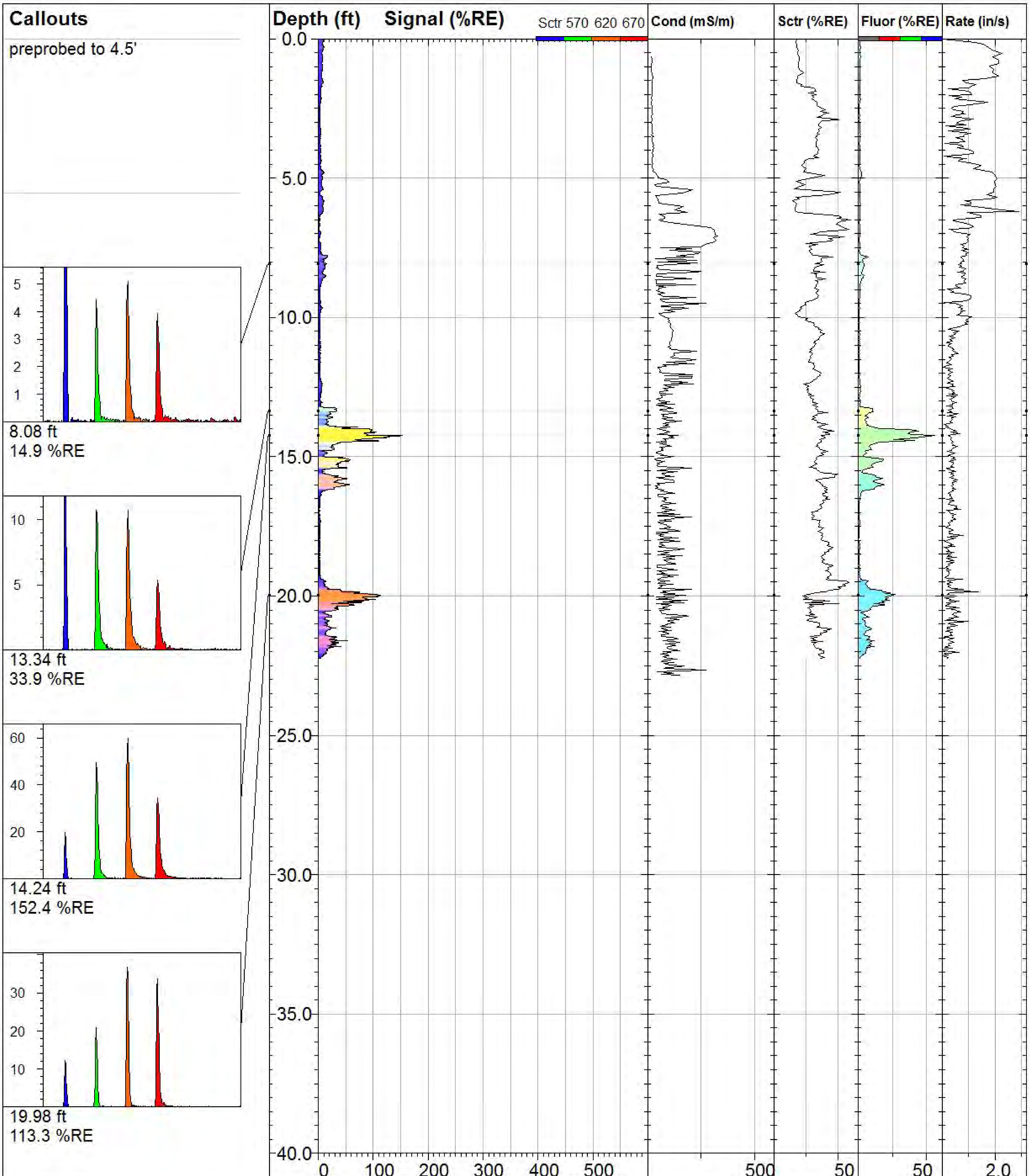
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239143.7821 /**	*Final depth:* **24.64 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270529.323 /**	*Max signal:* **198.1 %RE @ 15.60 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **35.0 ft**	*Date & Time:* **2013-03-20 08:31 PDT**



GWP_TG-14

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Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239204.4909 /**	*Final depth:* **22.23 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270500.945 /**	*Max signal:* **152.4 %RE @ 14.24 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **36.3 ft**	*Date & Time:* **2013-03-20 13:14 PDT**

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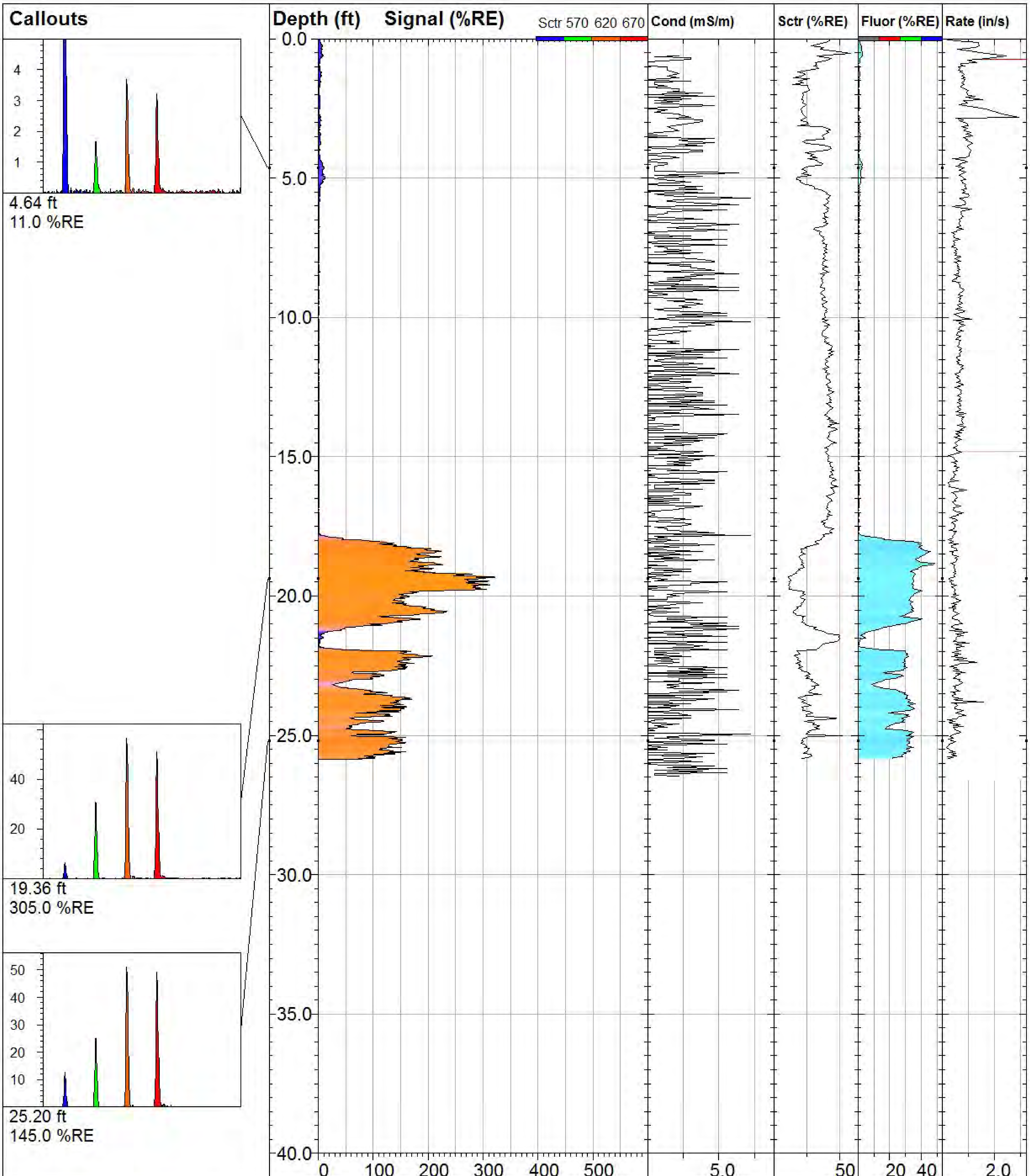

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GWP_TG-21

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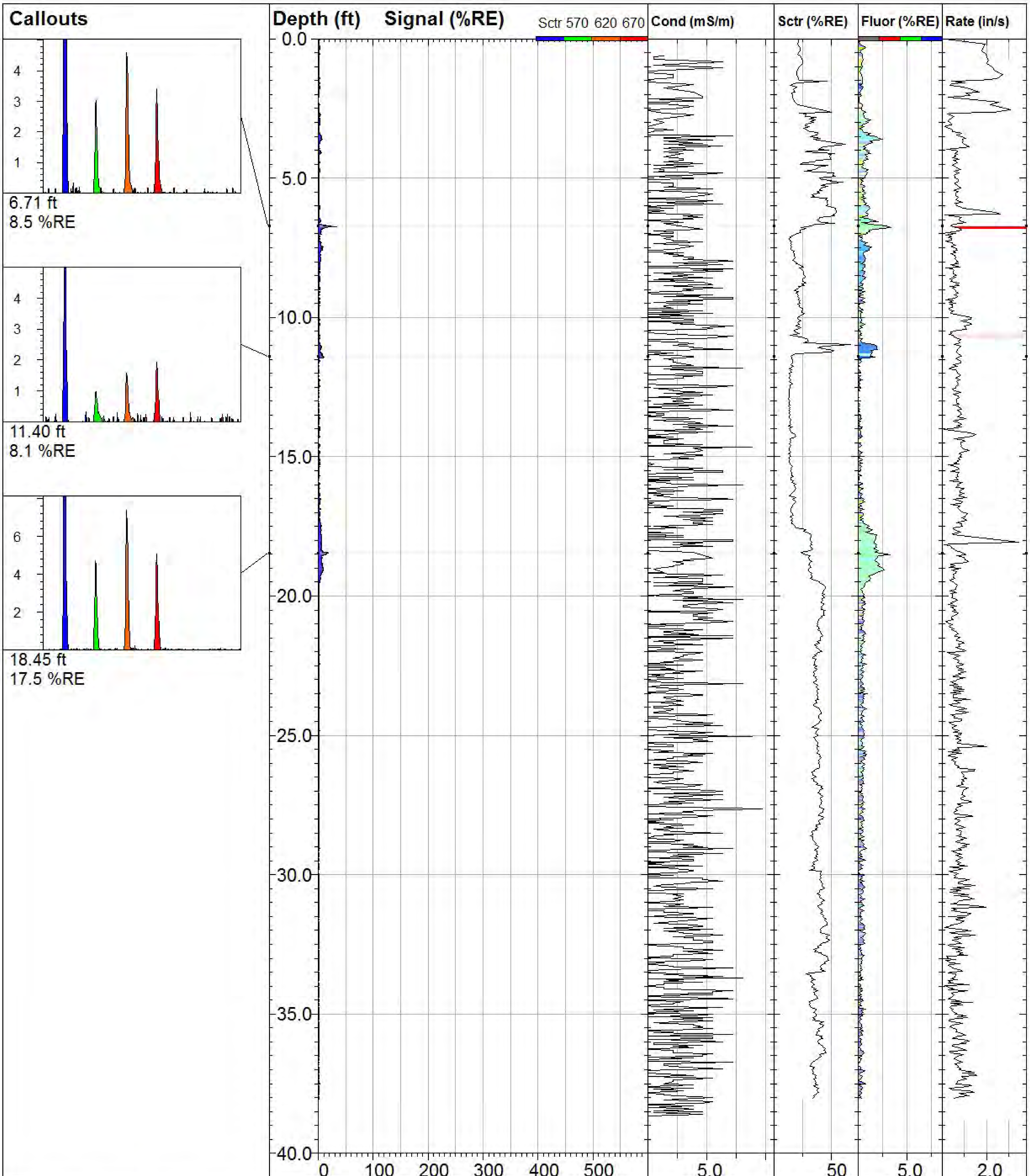
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239223.5495 /**	*Final depth:* **25.86 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1269703.395 /**	*Max signal:* **323.3 %RE @ 19.32 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **25.9 ft**	*Date & Time:* **2013-03-21 13:16 PDT**



GWP_TG-31

TarGOST By Dakota
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Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238788.0712 /**	*Final depth:* **38.04 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270253.225 /**	*Max signal:* **34.3 %RE @ 6.74 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **38.3 ft**	*Date & Time:* **2013-03-22 15:48 PDT**

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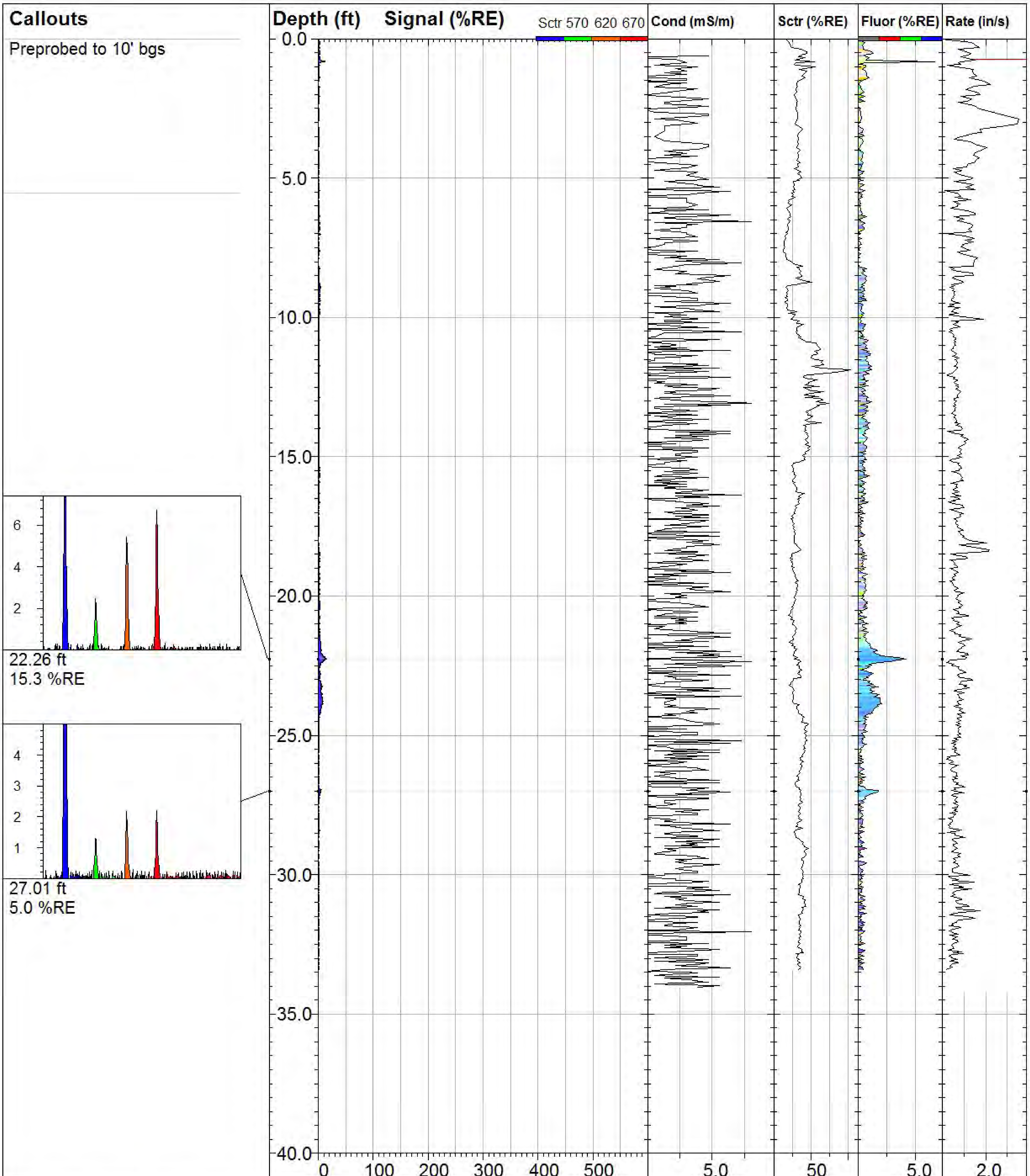

GWP_TG-32B

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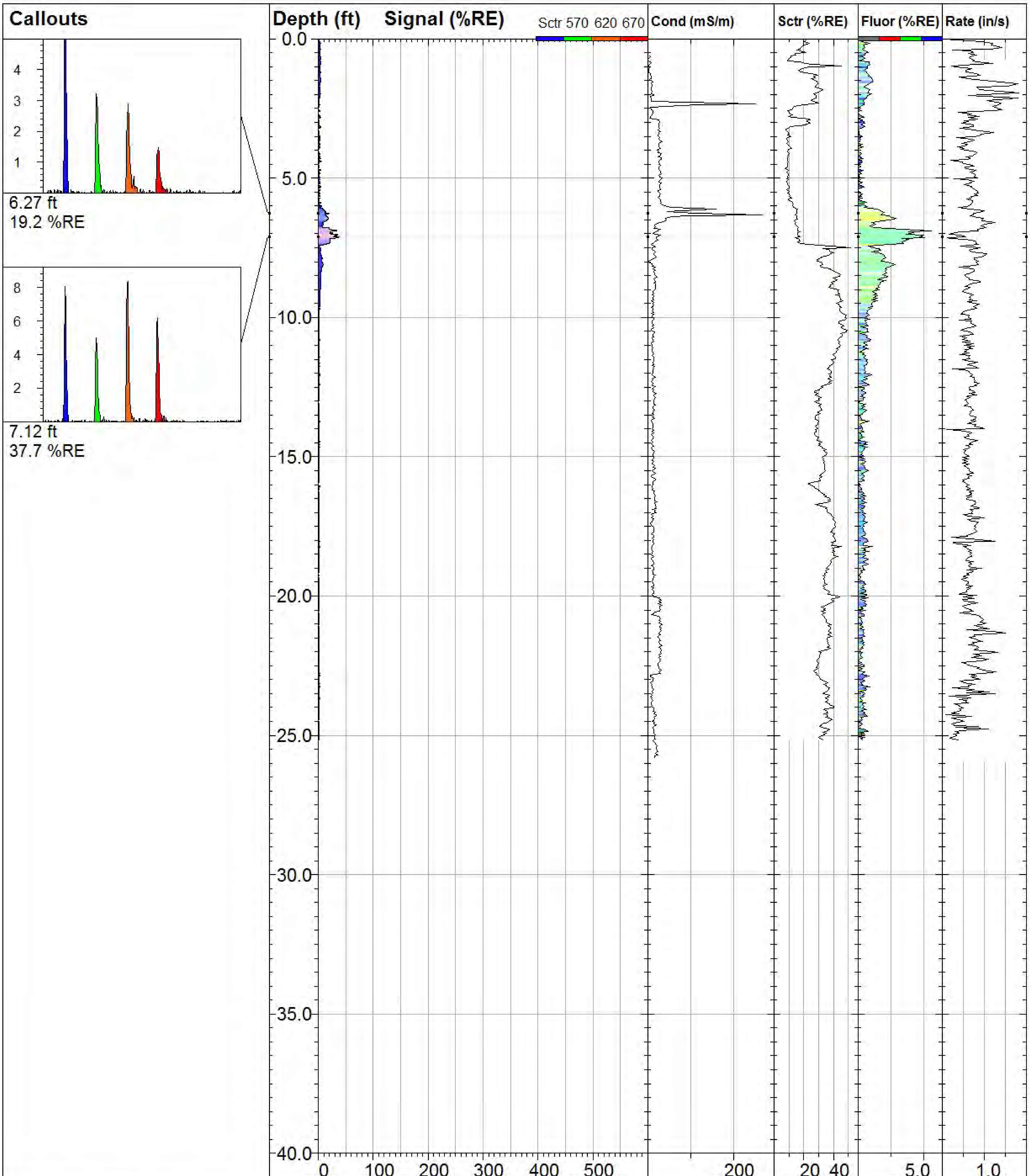
Site:	*Y Coord.(Lat-N) / System:*	*Final depth:*
Gas Works Park	**238860.1566 /**	**33.42 ft**
Client / Job:	*X Coord.(Lng-E) / Fix:*	*Max signal:*
GeoEngineers /	**1270251.303 /**	**15.3 %RE @ 22.26 ft**
Operator / Unit:	*Elevation:*	*Date & Time:*
SDA / TG1004	**37.2 ft**	**2013-03-22 17:35 PDT**



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GWP_TG-35

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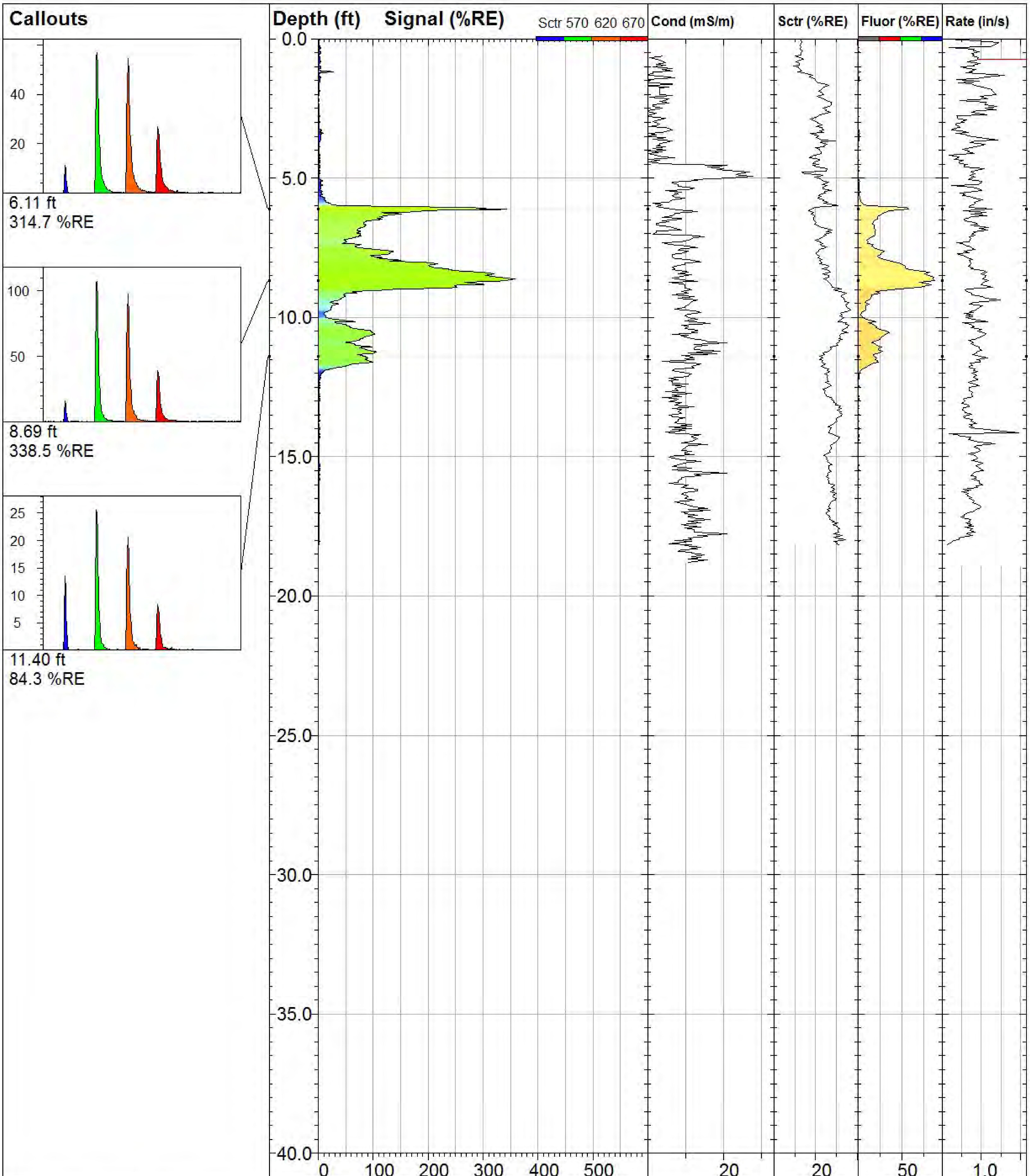
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238774.6398 /**	*Final depth:* **25.19 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270178.383 /**	*Max signal:* **37.7 %RE @ 7.12 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **26.2 ft**	*Date & Time:* **2013-03-25 11:36 PDT**



GWP_TG-36

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Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238869.2682 /**	*Final depth:* **18.17 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270180.147 /**	*Max signal:* **357.5 %RE @ 8.62 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **28.2 ft**	*Date & Time:* **2013-03-25 13:49 PDT**

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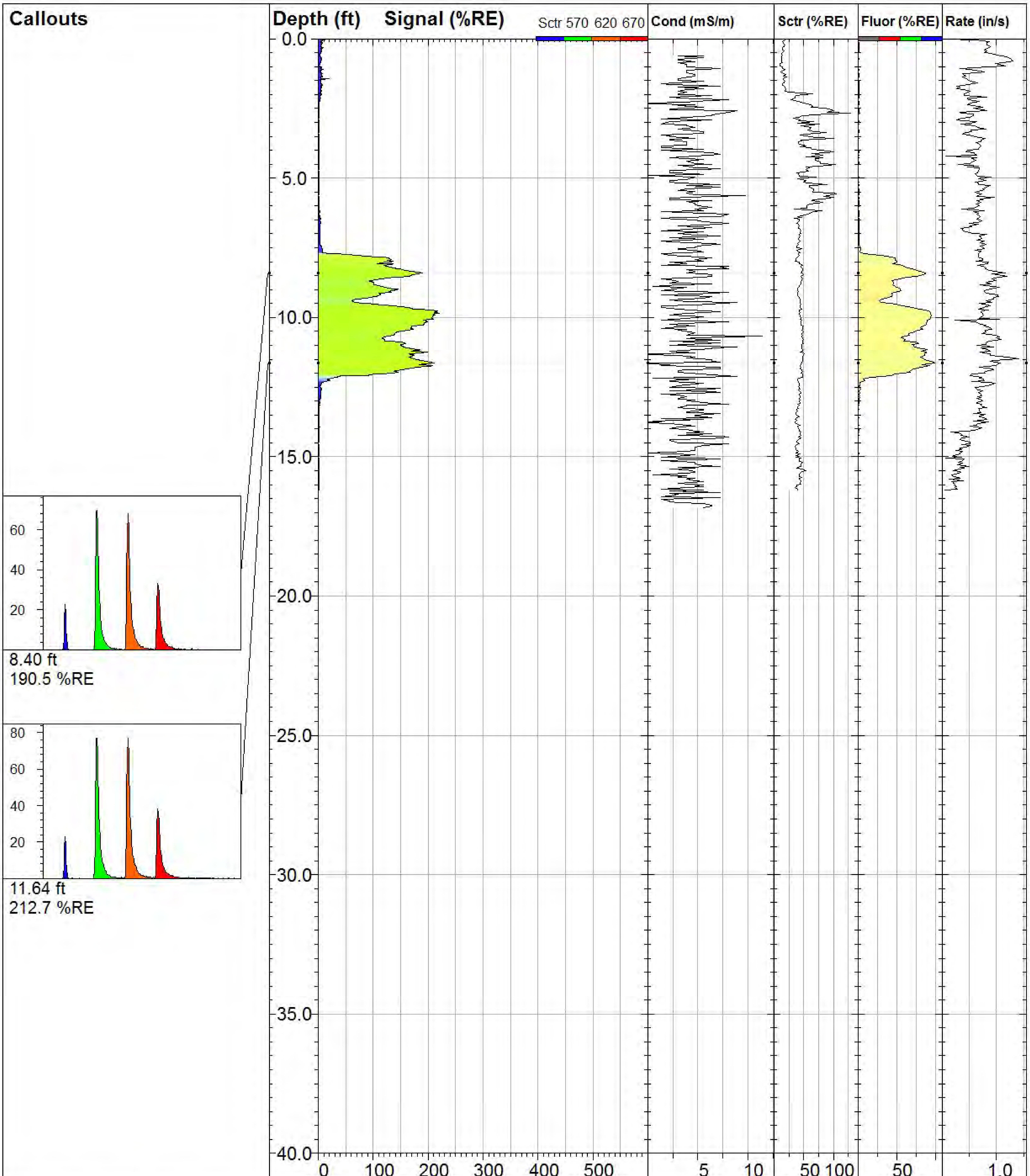

GWP_TG-38

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Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238985.015 /**	*Final depth:* **16.19 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270158.344 /**	*Max signal:* **220.5 %RE @ 9.85 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **30.8 ft**	*Date & Time:* **2013-03-25 16:17 PDT**

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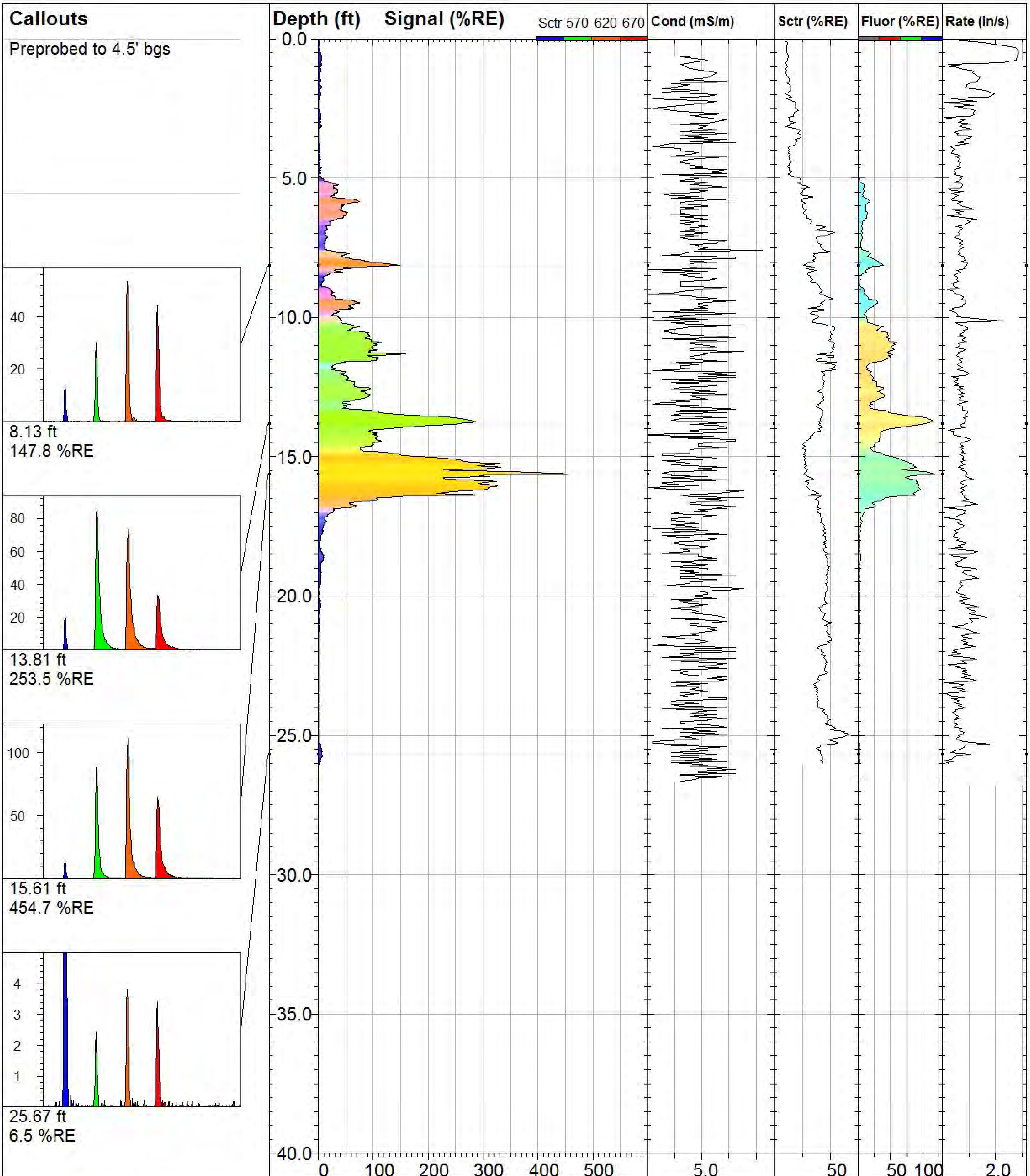

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GWP_TG-39

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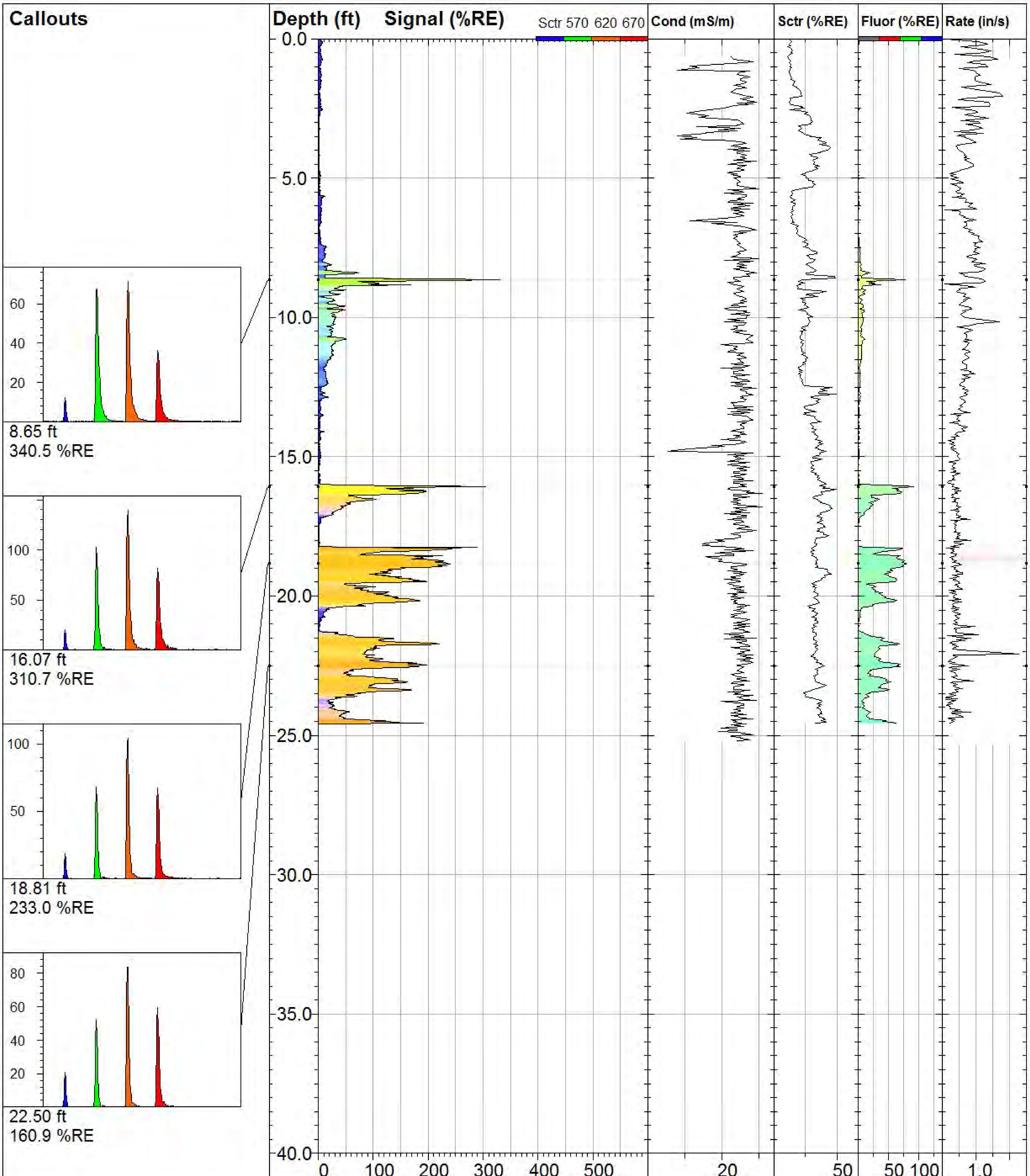
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239048.8756 /**	*Final depth:* **26.03 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270198.071 /**	*Max signal:* **454.7 %RE @ 15.61 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **35.7 ft**	*Date & Time:* **2013-03-25 17:09 PDT**



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GWP_TG-46

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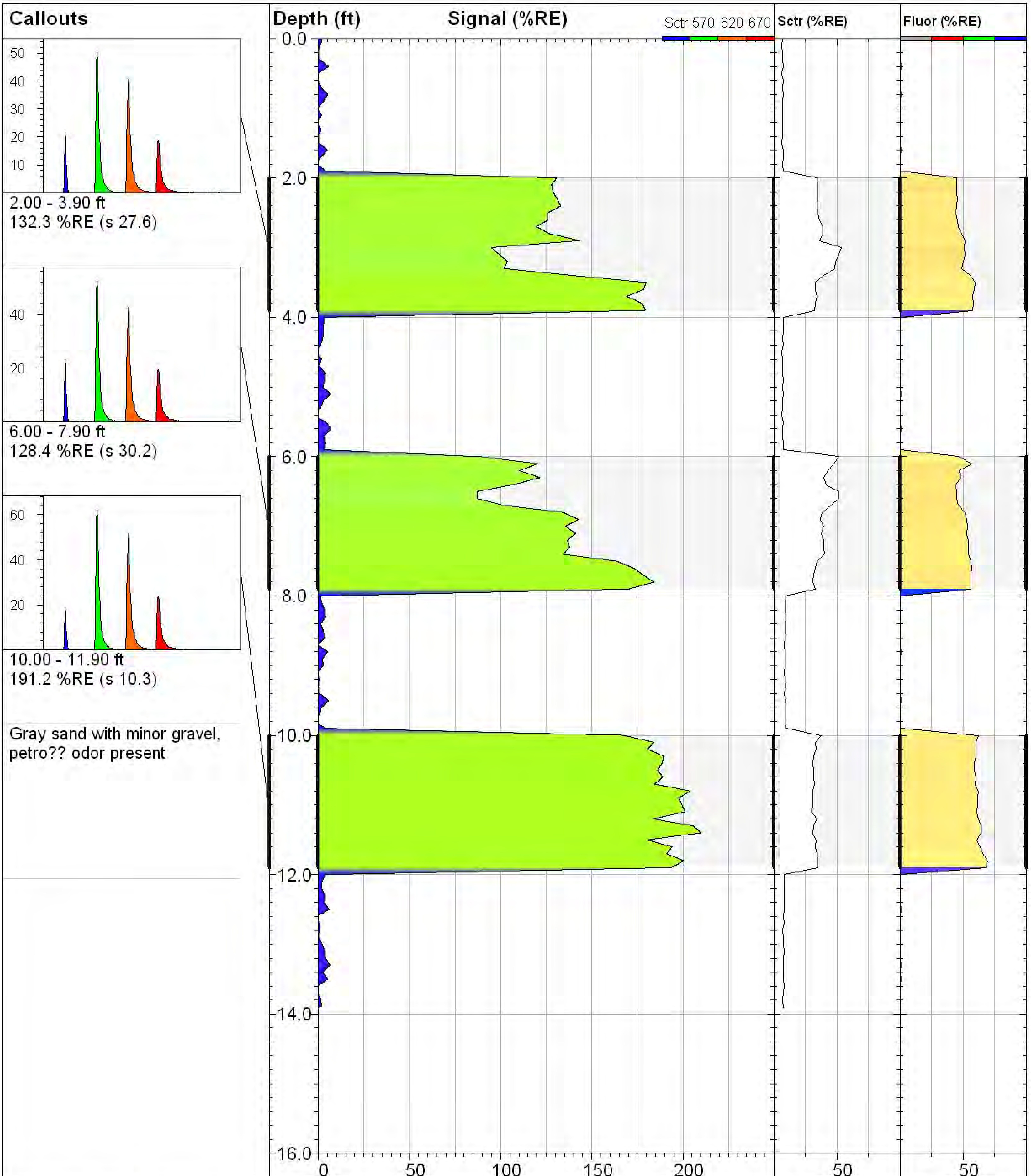
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239145.0135 /**	*Final depth:* **24.58 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270452.875 /**	*Max signal:* **340.5 %RE @ 8.65 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **38.7 ft**	*Date & Time:* **2013-03-26 15:44 PDT**

Select TarGOST Upland AOI Soil Confirmation Logs



GEI_12_11_15		TarGOST By Dakota www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **13.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **210.1 %RE @ 11.40 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 10:54 PDT**

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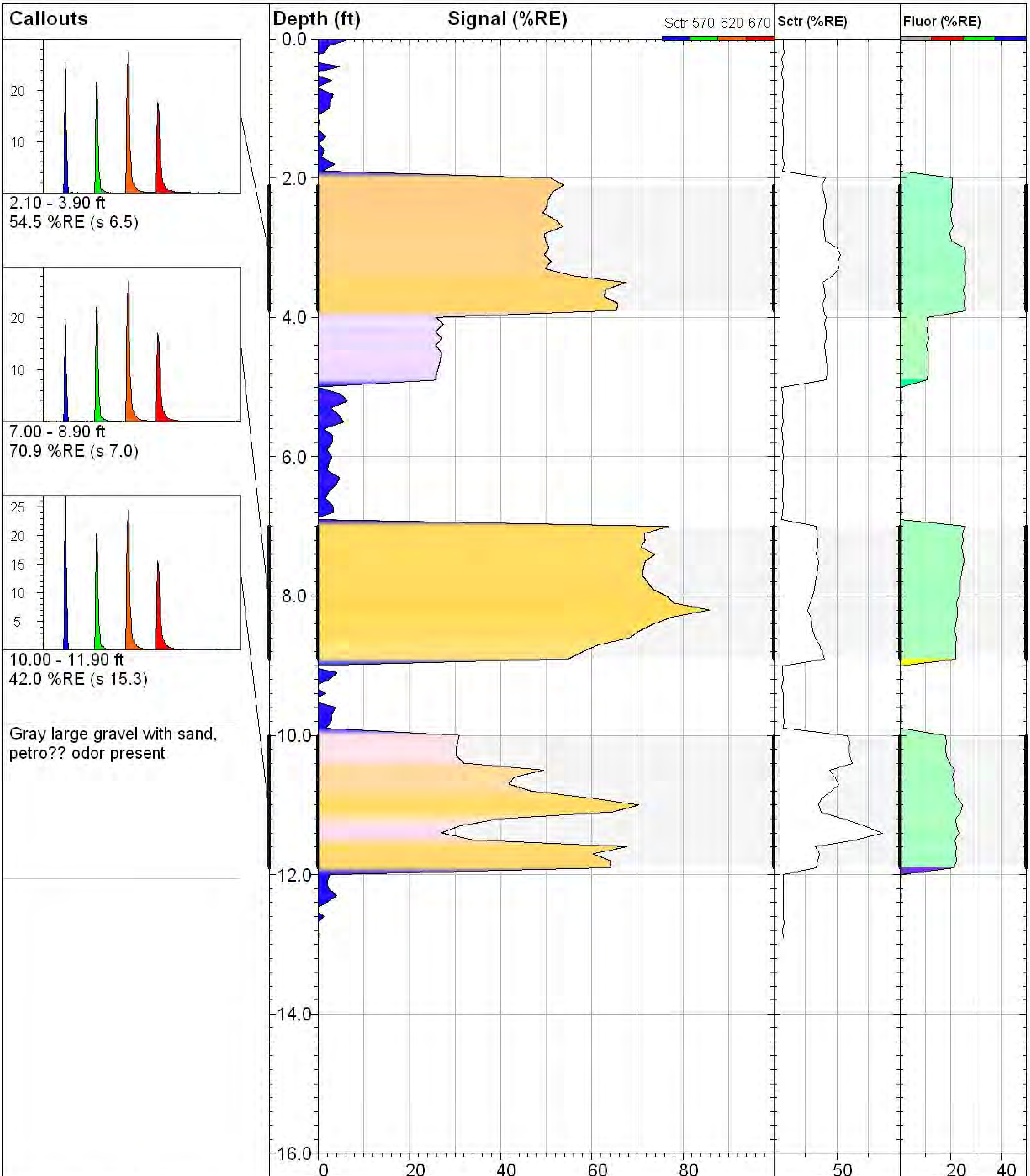

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GEI_12_15_17

TarGOST By Dakota
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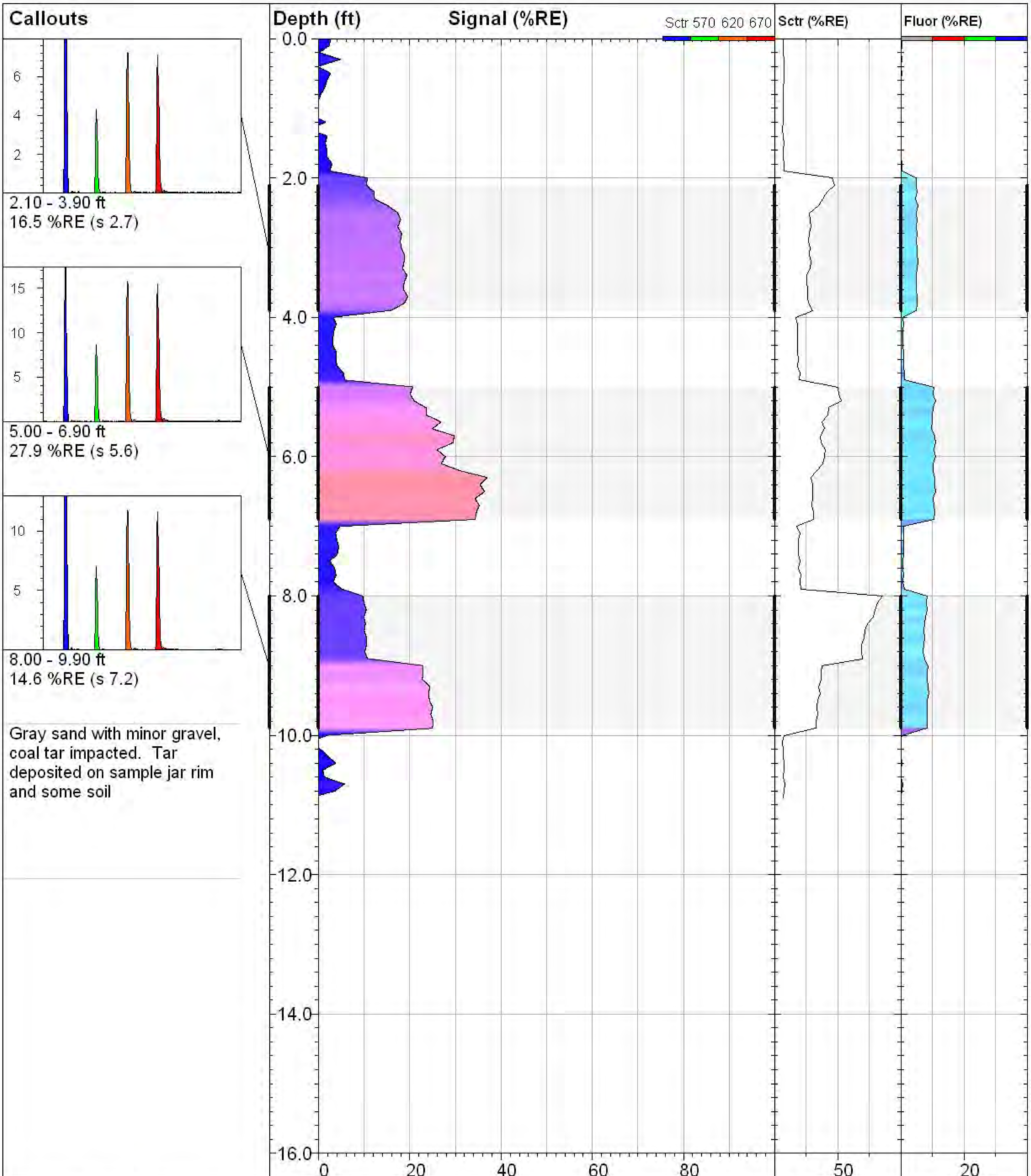
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **12.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **85.8 %RE @ 8.20 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 11:03 PDT**



GEI_12_25_26

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Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **10.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **37.0 %RE @ 6.30 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 11:21 PDT**

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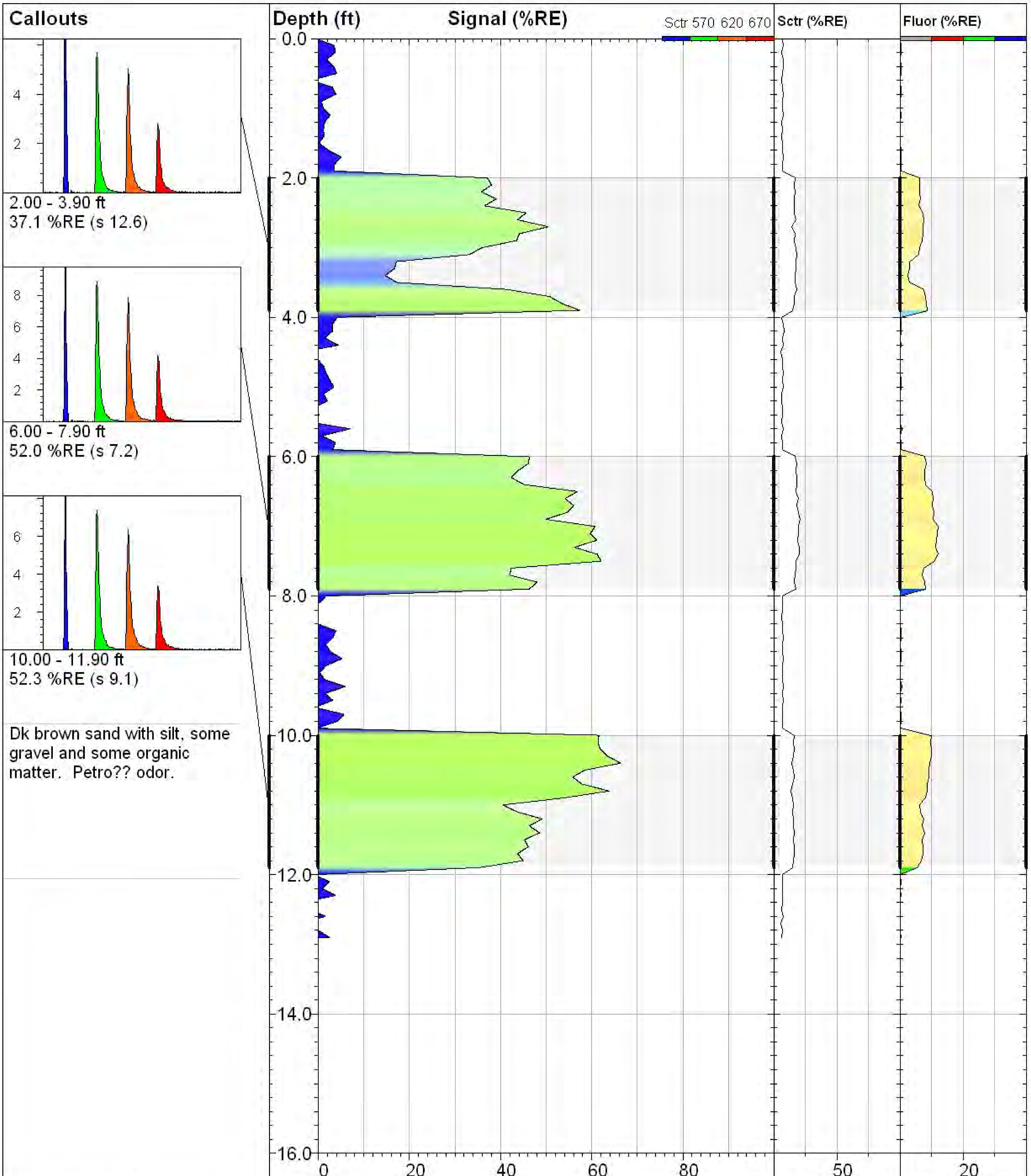

GEI_13_8_9.5

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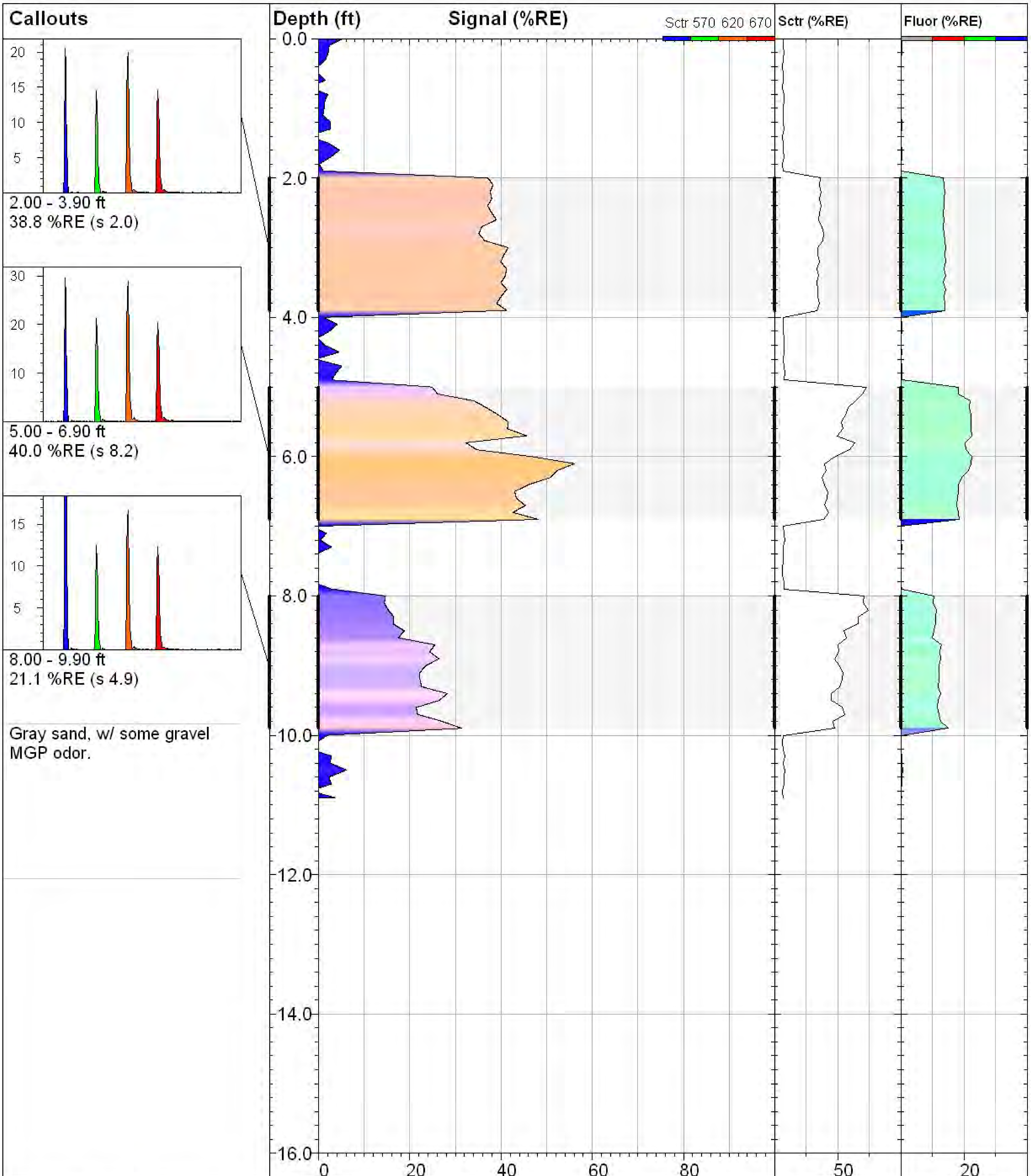
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **12.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **66.3 %RE @ 10.40 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 11:31 PDT**



DAKOTA TECHNOLOGIES
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WWW.DAKOTATECHNOLOGIES.COM

GEI_13_13_16		**TarGOST By Dakota** www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **10.90 ft**
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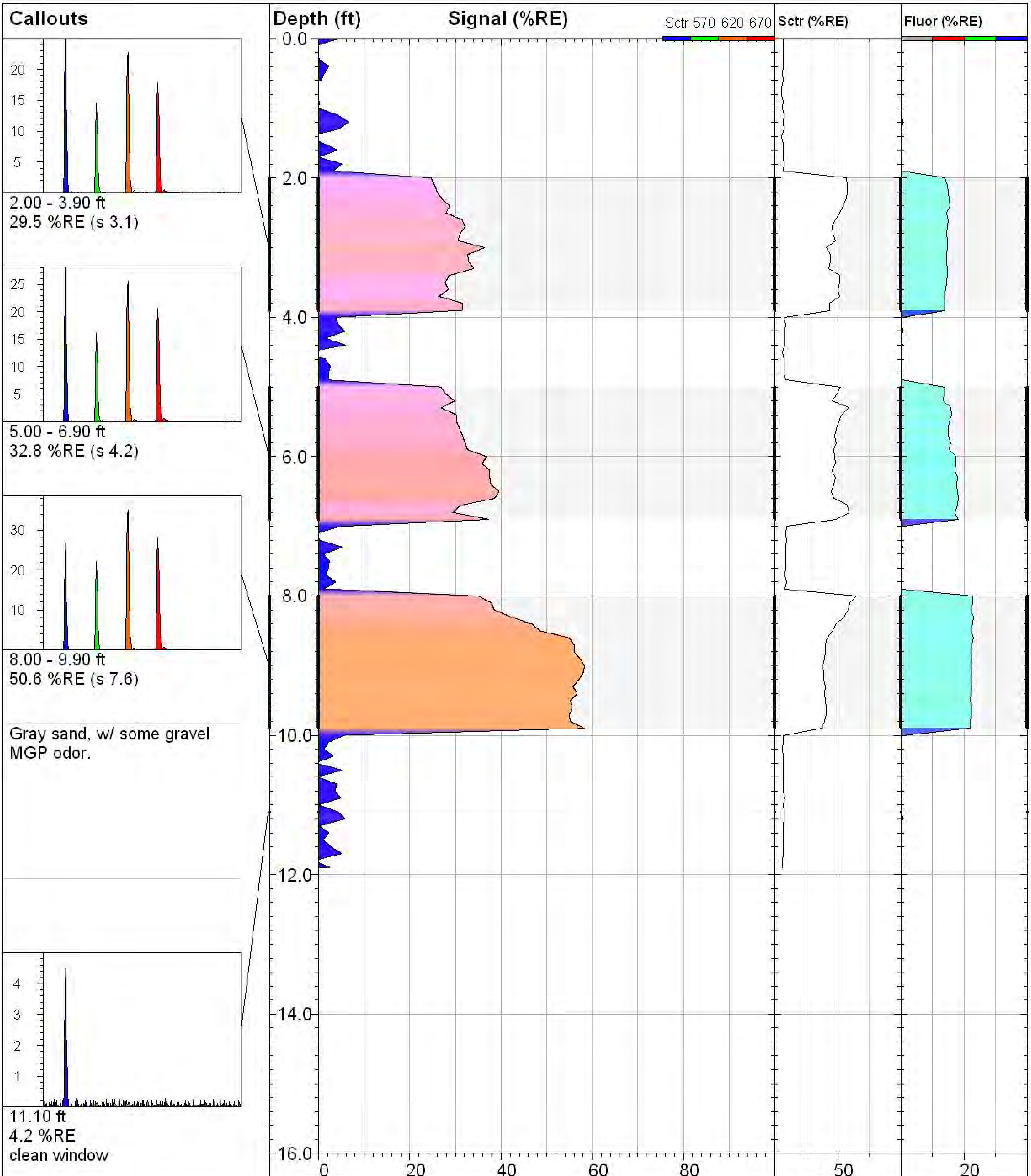

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TarGOST By Dakota
www.DakotaTechnologies.com

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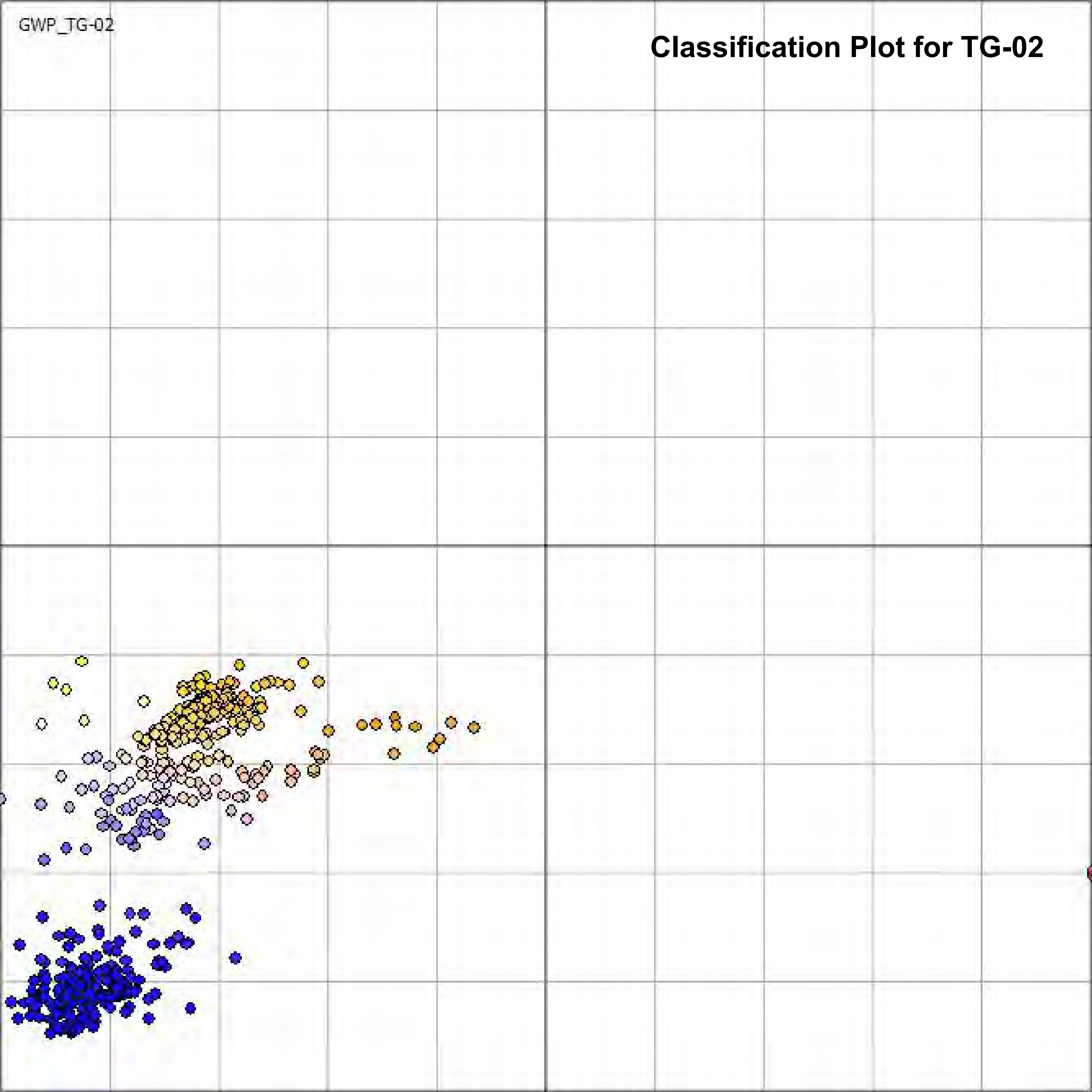
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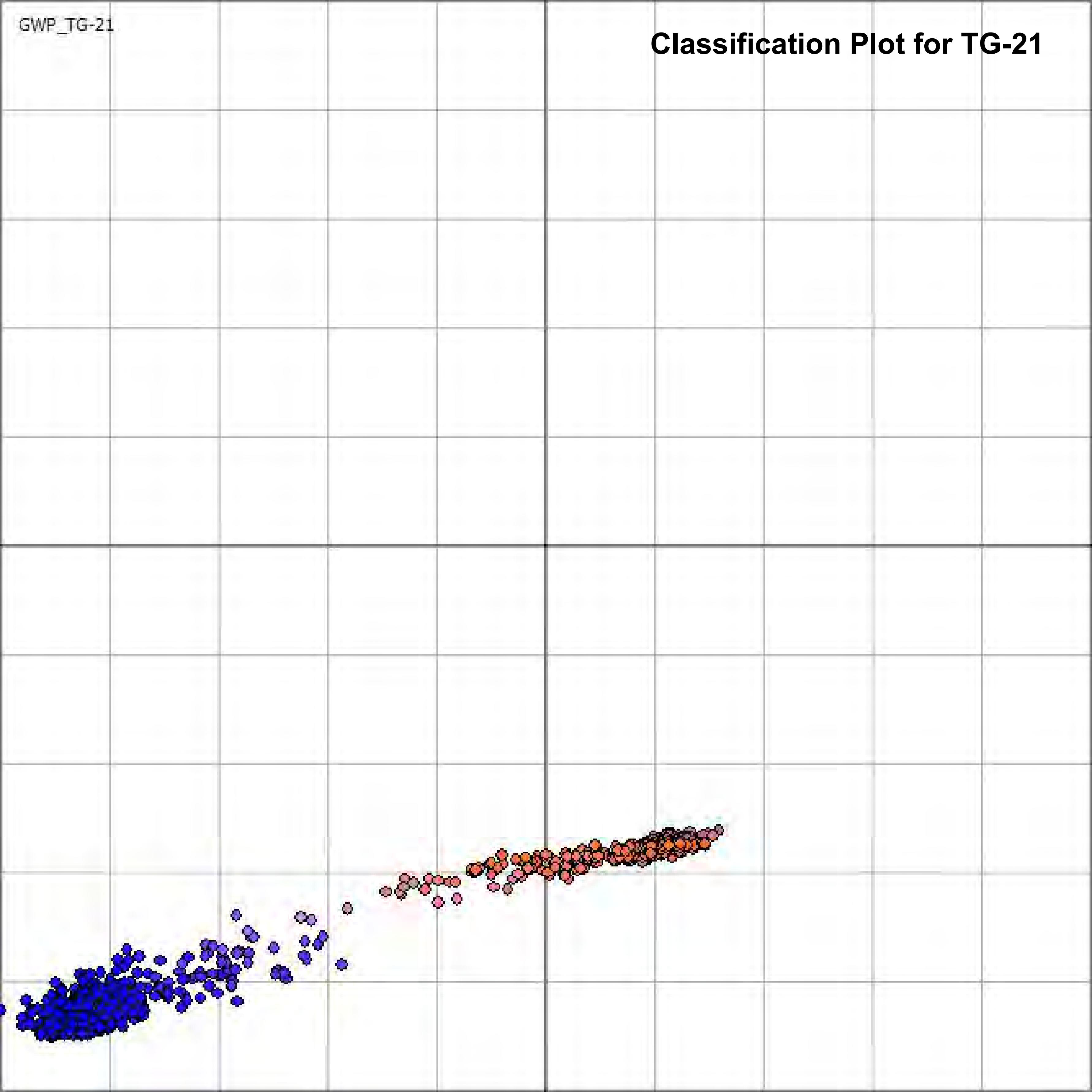
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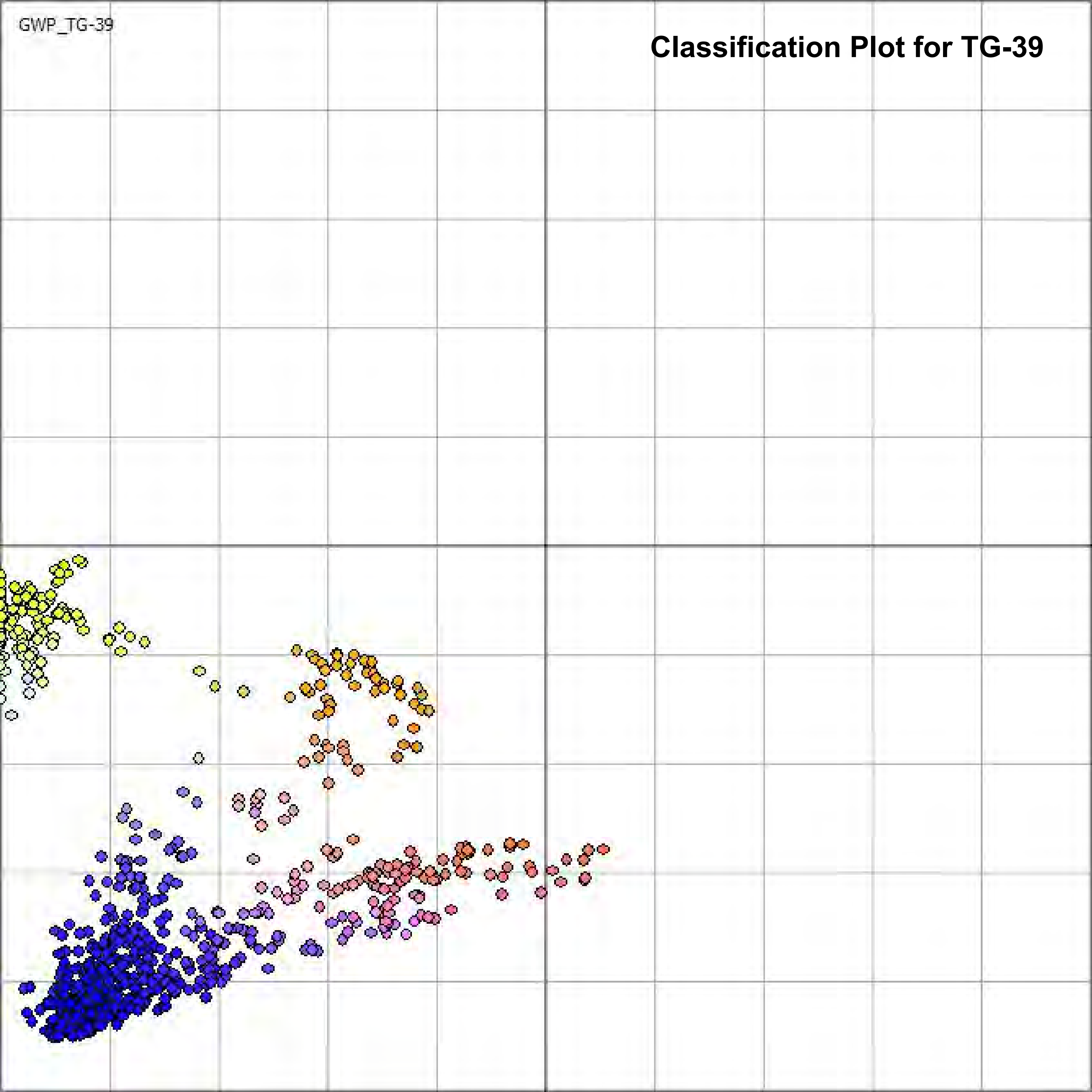
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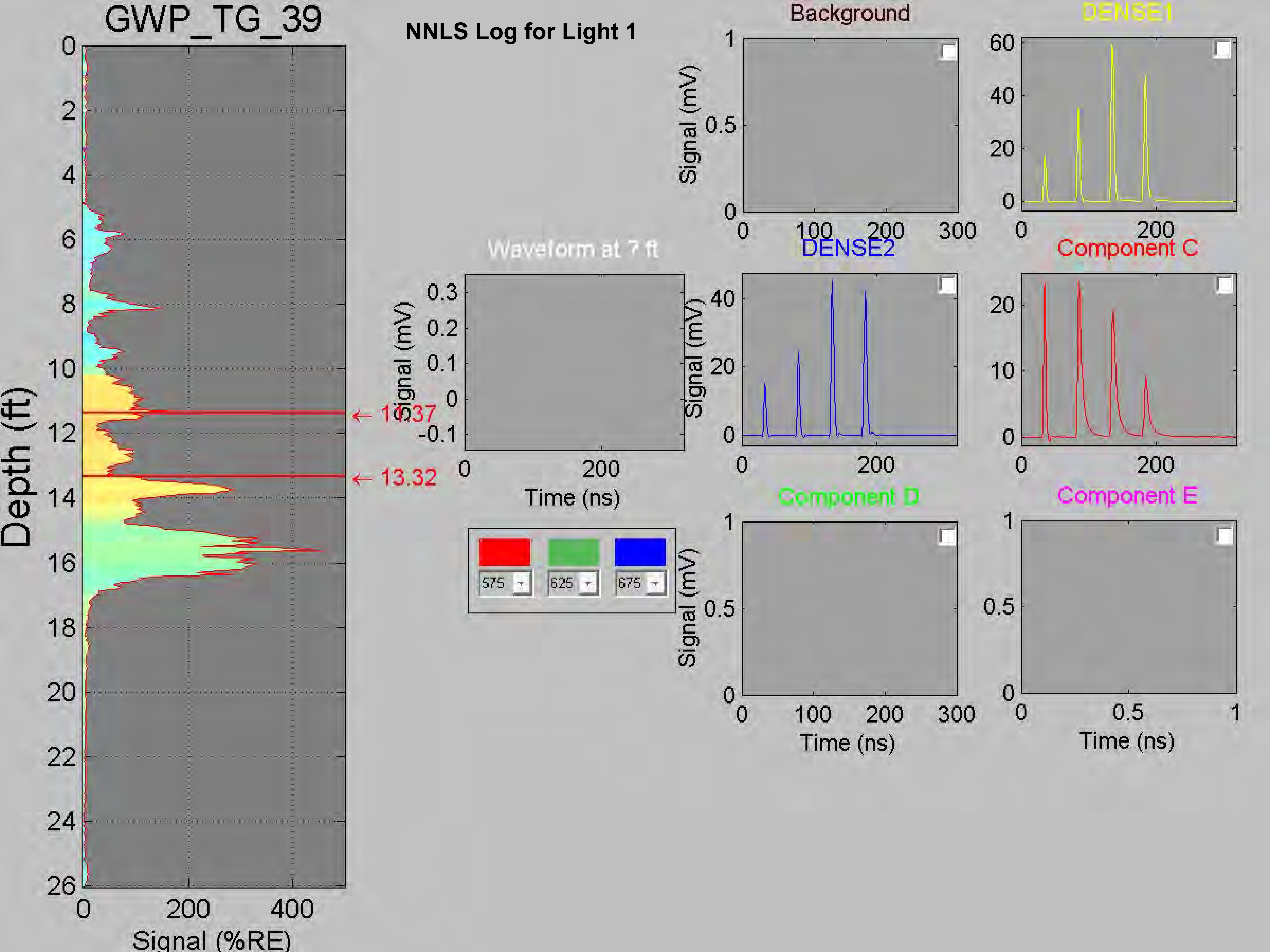
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Depth (ft)
Signal (%RE)
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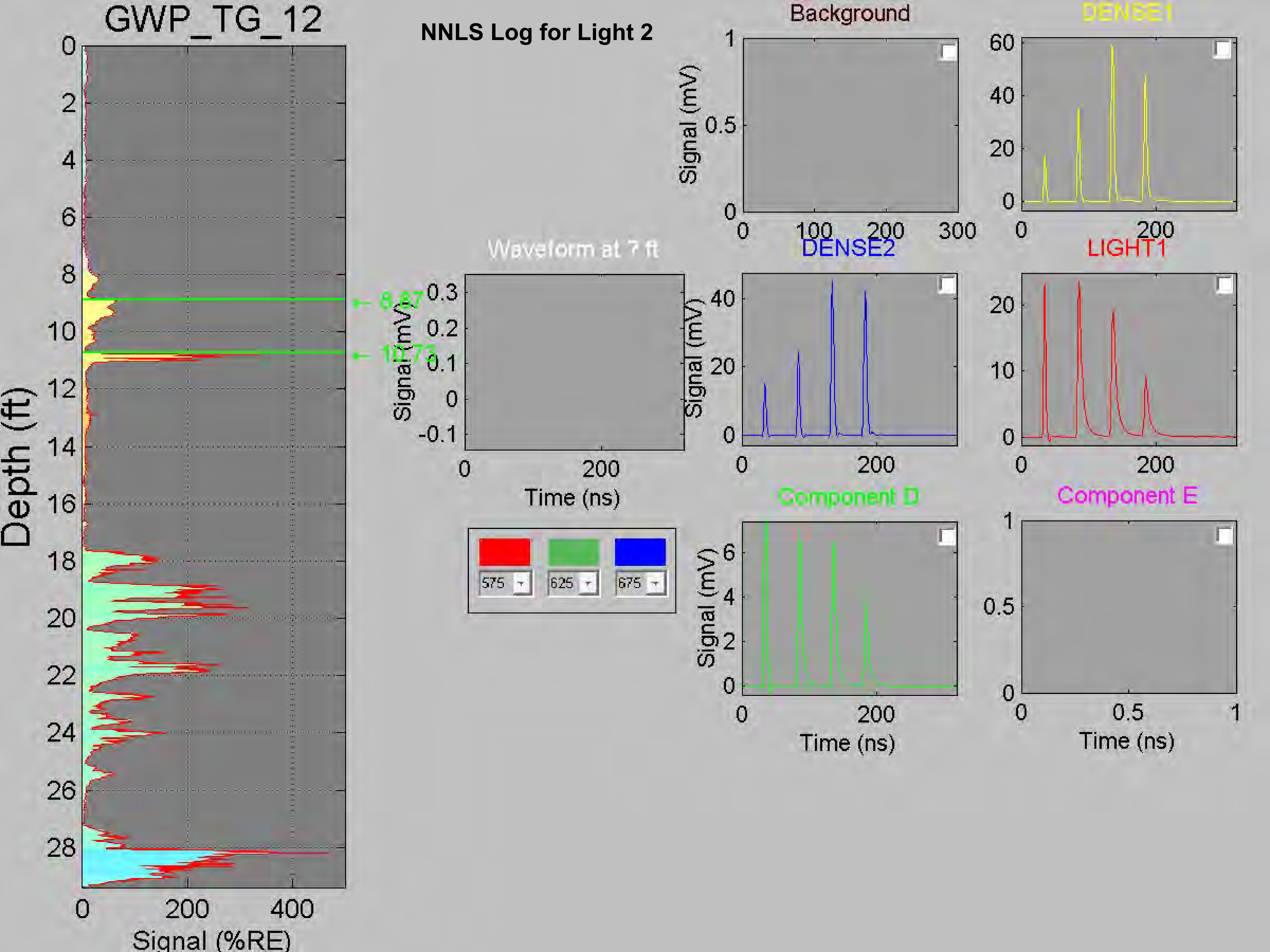
Waveform at 7 ft
Background
DENSE1
DENSE2
Component C
Component D
Component E
Signal (mV)
Time (ns)
575
625
675



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NNLS Log for Light 2
Depth (ft)
Signal (%RE)
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10.73
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DENSE1
DENSE2
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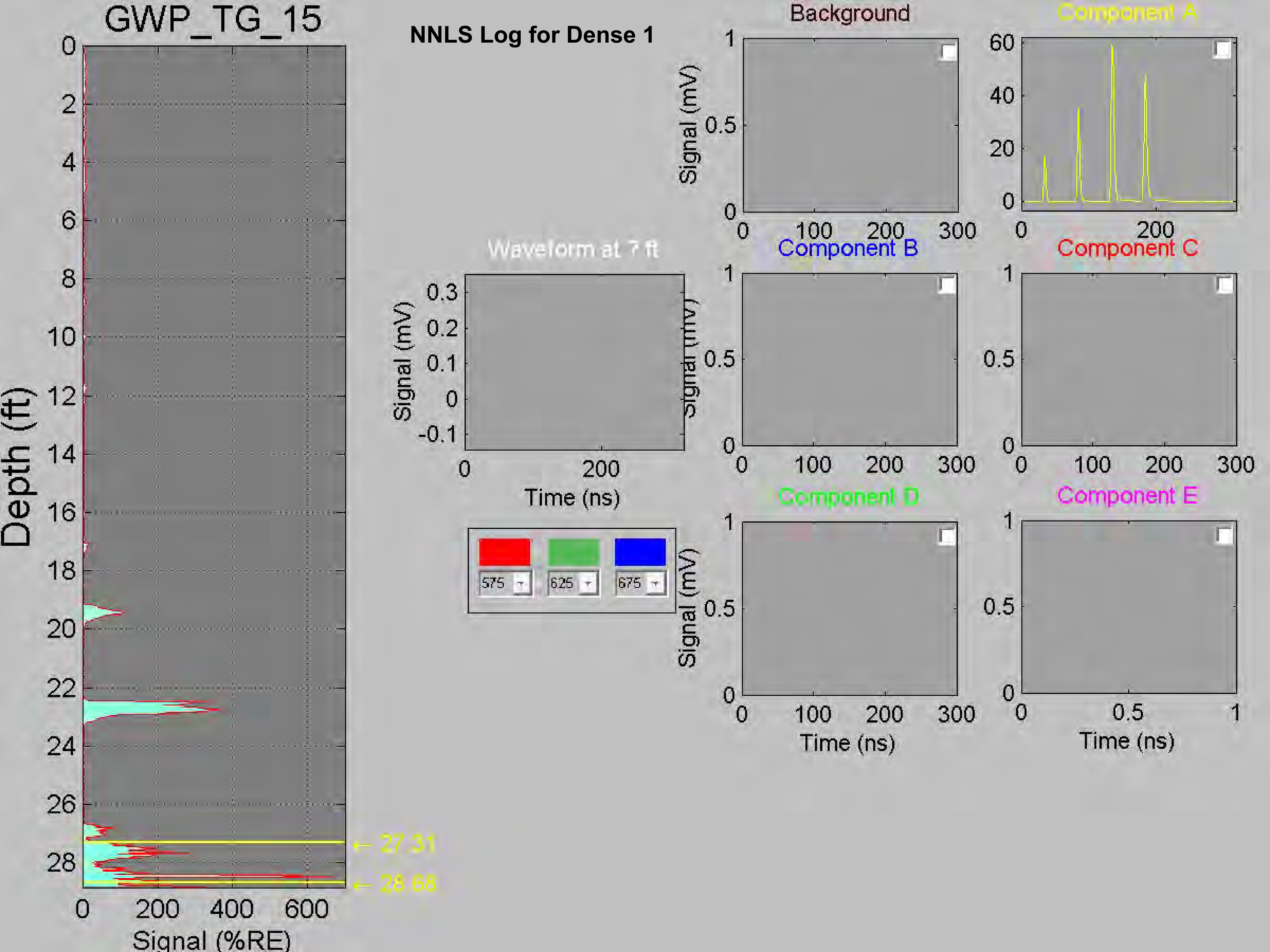
Component E
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675



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Depth (ft)
Signal (%RE)
27.31
28.68
Background
Component A
Component B
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Component D
Component E
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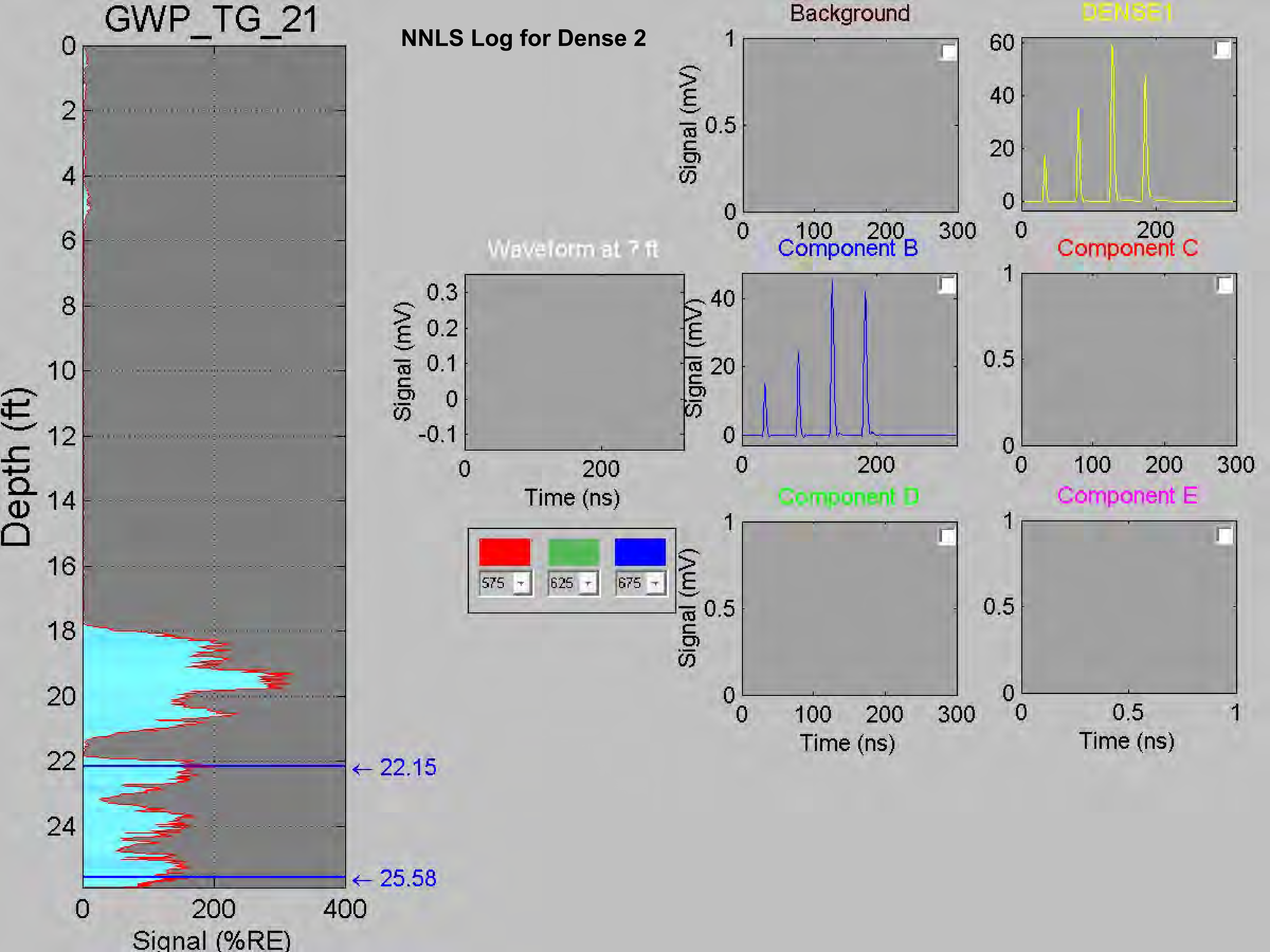
Signal (mV)
Time (ns)
575
625
675



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← 25.58
Background
DENSE1
Waveform at 7 ft
Component B
Component C
Component D
Component E
Signal (mV)
Time (ns)
575
625
675

ATTACHMENT 5F-3
Geomatrix DNAPL Migration Evaluation for Western Sediment Area (WSA)

Geomatrix

May 16, 2007
Project 12543

Ms. Allison D. Geiselbrecht
Floyd|Snider
Two Union Square
601 Union Street, Suite 600
Seattle, Washington 98101

Subject: DNAPL Migration Evaluation
Gas Works Park Sediment Western Study Area
Seattle, Washington

Dear Jane:

This letter provides the results of Geomatrix Consultants, Inc's (Geomatrix's) evaluation of the presence and potential mobility of dense nonaqeous phase liquid (DNAPL) in the shoreline area of the Gas Works Park Sediment Western Study Area (Western Study Area) and the possible need for a source control measure. The work was completed by Geomatrix under a subcontract agreement with Floyd|Snider, who is retained by the City of Seattle.

Background and Scope of Work

The City of Seattle has completed extensive investigations of the sediments in Lake Union adjacent to Gas Works Park in the Western Study Area. Floyd|Snider is in the process of preparing a Remedial Investigation (RI) report to document the investigation work and a Feasibility Study (FS) to evaluate potential remedies to address sediments impacted by polycyclic aromatic hydrocarbons (PAHs) originating from former manufactured gas plant (MGP) and associated tar refinery operations at the Gas Works Uplands. The two documents will be submitted as a combined RI/FS (Floyd|Snider, 2007a).

The FS will focus primarily on remediation options for contaminated sediments; however, migration of PAHs from upland areas through subsurface soils into lake sediments also will be addressed because it presents a potential mechanism for ongoing sediment impacts. PAHs can migrate from upland areas in the dissolved phase or as a separate DNAPL phase. DNAPL had been identified in borings completed within Gas Works Park during previous uplands investigations (The RETEC Group, Inc. [RETEC], 1998; Floyd|Snider, 2007a). DNAPL migration from upland source areas to sediments has been identified as a pathway at numerous coal gasification facilities and wood treating sites around the country, including several in the Puget Sound area. Migration of typical coal gasification-derived DNAPL can continue for many years after facilities had been closed, creating the potential for recontamination of sediment areas that had been previously remediated.

The objective of this DNAPL migration study was to assist Floyd|Snider as part of the Gas Works Sediment Western Study Area RI/FS, in evaluating the need for a possible constructed source control measure to prevent DNAPL present in soil in the Gas Works Uplands from recontaminating lake sediments. To meet this objective, Geomatrix performed the following scope of work:

- Observation and evaluation in the field of soil samples collected during the Floyd|Snider Gas Works Sediment Western Study Area Shoreline Investigation (Floyd|Snider, 2007b) to assess DNAPL presence;
- Evaluation of boring logs, cross-sections, and petrophysical data from the Gas Works Uplands and Western Study Area;
- Attendance at meetings with the Floyd|Snider project team to jointly review data and discuss findings; and
- Preparation of a letter report documenting the findings.

Conceptual Hydrogeologic Model

Site geology and hydrogeology are key factors in evaluating potential contaminant migration, particularly migration of DNAPL. The stratigraphy underlying the Gas Works Uplands consists of fill material overlying Pleistocene-age glacial deposits. The fill material is a highly heterogeneous mixture of various soil types and anthropogenic materials generated by historical operations. The thickness of uplands fill material varies from roughly 50 feet at Kite Hill to approximately 5 feet near the shoreline along the Harbor Patrol facility. Fill material is underlain by Recessional Stratified Drift, a glaciofluvial outwash consisting of coarse-grained and permeable materials (sand and gravels) interbedded with less permeable, more silty lenses. These stratified deposits based on geologic cross sections are interpreted to generally dip to the south toward Lake Union. The Recessional Stratified Drift, which is on the order of 15 to 35 feet thick along the shoreline, overlies the Vashon Till, a very dense basal till that is less permeable than the Recessional Stratified Drift.

Groundwater near the shoreline area is present at a depth of approximately 4 to 6 feet below ground surface, which is within the fill and Recessional Stratified Drift material. Groundwater flow is toward Lake Union (RETEC, 1998; Floyd|Snider, 2007a). Based on geologic cross-sections presented by RETEC (1998) and in the Gas Works Sediment Western Study Area RI/FS (Floyd|Snider, 2007a), mobile DNAPL present within either the fill or stratified drift would migrate primarily toward the lake, which is located hydrogeologically downgradient and geologically down dip (refer to Figures 4.3 and 7.3 from the Gas Works Sediment Western Study Area RI/FS Report [Floyd|Snider, 2007a]). The DNAPL present in the subsurface of the Gas Works Uplands has been shown (Floyd|Snider, 2005) to have a specific gravity of 1.0783 g/cc at 70 degrees F. The relatively low density implies that this DNAPL has the potential to be mobilized move with groundwater flow and via gravity forces (i.e., tendency to migrate down dip along stratigraphic units).

The Recessional Stratigraphic Drift is interbedded with coarser and finer grained beds and lenses. DNAPL migration in this material is anticipated to occur primarily within the coarser-grained units along contacts with underlying finer grained or lower permeability lenses. Interbeds within the stratified drift have been shown to be laterally discontinuous. Therefore, potentially mobile DNAPL would be expected to migrate laterally along a lower permeability lens until that lens pinches out, at which point the DNAPL could potentially migrate downward until it reaches another low-permeability lens, upon which it may again migrate laterally. This type of migration leads to a DNAPL distribution that is fingered and sporadic, as opposed to obvious "pools" of DNAPL. Fingered distributions and sporadic, discontinuous occurrences of DNAPL are common at sites with heterogeneous interbedded sediments like those present at Gas Works Park.

Fingered DNAPL distributions by nature are difficult to characterize, and as a result are difficult to evaluate in terms of mobility potential. DNAPL in this situation is typically present in thin lenses, and accurate measurement of DNAPL saturation in these thin lenses may not be possible using traditional nonaqueous phase liquid (NAPL) characterization testing, such as laboratory measurement of residual saturation. Experience at DNAPL sites has shown that, in most cases, predictions of DNAPL migration underestimate the amount of DNAPL present and the duration migration would occur.

Migration within the fill, which is not stratified, should be primarily downward; however, some lateral mobilization in the direction of groundwater flow could occur if and where this material is neutrally buoyant. DNAPL migration within the stratified drift is expected to be primarily lateral. Since DNAPL has been observed within the Recessional Stratified Drift at an elevation roughly equal to that of the impacted lake sediments, and since the DNAPL in this geologic unit would be expected to move laterally, DNAPL migration potential within the stratified drift is the primary focus of this evaluation.

The Vashon Till, which underlies the Recessional Stratified Drift, is a dense, lower permeability unit. DNAPL has been observed on top of the Vashon Till in three borings located near the shoreline on the Harbor Patrol property, which borders Gas Works Park to the west. However DNAPL at this depth is below the mud line elevation, and the till surface appears to dip well below the recent lake sediments (refer to Figure 4.3 from the RI/FS report [Floyd|Snider, 2007a]). Thus migration of DNAPL along the top of the Vashon Till is not considered a pathway of concern for recontamination of lake sediments.

Data Evaluation

Geomatrix completed the scope of work for this evaluation in close cooperation with the Floyd|Snider project team. Specifically, the primary data for the evaluation were collected by Floyd|Snider as part of their Shoreline Investigation (Floyd|Snider, 2007b), which is being completed in accordance with the "Shoreline Investigation Sampling and Analysis Plan" (Floyd|Snider, 2006) approved by the Washington State Department of Ecology (Ecology). To date, field work for the Shoreline Investigation has included drilling nine soil borings along the shoreline of the Gas Works Uplands (two adjacent to the Harbor Patrol property and seven along the Gas Works Park shoreline) between September 19, 2006, and October 2, 2006. The borings were drilled for multiple purposes, including analysis for the presence of DNAPL and assessment of the potential for DNAPL migration to sediments. The borings were advanced through the fill materials and Recessional Stratified Drift and into the top of the Vashon Till. Soil borings TSB-1 through TSB-3, TSW-1 through TSW-3, and TDW-1 through TDW-3 (as illustrated on Figure 1.1 from the RI/FS report [Floyd|Snider, 2007a]) were logged for stratigraphy and observed for the presence of DNAPL. Borehole logs will be included in the Shoreline Investigation Data Report (Floyd|Snider, 2007b) and reproduced as an appendix in the RI/FS. Soil samples were collected from borings TSB-2 and TDW-2 at depth intervals where DNAPL was observed (refer to boring logs). These samples were analyzed for petrophysical properties and residual NAPL saturation. The petrophysical laboratory testing results are included as an attachment to this report.

Direct lines of evidence commonly used to evaluate DNAPL presence in the subsurface include visual screening of soil borings and laboratory analysis of soil samples. DNAPL mobility requires the existence of both mobile DNAPL (i.e., DNAPL present at saturations greater than residual) and a sufficient head to exceed the entry pressure of the surrounding soil matrix. Visual evaluation of soil cores is sufficient to evaluate for the presence of DNAPL, but is not able to distinguish between mobile and immobile (i.e., residual or ganglia) DNAPL. Laboratory analysis of field samples for residual DNAPL saturation tends to provide bulk saturation estimates that will not capture elevated saturations in small (i.e., scale of inches) lenses. A significant volume of DNAPL can move, or finger, through a very thin lens or higher permeability pathway in the subsurface; thus, DNAPL saturation measurements from soil samples are of limited use in capturing the potential for migration of fingered DNAPL.

DNAPL head is also difficult to establish from field observations. Because visual evaluation of soil cores cannot distinguish between saturated and residual conditions, lenses of connected DNAPL cannot be reliably estimated from visual observation of a soil core. Additionally, comparison of DNAPL elevations between soil cores provides a measurement of driving head only if the DNAPL is connected between the measuring points and the pathway is in a drainage condition, which is not the case for the fingered DNAPL distributions present at Gas Works Park. Finally, quantification of matrix entry pressures is difficult in practice because of natural heterogeneity and the challenge of collecting a representative sample.

During drilling for the 2007 Shoreline Investigation (Floyd|Snider, 2007b), oil staining and possibly free-phase oil was visually observed in soil cores from five soil borings advanced along the Gas Works Park Shoreline. Two of these borings (TSB-3 and TDW-2) were located just a few feet from each other along the fenceline adjacent to the Harbor Patrol property (refer to Figure 5.23 from the Floyd|Snider [2007a] RI/FS Report). Depth intervals in which oil sheen or staining was observed in the soil cores are described on the boring logs included in the Shoreline Investigation Data Report (Floyd|Snider, 2007b) and reproduced in the RI/FS.

The following table summarizes field observations of DNAPL occurrence made during the October 2007 shoreline investigation (Floyd|Snider, 2007b). Soil and DNAPL observations are summarized on the boring logs presented in the Shoreline Investigation Data Report (Floyd|Snider, 2007b) and reproduced as an appendix in the RI/FS.

Boring	Approximate Depth (ft)	Field Observations
TDW1	All depths	No oil stain or sheen.
TDW2	15	Black oil blebs observed in narrow (about 0.5-ft) sample interval.
TDW3	6 to 14.5	Oil sheen.
TSB1	20 to 29	Slight oil stain and sheen.
TSB2	16 to 35.5	Oil sheen.
TSB3	16	Oil sheen; however, the interval from 18 to 29 feet was not sampled and observed due to poor sample recovery (heaving sands).
TSW1	All depths.	No oil sheen or stain observed; however, the interval from 0 to approximately 5 feet was not sampled and observed.
TSW2	All depths.	No oil sheen or stain observed; however, the interval from 0 to approximately 5 feet was not sampled and observed.
TSW3	All depths.	No oil sheen or stain observed; however, the interval from 0 to approximately 5 feet was not sampled and observed.

Black oil blebs that could be interpreted as DNAPL were observed in the core from boring TDW-2, at a depth of approximately 15 feet below ground surface (bgs), within a relatively narrow depth interval (less than 0.5 feet thick). Oil sheen and a few oil droplets were noted between approximately 16 feet and 30.5 feet bgs in the TSB-2 core, and at 16 feet bgs in the TSB-3 core; the depth interval between 18 feet bgs and 29 feet bgs was not logged at the TSB-3 location due to problems with heaving sands. The oily material observed at TSB-3 appeared to be very viscous and tar-like. Sheen was noted between approximately 6 and 14.5 feet bgs at TDW-3. Slight staining and sheen were noted between 20 and 29 feet bgs at boring location TSB-1, which is located approximately 120 feet east of TSB-3. No sheen or staining was noted in the soil cores from location TDW-1 or from shallow boring locations TSW-1, TSW-2, and TSW-3 located near the boundary of the Eastern and Western Study Areas (refer to Figure 5.23 from the RI/FS). Soil cores at the three shallow soil boring locations were not logged between approximately ground surface and 5 to 6 feet bgs. During previous investigations (RETEC, 1998), DNAPL was encountered in three monitoring wells and within the borings for those wells (DW-4, DW-5, and DW-6) on the Harbor Patrol property. These wells are in a line perpendicular to the shoreline approximately 150 feet northwest of TSB-2, which also contained DNAPL. The DNAPL within the wells on the harbor Patrol property appears to be within the Stratified Drift within DW-4, the well farthest back from the shoreline, whereas within DW-5 and DW-6, the DNAPL has been observed at the base of the Stratified Drift, perched on top of the low permeability Vashon Till. This suggests that DNAPL on Harbor Patrol Property has migrated downward to a depth that will not impact sediments.

To further assess the nature of the oil blebs and oil sheen observed, soil samples from a depth of 21.3 feet below ground surface (bgs) at boring TSB 2, and from depths of 15.5, 16.8, and 18.3 feet bgs at boring TDW-2 were collected and submitted to the laboratory for quantification of DNAPL saturation. Reported DNAPL residual saturations ranged from 2.1 to 5.6 percent of sample pore volume. These residual saturation values suggest that the DNAPL present in the sample is at low saturation compared to water and that DNAPL present in soil in this saturation range would not be mobile. However, visual observations in the field indicated that DNAPL was present within a thin lens in the TDW-2 soil core, and, as noted above, it is unlikely that the bulk laboratory saturation measurement captured the actual DNAPL saturation within this small interval. Therefore, the laboratory saturation measurements should not be relied upon to conclude that DNAPL present in the vicinity of TDW-2 is not potentially mobile. As noted previously, the relatively high viscosity and low density of coal tar DNAPL implies that continued slow lateral migration over confining units may still be occurring decades after initial introduction to the subsurface assuming that conditions for DNAPL migration exist.

Based on the soil borings installed as part of the Shoreline Investigation and on previous studies in the area (RETEC, 1998), there appears to be a limited area along the boundary of Gas Works Park and the Harbor Patrol property extending into the Harbor Patrol facility where DNAPL may be present in the subsurface at depths that could be of concern for potential migration toward the offshore sediments. The area of DNAPL is limited and no thick zones of DNAPL saturation have been identified. DNAPL encountered in borings appears to be present in very thin lenses; the vertical distribution and spacing of DNAPL in lenses appear to be infrequent, and the lenses are likely laterally discontinuous. As a result, although there is a potential for DNAPL to migrate toward the offshore sediments in the future, this potential does not appear to warrant consideration for DNAPL migration control, such as a subsurface barrier wall.

Conclusions

The purpose of this DNAPL migration study was to evaluate the need for a possible constructed source control measure to prevent DNAPL present in soil in the Gas Works Uplands from recontaminating lake sediments. DNAPL was encountered during previous Upland investigations on the Harbor Patrol property; however, in the wells closest to the Lake, the DNAPL occurs at a depth that is unlikely to impact sediments. DNAPL has been identified in offshore sediments, although it is not known if the sediments are affected by DNAPL migration from the Uplands or from an offshore release. At a number of sites in the northwest where DNAPL has been identified, subsurface barrier walls have been installed to prevent further migration. Examples of DNAPL sites where subsurface barrier walls have been installed to limit migration are the Puget Sound Resources Superfund Site in Seattle, the International Paper Wood Treating site in Longview, Washington, and the Weyerhaeuser Wood Treating facility in Everett, Washington.

As part of this investigation, a total of nine borings were installed. Of these nine borings, oil staining or sheen was observed in five, all of which are near the boundary between the Harbor Patrol and the Park. Only one of the borings, TDW-2, located along the property boundary of the Harbor Patrol facility, had observations that indicated the likely presence of DNAPL, and this occurrence was within a thin lens of less than 0.5-ft thick at a depth of about 15 feet. The data from these borings combined with information on DNAPL on the Harbor Patrol property indicate the following:

- DNAPL is present in the nearshore area in a limited area that includes the Harbor Patrol property and a portion of Gas Works Park along the property line between the Harbor Patrol and Gas Works Park;

- DNAPL encountered is present in thin, discontinuous lenses but does not represent a thick DNAPL-saturated zone in the nearshore area at depths that would be expected to migrate to the sediments;

- Petrophysical testing of DNAPL-containing soil samples indicates DNAPL is at a relatively low percentage relative to water and is unlikely to migrate; however this testing may have underestimated mobility based on the size of the sample tested compared to the thin nature of the DNAPL layer in the sample.

Based on the above findings from visual observations and petrophysical testing of DNAPL occurrence and potential mobility, inclusion of a remedy such as a subsurface barrier wall in the FS to address DNAPL migration from the nearshore area to the sediments is not warranted. Some limited DNAPL migration may occur within the thin, discontinuous lenses but this does not justify the need for a source control barrier.

Sincerely yours,
GEOMATRIX CONSULTANTS, INC.

Bettina Longino
Bettina Longino, Ph.D.
Senior Environmental Consultant

Gary Dupuy, L.Hg.
Principal Hydrogeologist

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ATTACHMENT 5F-4

Floyd|Snider GWS WSA Data Report
Appendix G – Supplemental PAH Analyses

Attachment 5F-4

Floyd|Snider

Gas Works Sediment Western Study Area Data Report

Appendix G - Supplemental PAH Analyses

Gas Works Sediment
Western Study Area

Data Report

Appendix G
Supplemental PAH Analyses

December 7, 2005

List of Tables

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Supplemental PAH Analyses

INTRODUCTION

A subset comprising eight sediment samples was analyzed for GC/MS full scan analyses by Zymax Laboratories. This testing was not proposed in the RI/FS SAP, but was performed to explore GWS-WSA PAH sources. Sediment samples submitted for forensics analyses were selected based on spatial distribution and PAH concentration. GC/MS full scan analyses is not a quantitative method, rather it generates qualitative results in which the analyst identifies likely PAH sources based on the PAH fingerprinting pattern and professional judgment. Furthermore, laboratory deliverables provided are minimal, and do not include quantitative analyte concentrations. Typically, they include chromatograms (only if requested) and verbal evaluations from the analyst. Standard Form 1s, calibration curves, and other "typical" data deliverables are not generated and/or not provided.

DESCRIPTION OF METHODS

Sediment samples are sonicated with methylene chloride solvent and the solvent extract concentrated. Extracts and products that are highly colored are cleaned by removing polar and asphaltene compounds in a silica gel column.

Extracts and product samples are directly injected into a GC equipped with a 60 meter DB1 column to separate the hydrocarbons, which are detected with a MS in full scan mode, interfaced to the GC. Hydrocarbons in the range of C_{10} to C_{40} are identified. By scanning the ion fragments, chromatograms of a number of classes of hydrocarbons are generated, as shown in Figures G.1 through G.16. Aromatic hydrocarbons are identified by scanning over a large number of ion fragments, and the results are normalized in a bar diagram.

RESULTS

Aromatic hydrocarbons (e.g., benzene, ethylbenzene, toluene, and PAHs) are present in a wide-range of materials, including many of the waste streams from manufactured gas plants, such as lamp black and tar, as well as waste streams from other industrial activities. In addition, they occur in the majority of petroleum products, including both crude oil and refined products from gasoline to heavy fuel oils. Thus, the simple presence of aromatic hydrocarbons such as PAHs is not indicative of the source material.

Aliphatic hydrocarbons, on the other hand, are rarely present in any combusted, or pyrogenic, material. The act of combustion causes them to break down. Aliphatic hydrocarbons are a primary component of petroleum products since they are present in crude oil, and often represent the major fraction of refined petroleum products. The presence of aliphatic hydrocarbons in the sample then becomes a marker for the presence of petroleum fuels or products.

Figure 4.23 in the Data Report shows the location of samples and an interpretive description of each result. Chromatograms, both GC/MS in Selective Ion Monitoring Mode as well as Total

Ion Scan, for each sample are presented in Figures G.1 through G.16. Interpretive results of potential PAH sources are summarized in Table G.1.

Gas Works Sediment
Western Study Area

Data Report

Appendix G
Supplemental PAH Analyses

Tables

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Table G.1
Supplemental PAH Analyses Results

Sample ID	Sample Type	Sample Depth	Description
GWS-SG05	Surface	0 to 10 cm	Pyrogenic components present; no measurable petroleum.
GWS-EC07	Subsurface	3.3 to 4.6 feet	High concentrations of benzene, ethylbenzene, and naphthalene. Pyrogenic components present; no measurable petroleum.
GWS-SG07	Surface	0 to 10 cm	Pyrogenic and petroleum fuel-related components present.
GWS-SG16	Surface	0 to 10 cm	Pyrogenic and petroleum fuel-related components present.
GWS-EC13	Subsurface	9.1 to 10.6 feet	High concentrations of benzene, ethylbenzene, and naphthalene.
GWS-EC12	Subsurface	1.5 to 3.4 feet	High concentrations of benzene, ethylbenzene, and naphthalene.
GWS-EC14	Subsurface	0.7 to 2.6 feet	Heavily weathered sample.
GWS-SG12	Surface	0 to 10 cm	Pyrogenic and petroleum fuel-related components present.

Gas Works Sediment
Western Study Area

Data Report

Appendix G
Supplemental PAH Analyses

Figures

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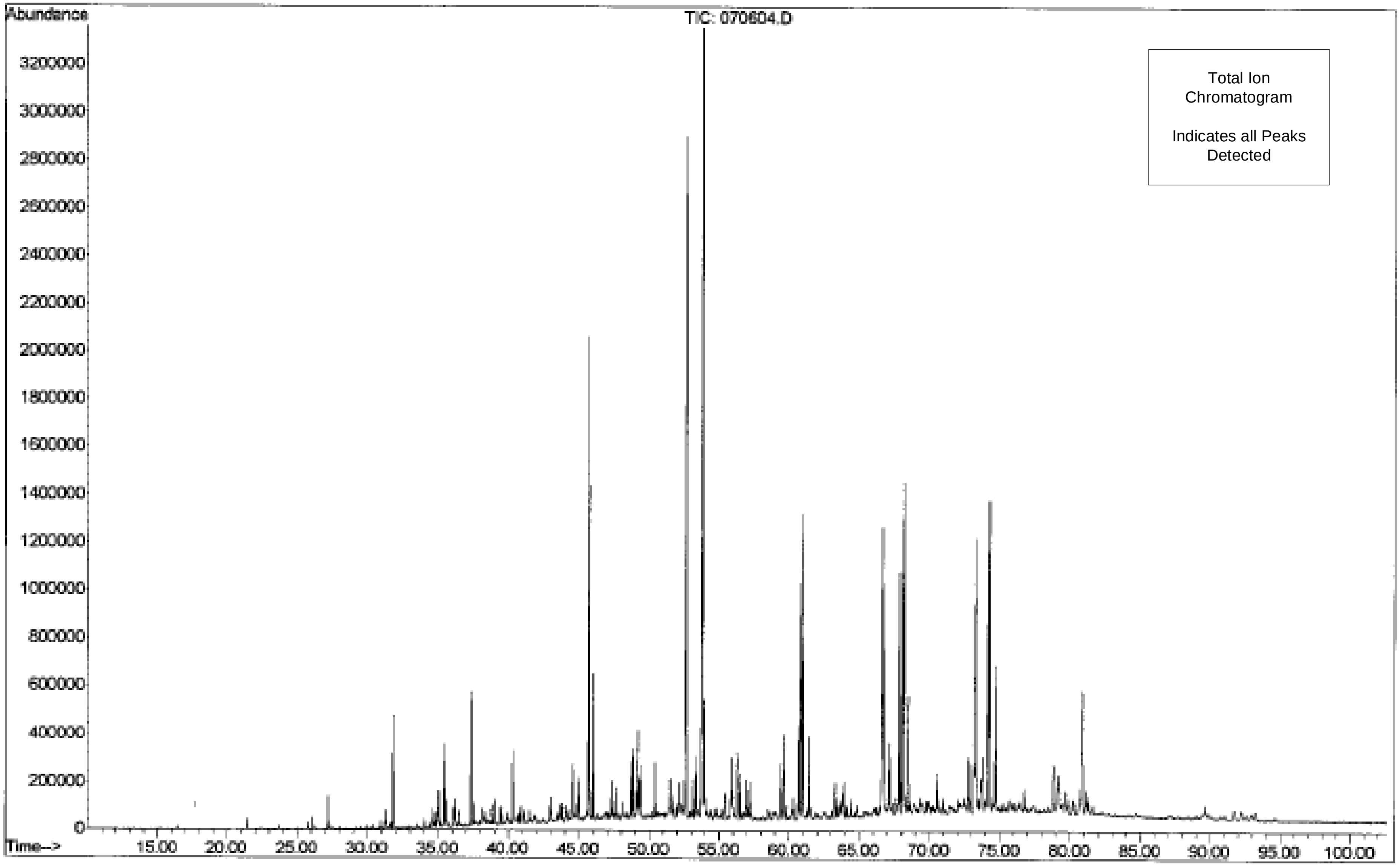

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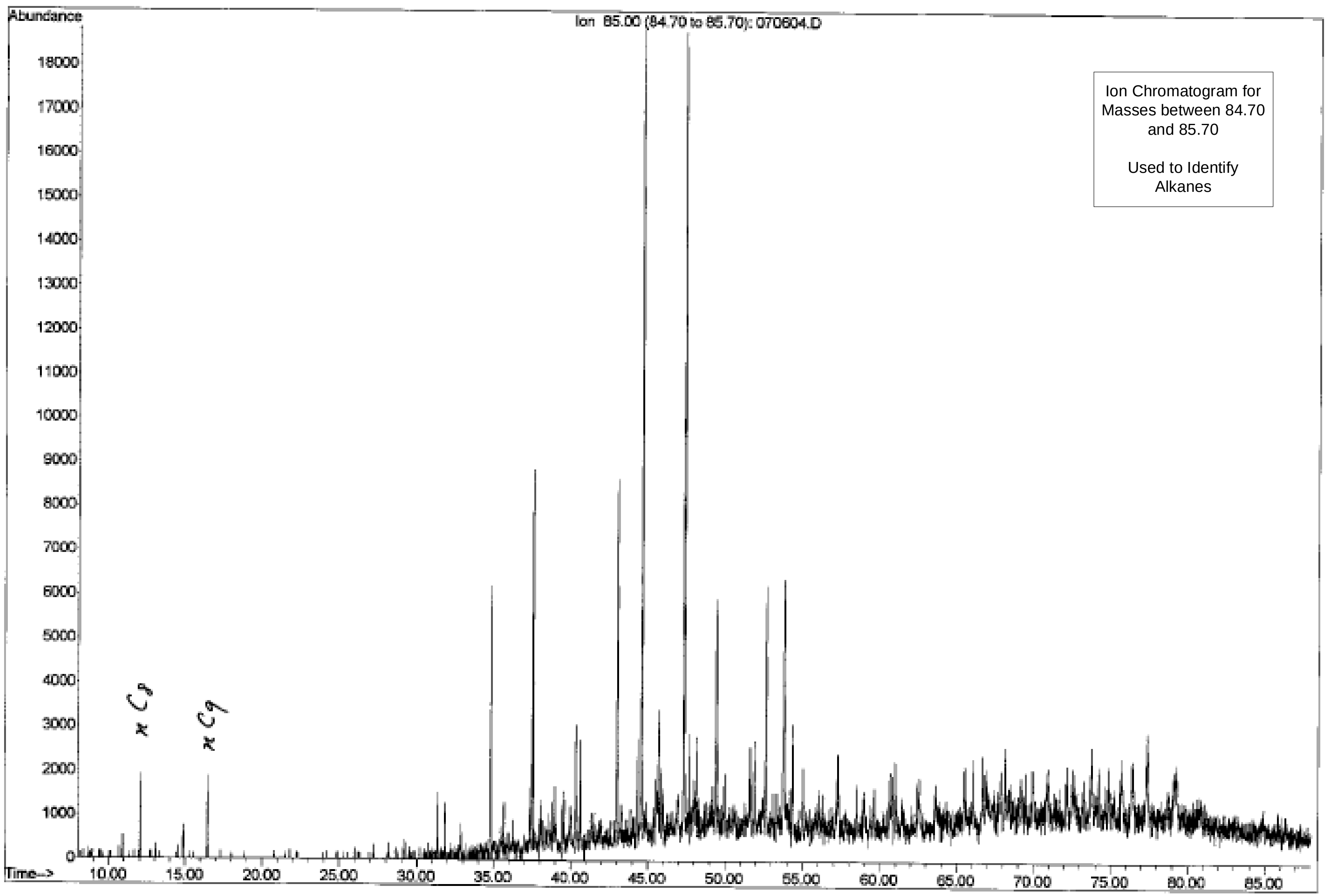
Data Report
Gas Works Sediment Western Study Area
City of Seattle

Figure G.1
Sample GWS-SGO5 Total Ion Chromatogram



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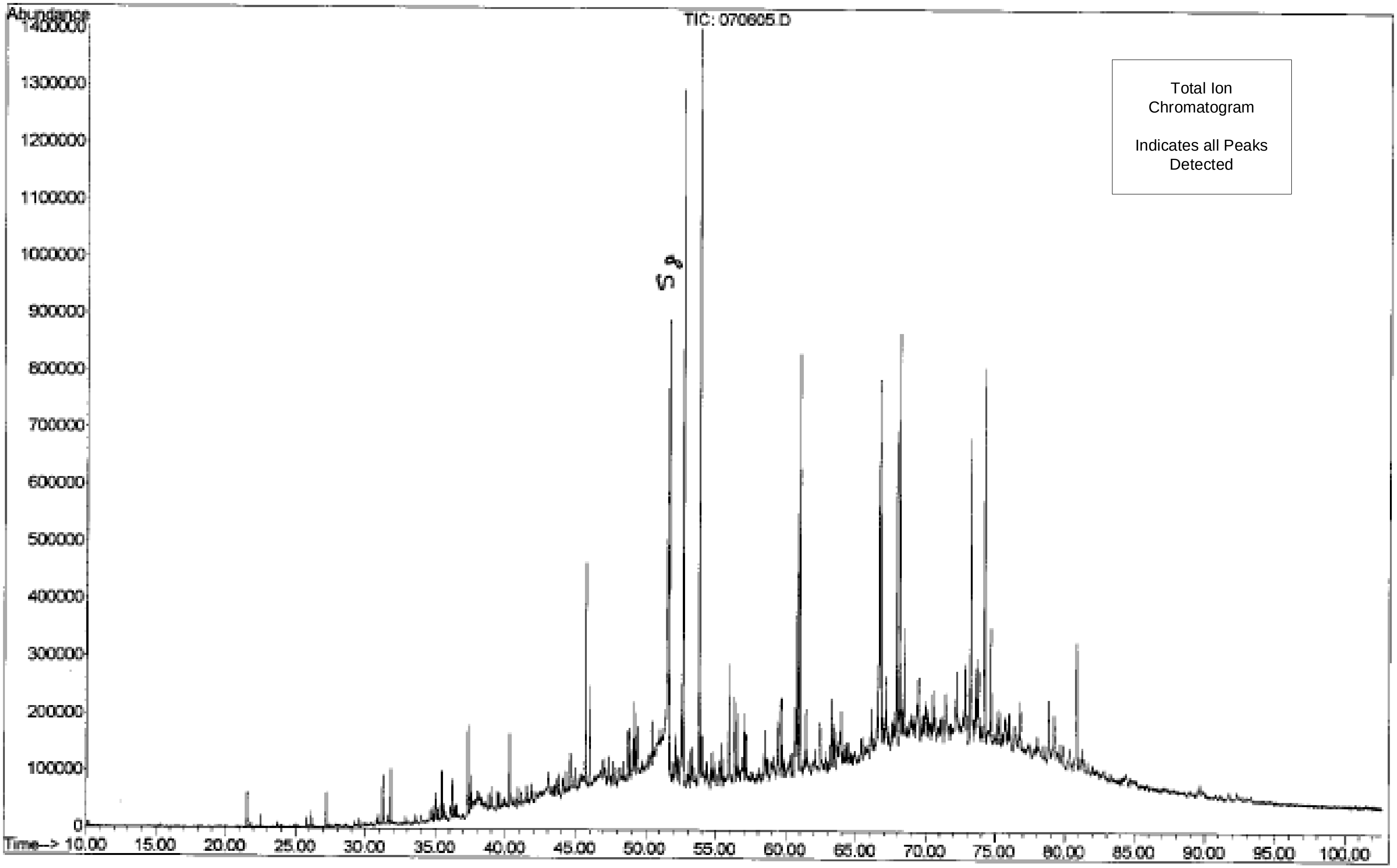
Gas Works Sediment Western Study Area
City of Seattle

Figure G.2
Sample GWS-SG05 Selective Ion Monitoring Chromatogram



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Gas Works Sediment Western Study Area
City of Seattle

Figure G.3
Sample GWS-SG07 Total Ion Chromatogram

F:\projects\COS-SPUDR\Task 5 Data Analysis-Data Report\Ecology Review Draft\Appendices\G - Supplemental PAH Analyses\Figures\GWS-SG07_G3 113005.vsd

December 7, 2005

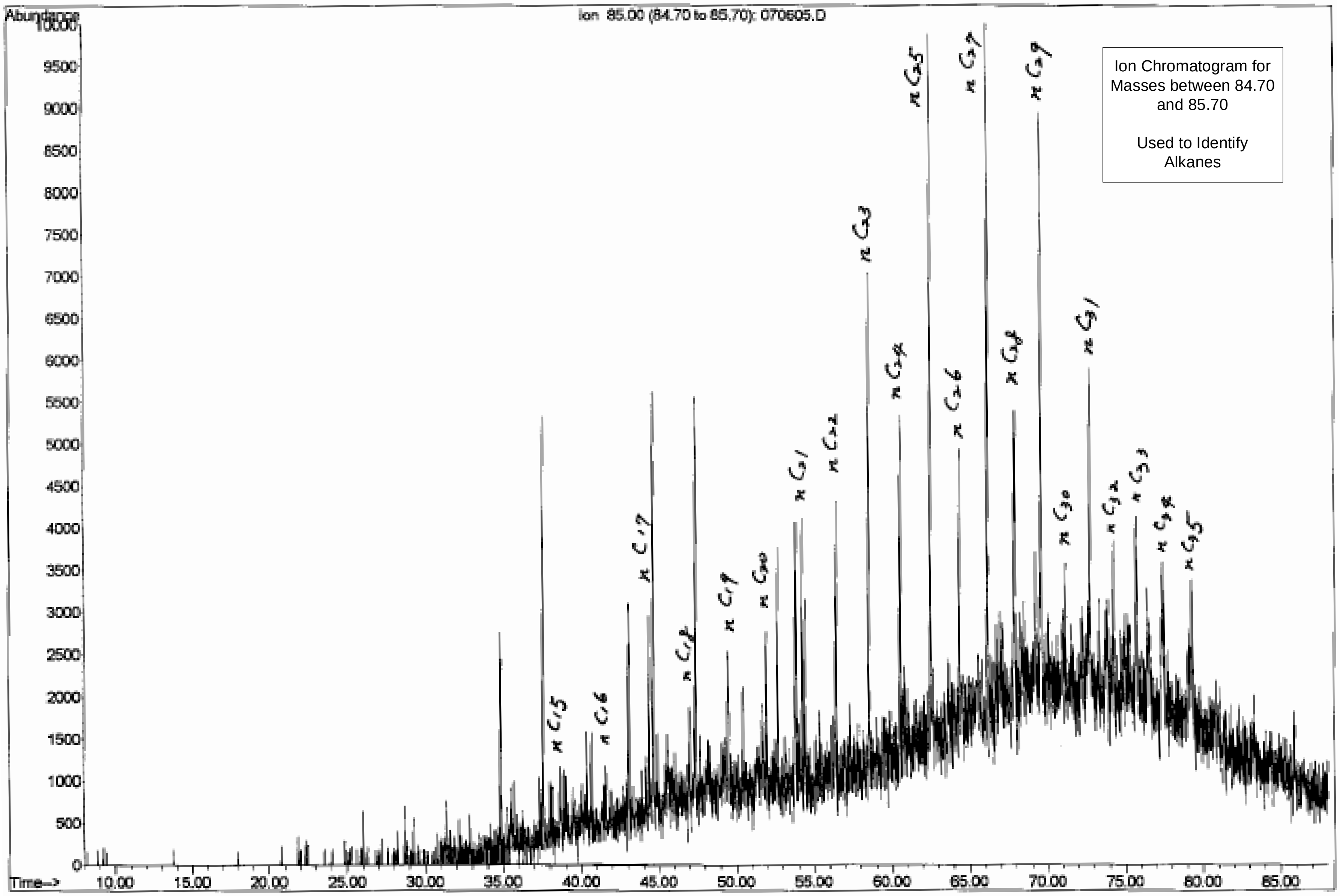

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Figure G.4
Sample GWS-SG07 Selective Ion Monitoring Chromatogram

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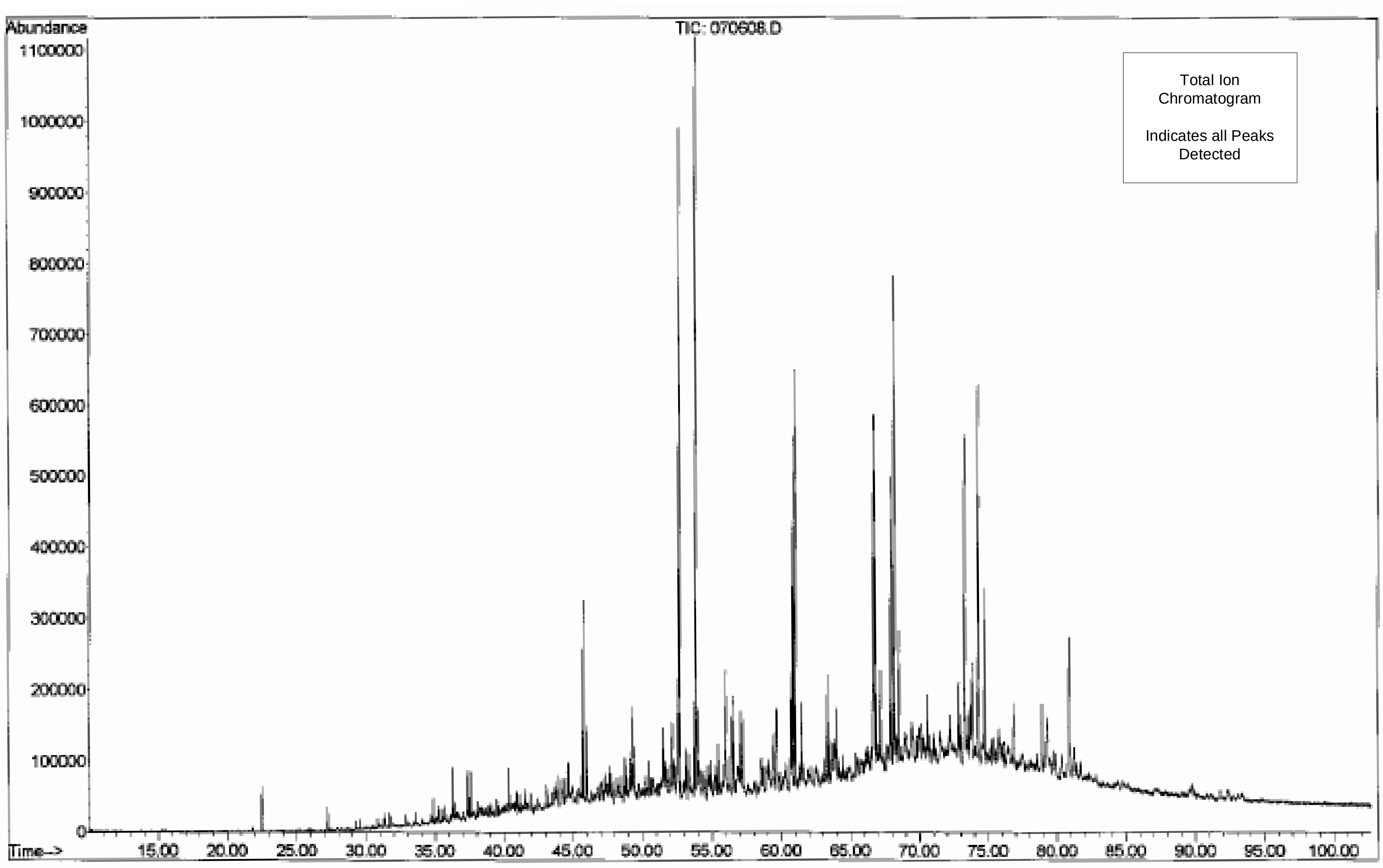

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Figure G.5
Sample GWS-SG12 Total Ion Chromatogram

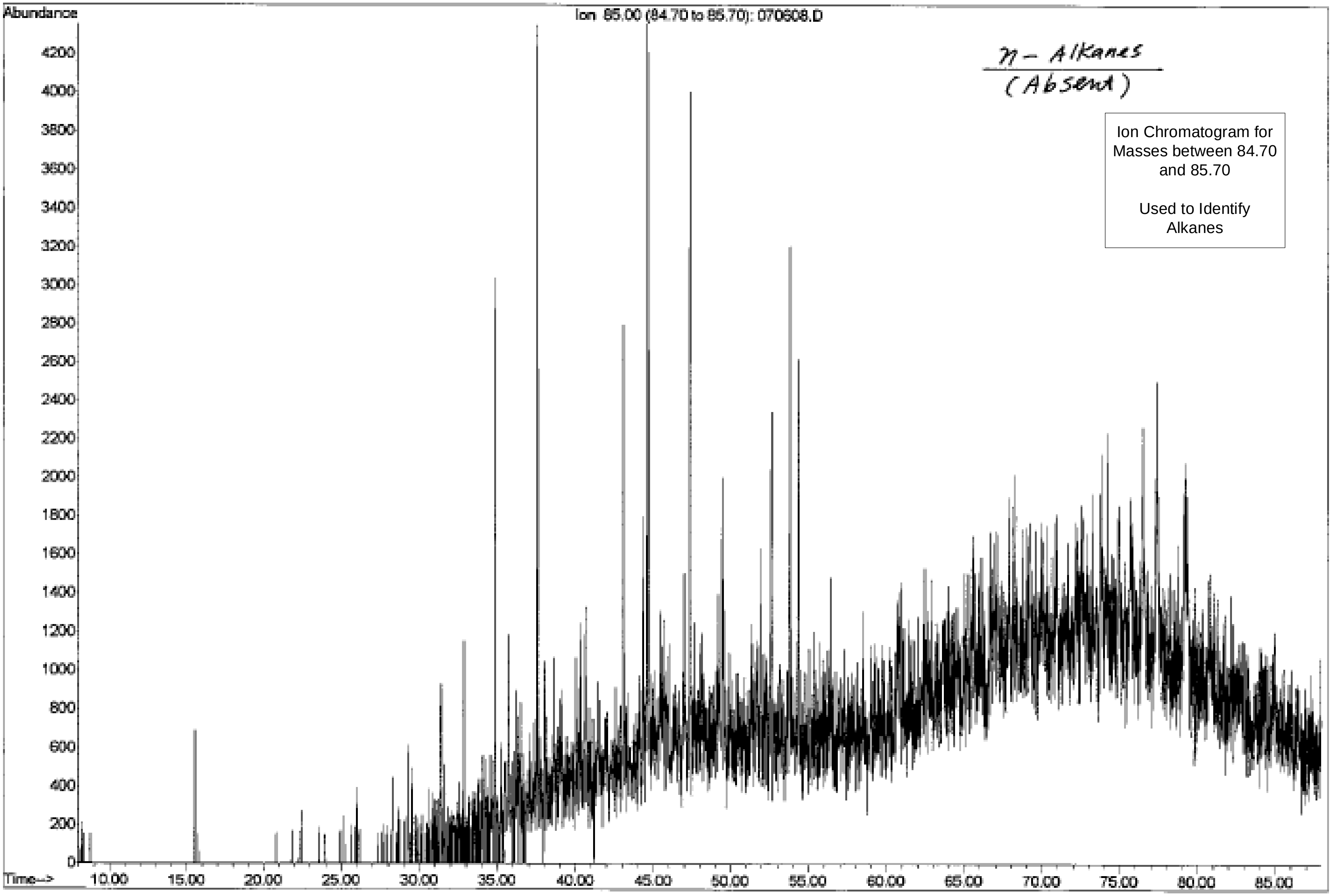

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Figure G.6
Sample GWS-SG12 Selective Ion Monitoring Chromatogram

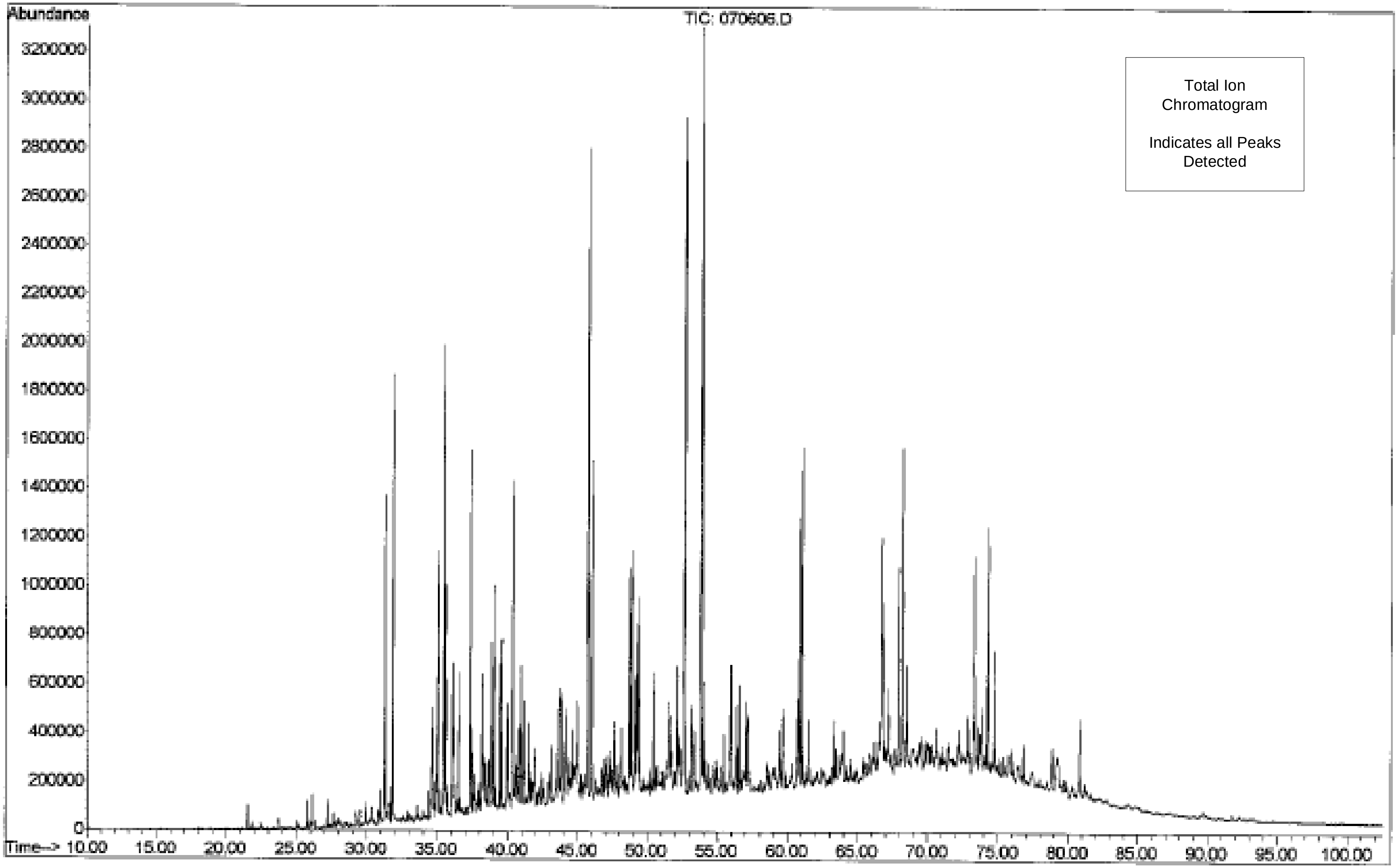

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Figure G.7
Sample GWS-SG16 Total Ion Chromatogram

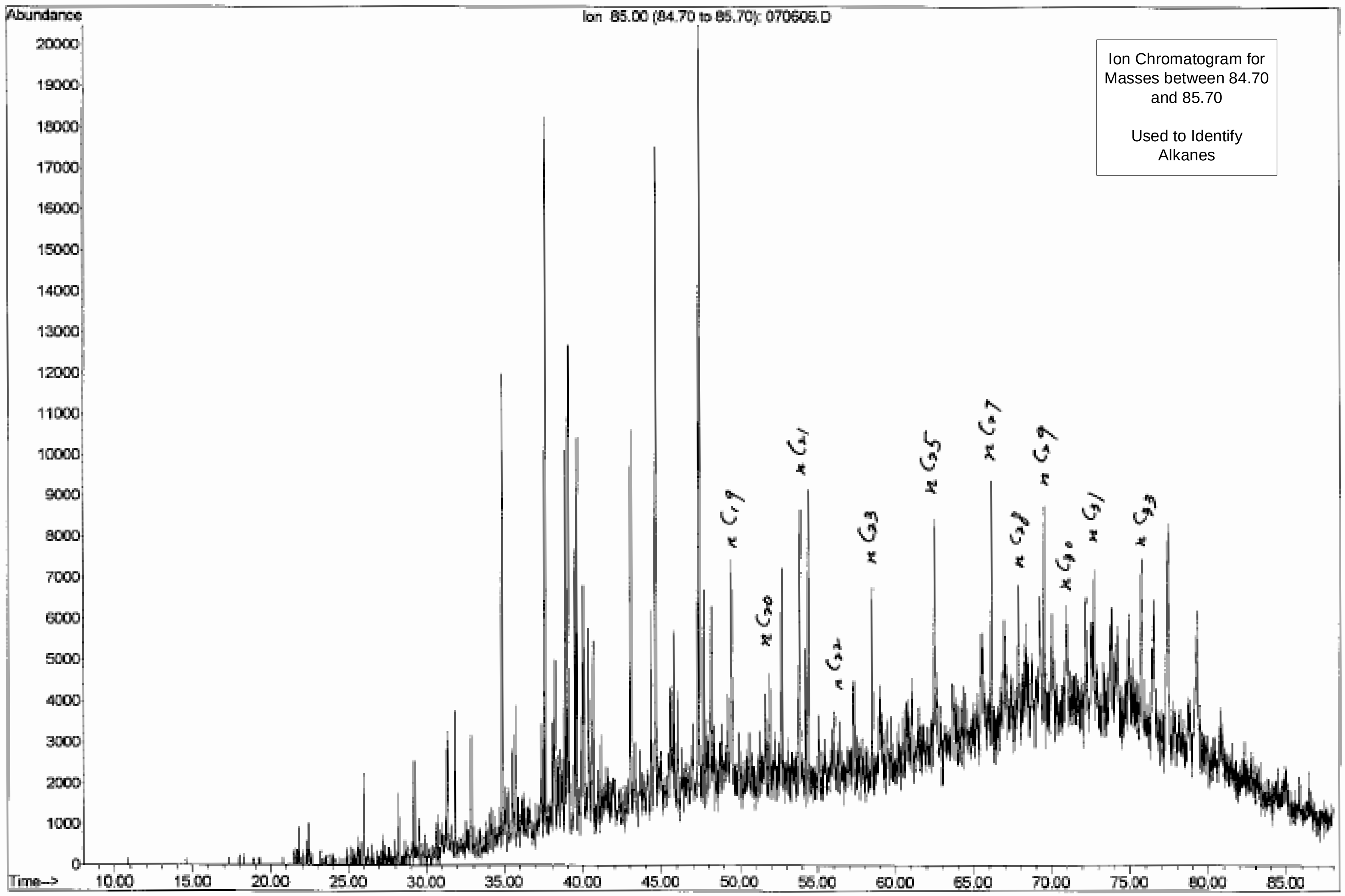

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Figure G.8
Sample GWS-SG16 Selective Ion Monitoring Chromatogram

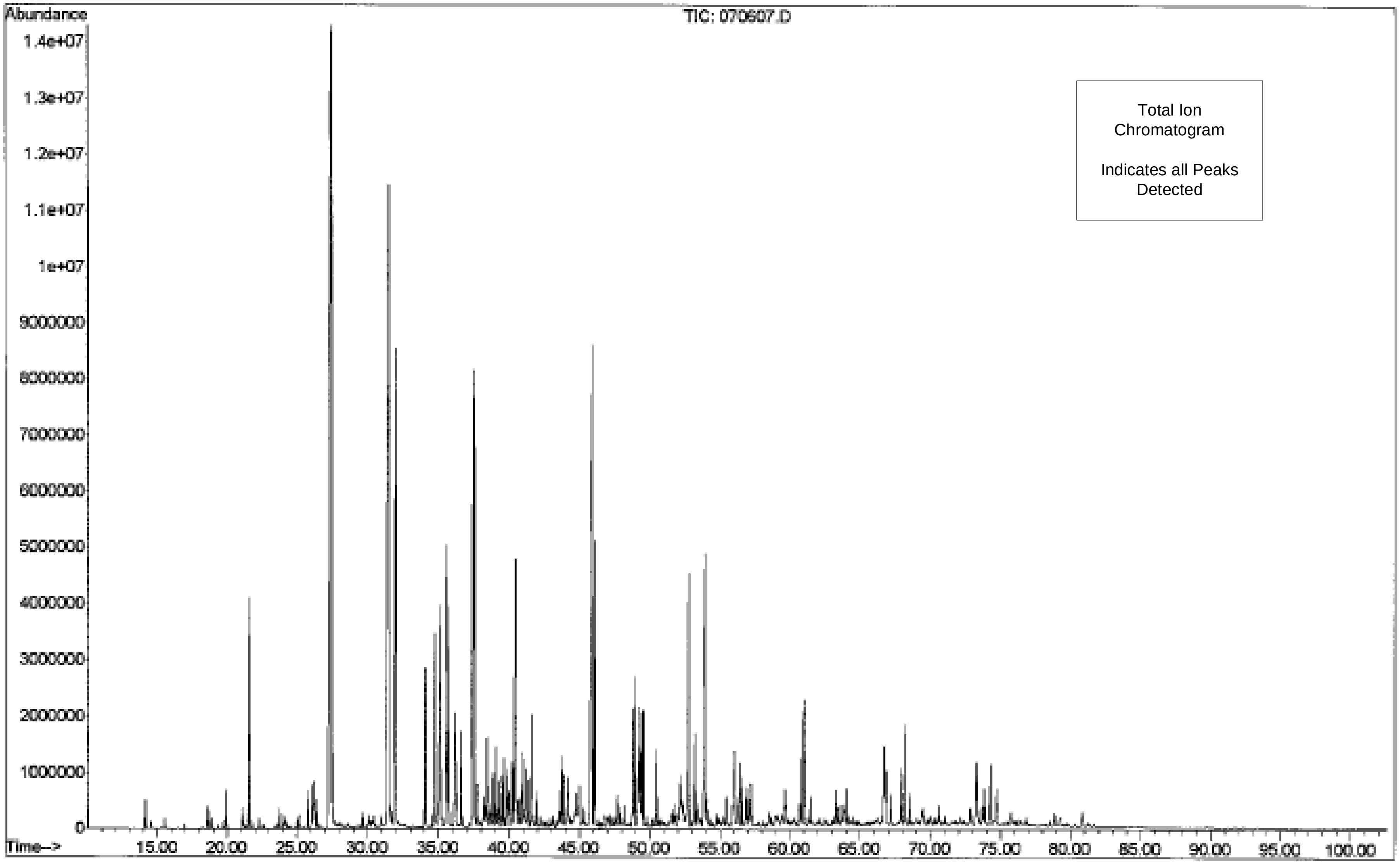

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Figure G.9
Sample GWS-EC07-0034 Total Ion Chromatogram

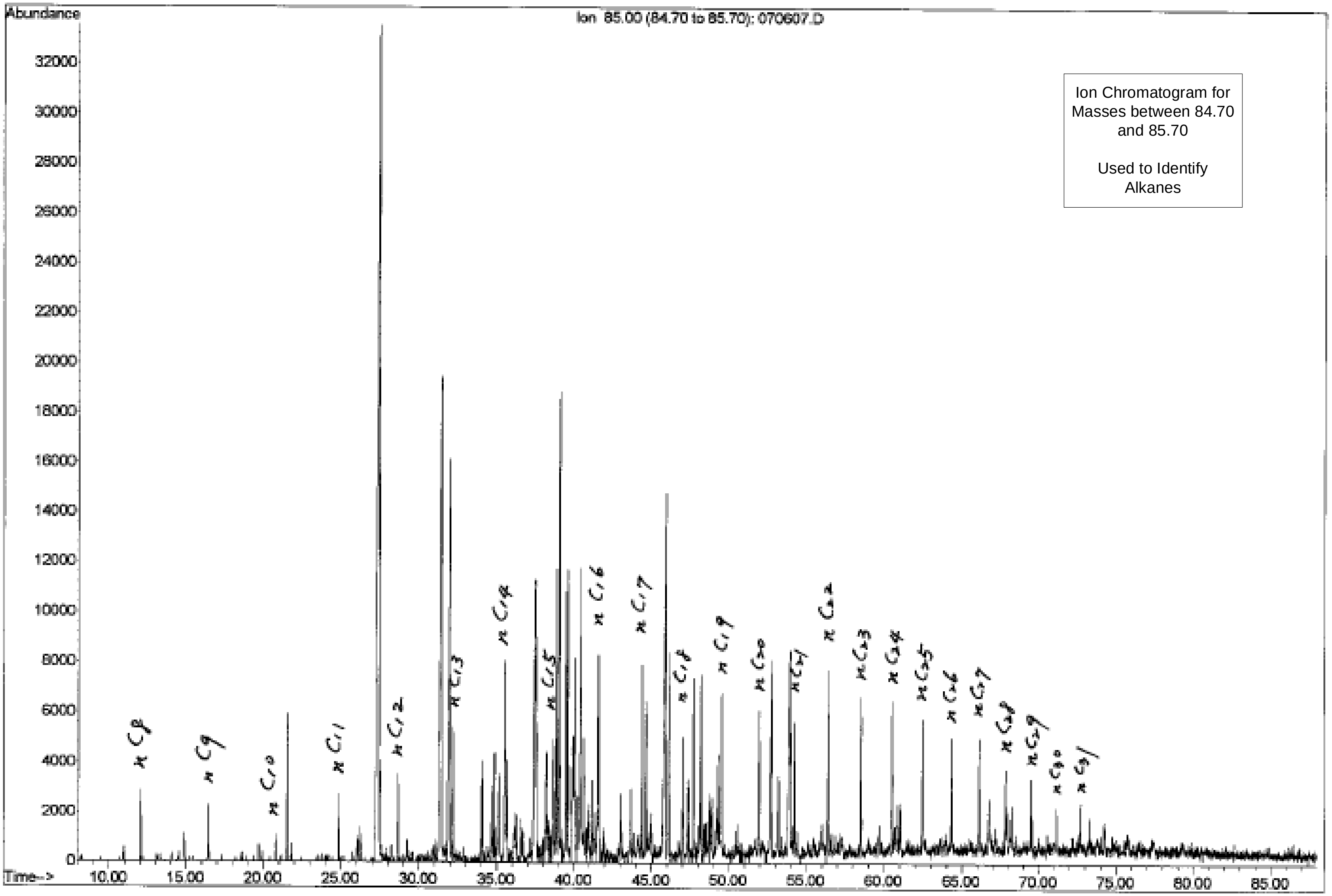

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Figure G.10
Sample GWS-EC07-0034 Selective Ion Monitoring Chromatogram

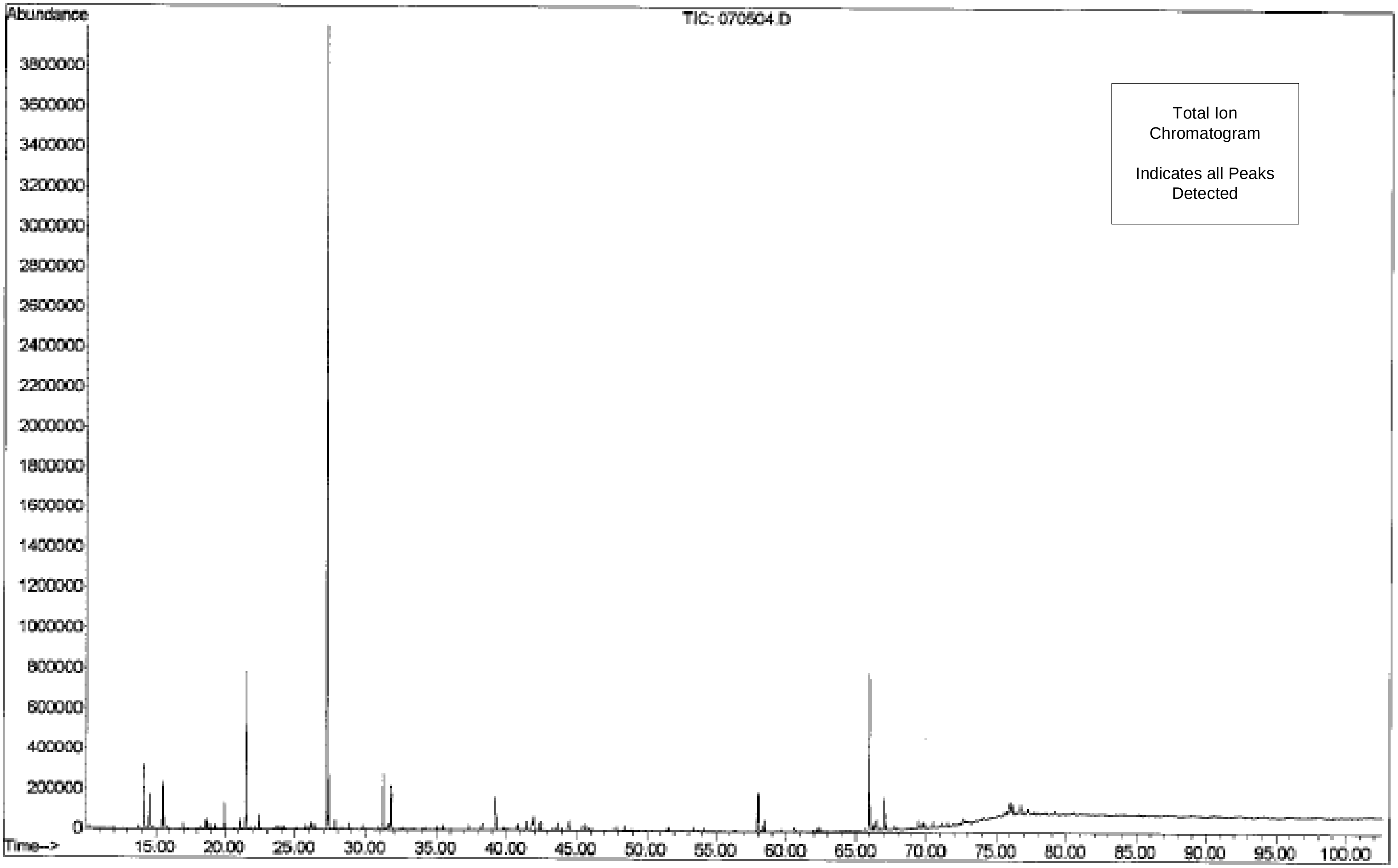

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Figure G.11
Sample GWS-EC12-0008 Total Ion Chromatogram

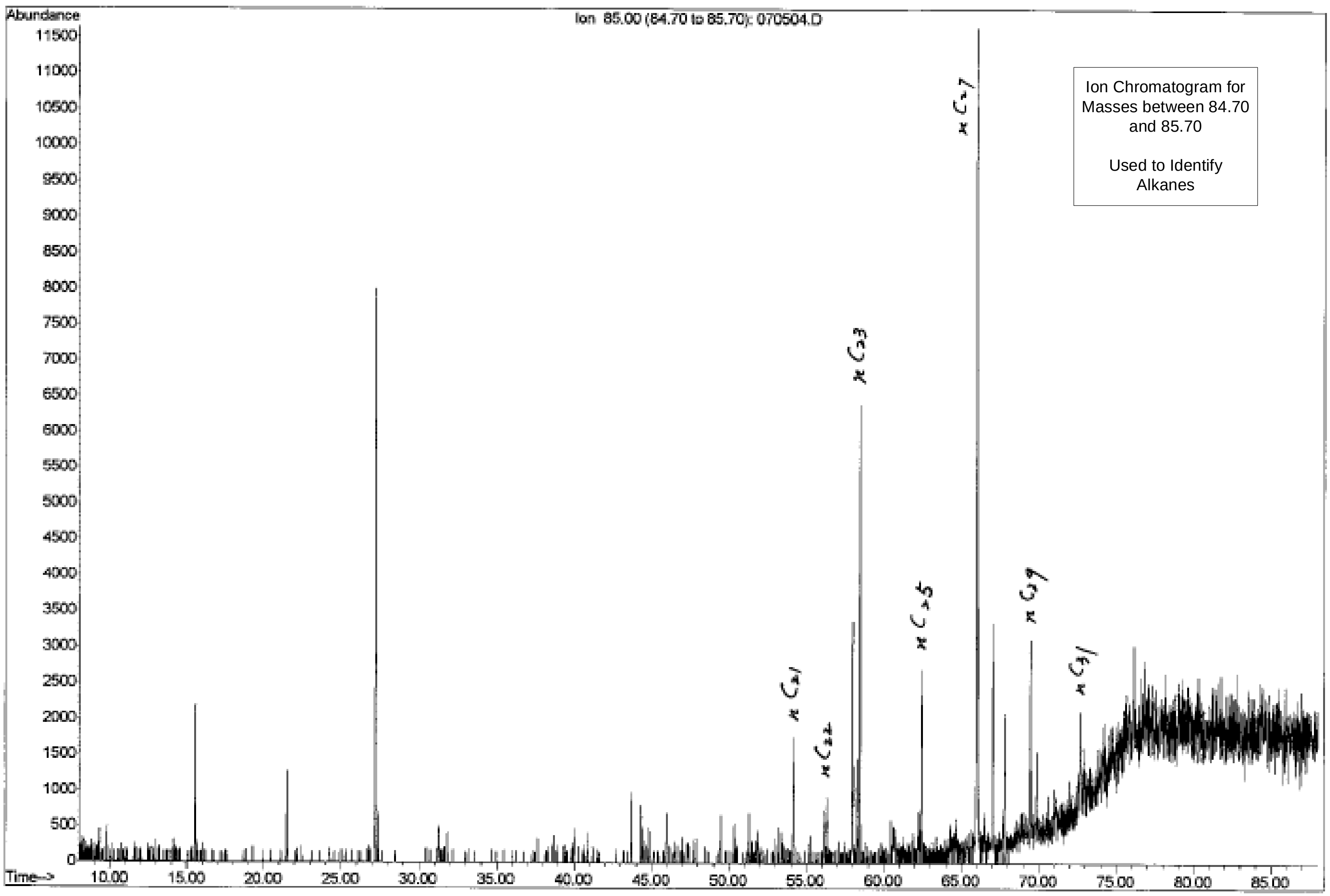

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Figure G.12
Sample GWS-EC12-0008 Selective Ion Monitoring Chromatogram

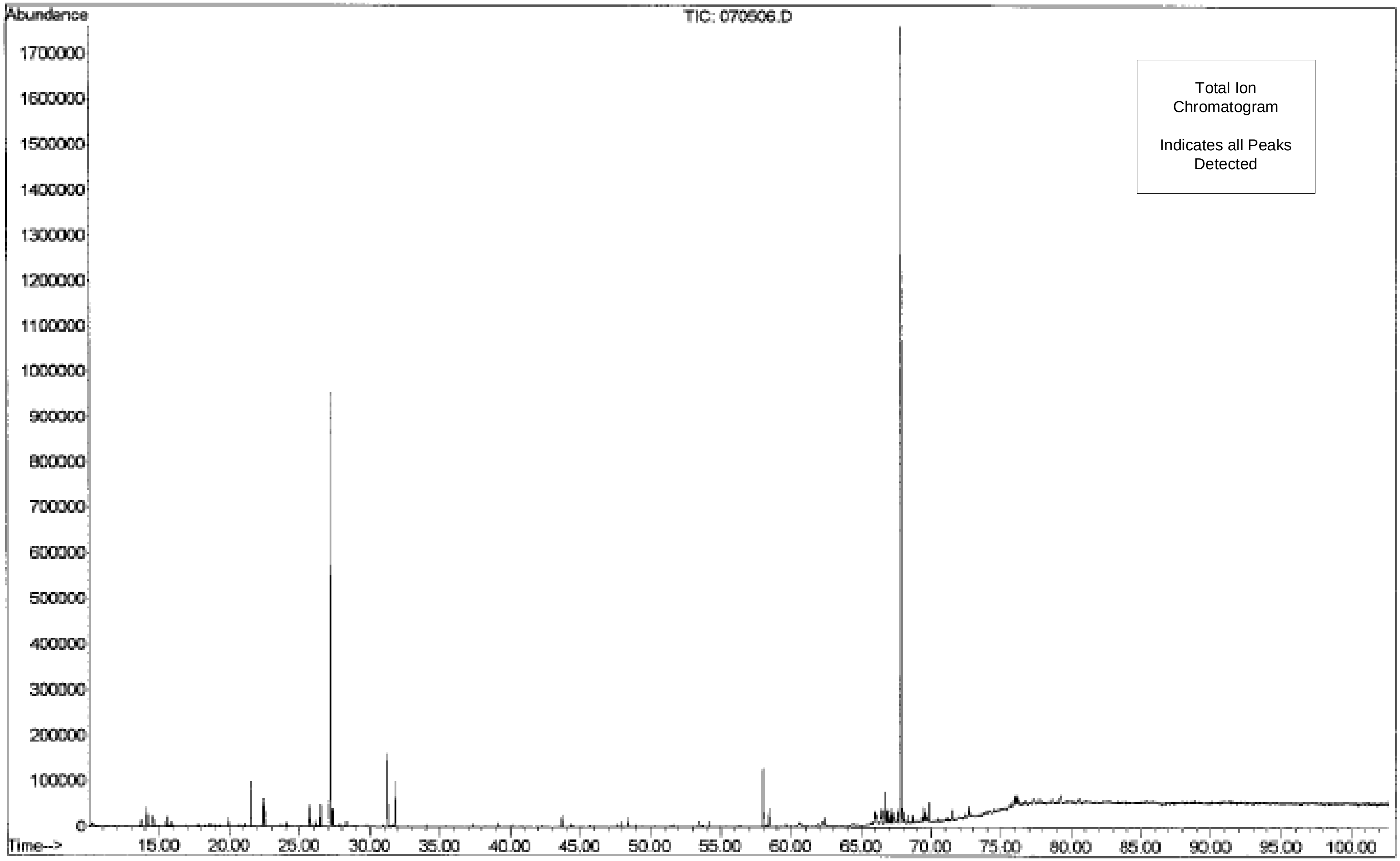

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Figure G.13
Sample GWS-EC13-0090 Total Ion Chromatogram

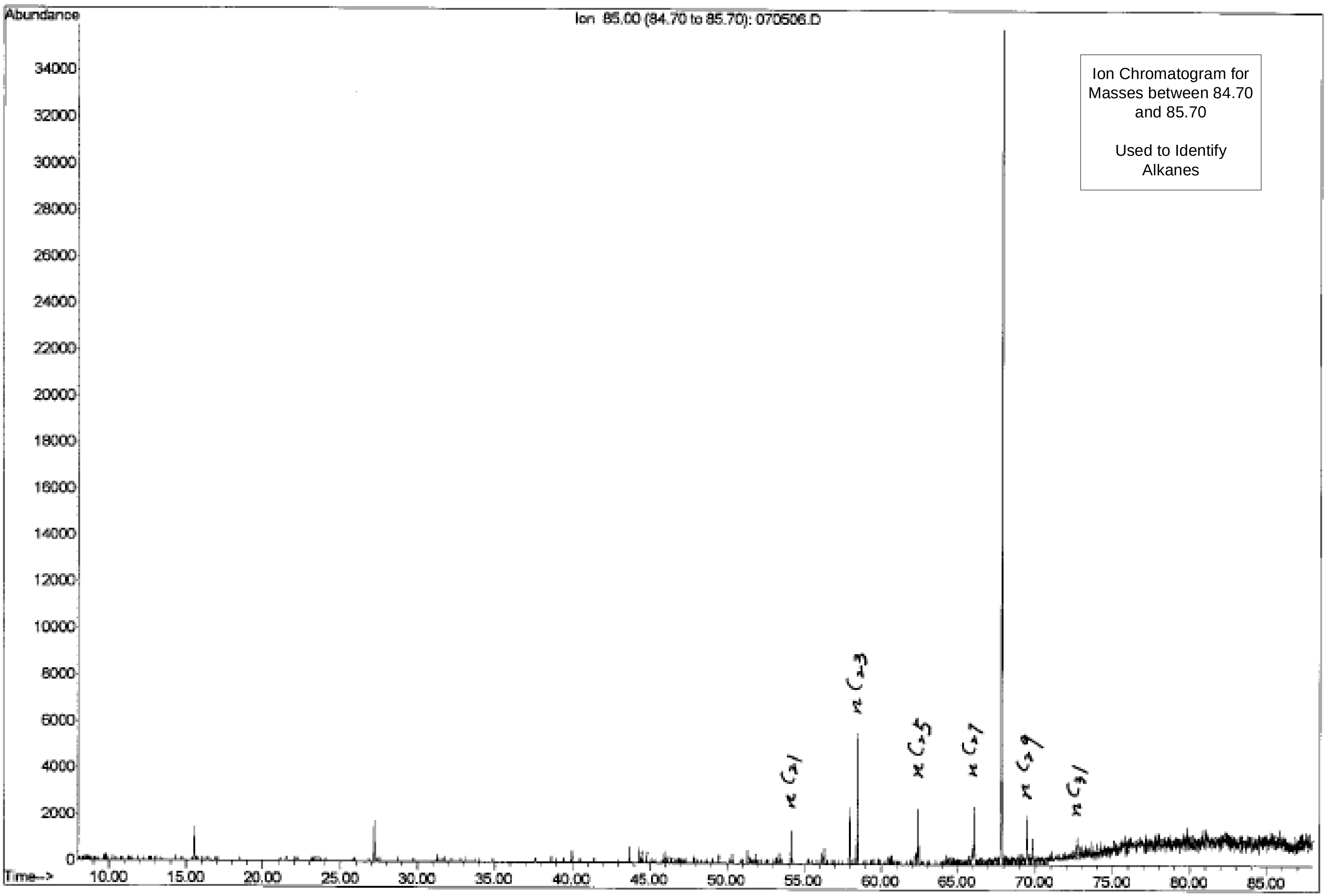

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Figure G.14
Sample GWS-EC13-0090 Selective Ion Monitoring Chromatogram

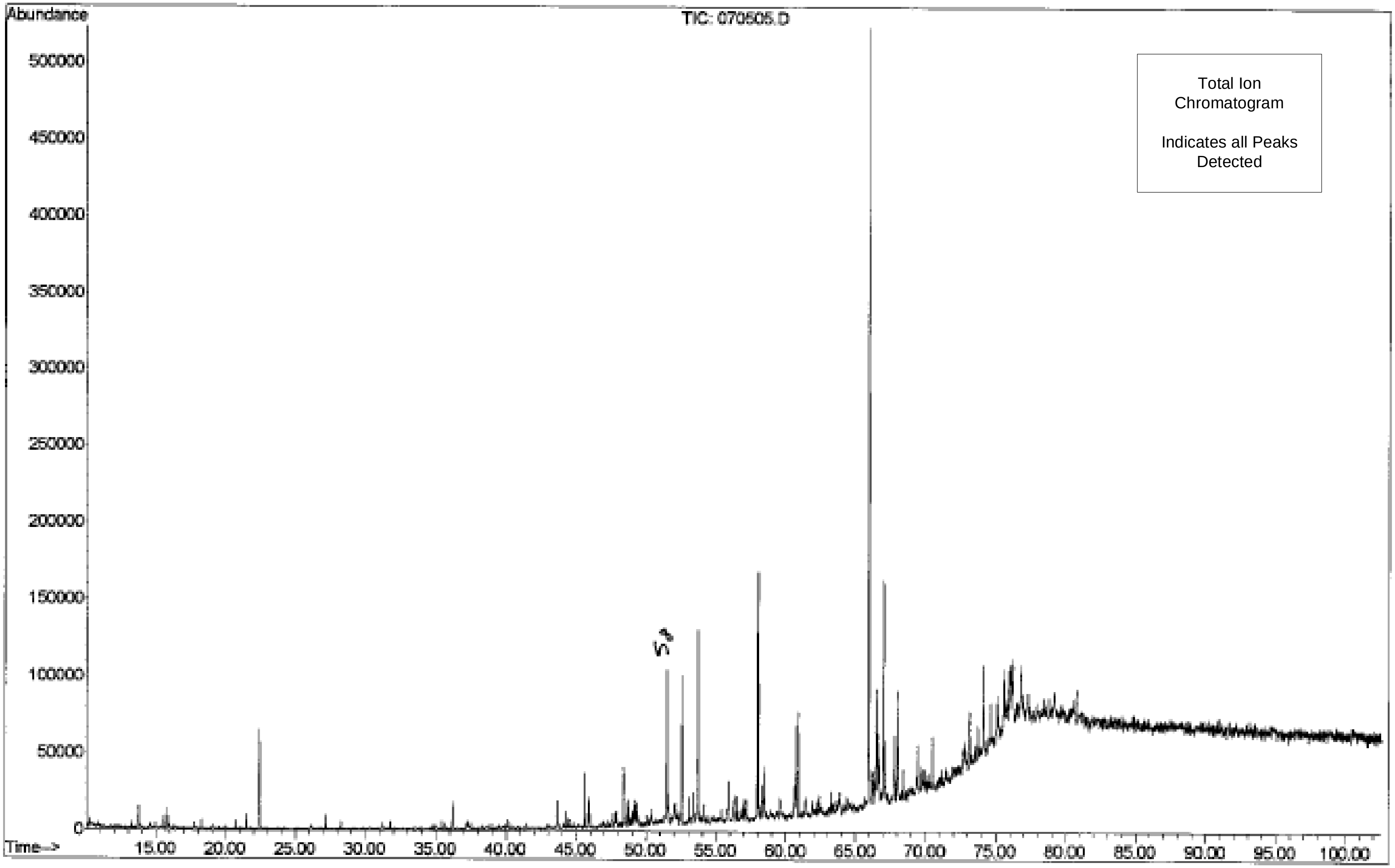

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Figure G.15
Sample GWS-EC14-0008 Total Ion Chromatogram

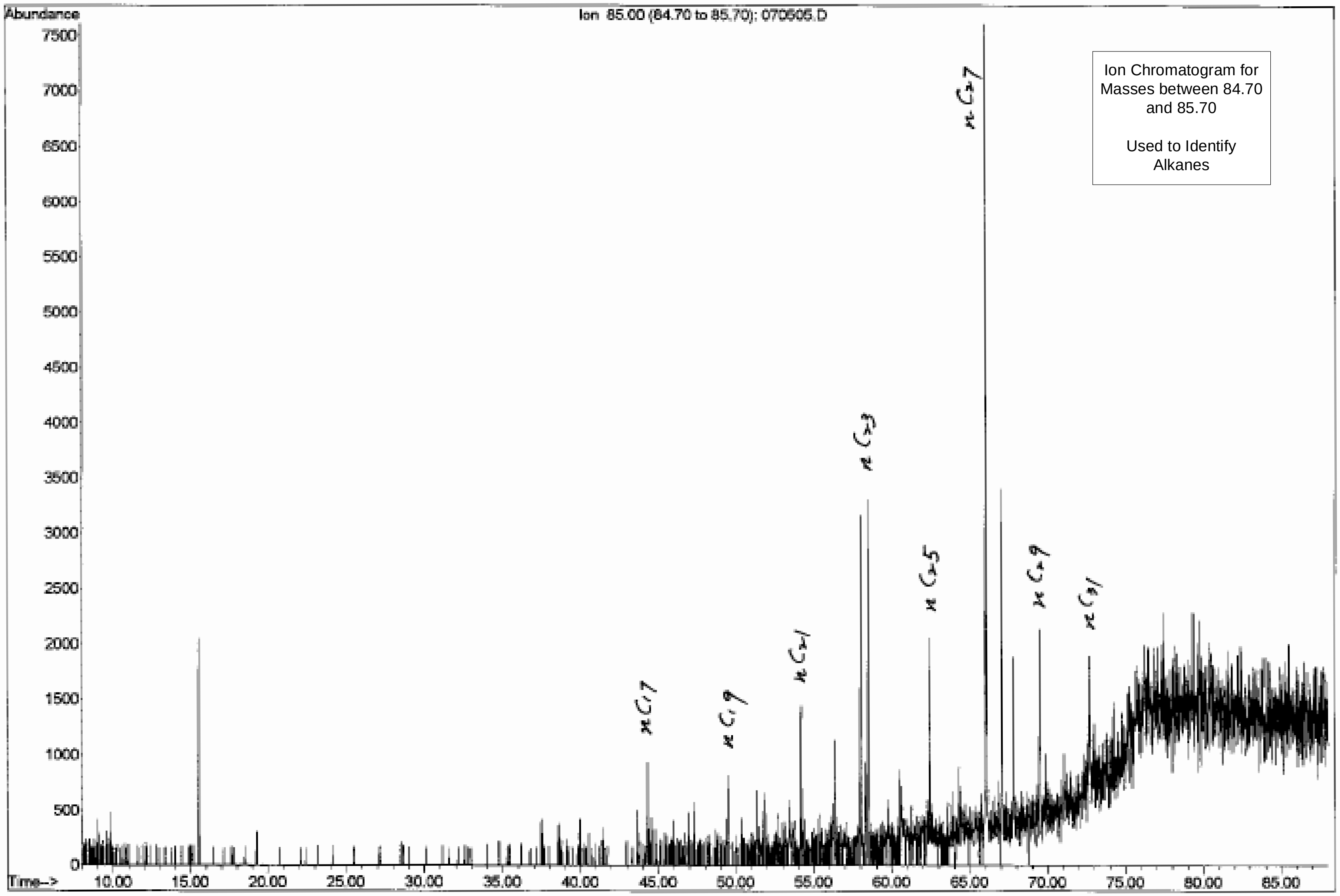

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Figure G.16
Sample GWS-EC14-0008 Selective Ion Monitoring Chromatogram