Project Report

Optical Image Profiler (OIP) Logging

Brooklyn, MI Test Site

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March 15, 2016

Optical Image Profiler (OIP) Project Report

Introduction:

The Optical Image Profiler (OIP) was used to perform fuel fluorescence logging at multiple locations at a former truck stop located outside of Brooklyn, MI. Field work was performed from February 1-3, 2016. Geoprobe Systems® was invited to perform OIP logging at this location by the site consultant and state regulator. The purpose of the field work was to evaluate the performance of the OIP system on a typical site and compare OIP data to information collected with other technologies.

This report includes details of the methods and equipment used for this field work, copies of all OIP logs collected at the site, cross sections through selected log locations, and a discussion of the data.

Site Location:

The site for this field work is located in Jackson County, Michigan. A location map is shown in Figure 1.

Figure 1: Site location: Brooklyn, MI

Equipment and Procedures:

OIP logging for this project was performed using an OP6560 OIP probe (Geoprobe® MN 224739) attached to 1.75in (4.4cm) diameter probe rods. This probe is equipped with an onboard camera to collect soil images through a sapphire window produced by both UV (265 nm) and visible light sources. Simultaneous measurements of soil electrical conductivity (EC) are collected using a dipole array. All logging was performed using the UV light source. A typical OIP log from the site is shown in Figure 2.

The OIP system was operated by Dan Pipp of Geoprobe Systems®, Salina, KS. Logging activities at the site were observed during all three days of operation by Mark Peterson of Compliance, Inc., Brighton, MI, and Sheryl Doxtader of the Michigan Department of Environmental Quality.

At selected depths, the OIP operator stopped the probe and captured still images using visible light and UV light. Depths where these still images are available in the log file are indicated by the red dots marked on the vertical axis on the right side of the log.

The OIP probe was advanced into the ground using a Geoprobe® Model 7730 probing machine. The percussion hammer on this unit was equipped with a drive cushion (MN 206456). Rate of advancement of the probe ranged from 3ft (0.91m) per minute to 5ft (1.52m) per minute with an approximate average of 4ft (1.22m) per minute. Boring locations in asphalt and concrete areas of the site were drilled at the surface and pre cleared to approximately 1ft (30cm) prior to tool advancement.

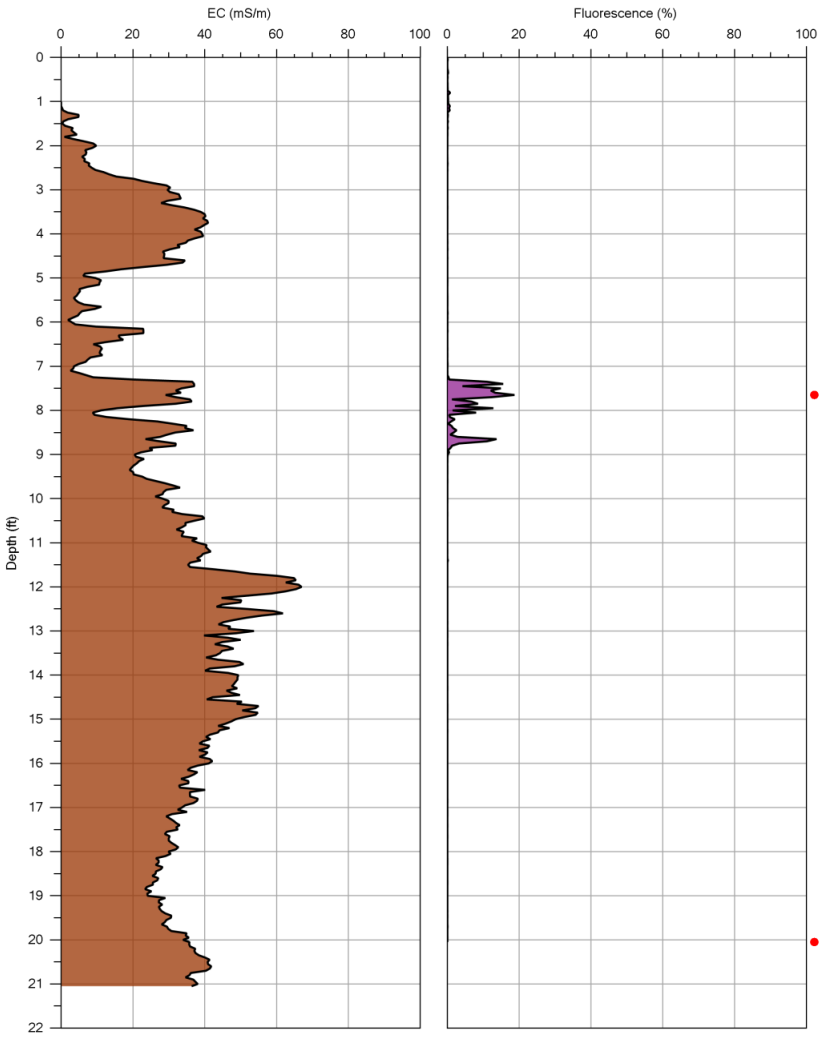


Figure 2: Typical OIP log from the site (GL-16).

Log Quality Assurance (QA)

QA testing of the OIP logging system was performed before and after each log on the electrical conductivity circuit as well as the fluorescence detector. This was done to ensure the sensors were working properly before and after each log. The EC dipole array was tested using a standard resistive load dipole tester (MN 205724). To check the OIP fluorescence detection system, cuvettes of diesel fuel and motor oil were placed in front of the sapphire window and fluorescence was measured. Typical measurements were 60%-80% fluorescence in each reference test.

Log Production:

Daily production of logs at the site is shown in Figure 3. A total of 39 logs and 786ft (239.6m) of total logging were performed during the three day project.

2/1/2016	Total Depth (ft)	2/2/2016	Total Depth (ft)	2/3/2016	Total Depth (ft)
GL-06 11:02	20.1	GL-11 09:04	20.2	GL-24 08:35	20.5
GL-02 11:50	20.4	GL-12 09:41	20.1	GL-25 09:18	20.2
GL-03 12:20	21.2	GL-15 10:52	20.0	GL-28 09:53	20.3
GL-04 12:48	20.2	GL-16 11:18	20.1	GL-31 10:32	20.0
GL-07 13:49	20.2	GL-17 12:44	20.1	GL-30 10:57	20.1
GL-08 14:14	20.1	GL-18 13:42	20.2	GL-33 11:27	20.1
GL-10 14:42	20.1	GL-20 14:11	20.1	GL-32 11:45	20.2
GL-13 15:06	20.2	GL-22 14:39	20.2	GL-34 12:08	20.1
GL-14 15:30	20.2	GL-19 15:19	20.1	GL-36 13:34	20.1
GL-01 16:24	20.3	GL-23 15:48	20.1	GL-35 13:57	20.2
GL-05 16:49	20.1	GL-26 16:11	20.1	GL-38 14:21	20.1
GL-09 17:18	20.1	GL-27 16:36	20.1	GL-37 14:47	20.2
				GL-09R 15:10	20.0
				GL-03R 15:37	20.1
				GL-42 16:00	20.1
Daily Footage	**243.0 ft (74.1m)**		**241.1ft (73.5m)**		**301.9ft (92m)**

Figure 3: Daily OIP log production.

Log Locations:

All OIP logs for this project were co-located with logs made using a UVOST® logging system. Log locations are shown on the site map (Figure 4). Each OIP log was placed within a distance of approximately 3ft (0.9m) of a corresponding UVOST® log. UVOST® log locations are designated as "LIF-01, LIF-02, etc." and the corresponding OIP log locations are designated as "GL-01, GL-02, etc." Of the 43 UVOST® logs made on the site, 37 were replicated with an OIP log.

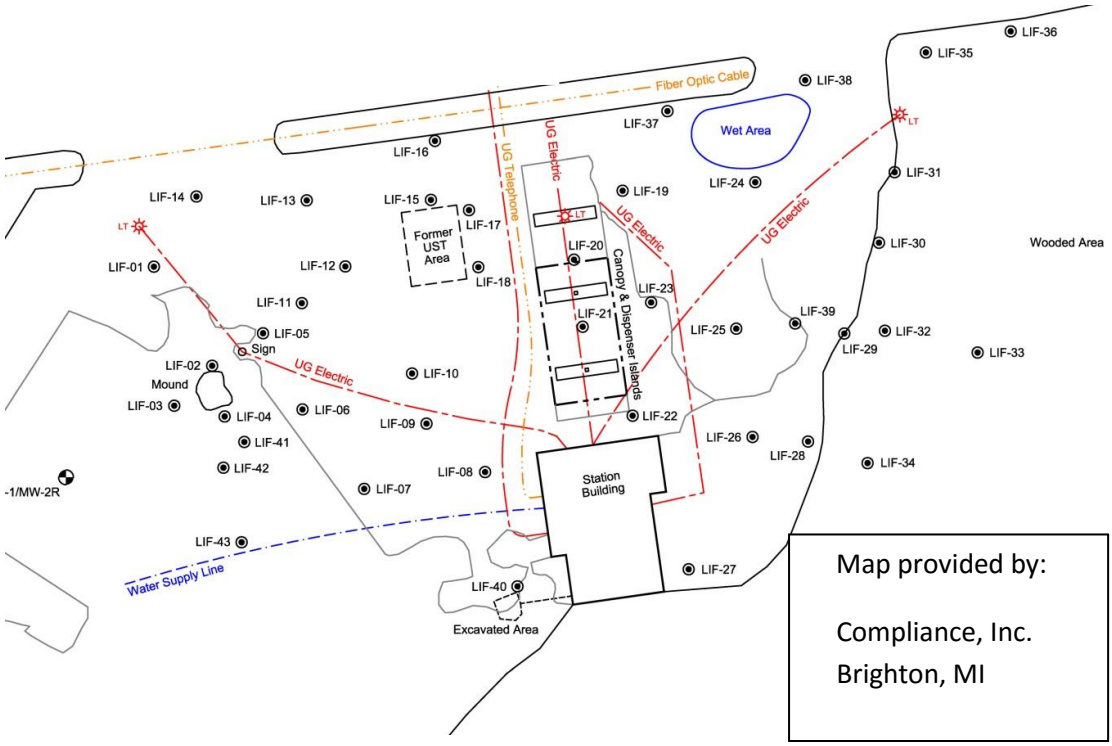


Figure 4: Site map with log locations.

Results and Discussion:

Logging was performed without any breakdown or equipment failure during the 3-day period.

Baseline values on OIP logs are typically less than <1% in areas with no detectable hydrocarbon NAPL impacts. At locations with hydrocarbon impacts, OIP fluorescence typically ranged from 15% up to 75% of the image area. Figure 5 shows log GL-25 and select images from the log. Included in these images are both non-fluorescent (background) soils and areas of high fluorescence (hydrocarbon impact).

Cross sections through selected OIP logs are provided in Appendix A with maps (Figure A1 and A2) showing the logs included in each cross section.

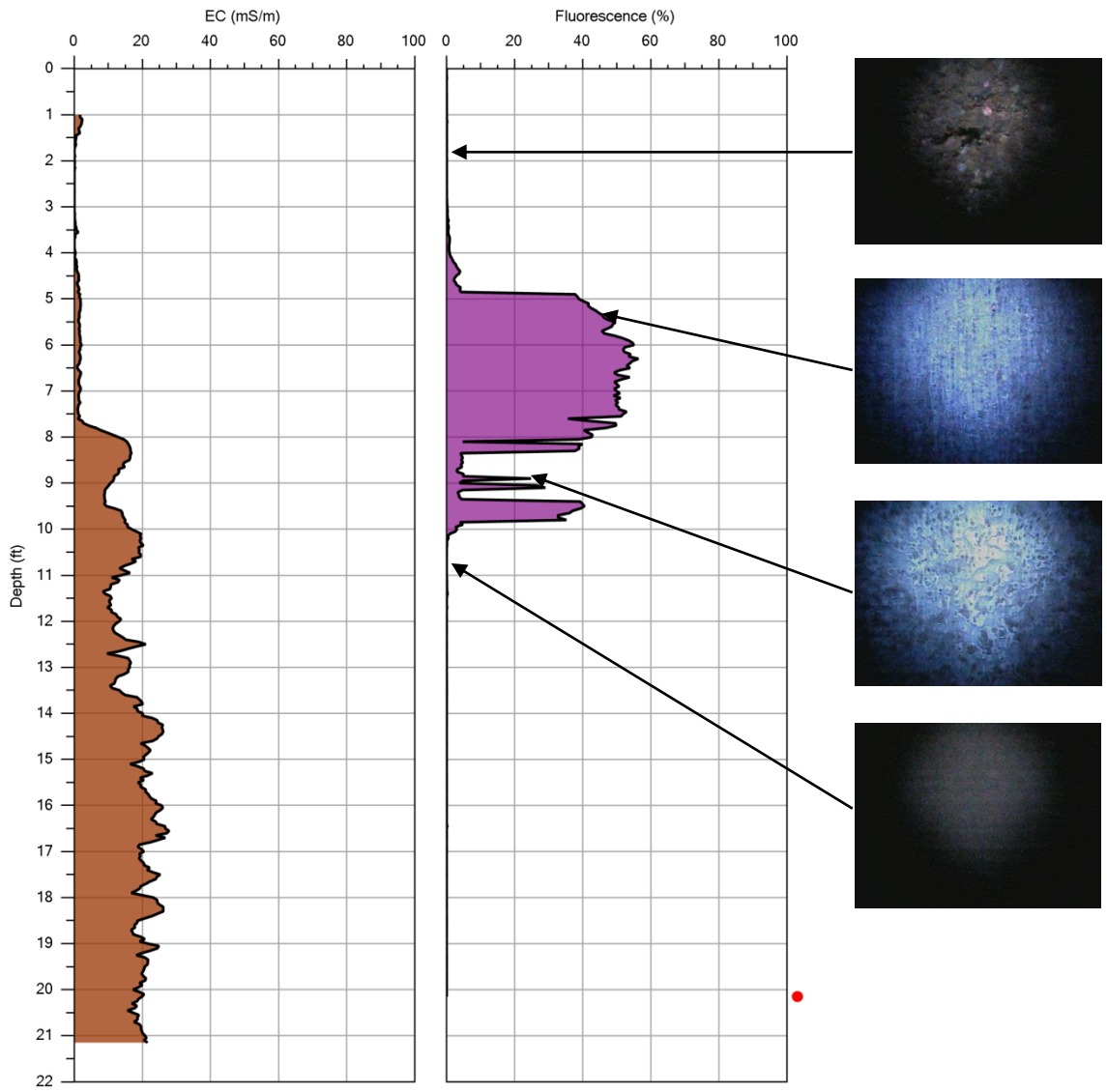


Figure 5: Log GL-25 with UV images from 1.95ft (0.59m), 5.35ft (1.63m), 8.85ft (2.7m) and 10.60ft (3.23m).

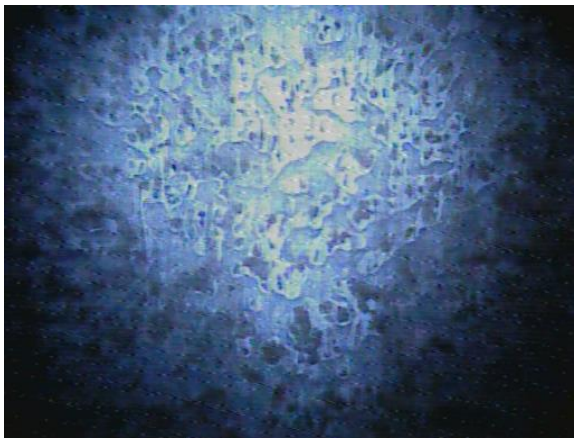


Figure 6: Fuel fluorescence below the water table.

The image in figure 6 is from Log GL-25, 8.85ft (2.7m) (shown in Figure 5). This image shows fuel fluorescence in soil below the water table. This image illustrates fuel as an immiscible phase in water. The fuel has separated from the soil particles and is pressed over the face of the window with water as its surrounding matrix.

Comparison to UVOST® logs from the Site:

Logging performed at this site provides a useful opportunity to compare fluorescence logs made with the OIP technology to those made using UVOST®. These two technologies use very different methods of measuring UV induced fluorescence of hydrocarbon NAPL in soil. UVOST® uses an up-hole pulsed laser light source (308nm). This UV light is transmitted down a fiber optic line to the sapphire window. Fluorescent light emitted by hydrocarbons in the soil is then returned up a second fiber optic line where light intensity is measured using spectroscopic methods. The UVOST® technique gives a log of fluorescence intensity (Signal (%RE)) as well as multi-wavelength waveforms that are indicative of the type of fuel being encountered.

In contrast to UVOST®, OIP uses both a down-hole light source and a down-hole detector. The light source is a UV LED (265nm) and detection is performed by visible light imaging with a CMOS camera. Rather than a fluorescence intensity log with depth, the OIP measures the percent of image area exhibiting hydrocarbon fluorescence. OIP logs do not yield fuel waveform signatures. They do give soil images that contain visual information about the distribution of hydrocarbons in the soil matrix.

What can be compared between the two techniques are their logs of hydrocarbon NAPL position and relative response. This is the log of "Signal (%RE) given by UVOST® logs and the log of "Fluorescence (%)" shown on OIP logs. This report only attempts to make general observations on the comparability of these two log types; more thorough statistical treatment would require a more extensive logging effort than was performed on this one site.

UVOST® logging was performed at the site under the direction of Compliance, Inc., of Brighton, MI from January 25 to February 3, 2016. A total of 43 UVOST® logs were made during this time. OIP logs were made at 37 of the UVOST® locations at the site, with corresponding logs being offset by approximately 3ft (0.91m) at each location.

Of the 37 replicate locations, 8 locations showed no detectable hydrocarbon NAPL impact by either technology. The non-detect log locations are 03, 07, 08, 27, 33, 34, 36 and 38.

Twenty-five of the logs exhibited fuel fluorescence on both technologies. In general, OIP and UVOST® logs in this group show good agreement across the site and typically display similar beginning and ending depths of fuel impact and similar pattern or shape of fuel fluorescence log in the impacted zone.

Beginning and ending depths of detected fluorescence are shown in Figures 7 and 8. These graphs show how closely the two technologies agree in assessing the thickness of the predominant hydrocarbon NAPL impacts starting at depths greater than 2 ft. (0.6m) at the site. A >5% signal cutoff was used to determine where the beginning and ending points of log fluorescence in the graphs. Missing data points or lines in either of the graphs indicate that fluorescence signal above the cutoff was not detected at that location for that technology.

Three logs exhibited detectable hydrocarbon NAPL on one log type and not the other. Log LIF-42 exhibited fuel fluorescence where none was displayed on the co-located OIP GL-42 log. Likewise, 2 OIP logs (GL-14 and GL-22) exhibit fuel fluorescence where little to none was displayed on the co-located UVOST® logs (LIF-14 and LIF-22). It is possible that the difference in response at these locations is attributable to spatial variability in the distribution of hydrocarbons. This type of variability within duplicated logs is not uncommon even when replicate logs are made using the same technology. Time did not permit more extensive study of the difference in response at these four locations.

Appendix B provides graphs of co-located OIP and UVOST® logs for each location. On each page, the location EC and OIP fluorescence (% image area) along with the co-located UVOST® fluorescence (%RE) log are shown.

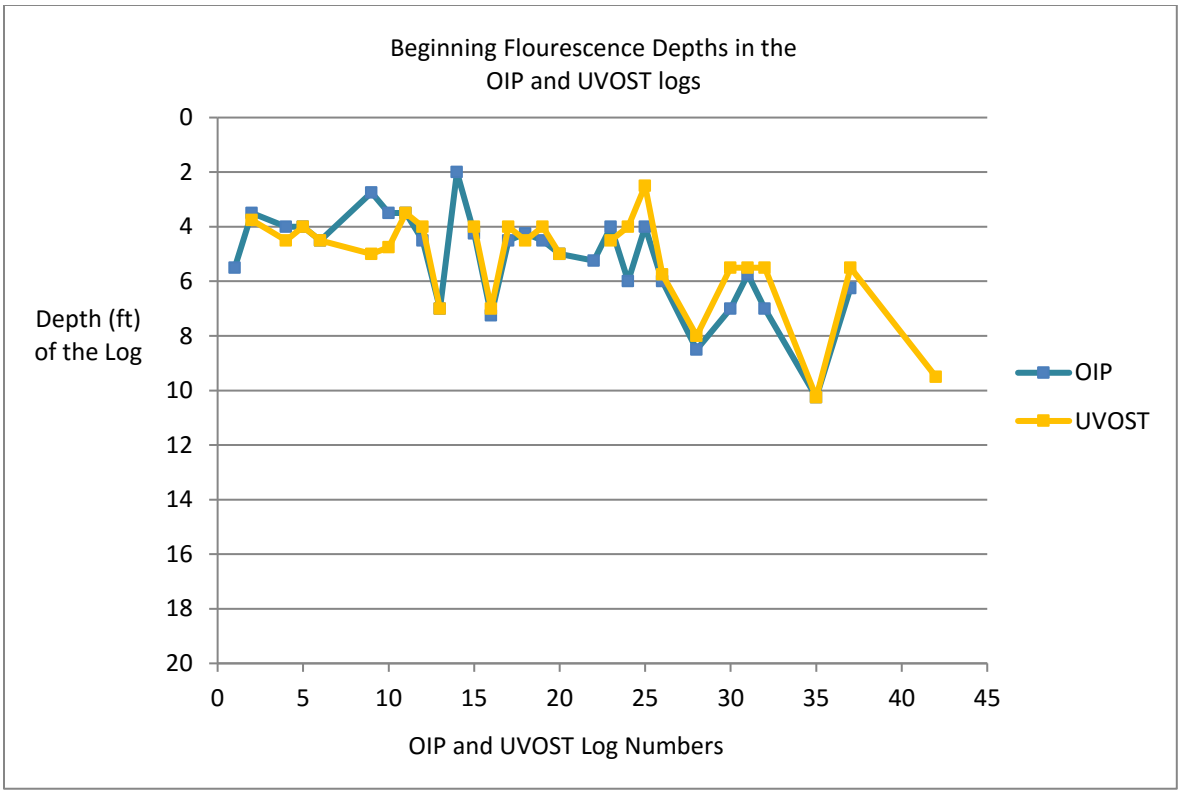


Figure 7: Chart of the beginning depths of detected fluorescence in the OIP and UVOST® logs.

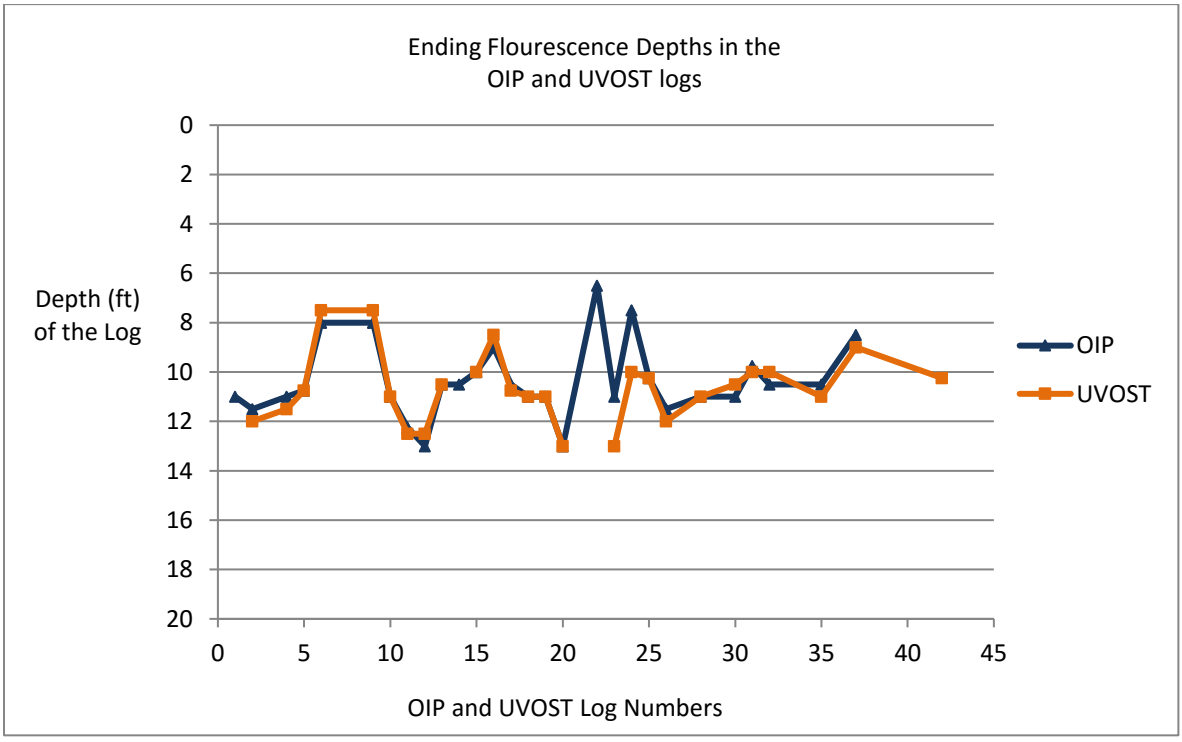


Figure 8: Chart of the ending depths of detected fluorescence in the OIP and UVOST® logs.

Appendix A
OIP Log Cross Sections

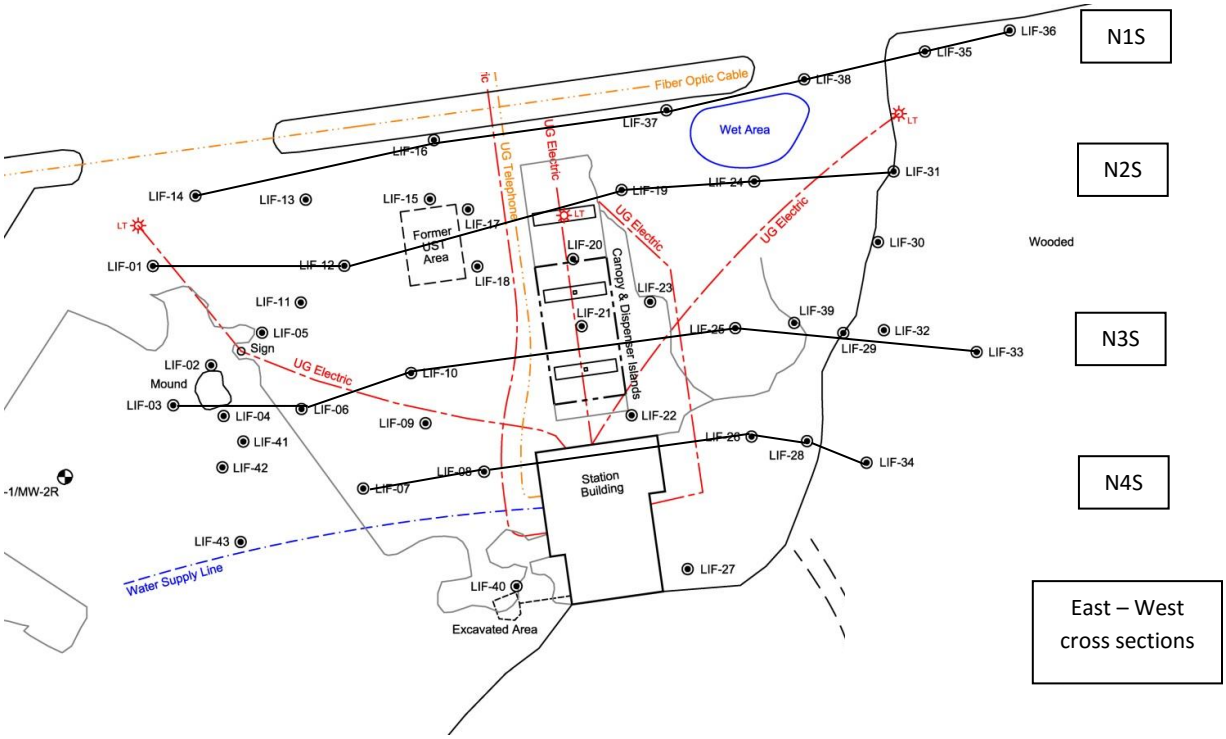


Figure A1: Site map of the E-W cross sections

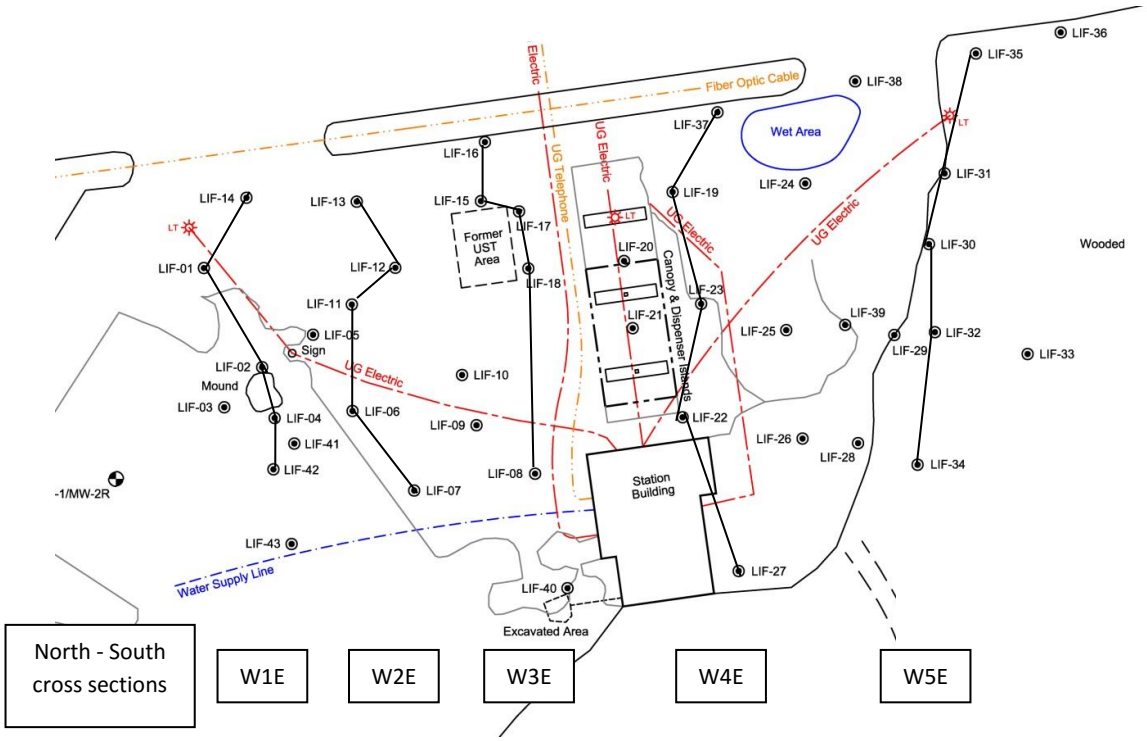
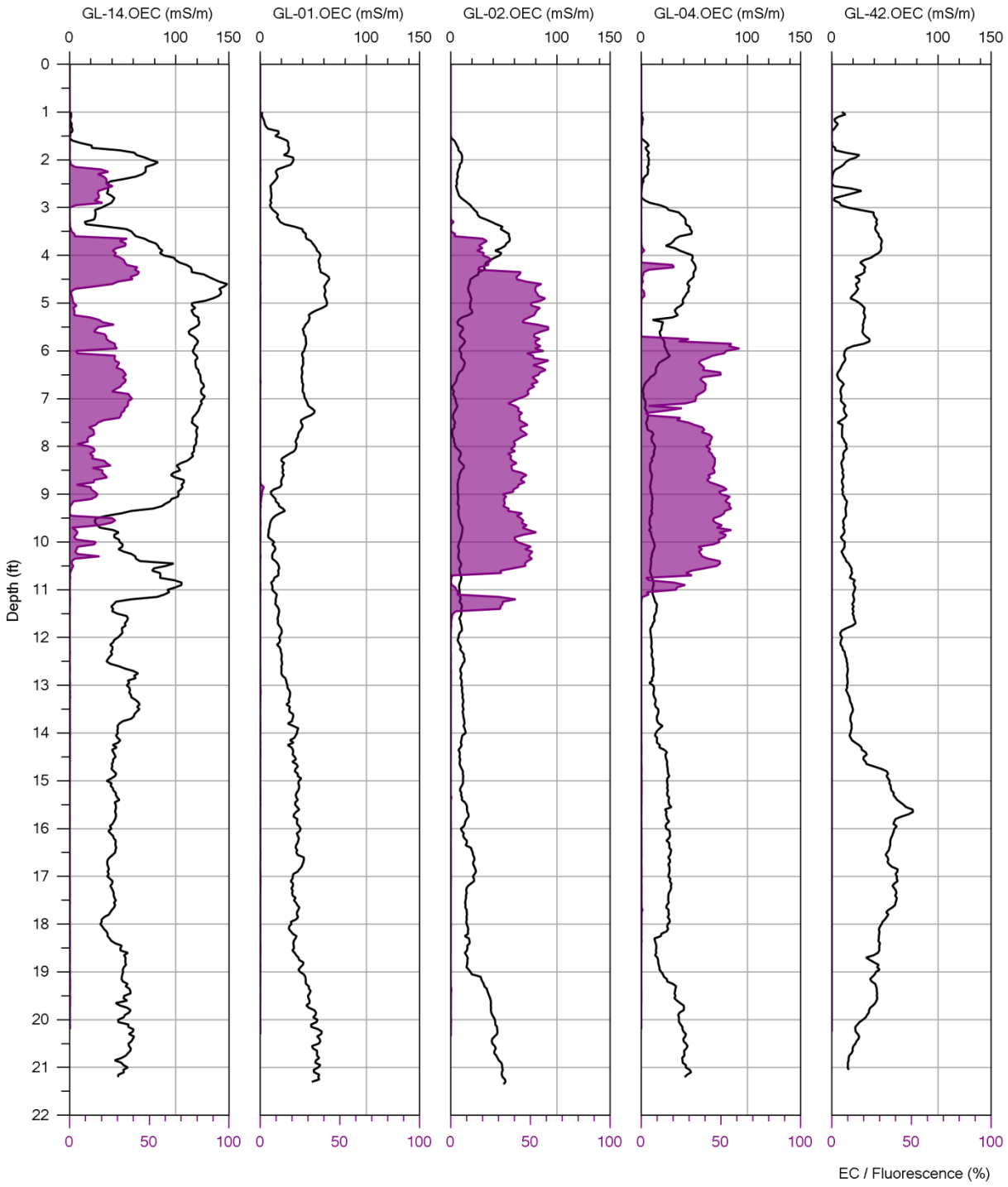
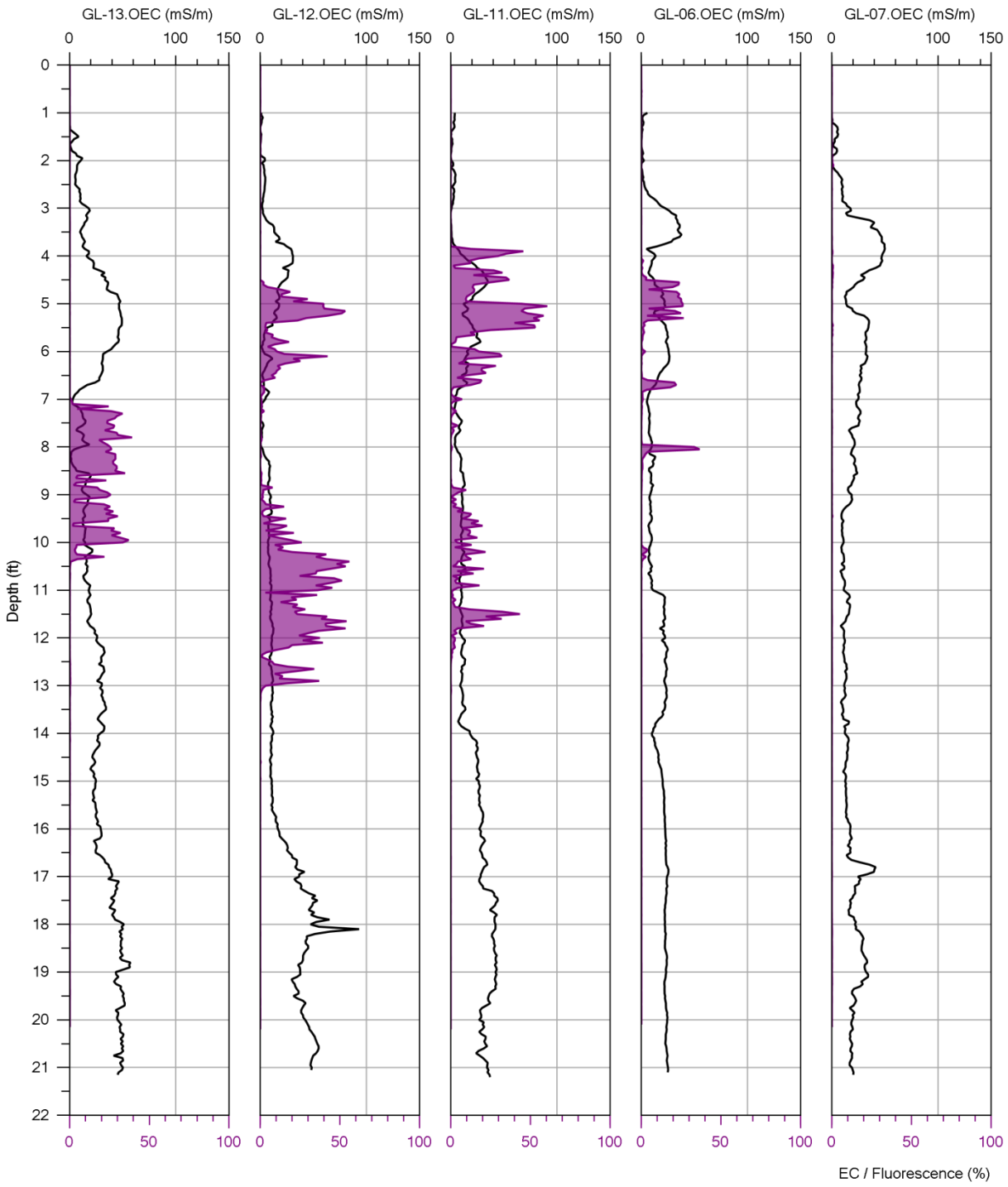


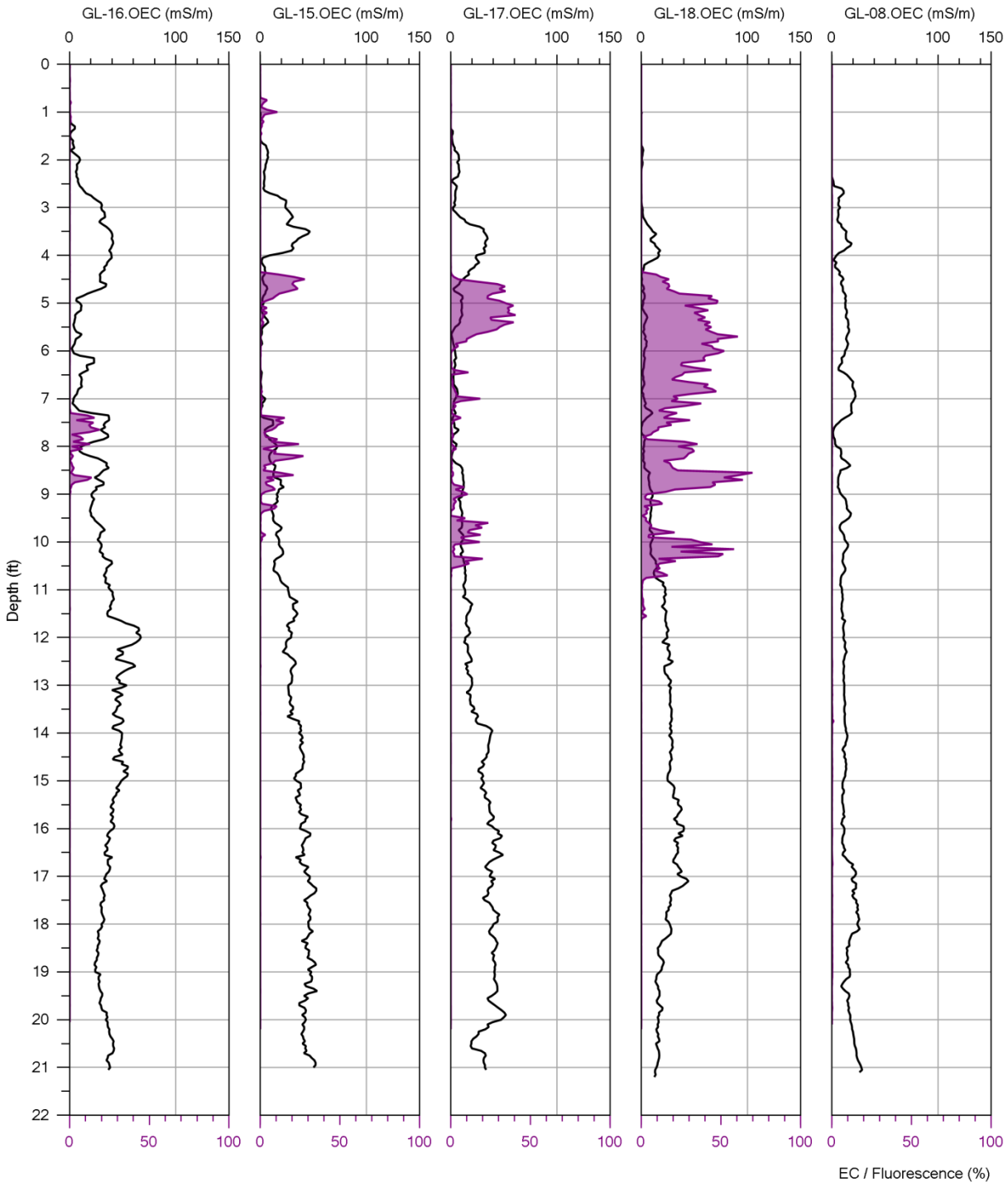
Figure A2: Site map of the N-S cross sections



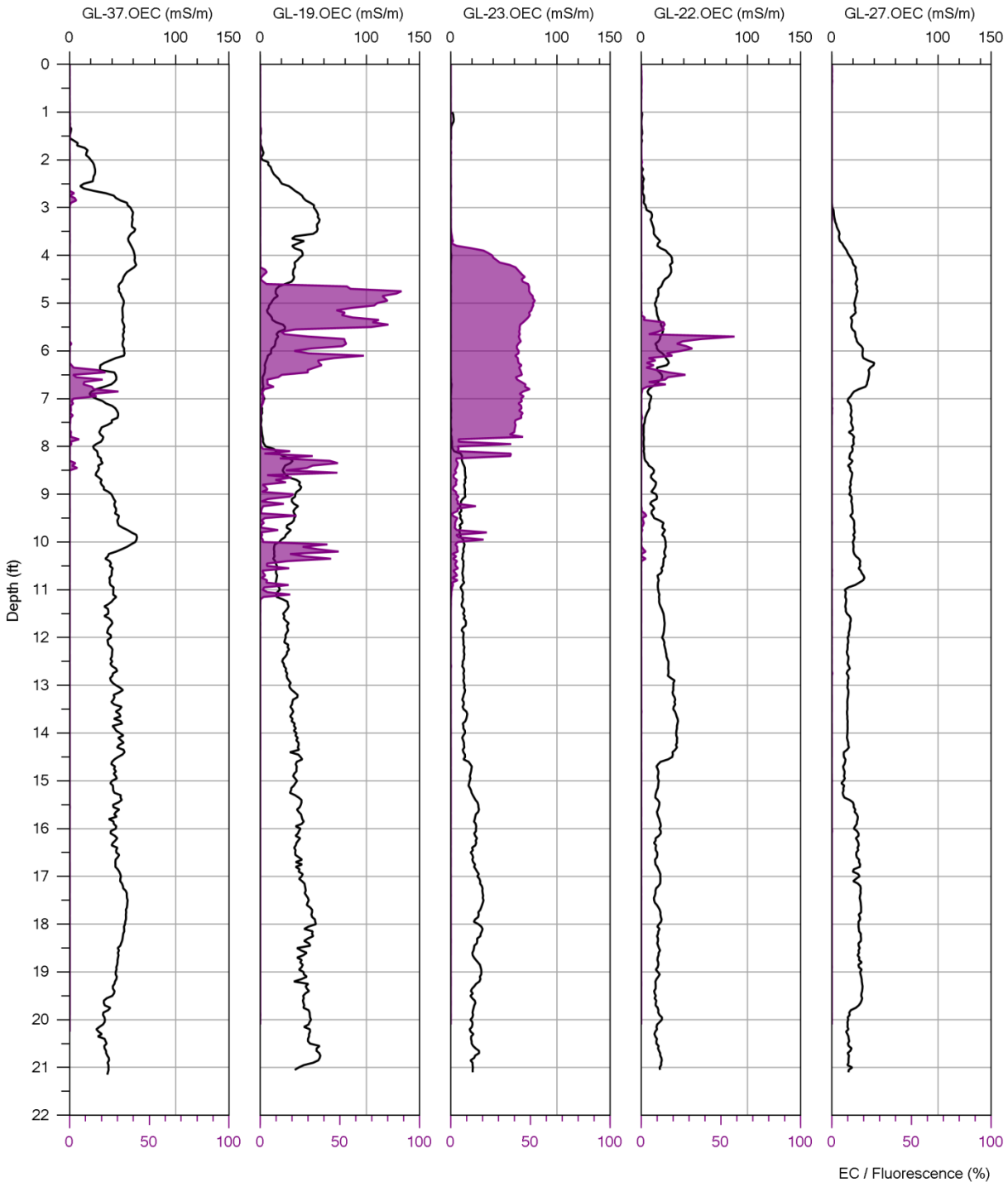
Cross Section: North to South W1E



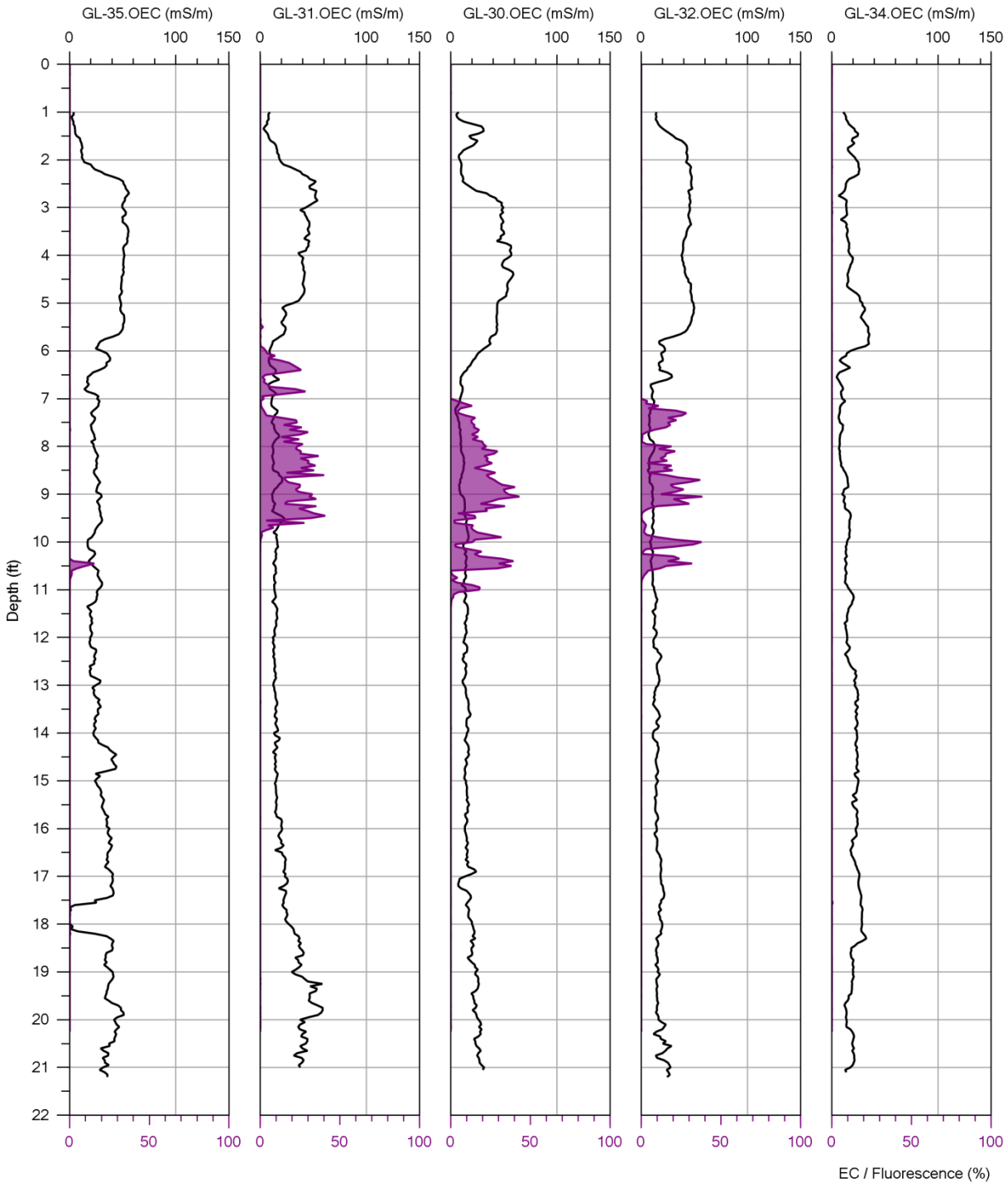
Cross Section: North to South W2E



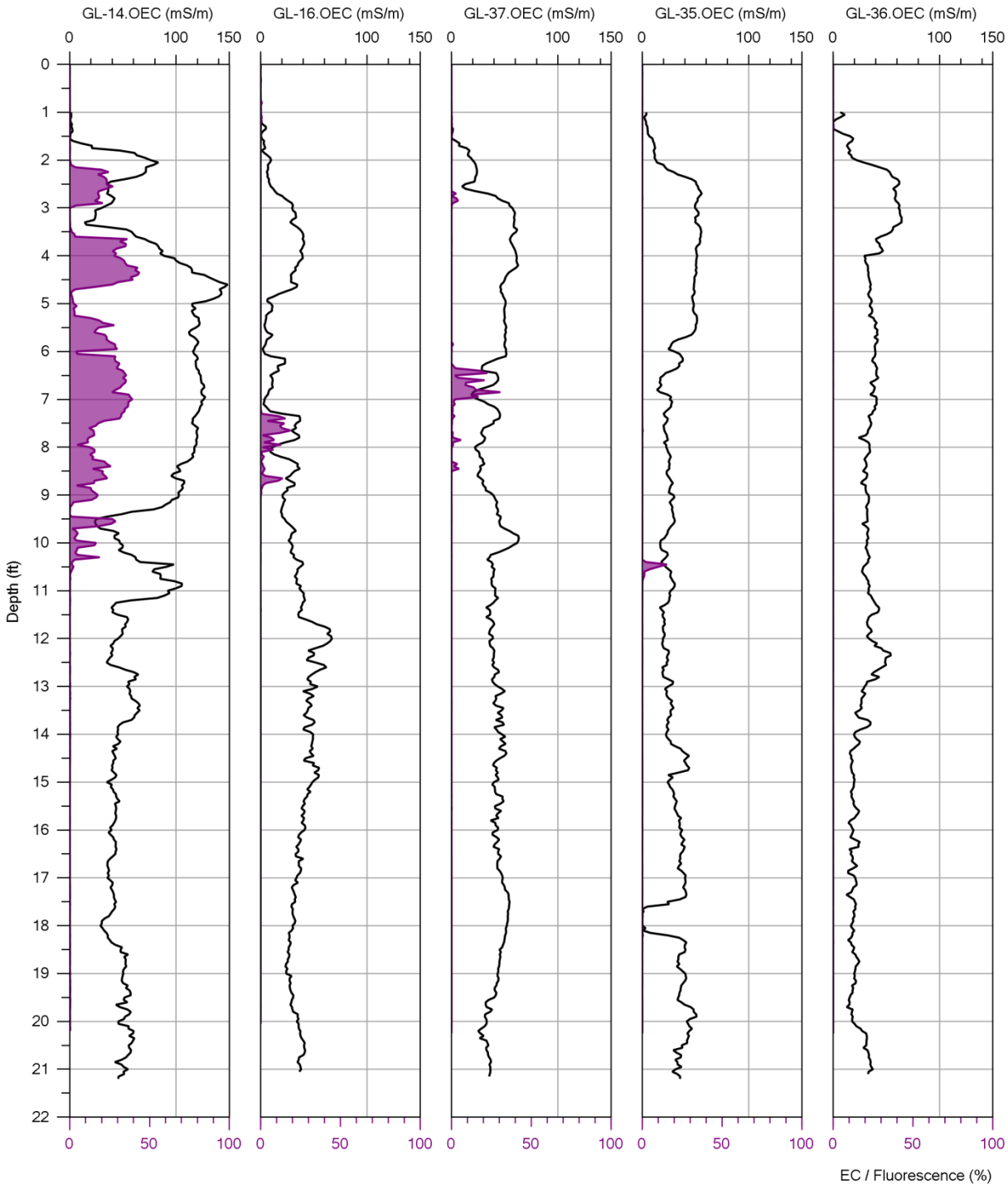
Cross Section: North to South W3E



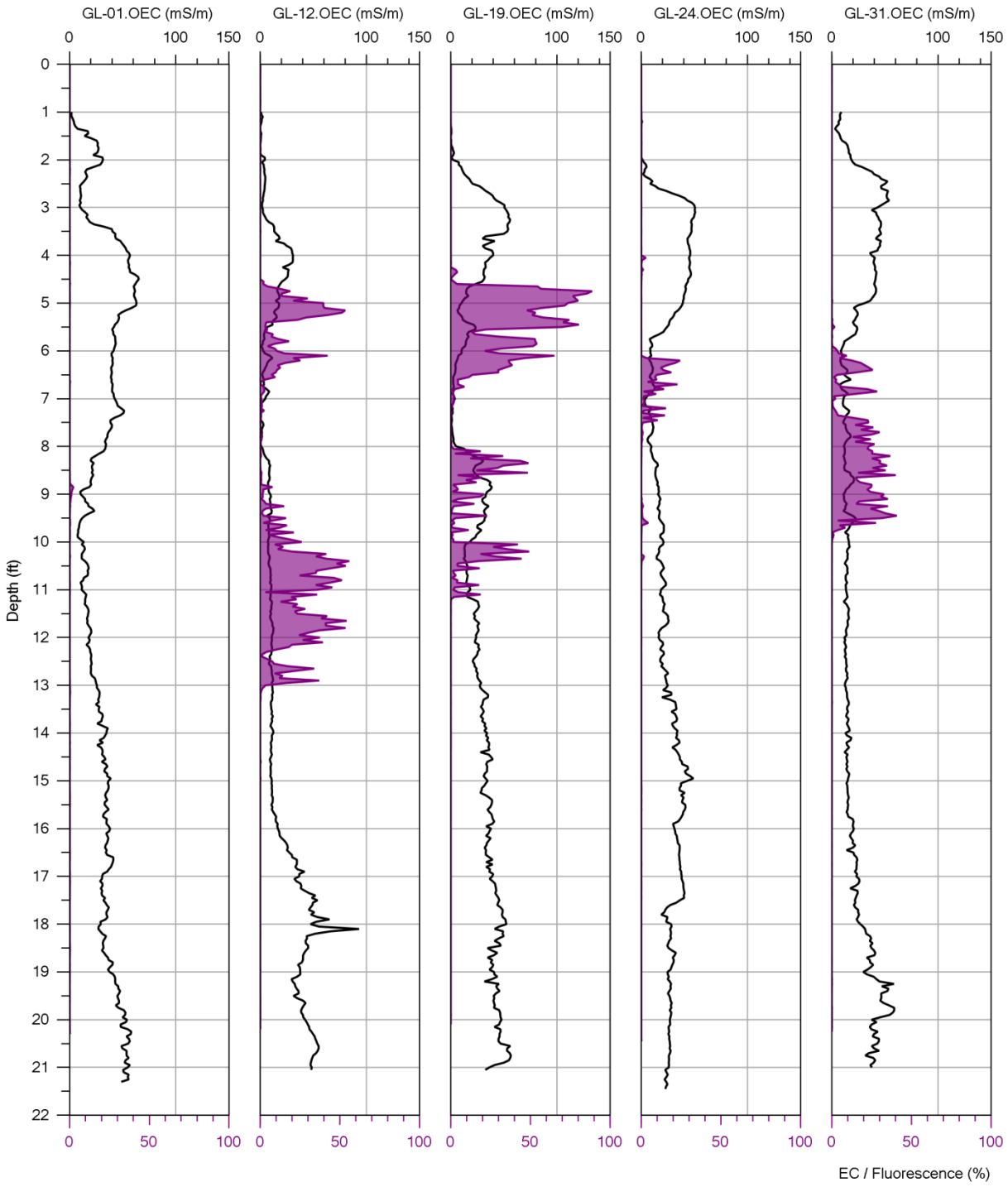
Cross Section: North to South W4E



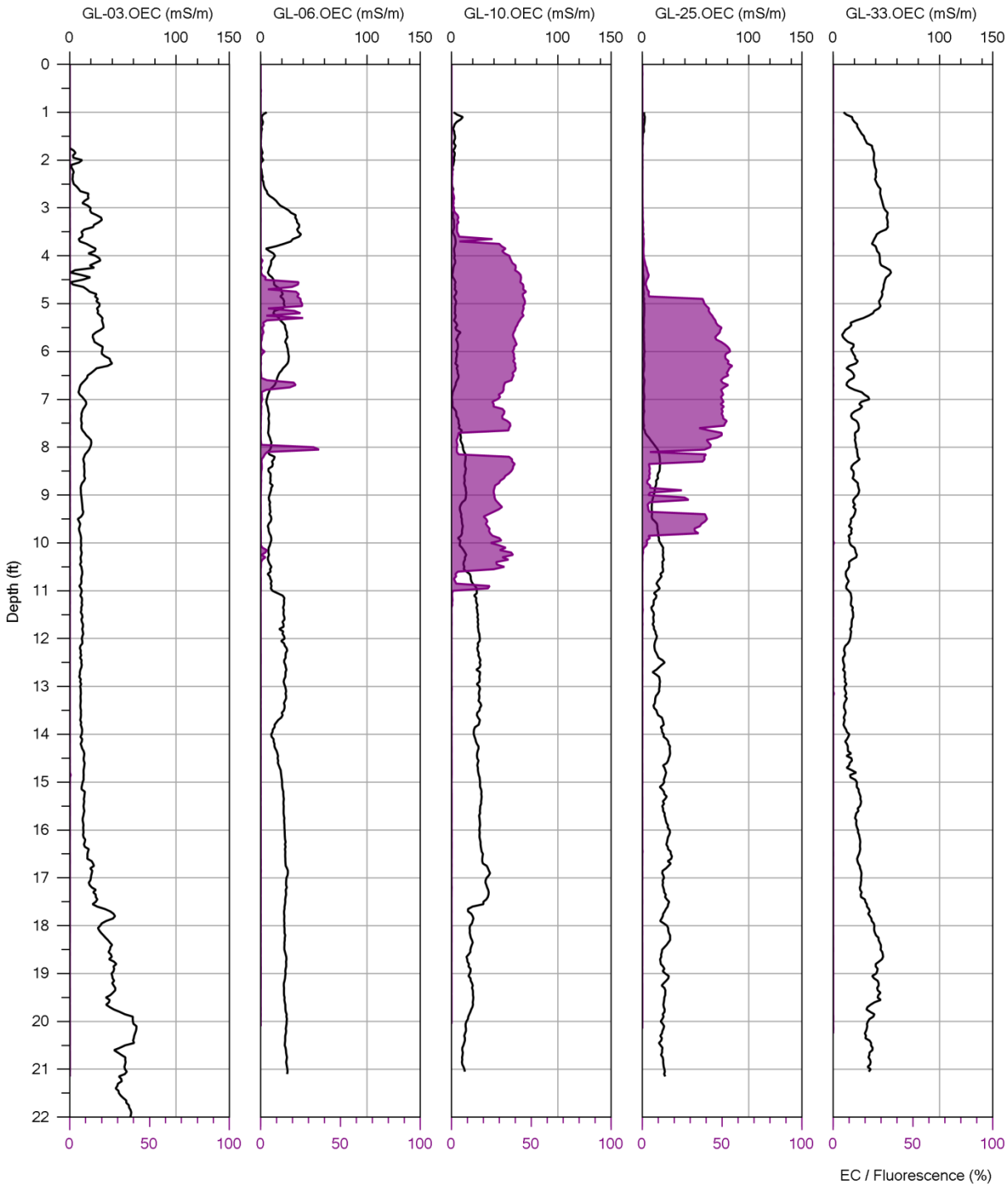
Cross Section: North to South W5E



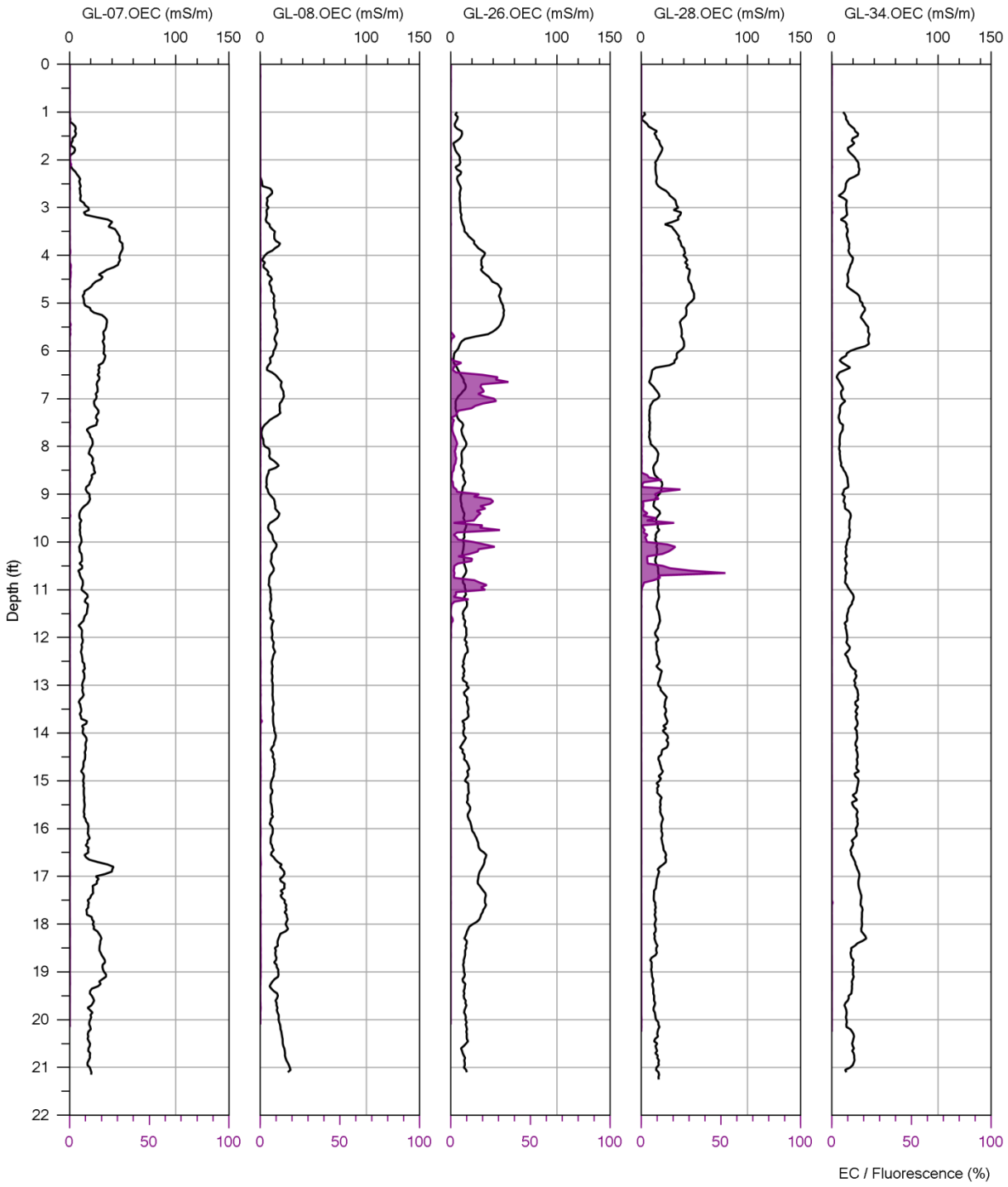
Cross Section: West to East N1S



Cross Section: West to East N2S



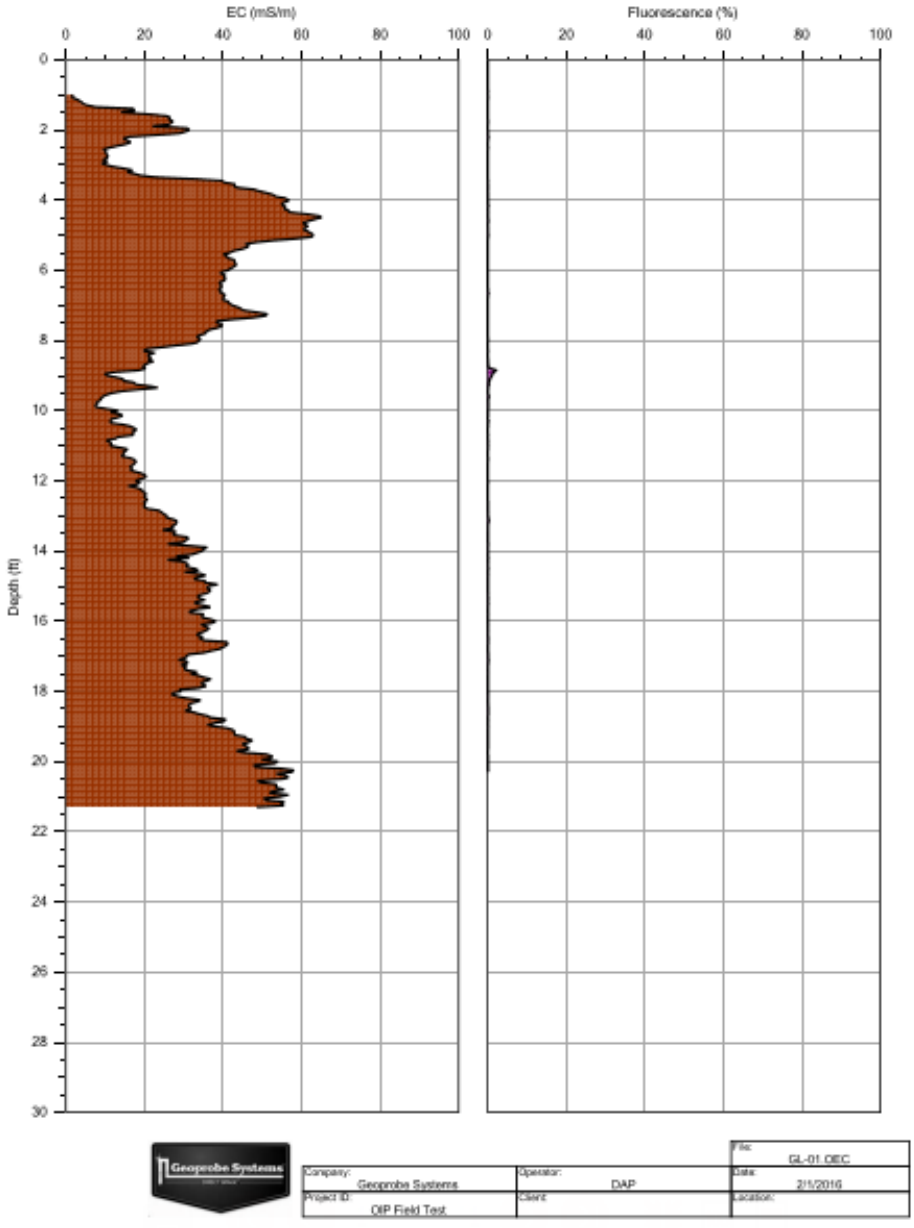
Cross Section: West to East N3S



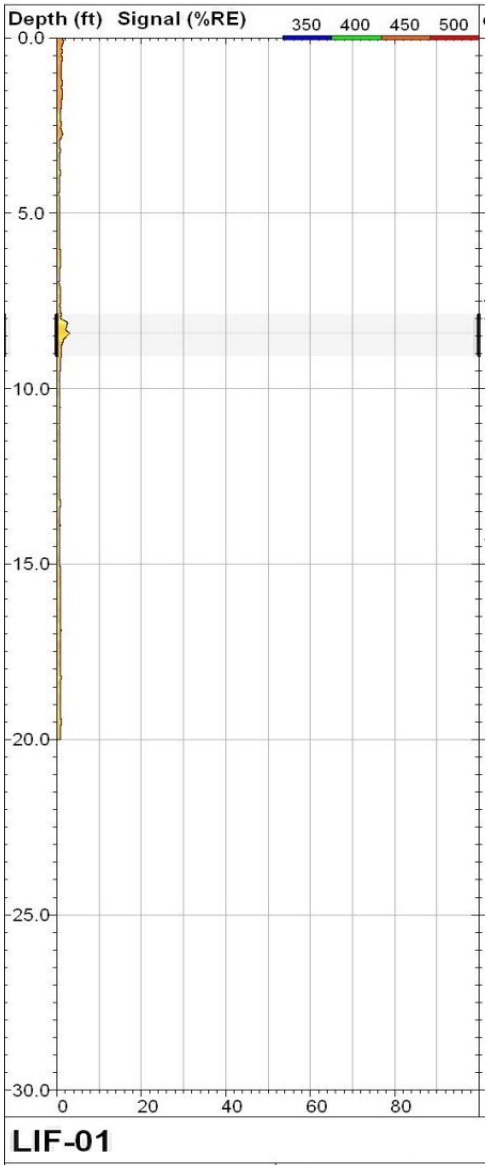
Cross Section: West to East N4S

Appendix B
EC-OIP with UVOST® Logs

Geoprobe EC-OIP Log



UVOST Log



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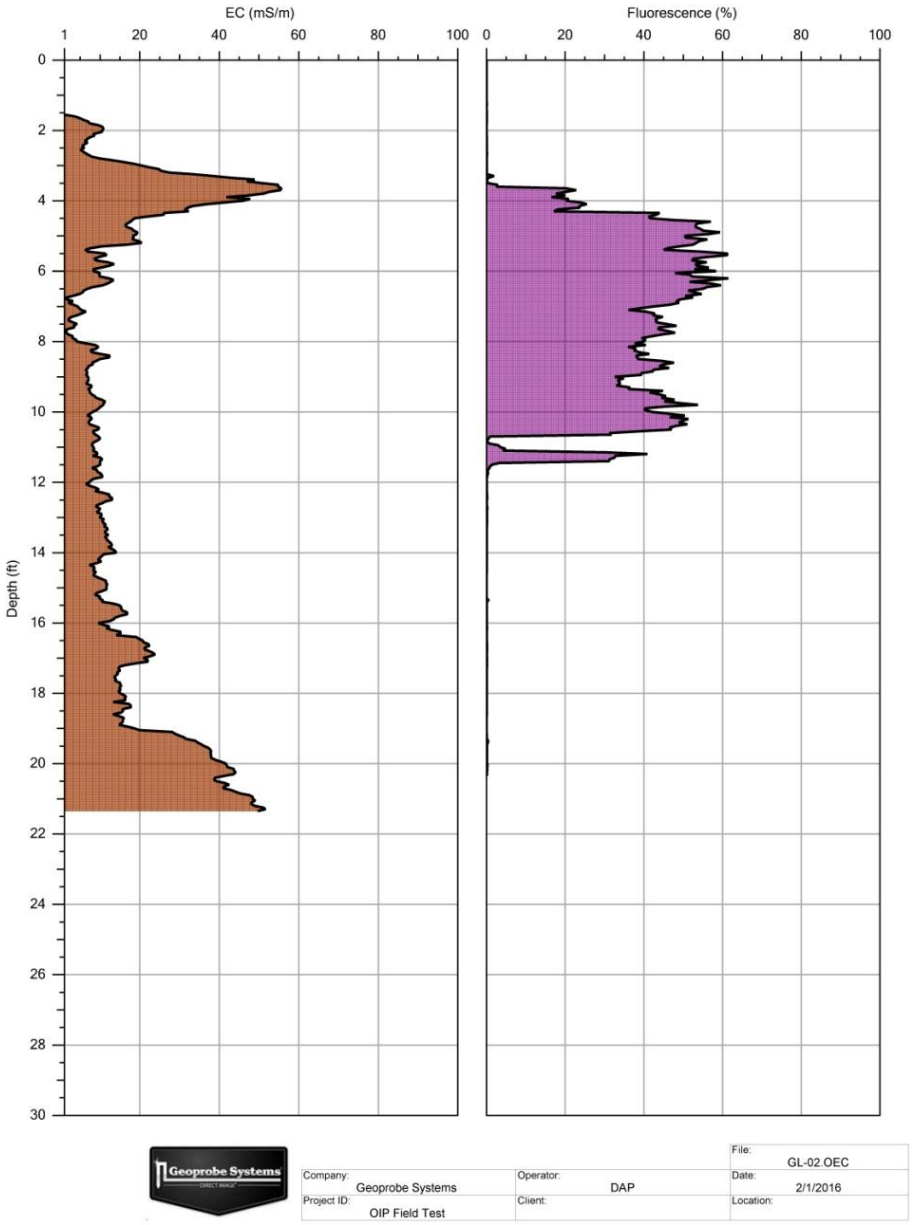

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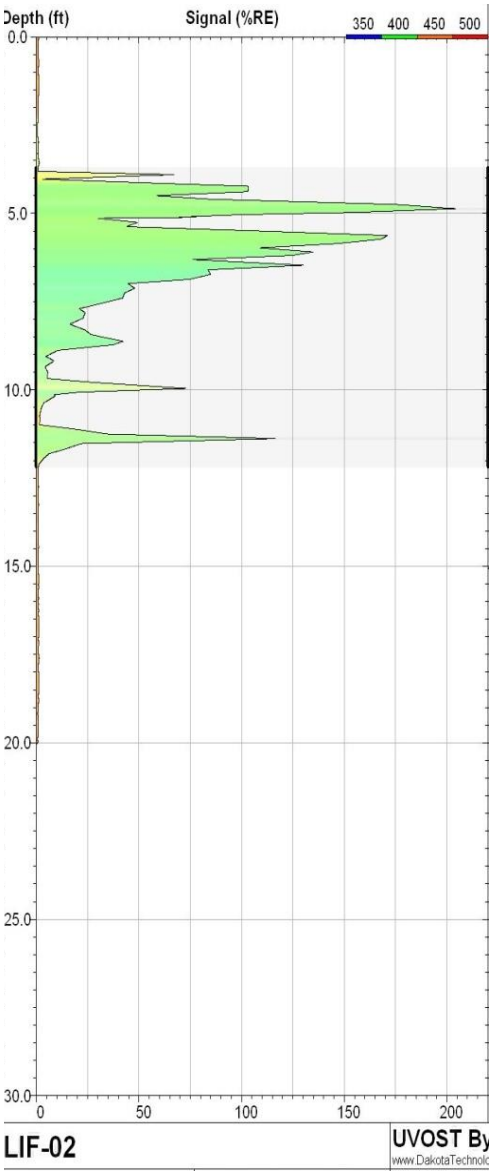

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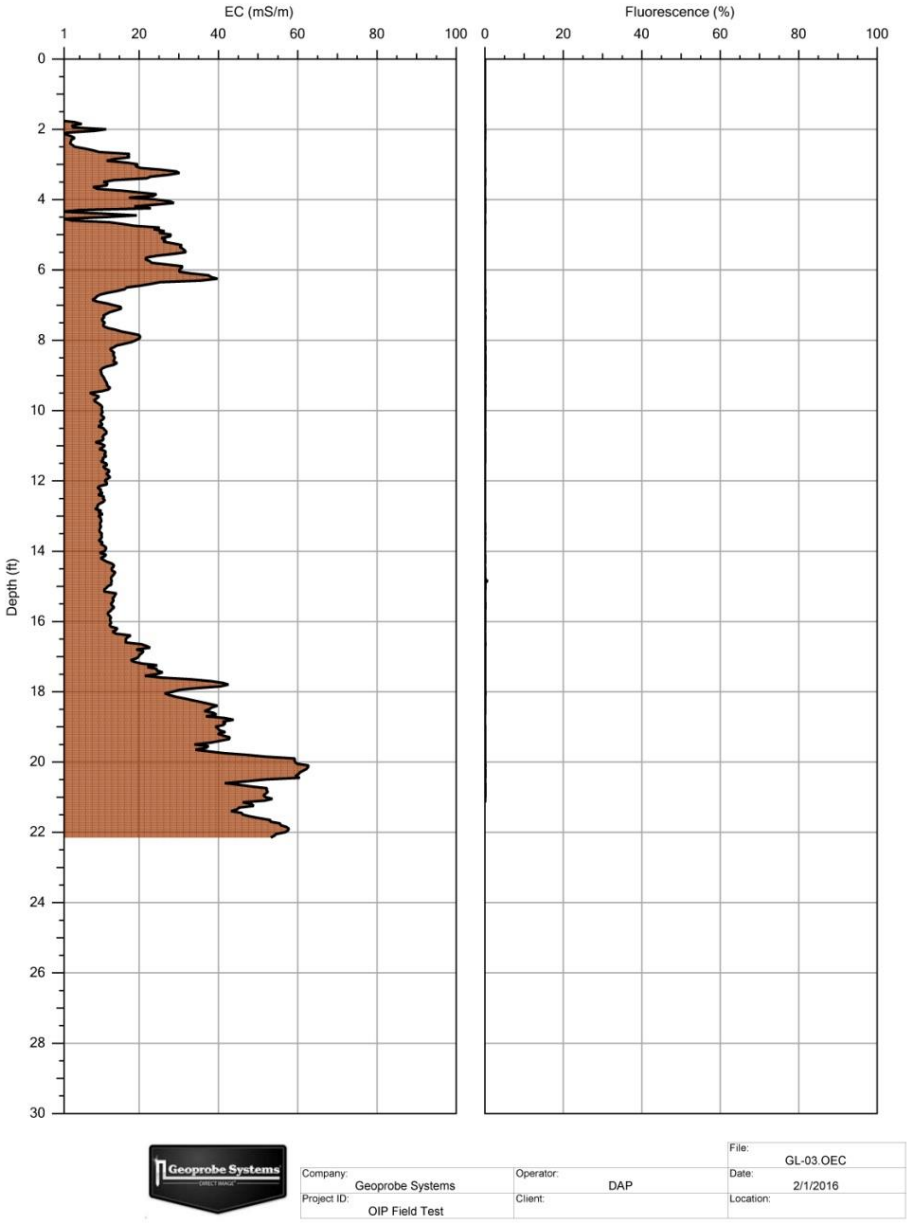

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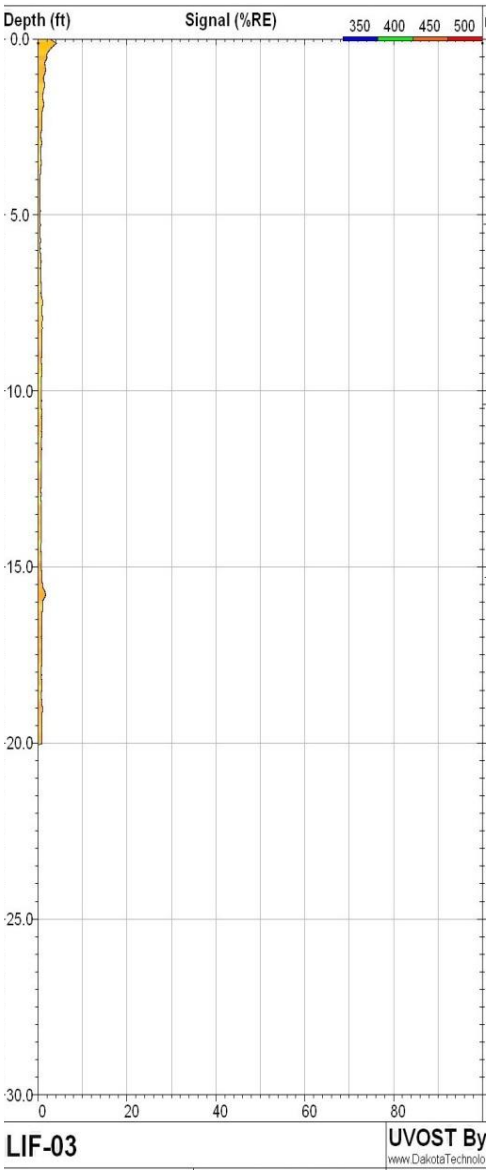

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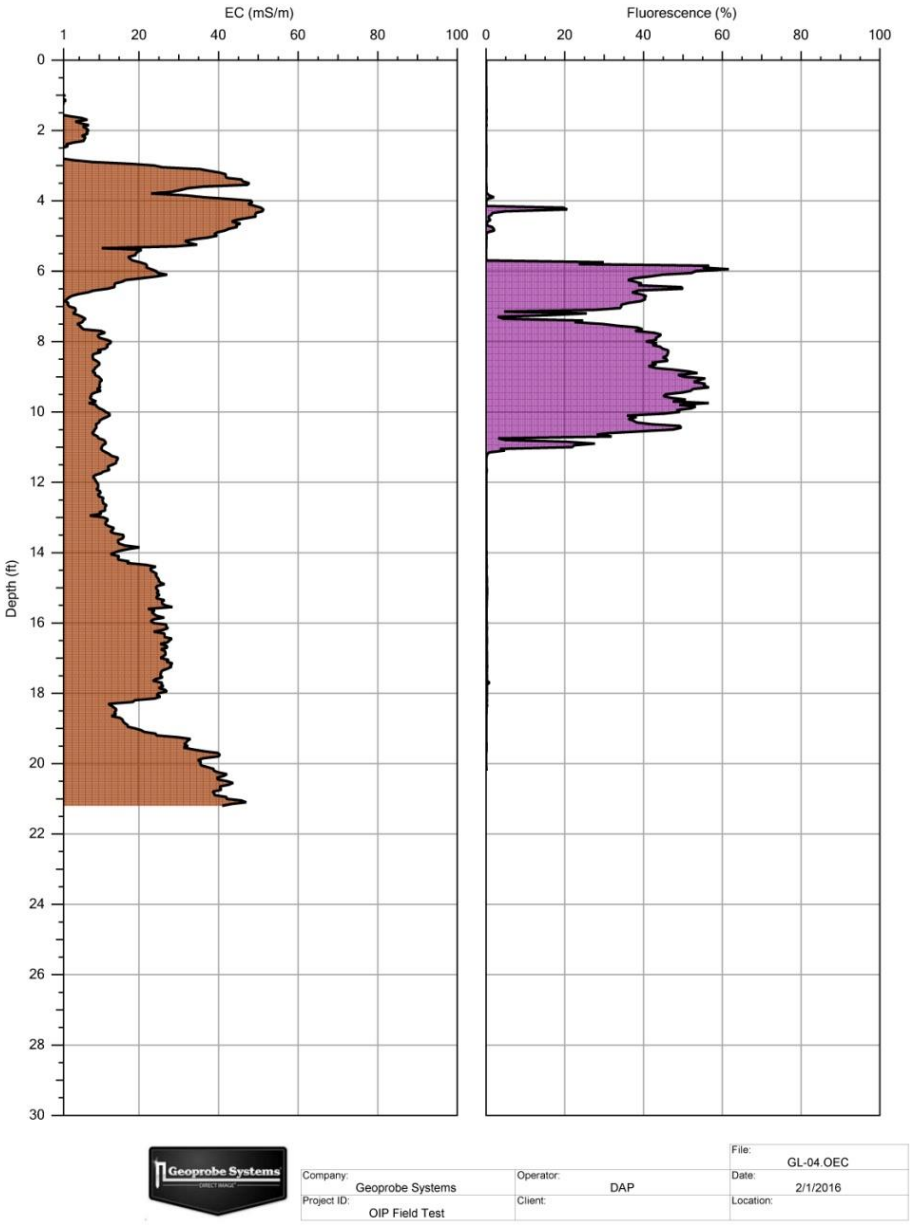

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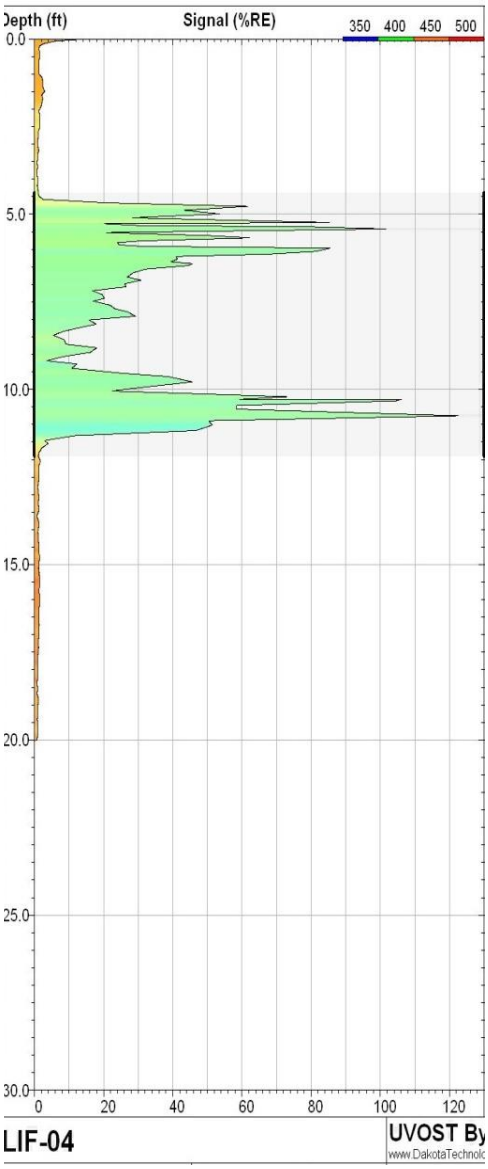

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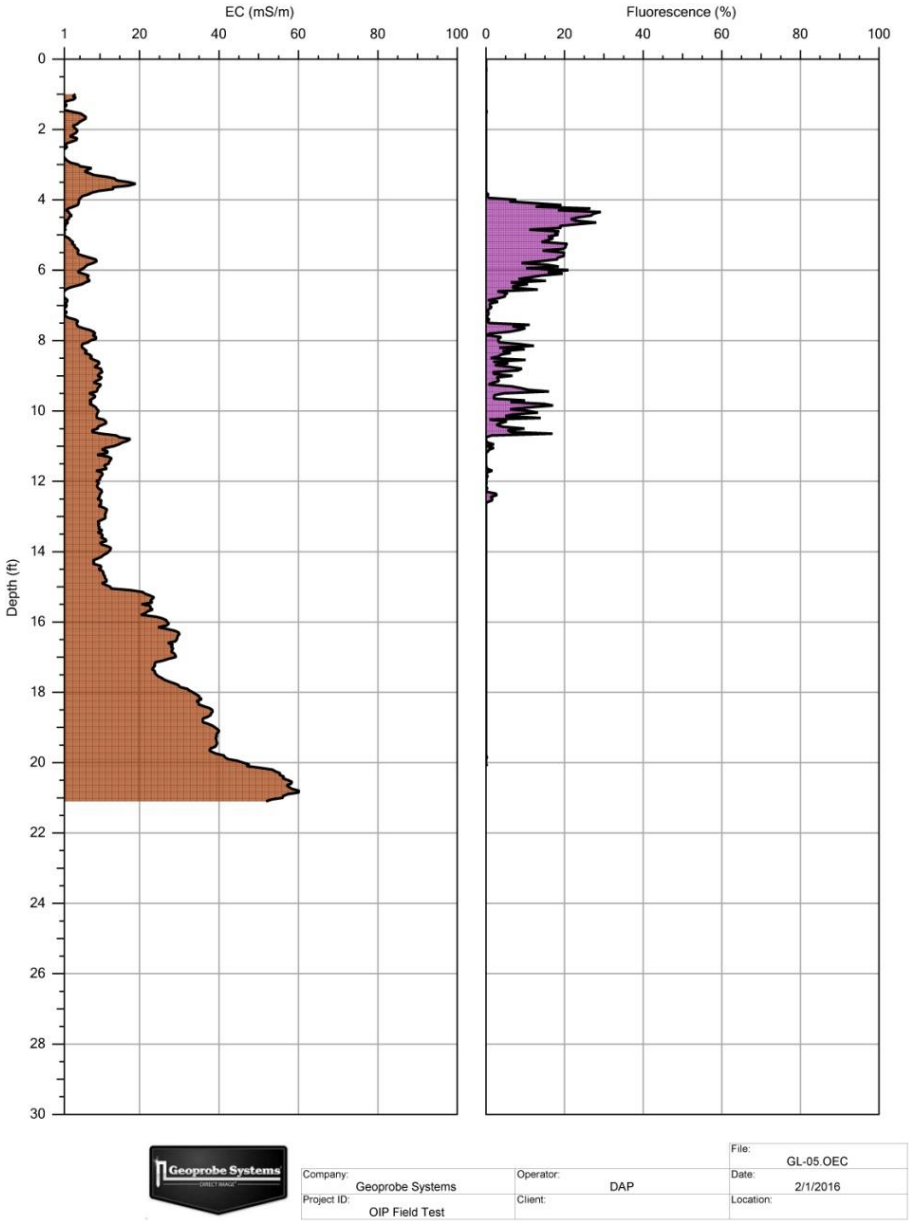

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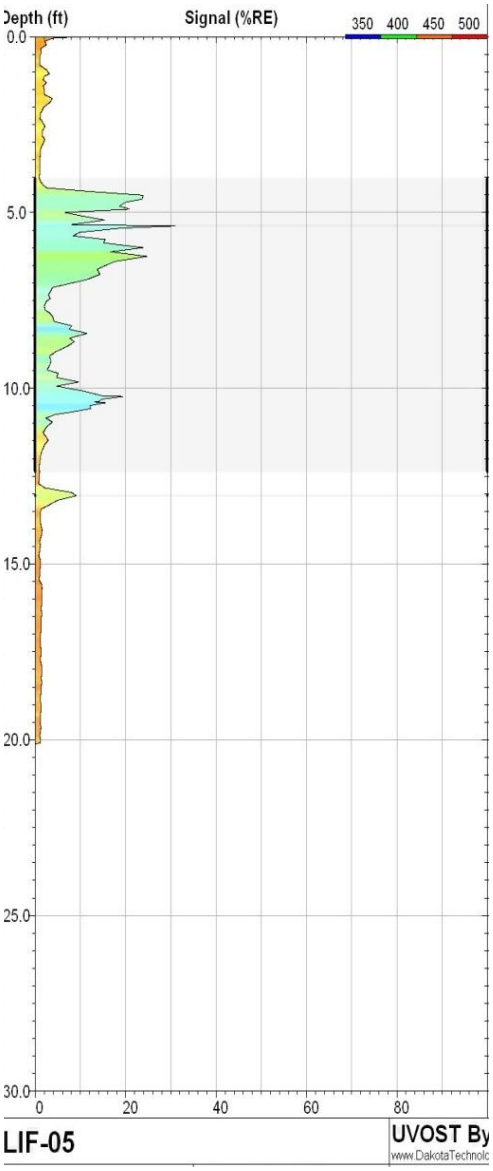

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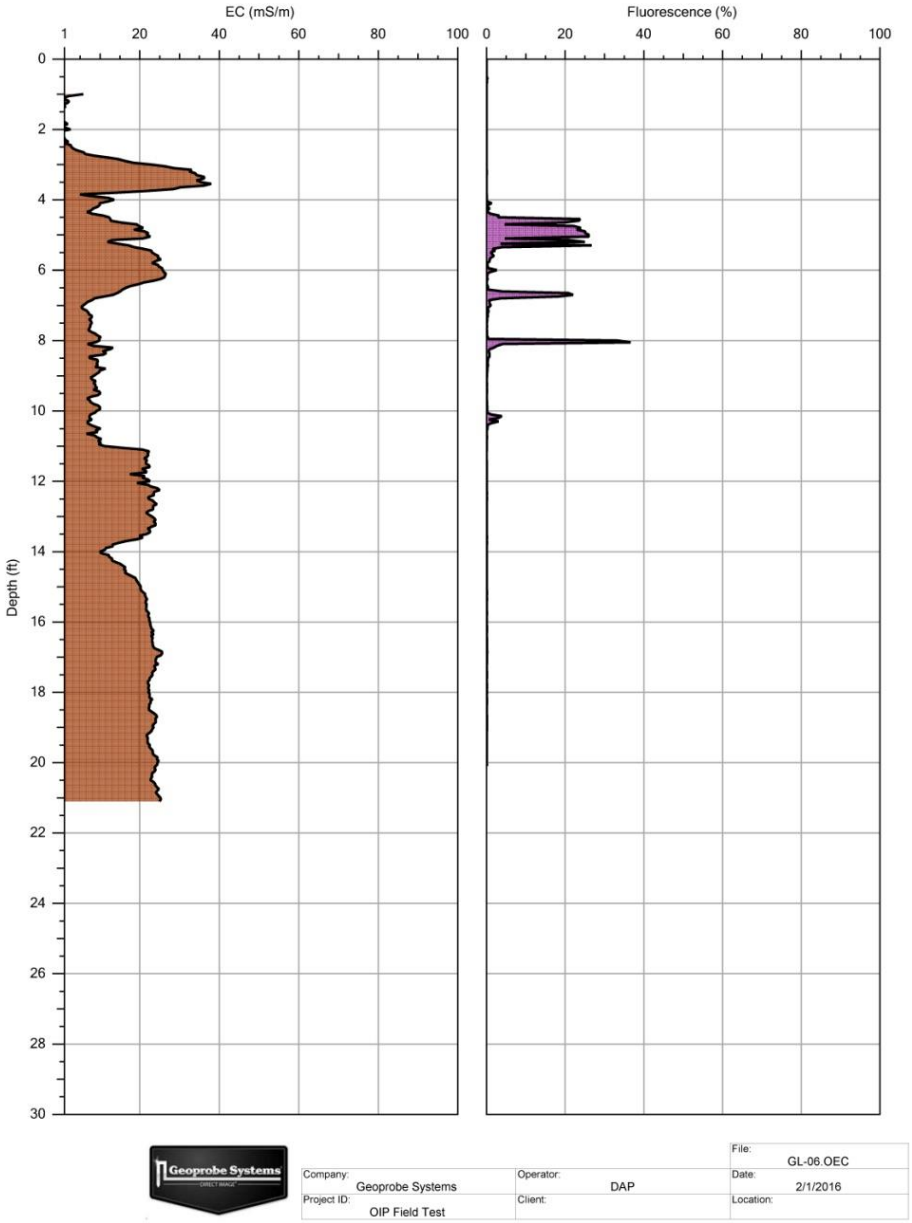

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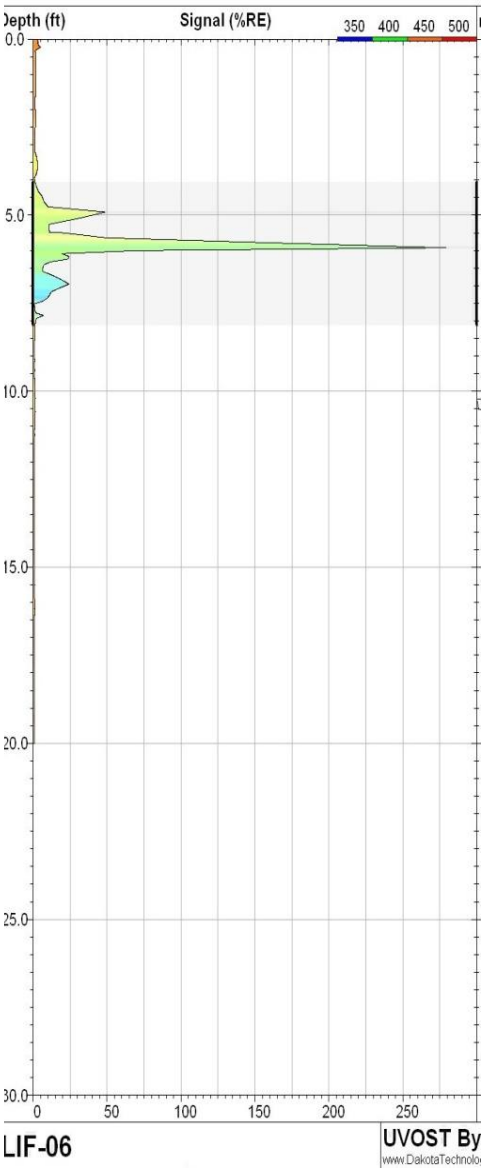

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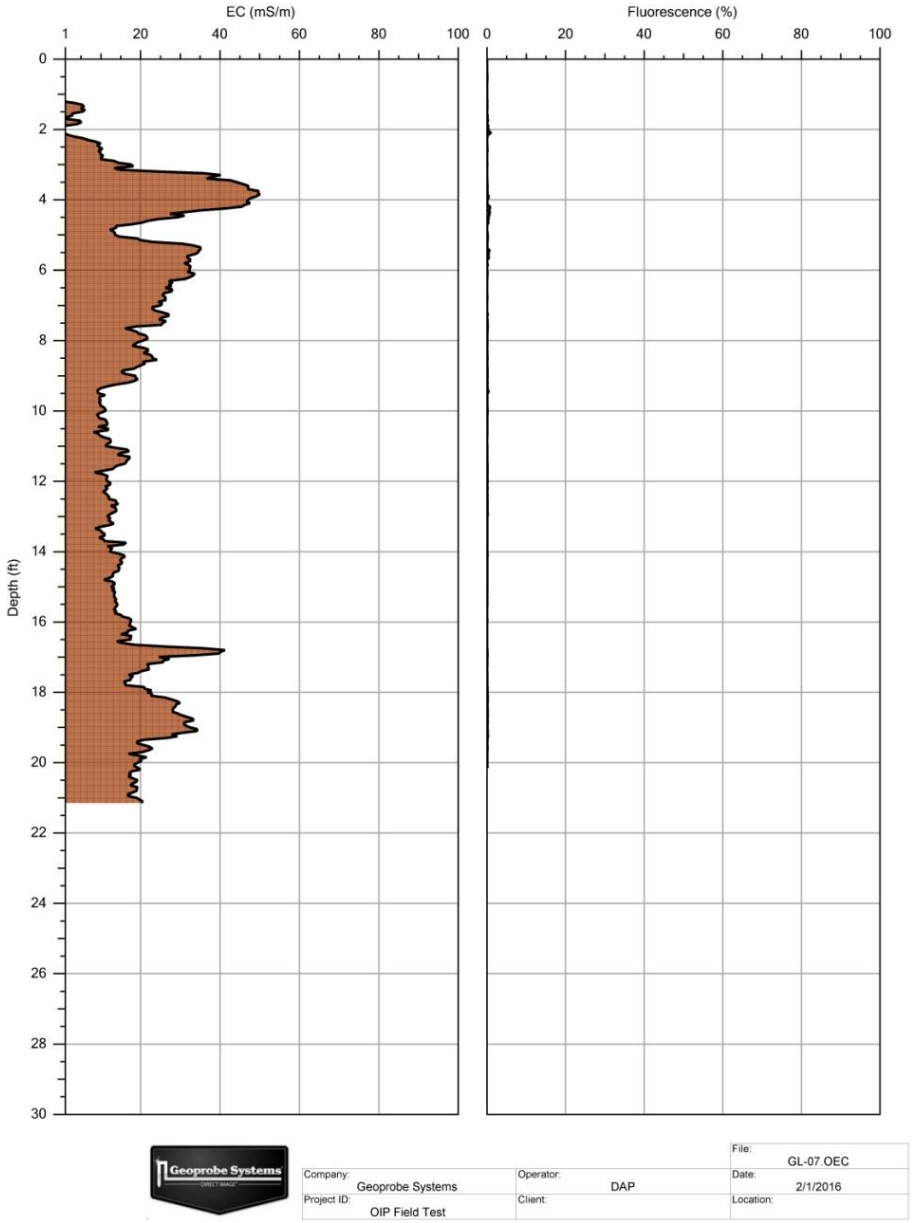

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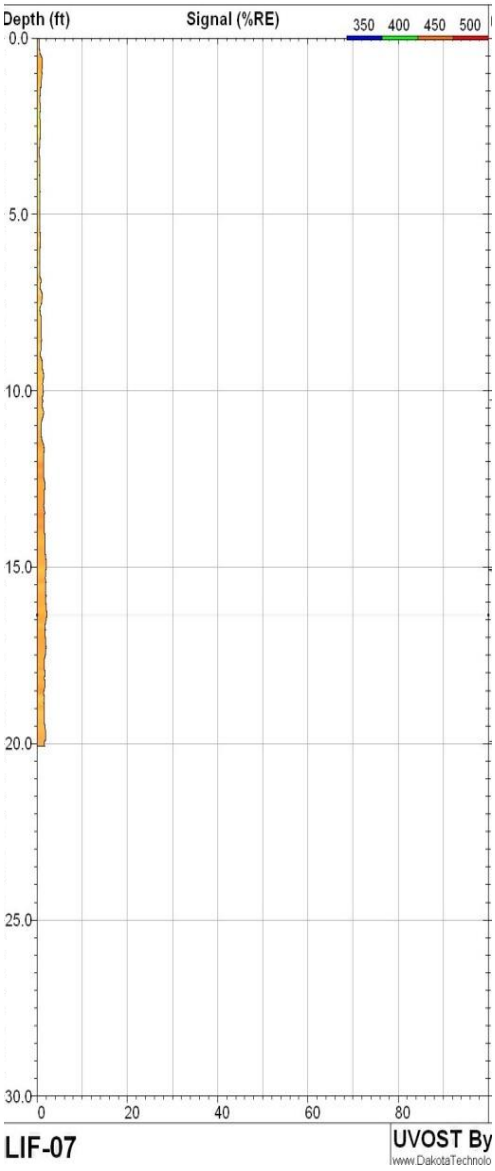

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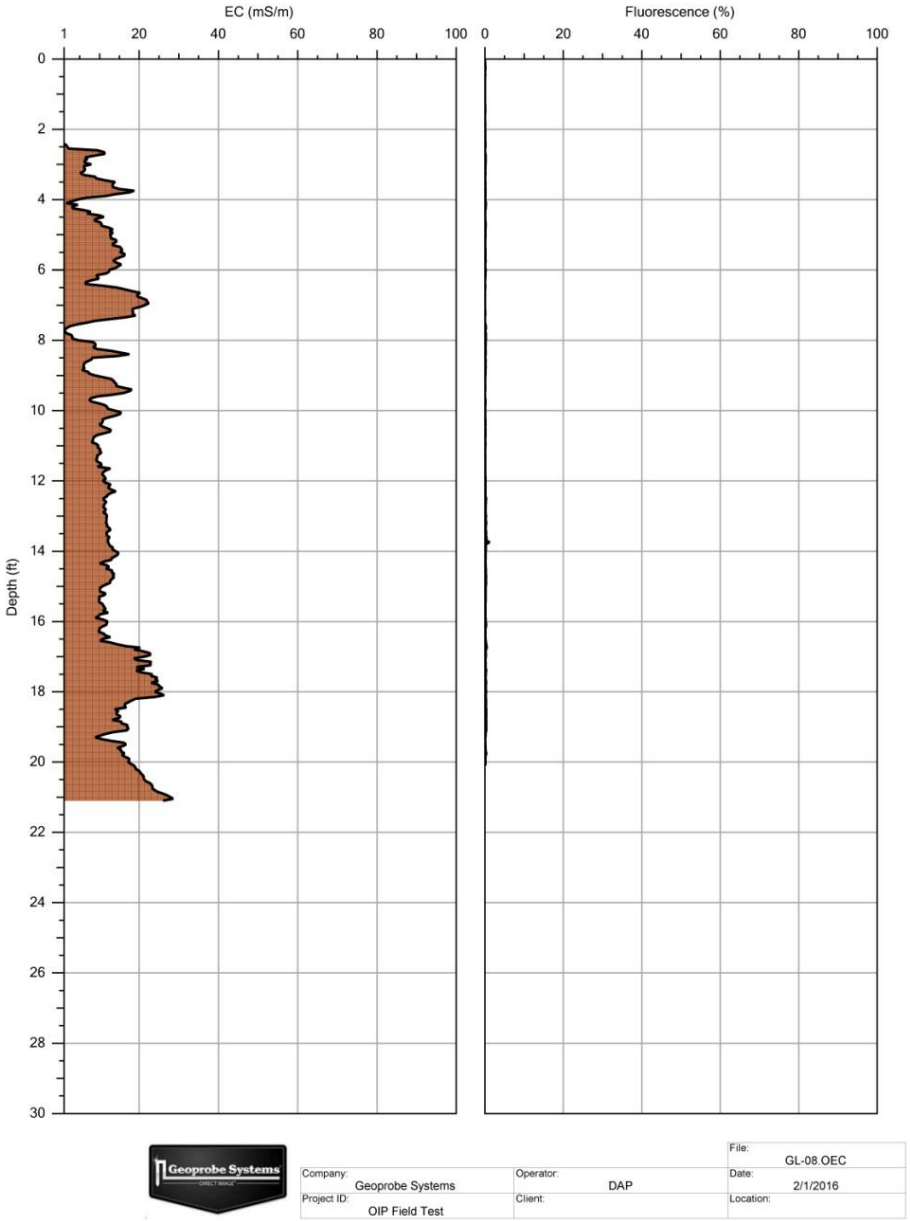

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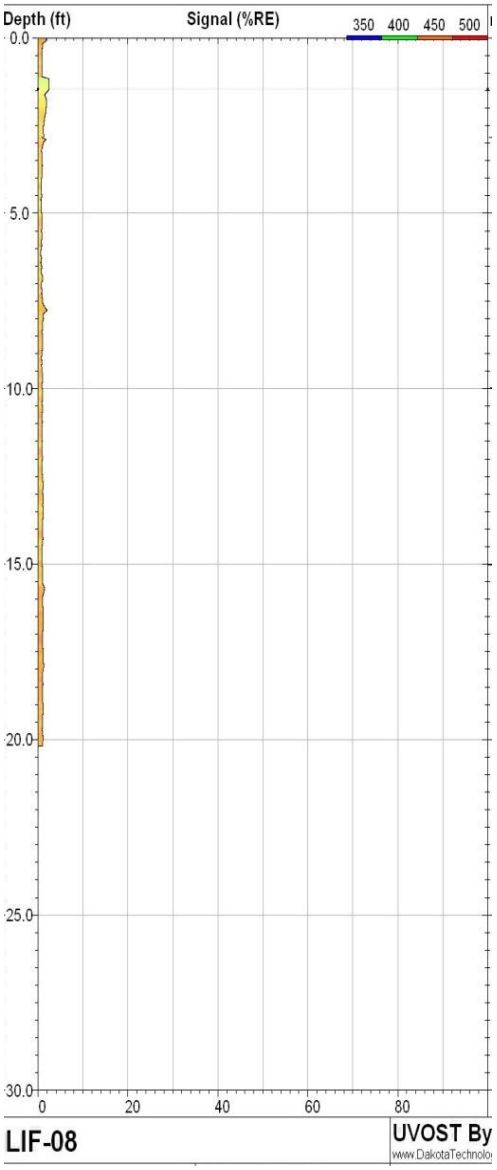

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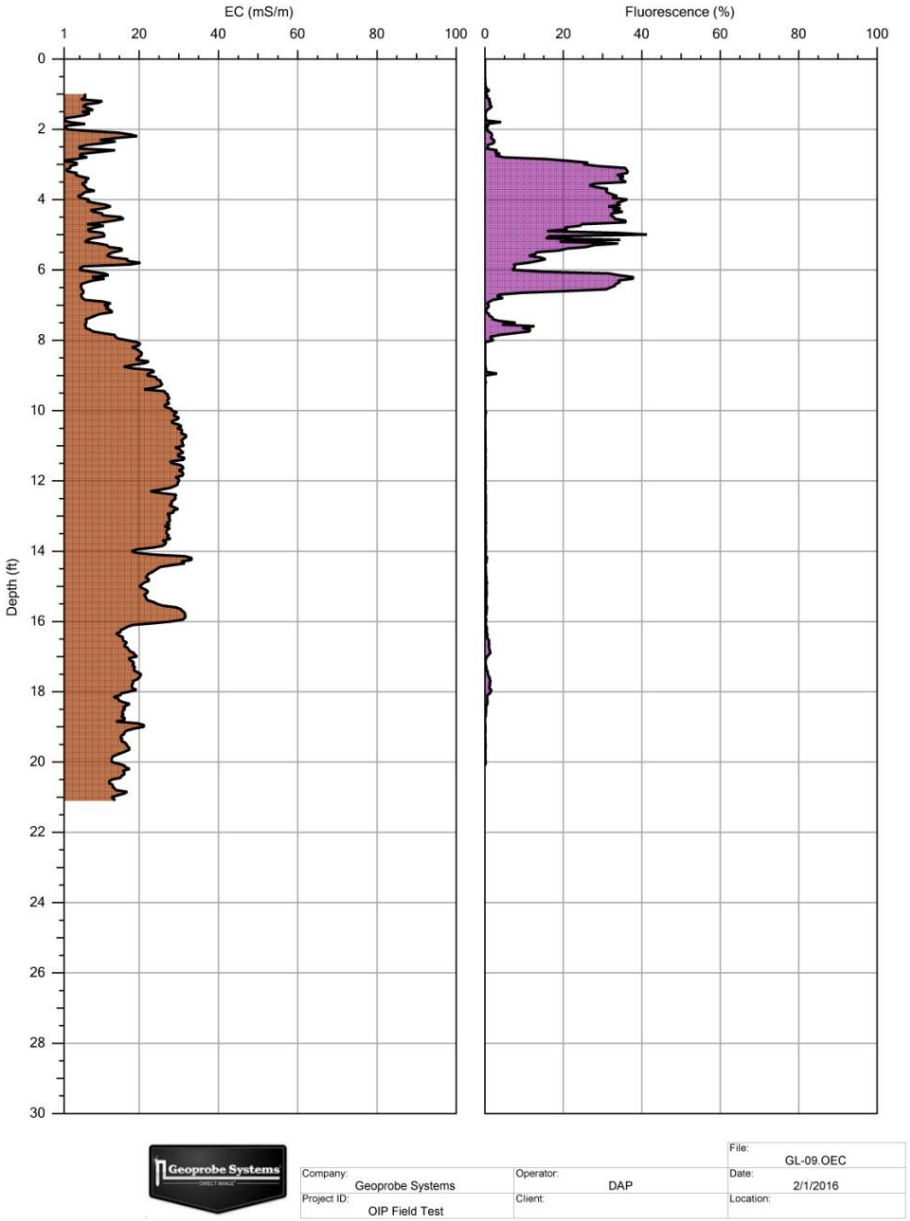

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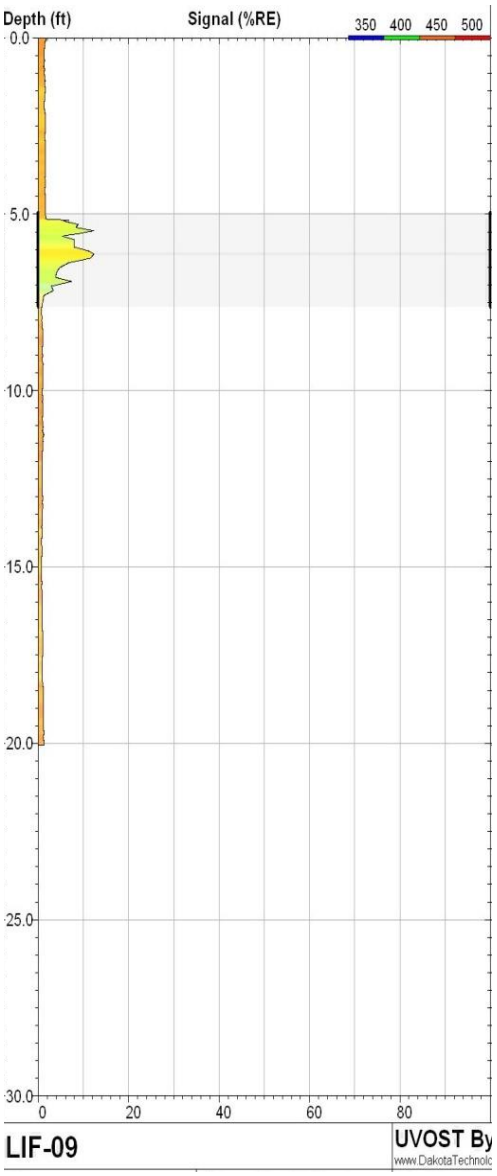

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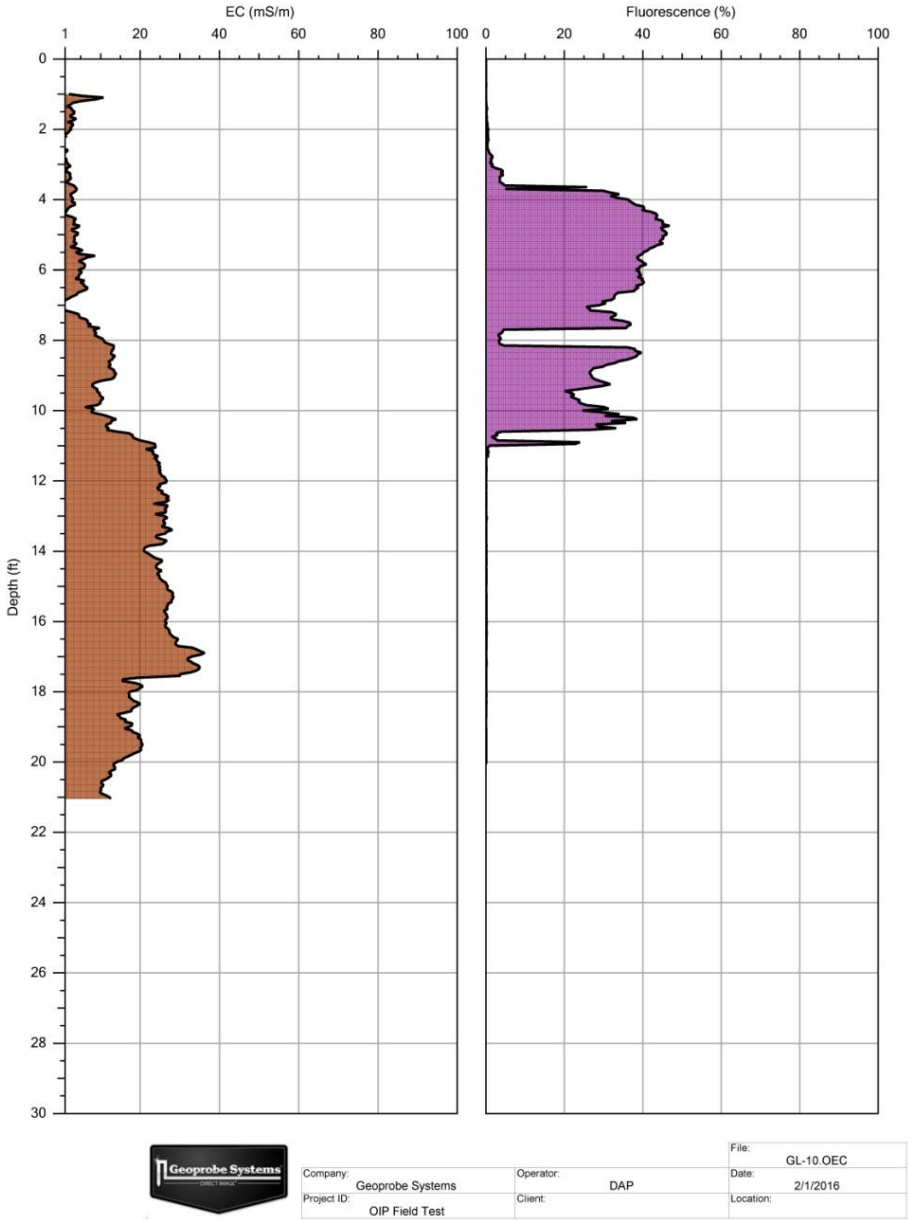

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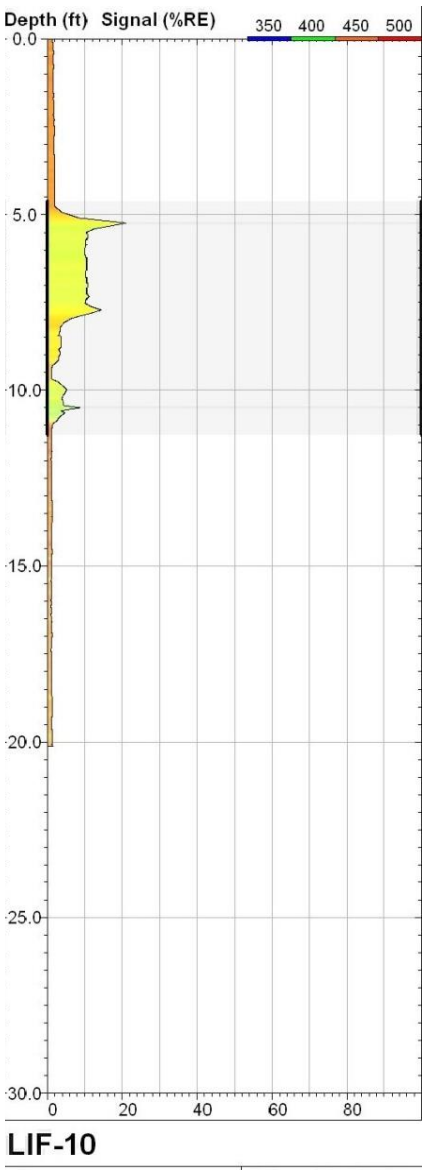

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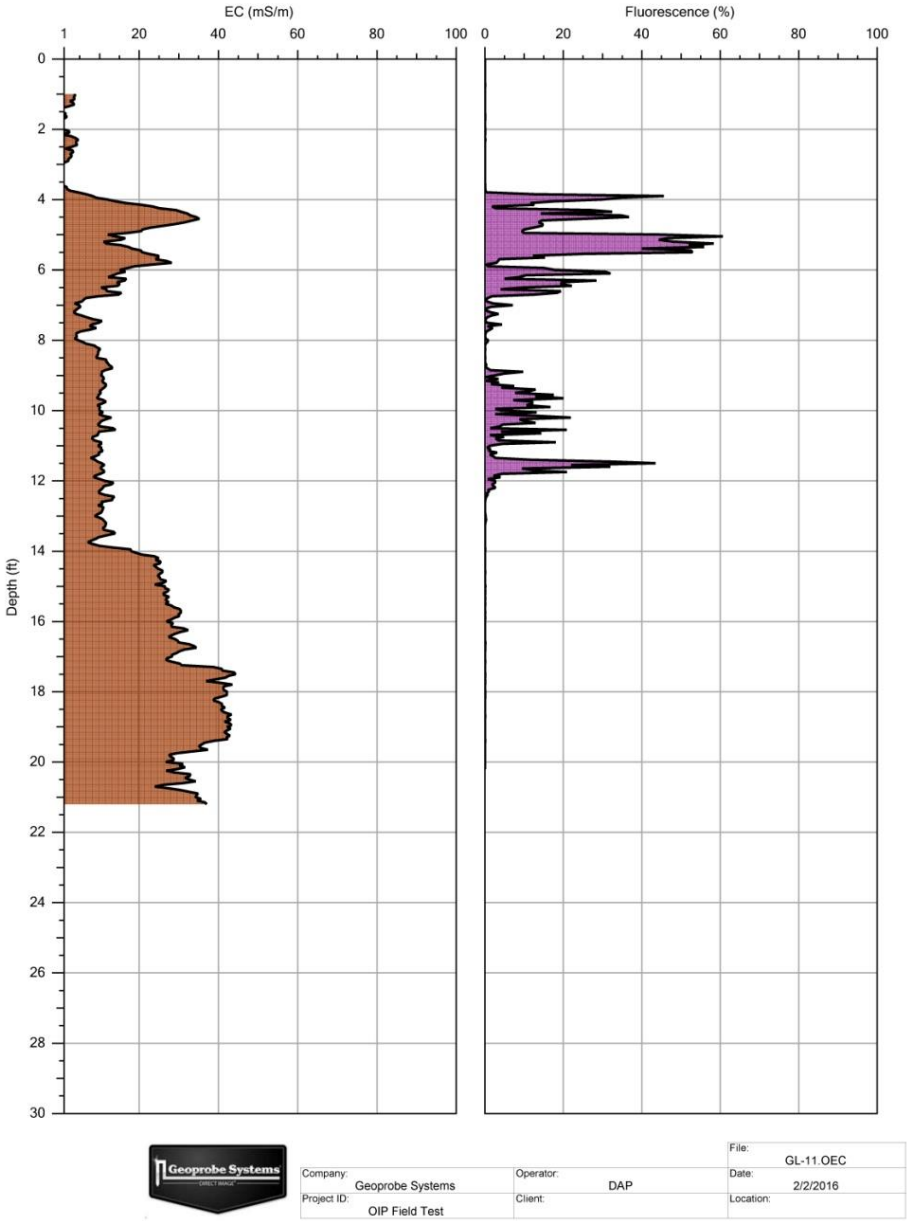
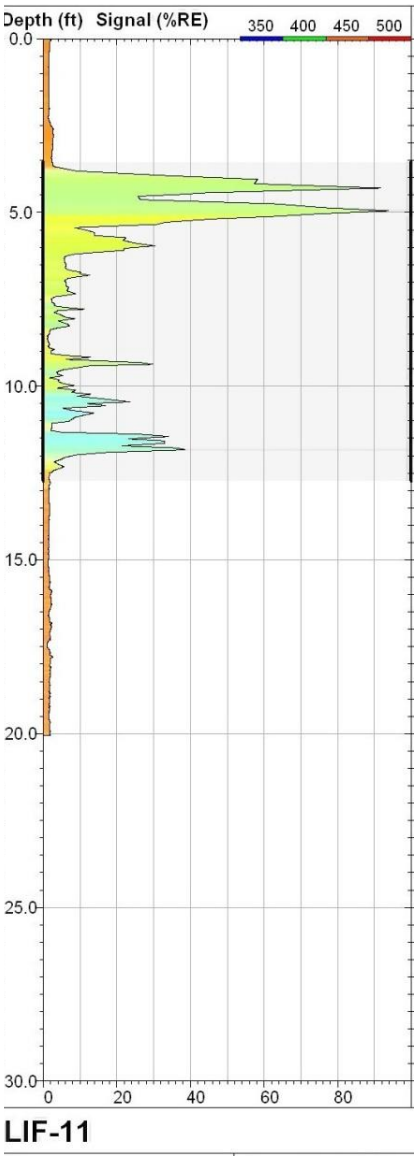
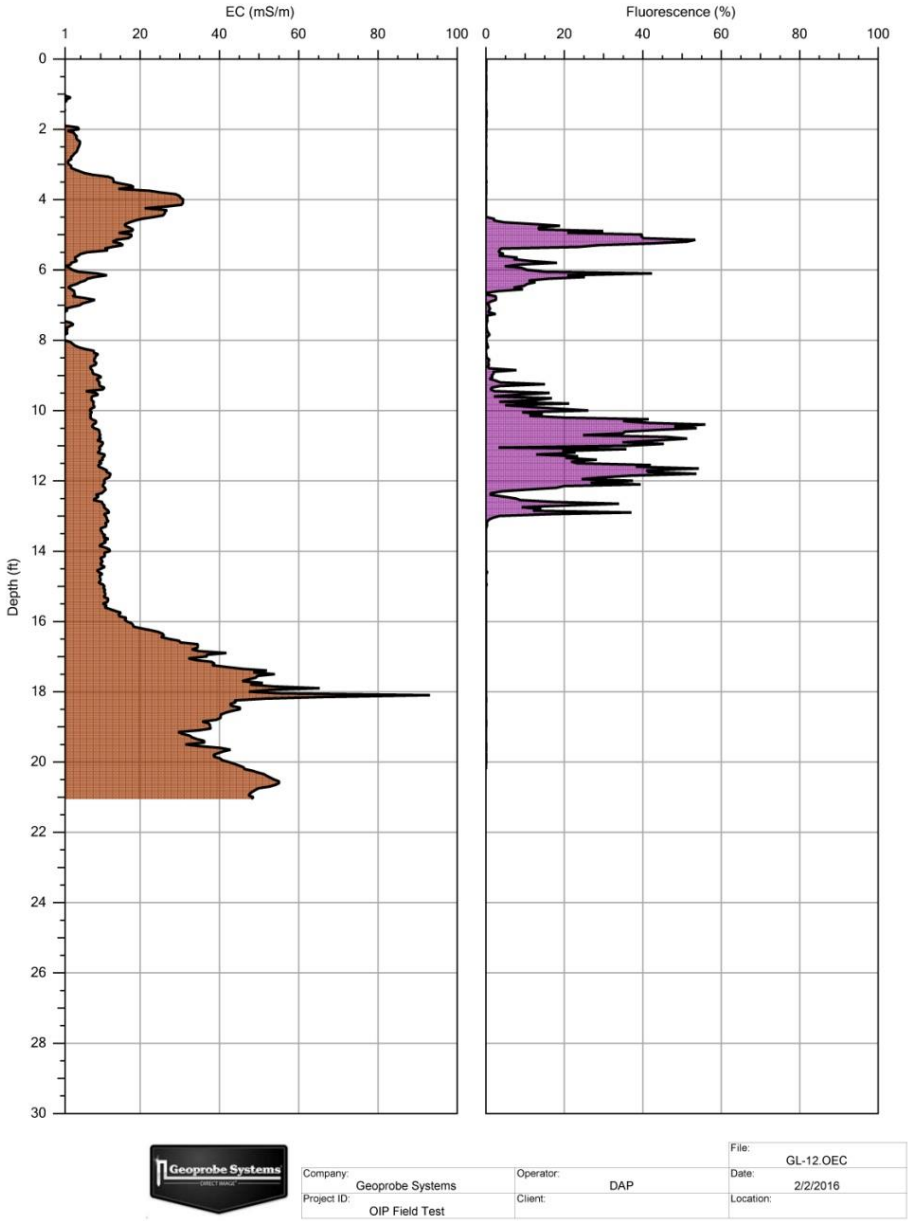


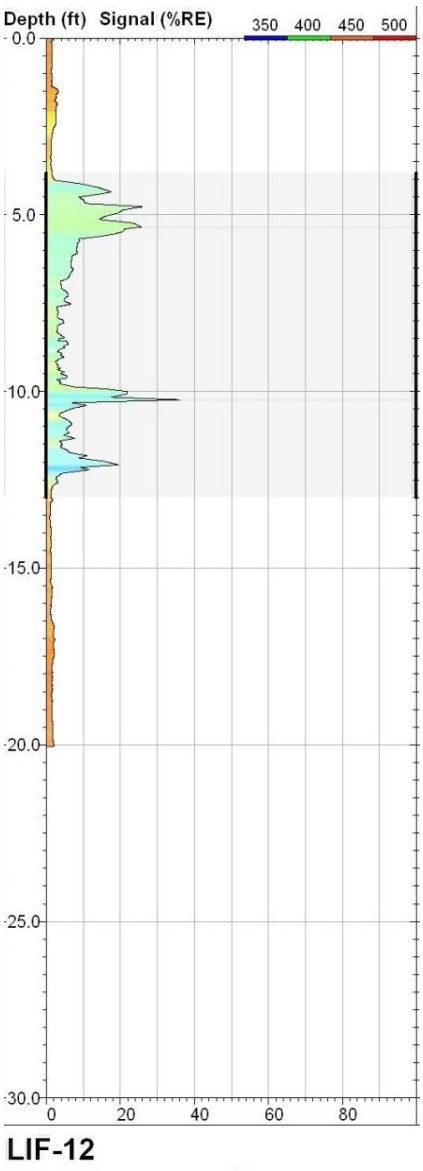
UVOST Log



Geoprobe EC-OIP Log



UVOST Log



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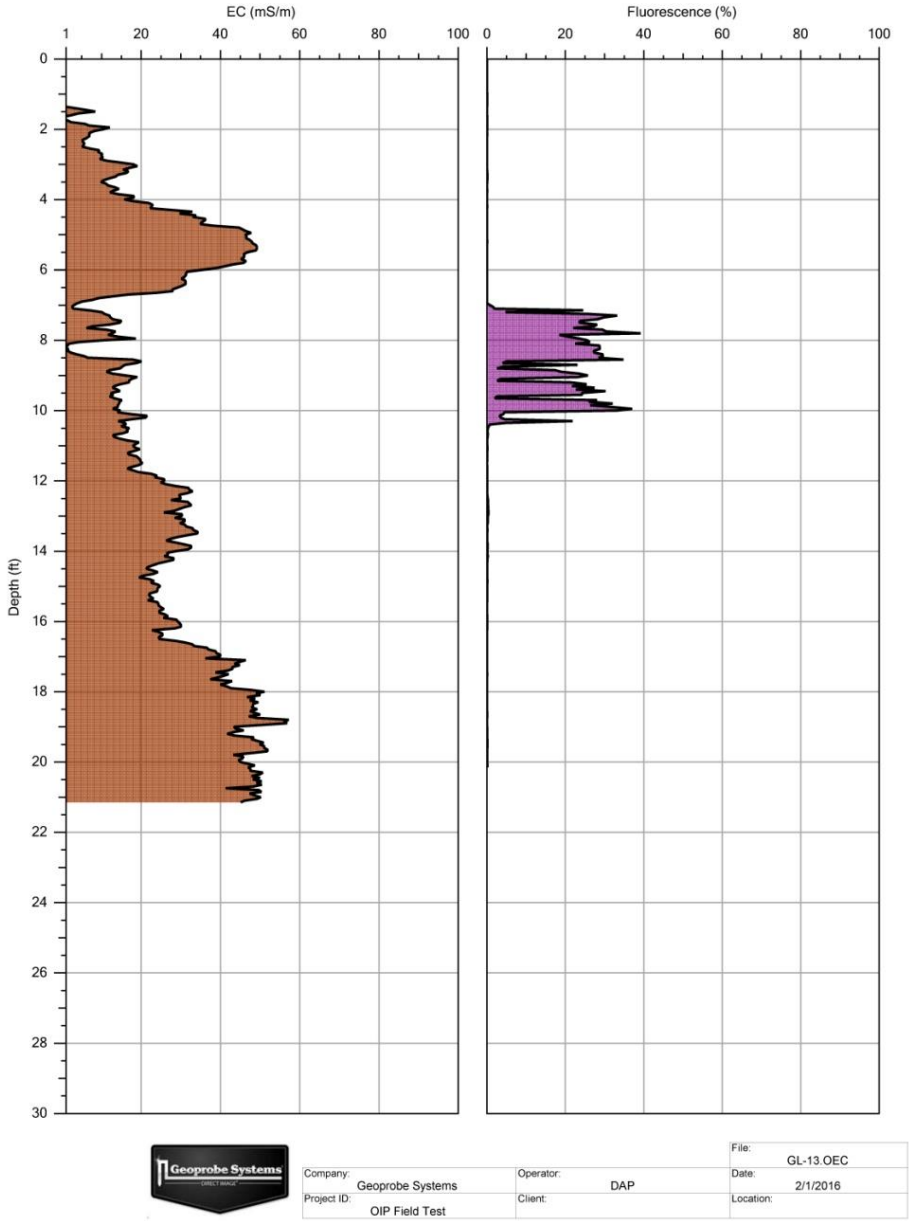

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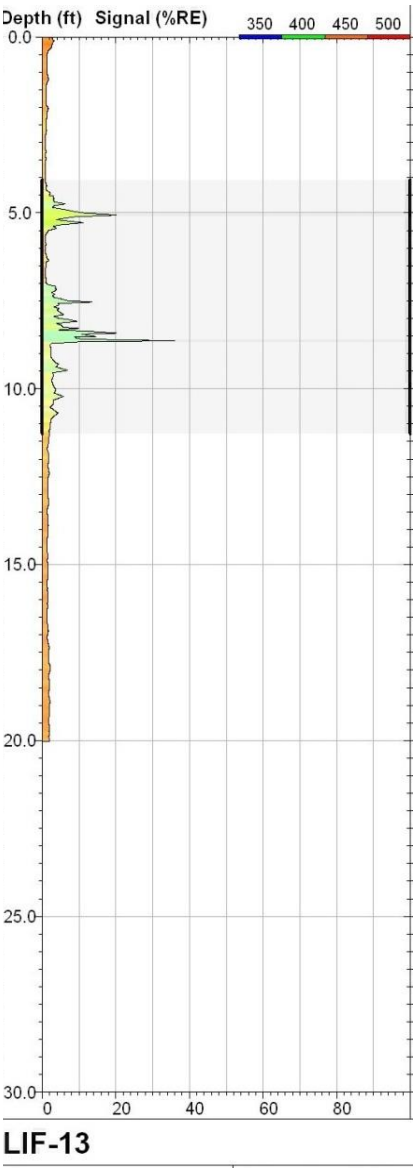

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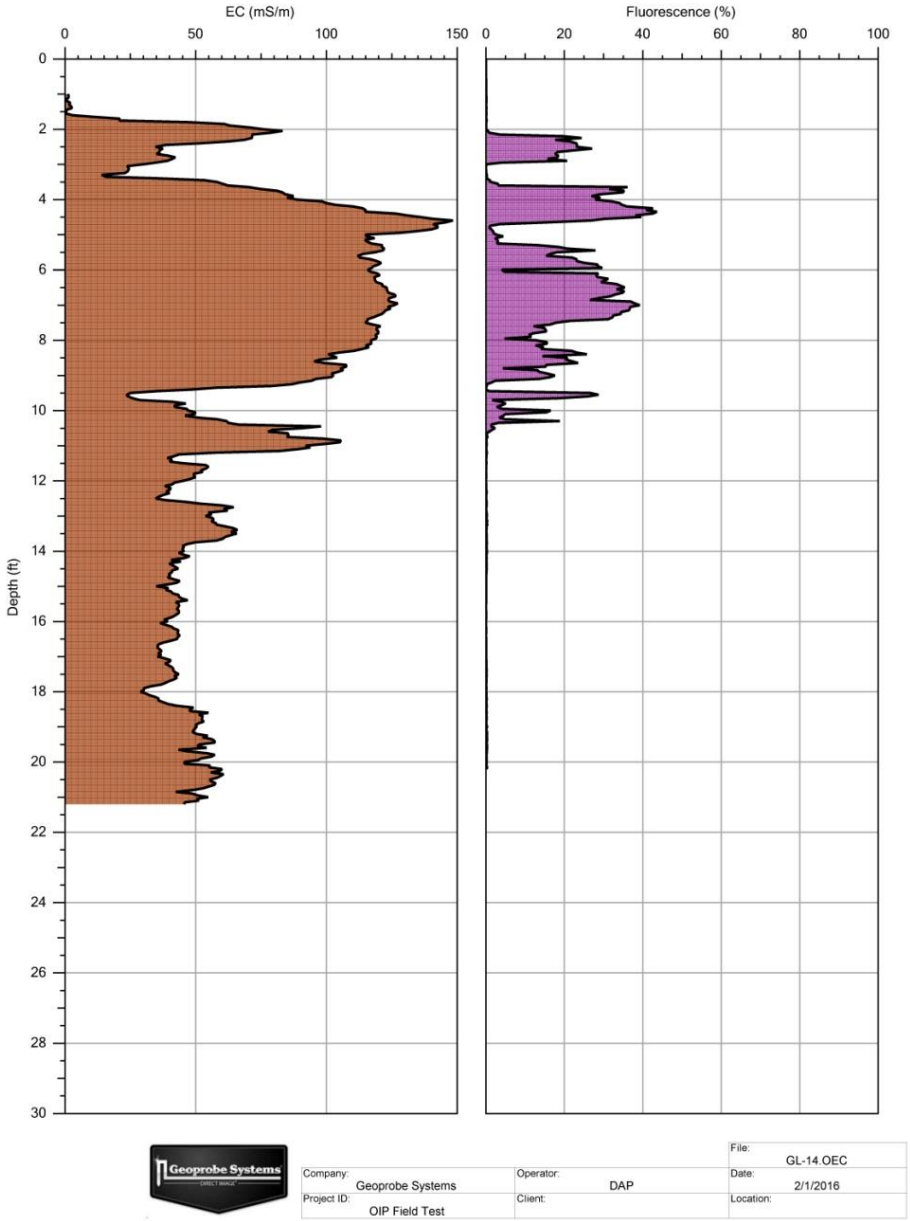

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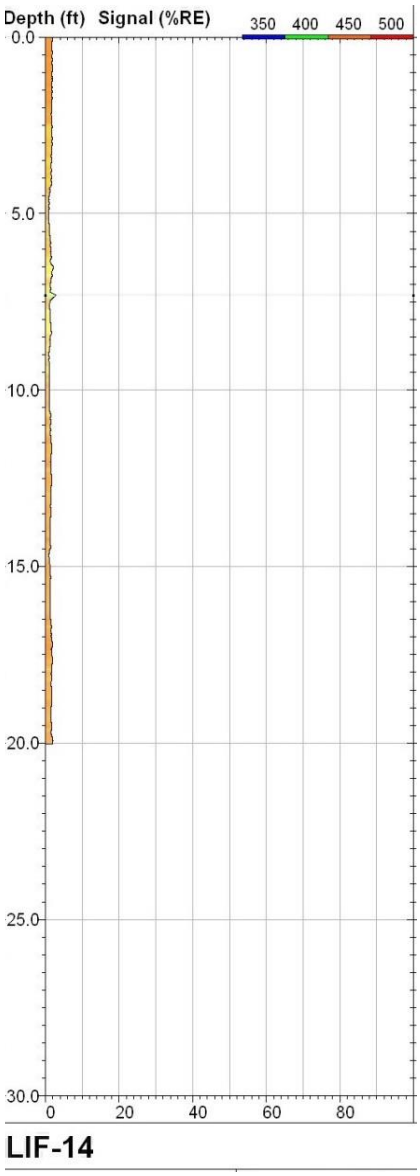

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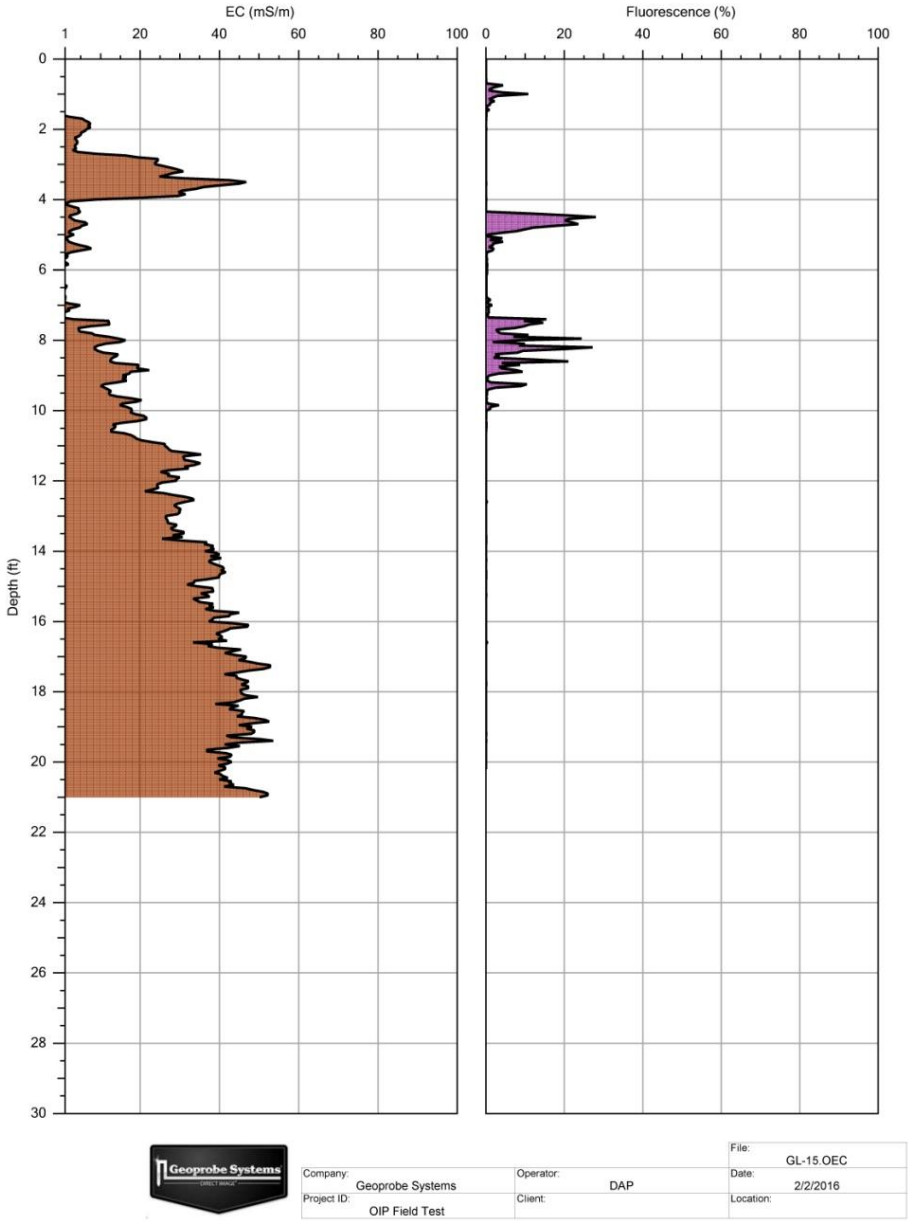

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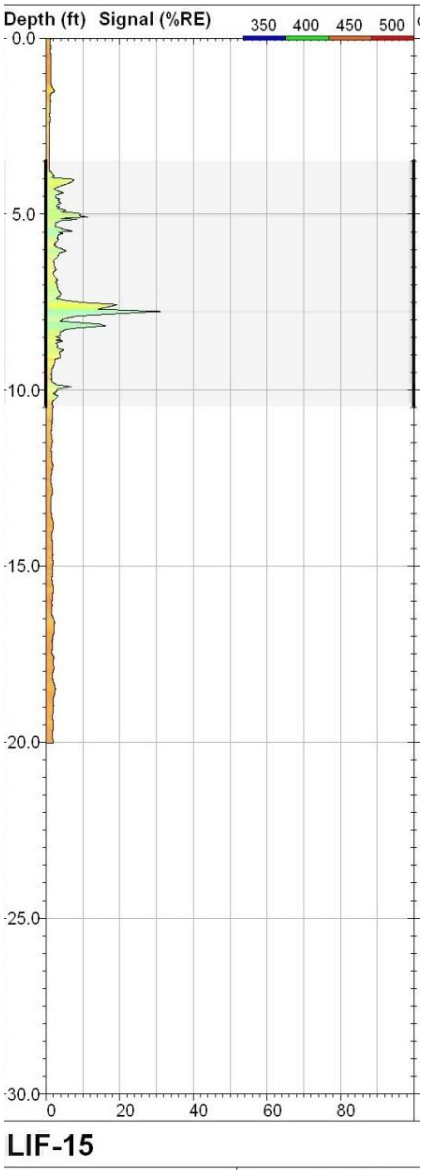

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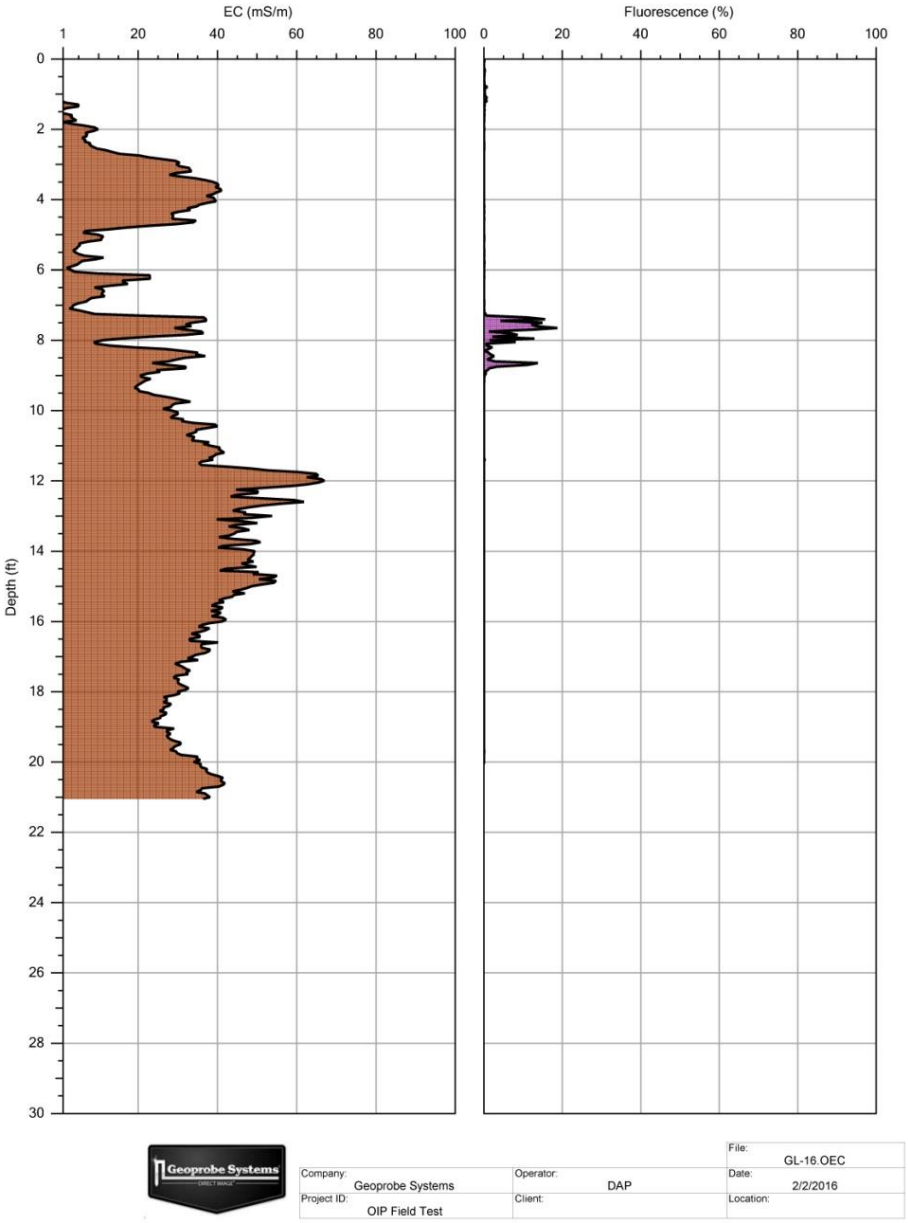

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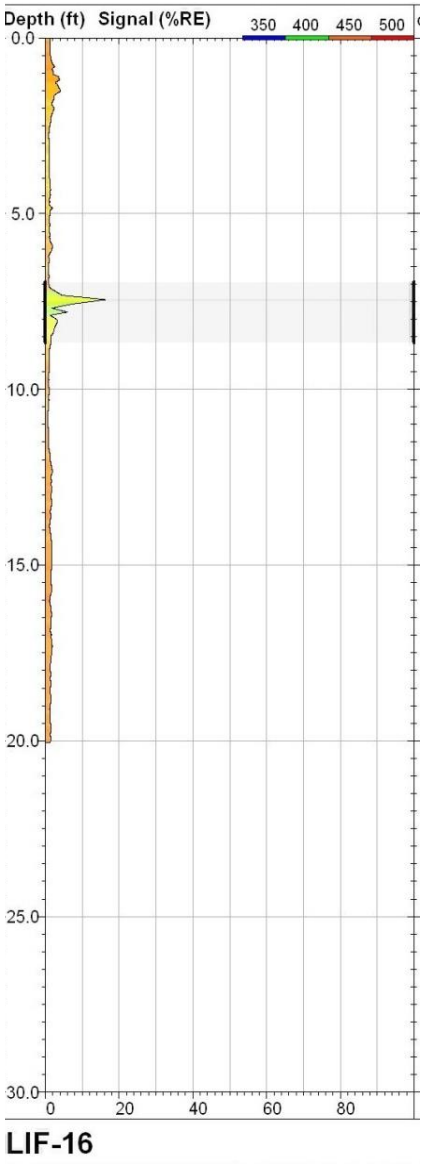

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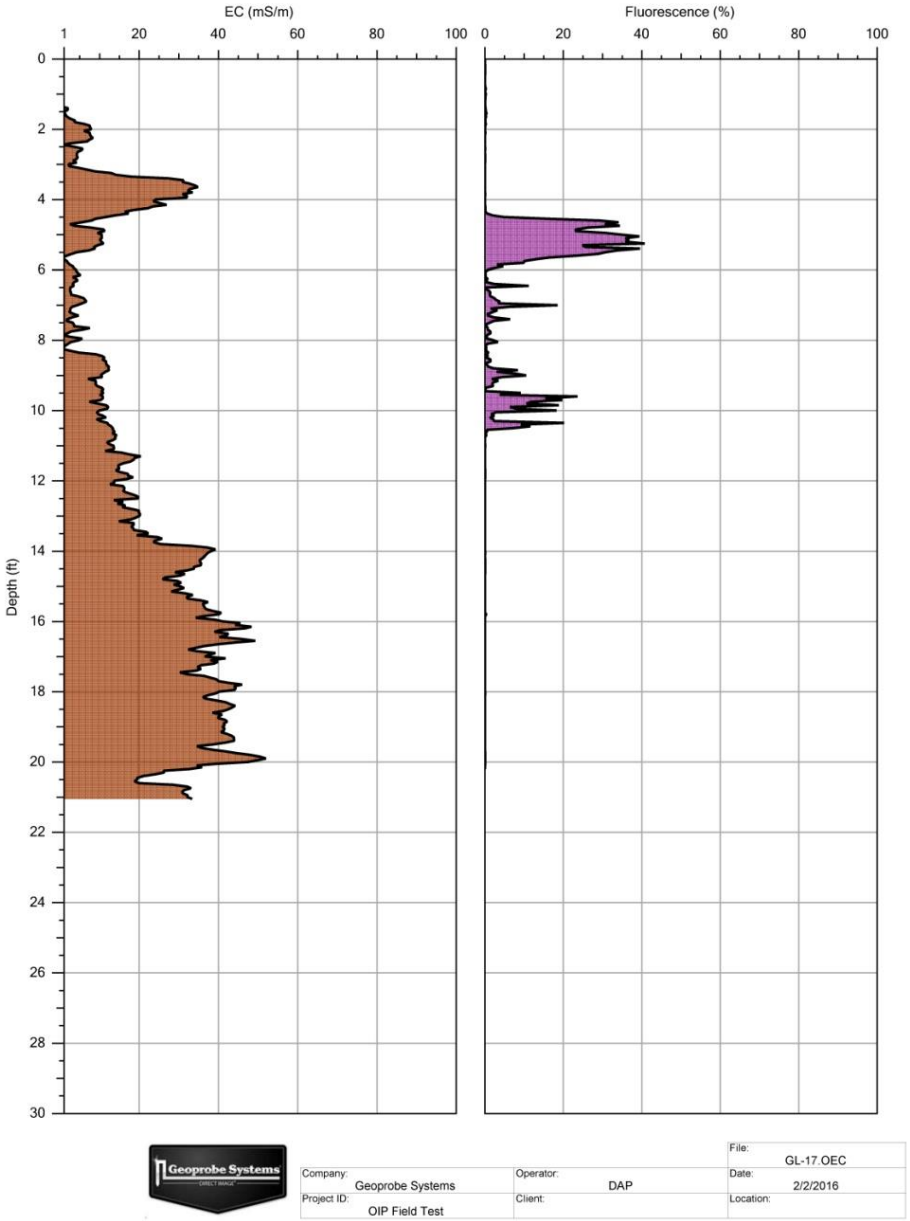

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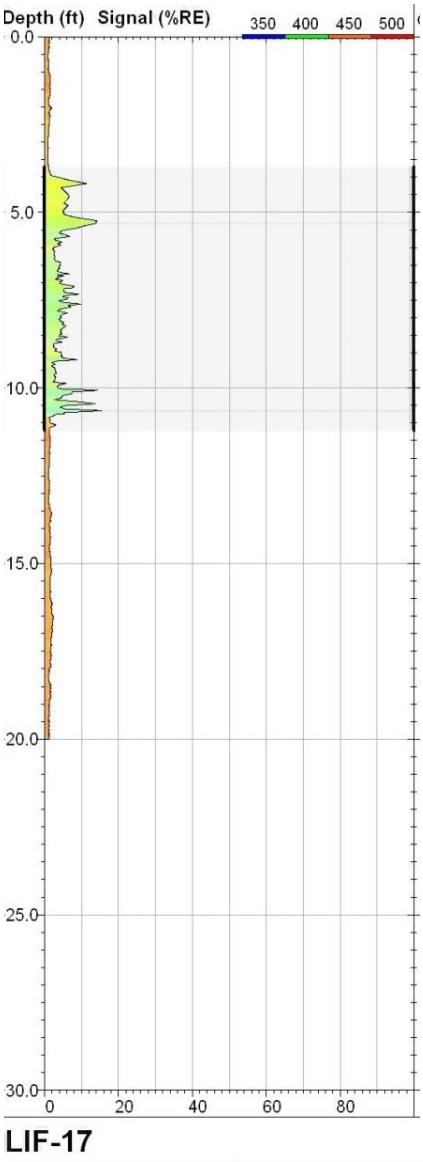

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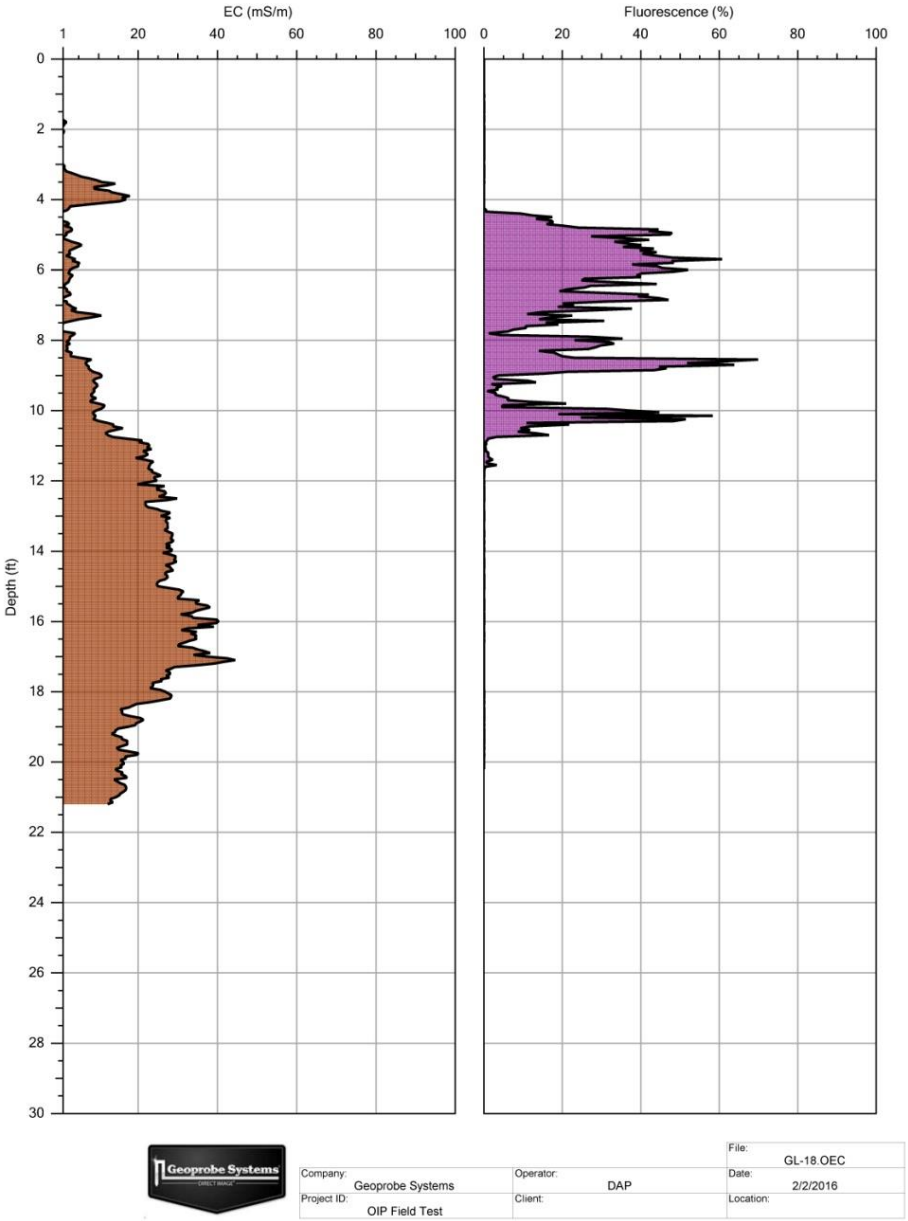

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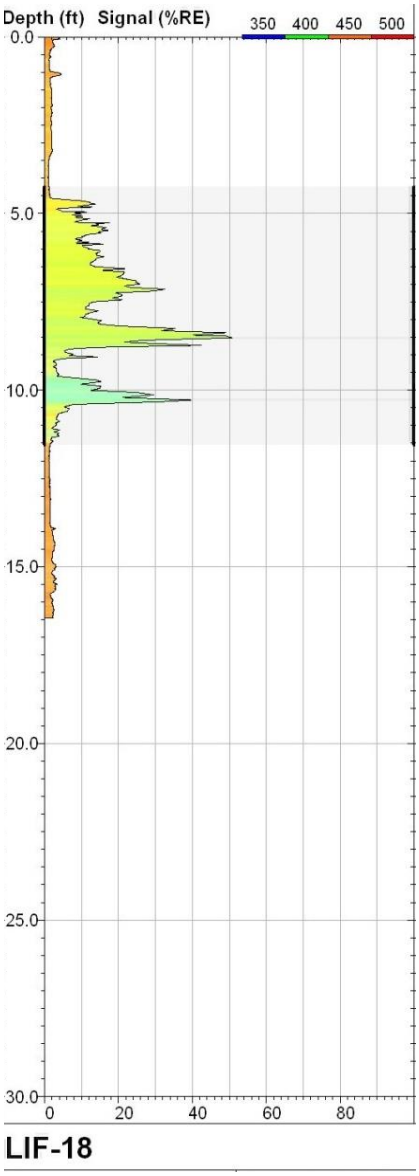

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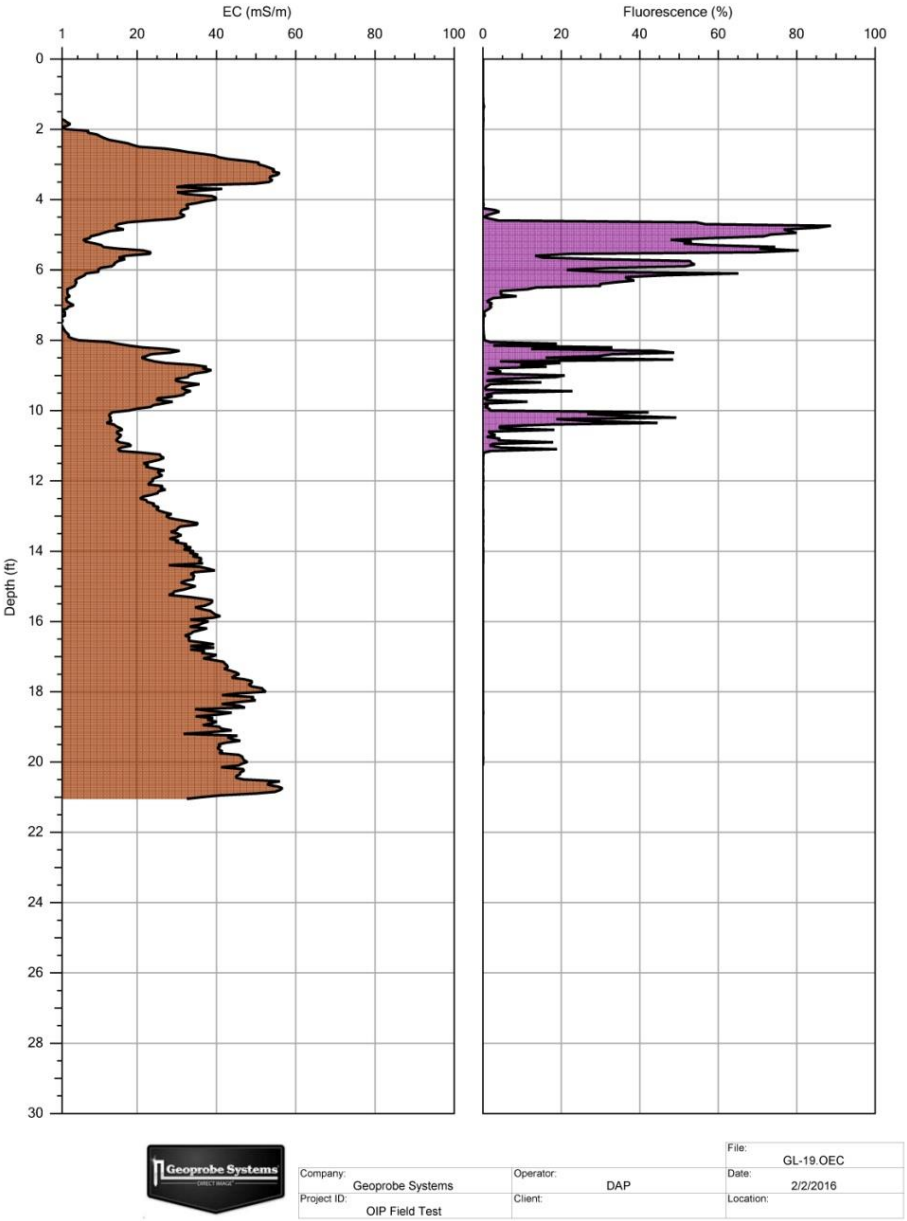

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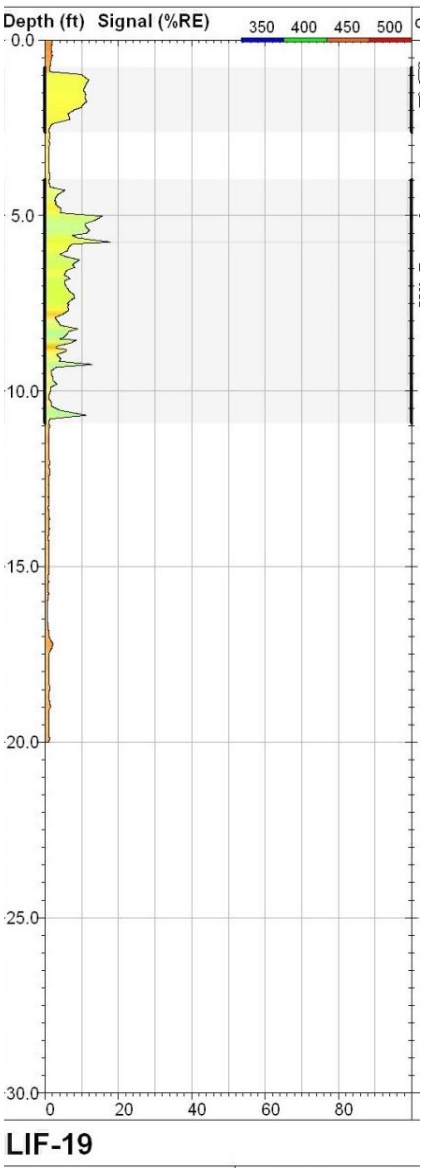

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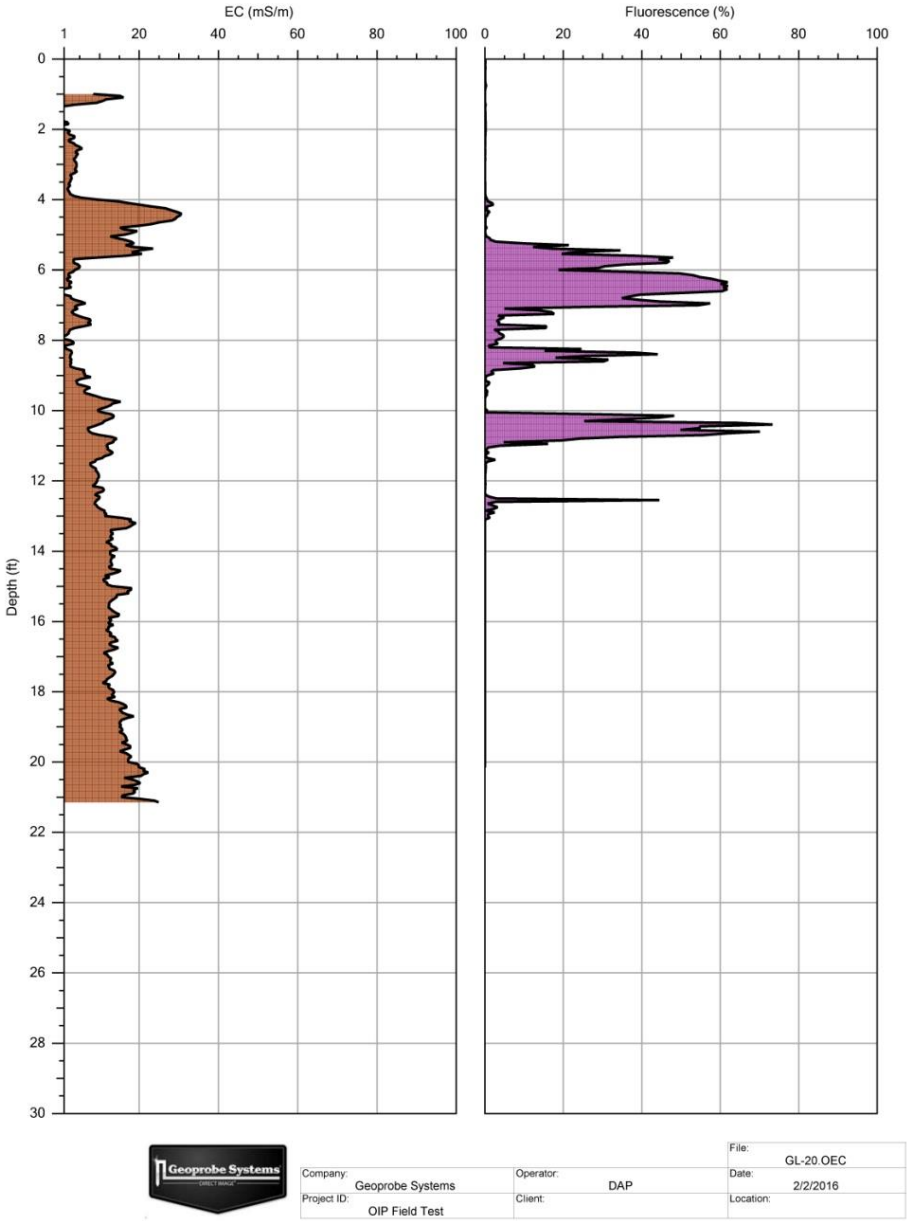

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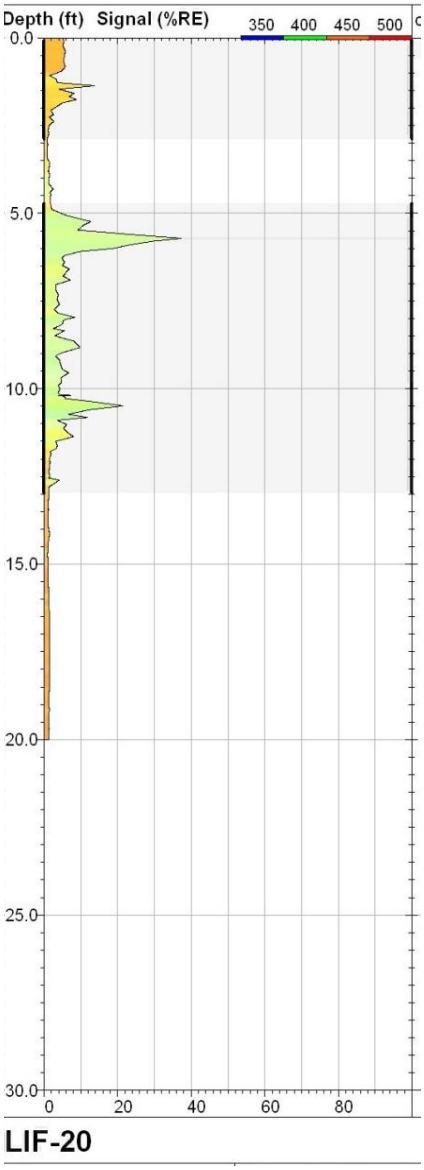

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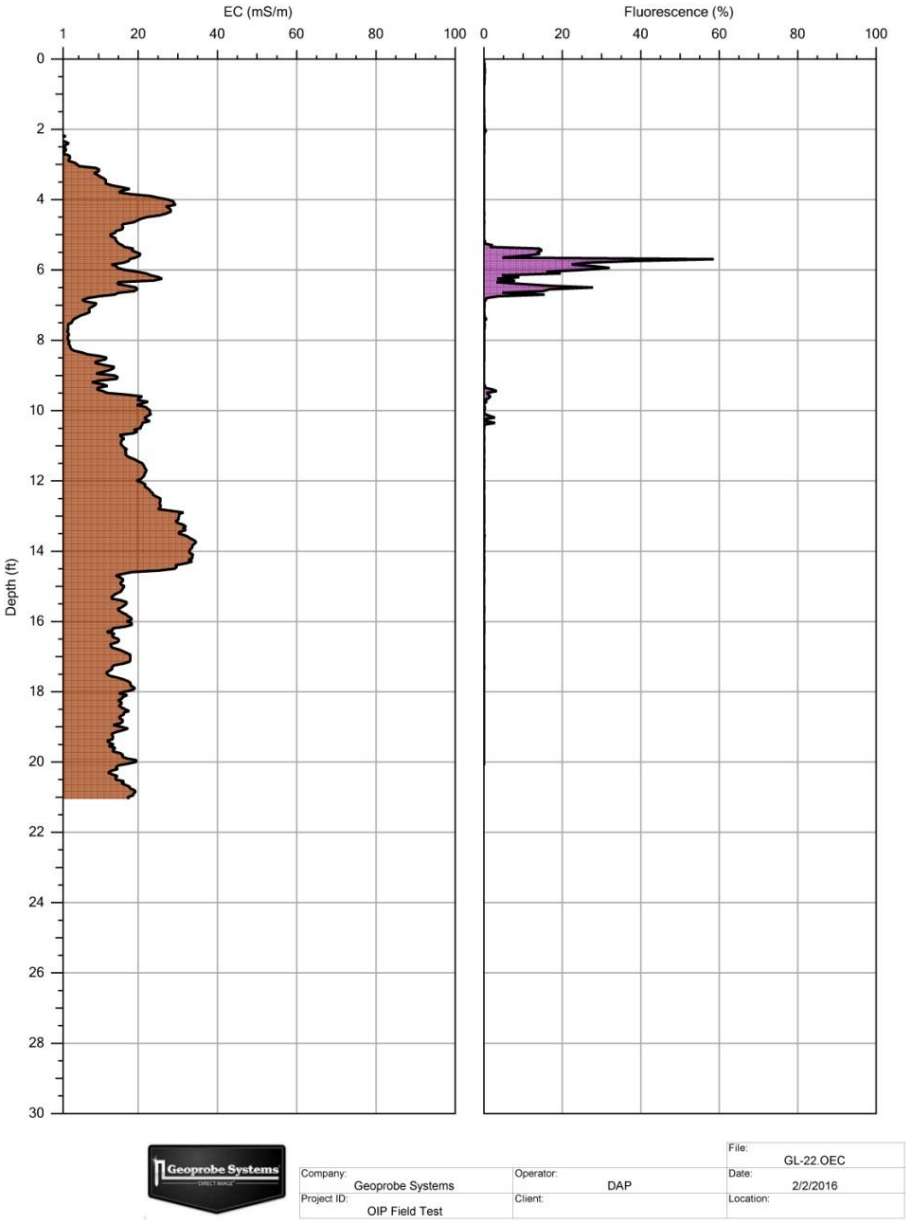

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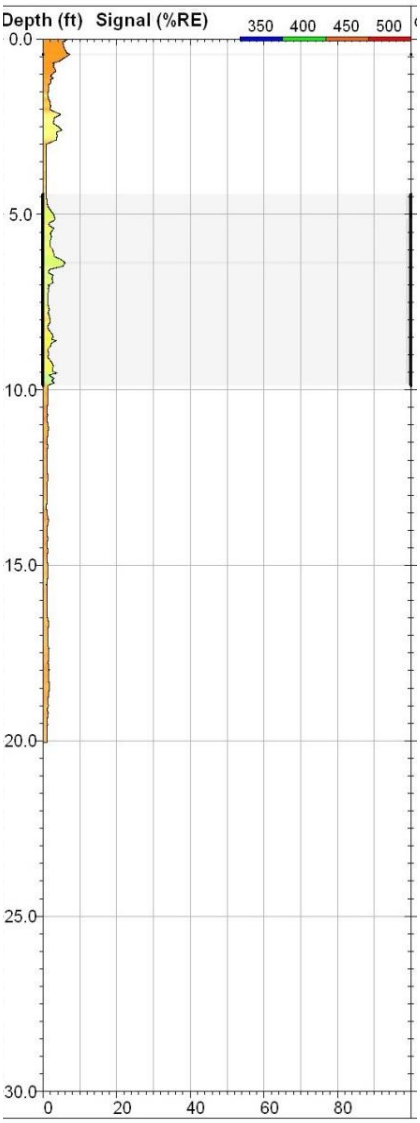

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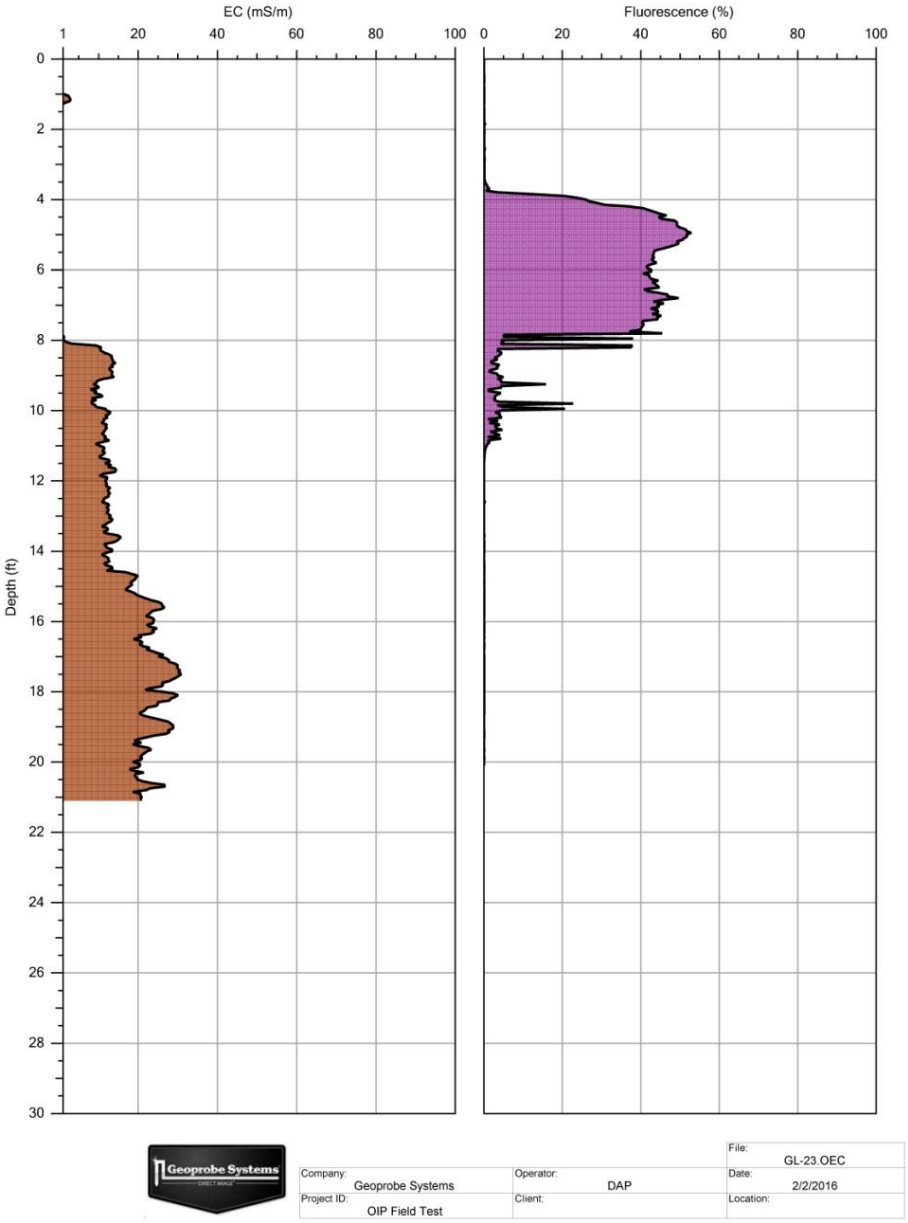

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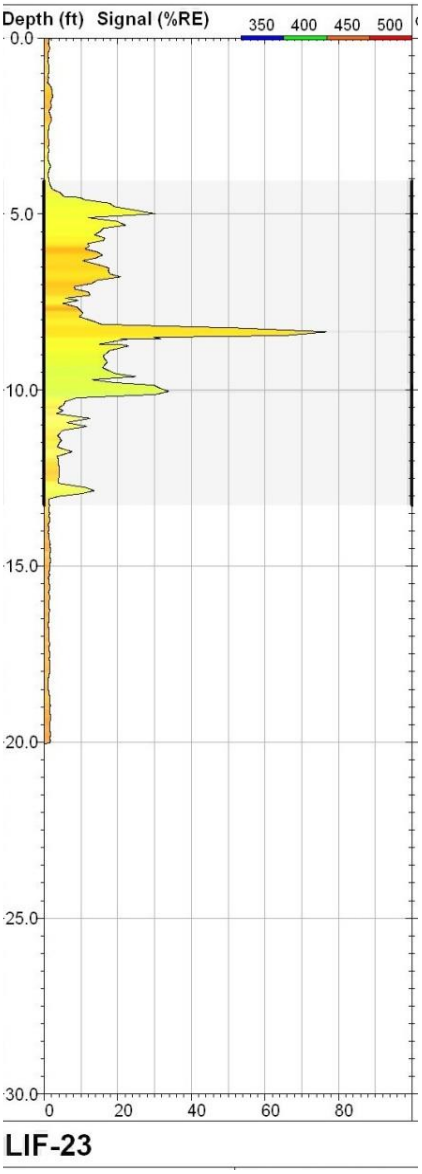

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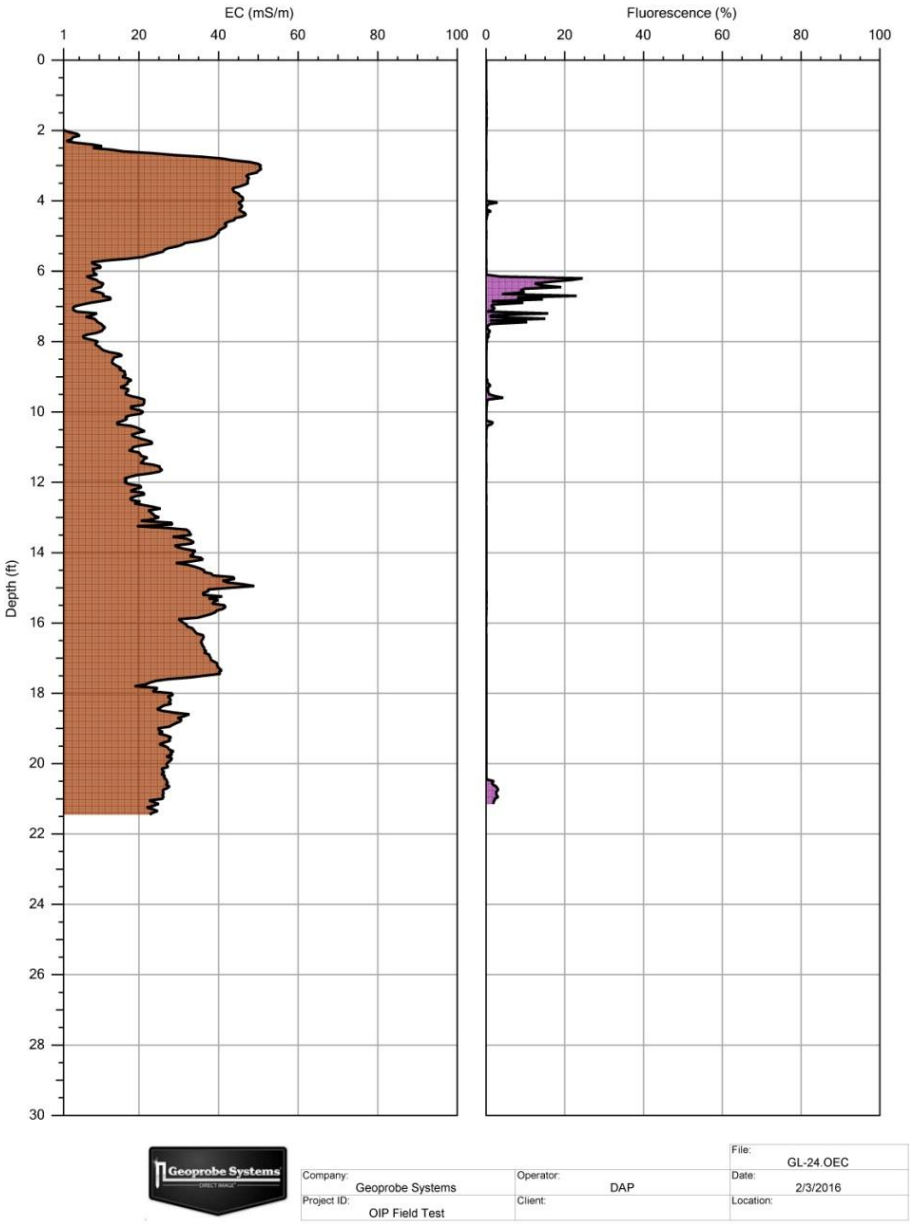

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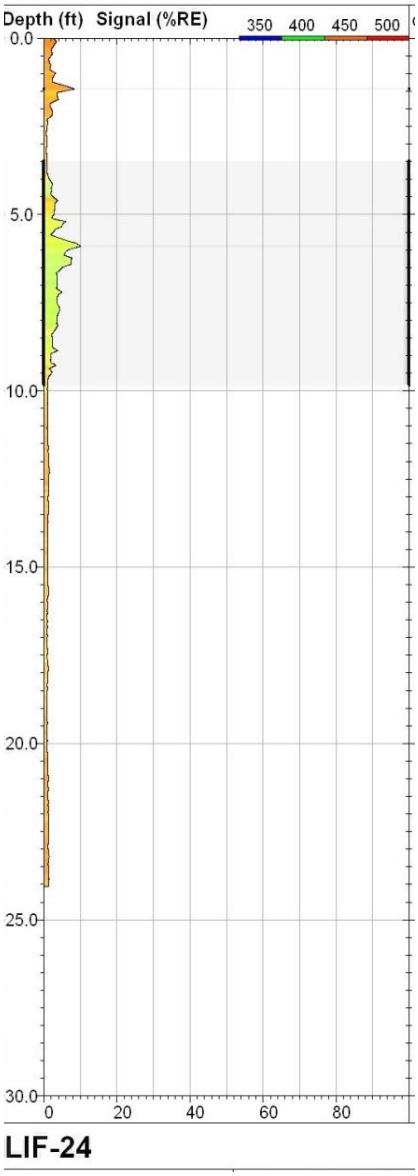

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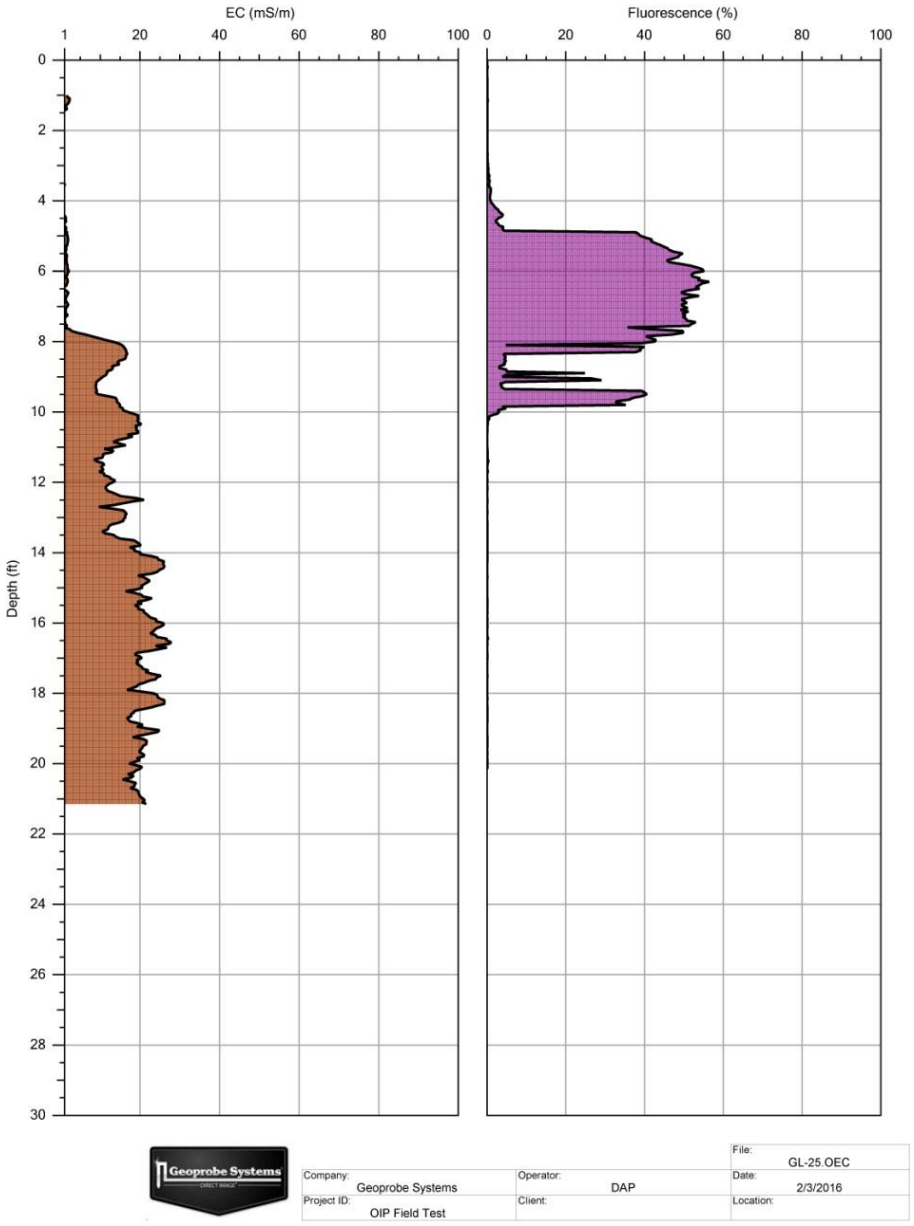

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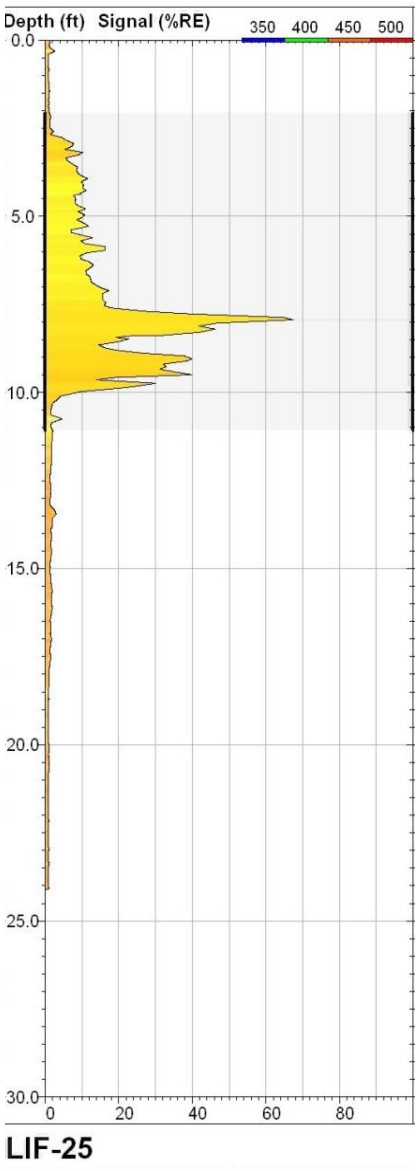

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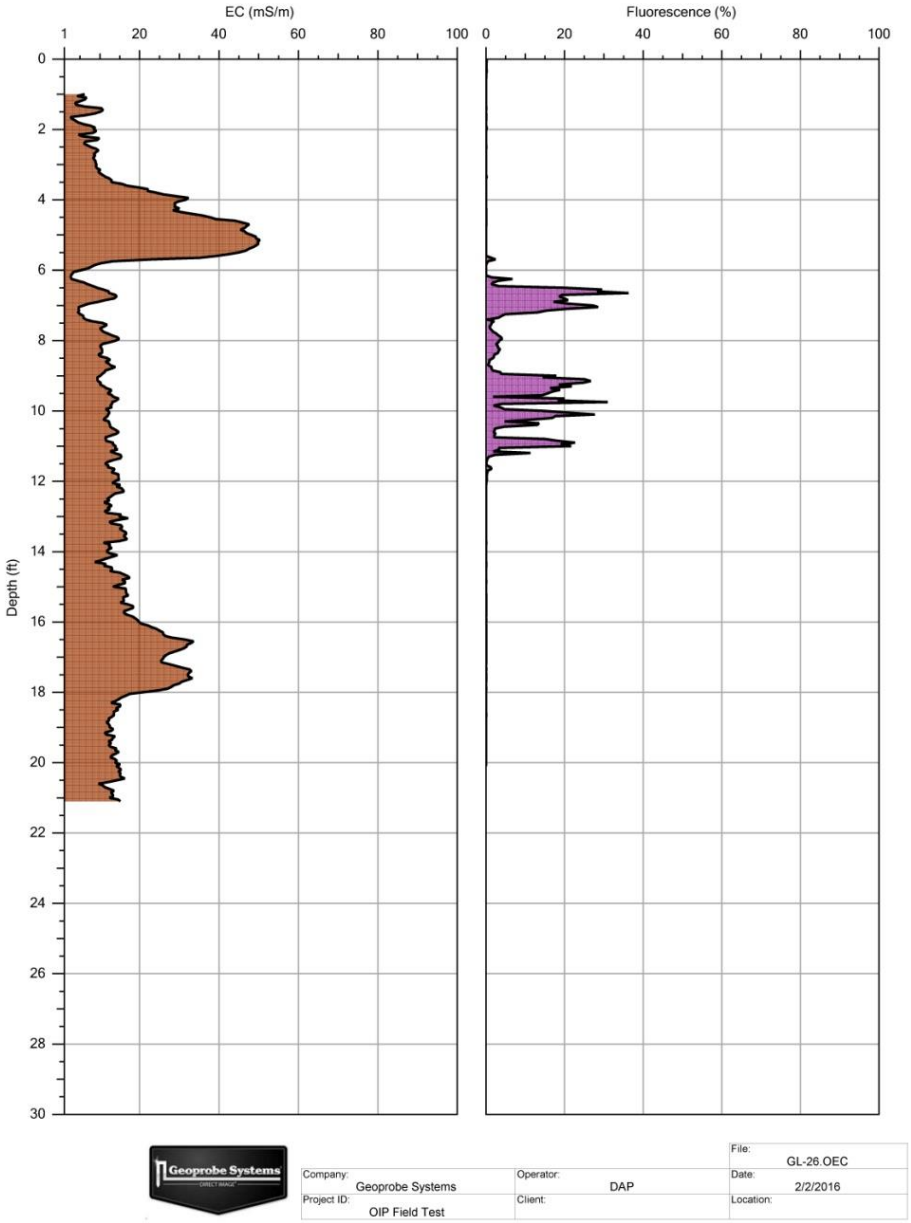

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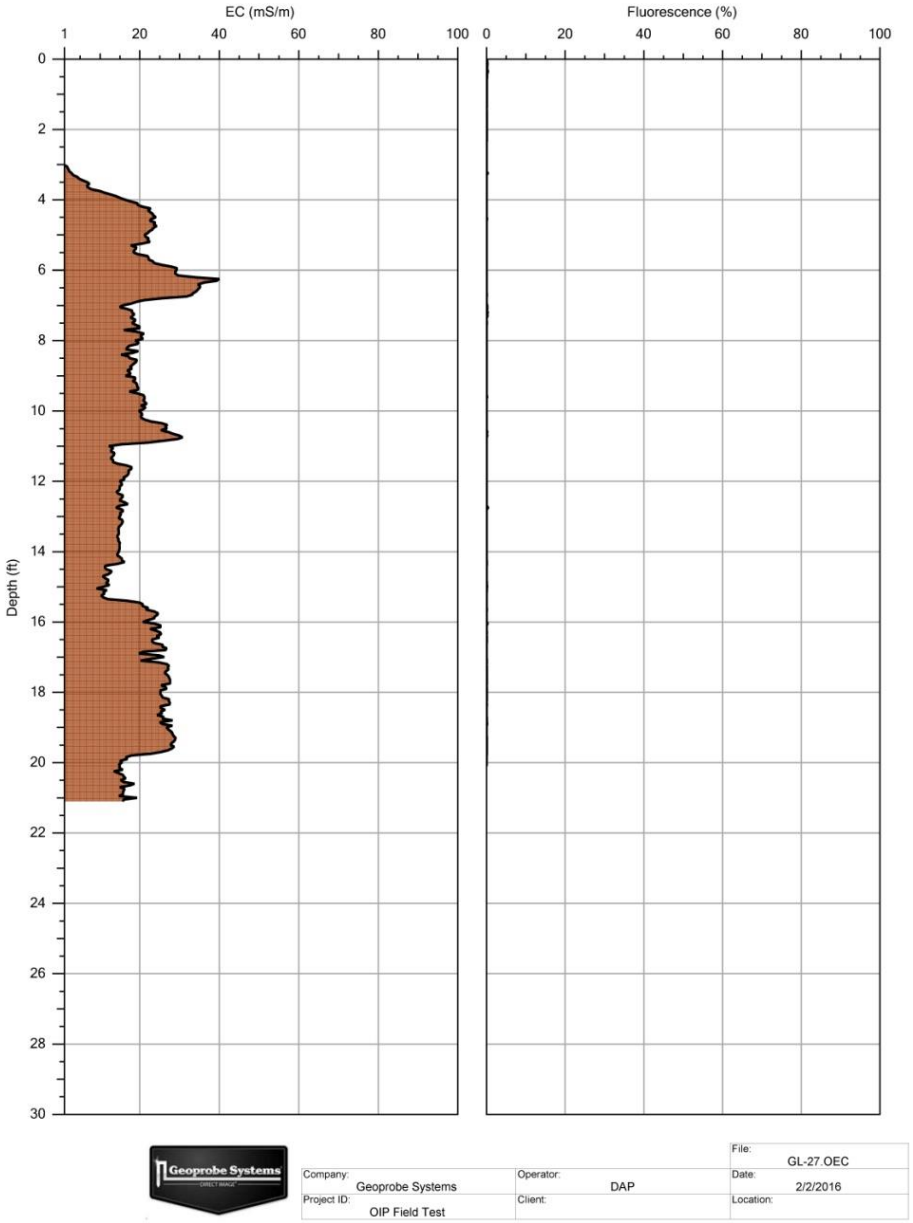

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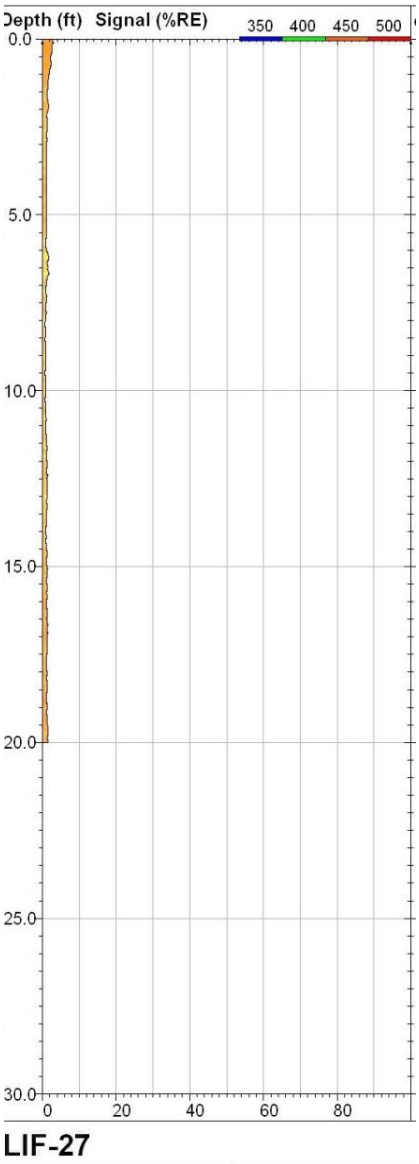

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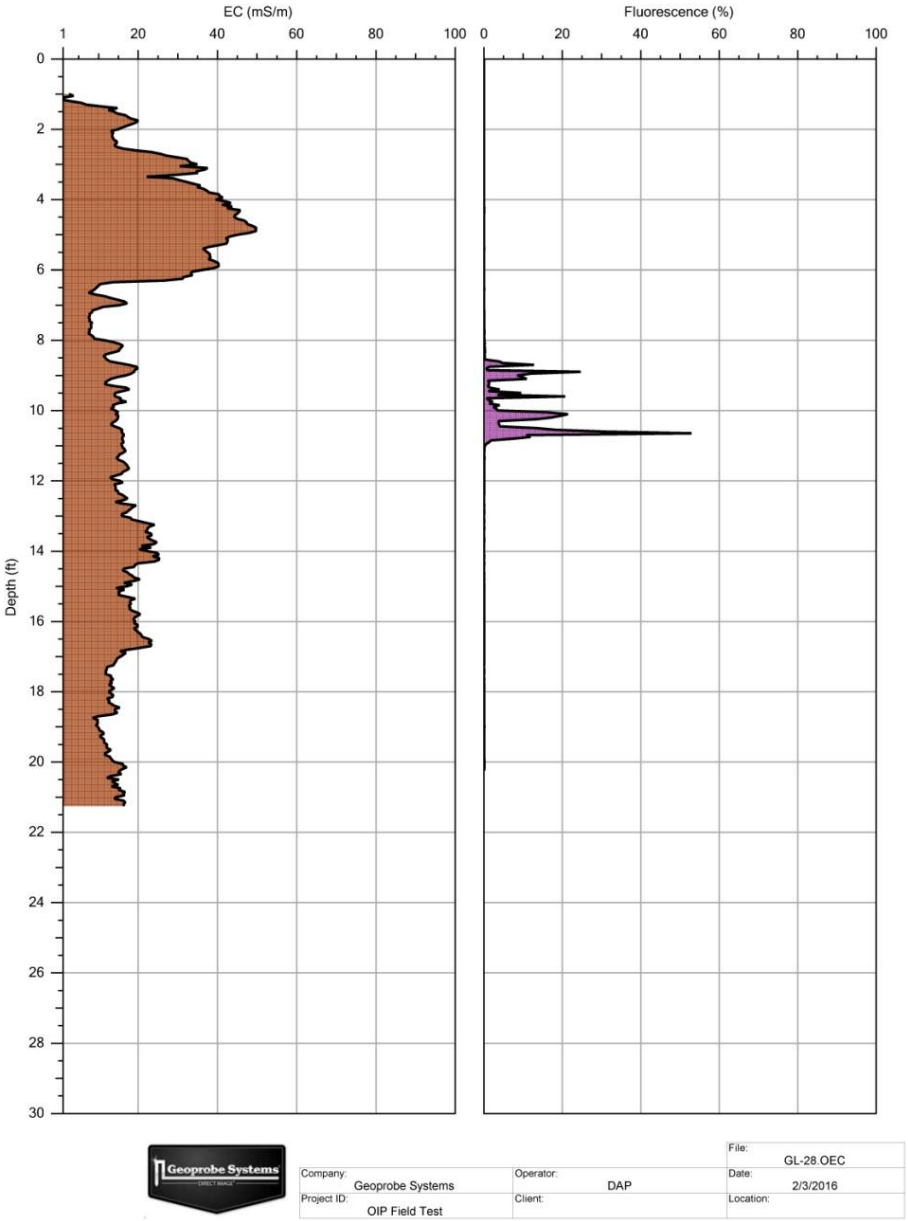

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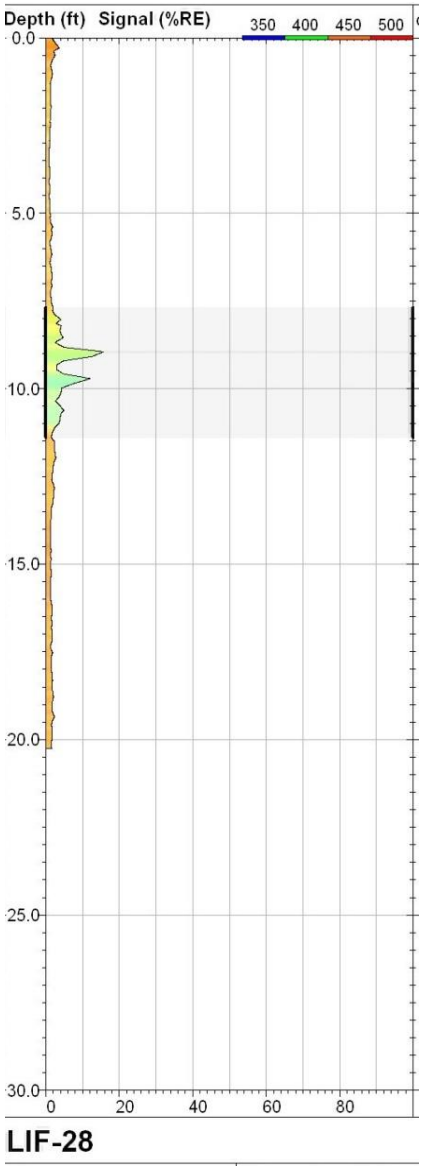

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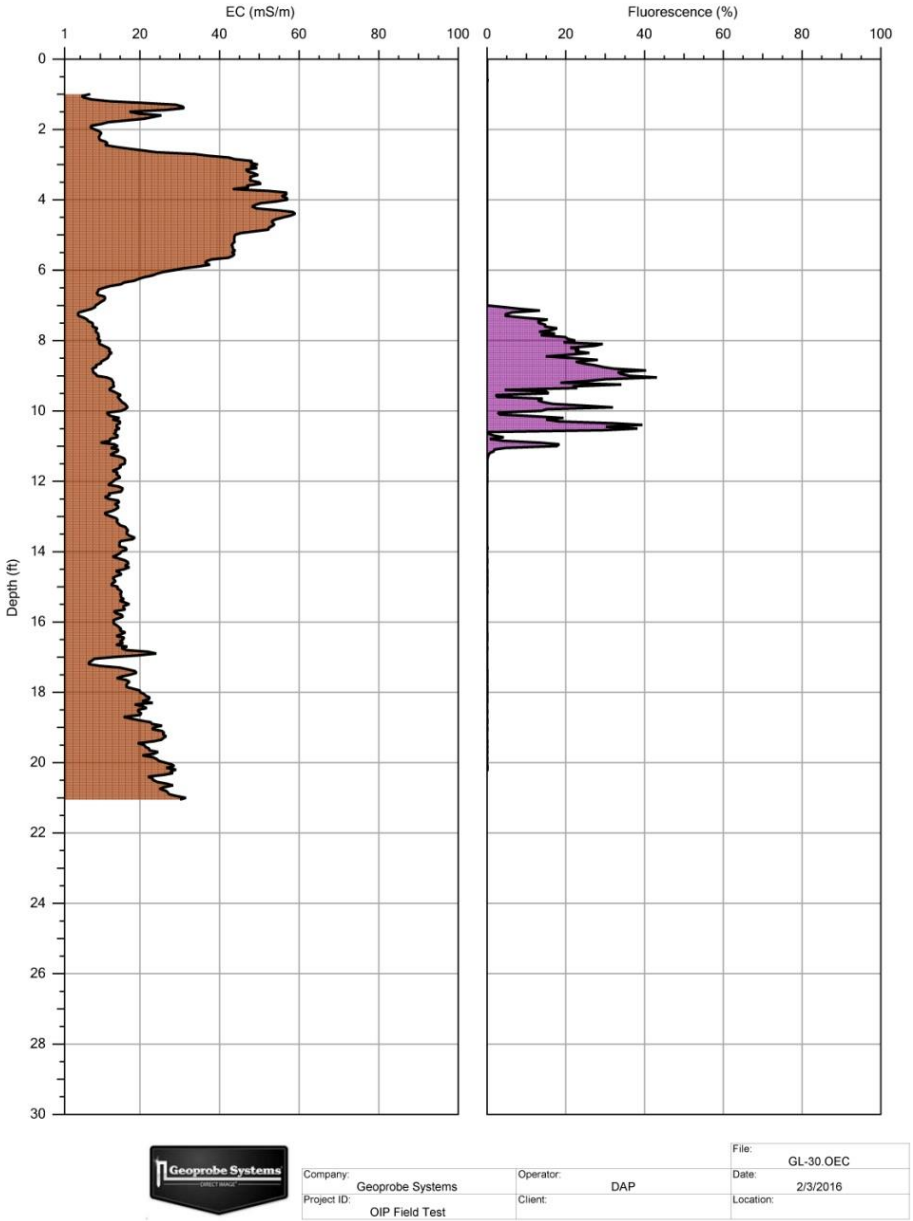

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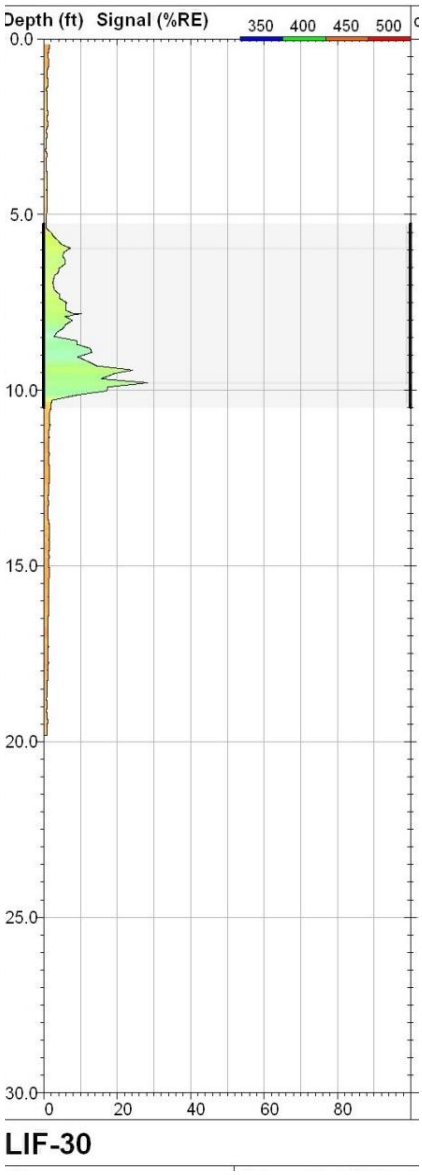

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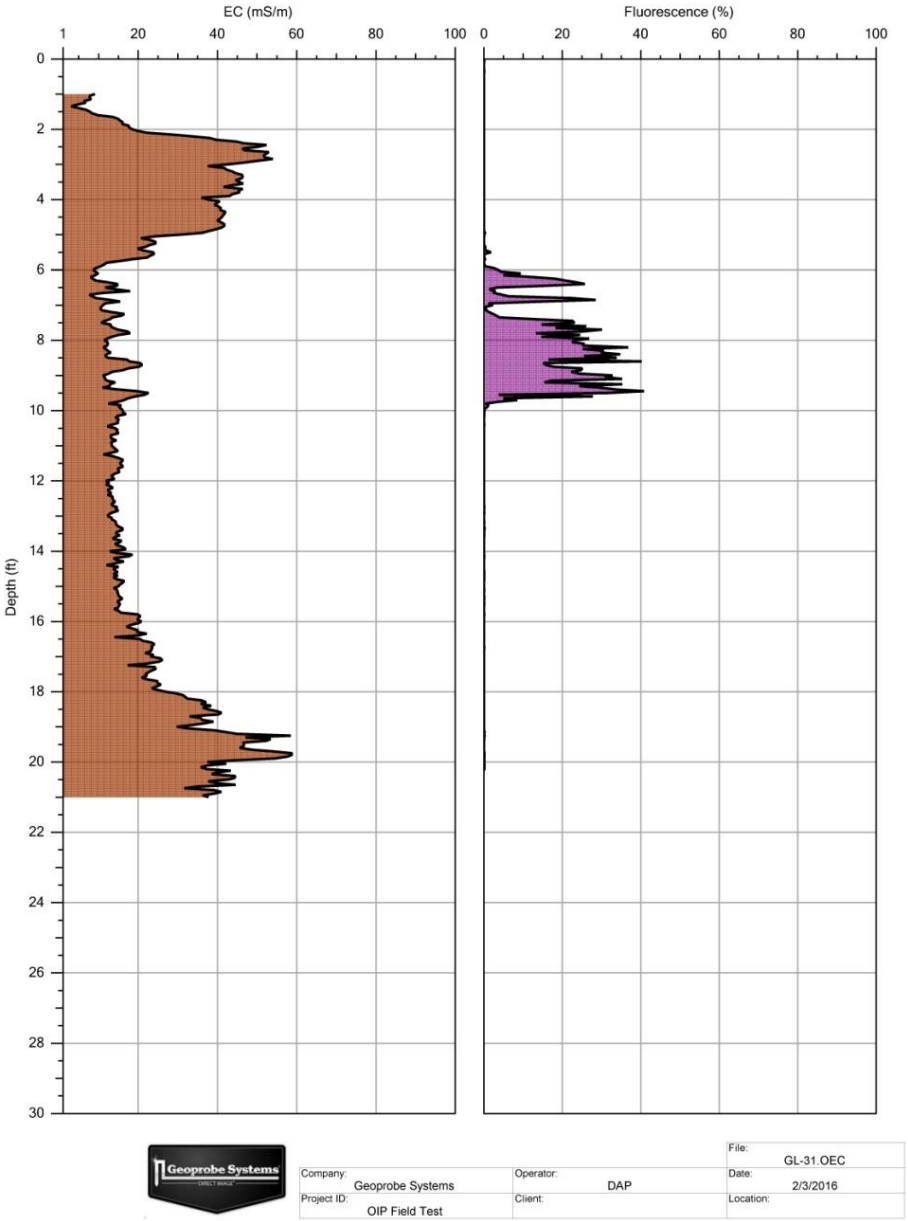

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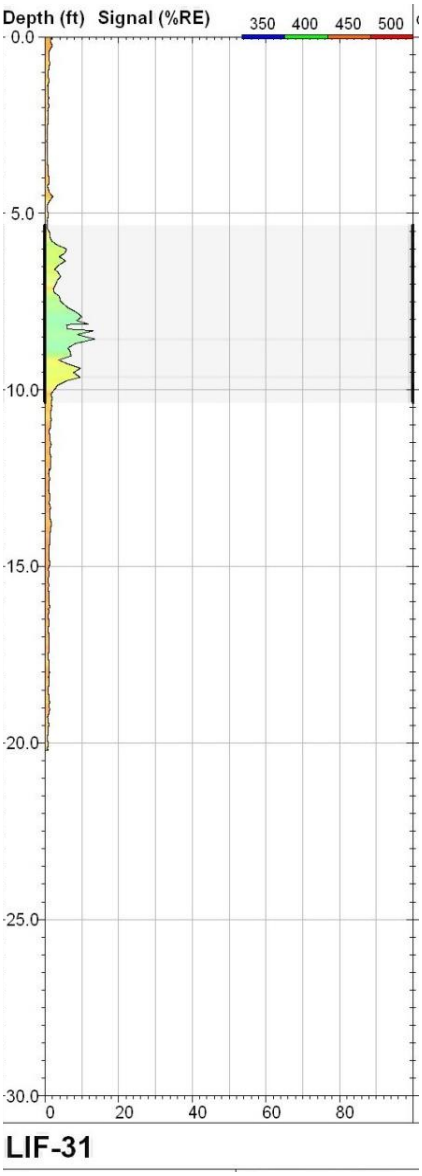

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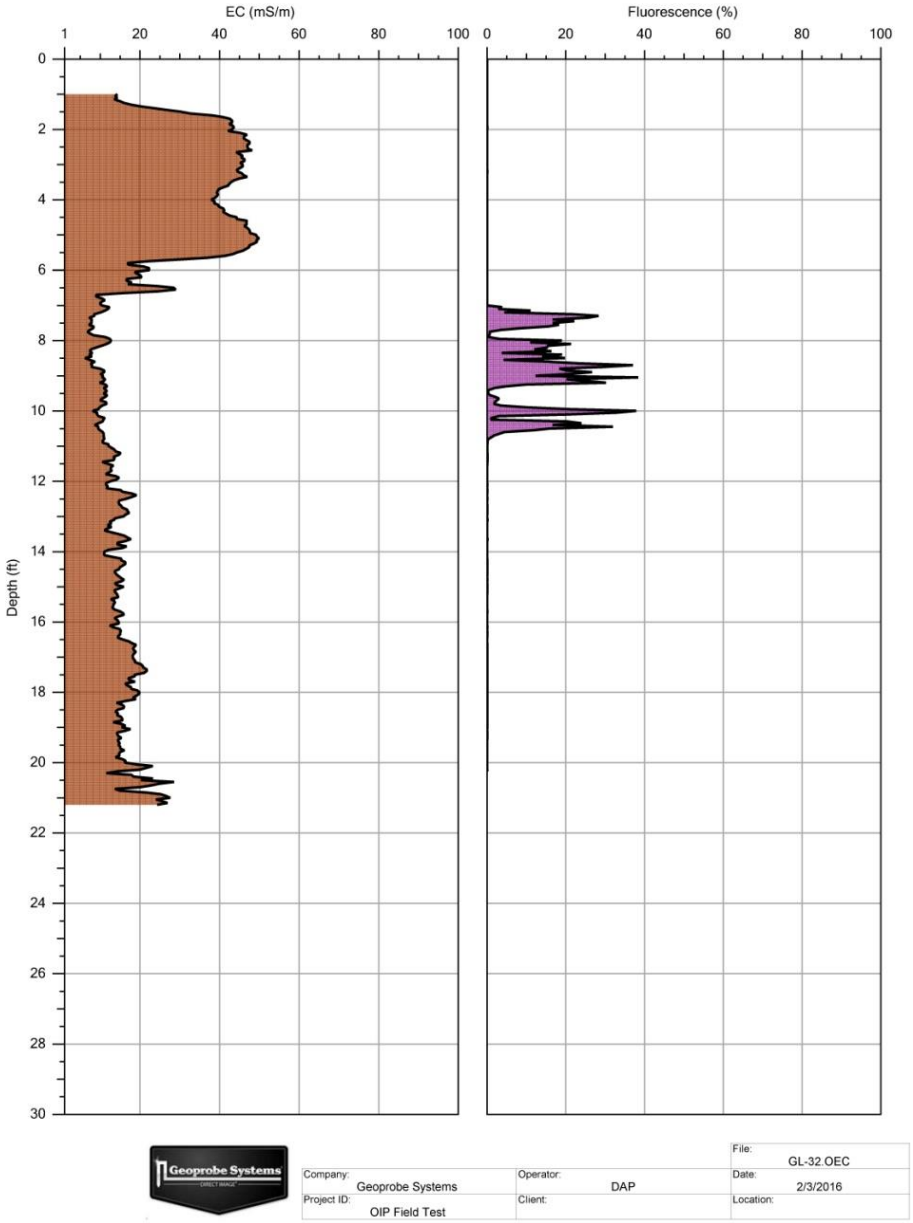

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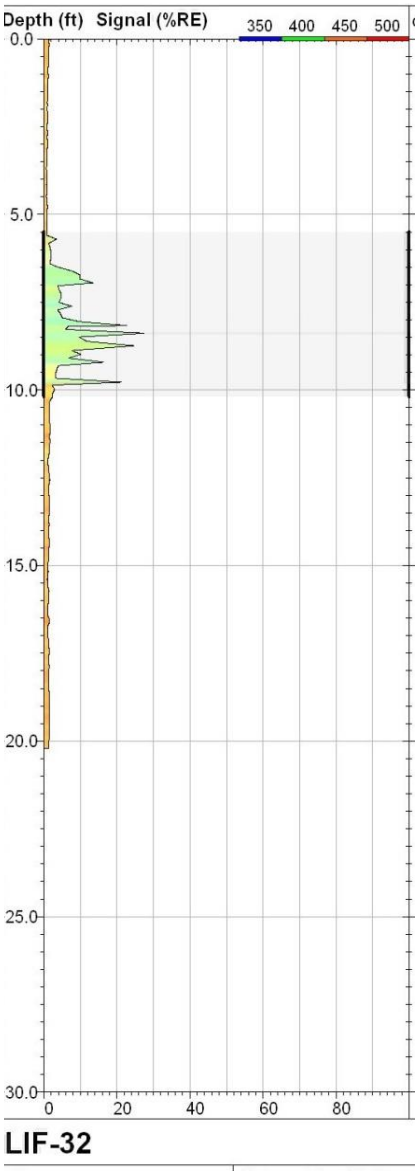

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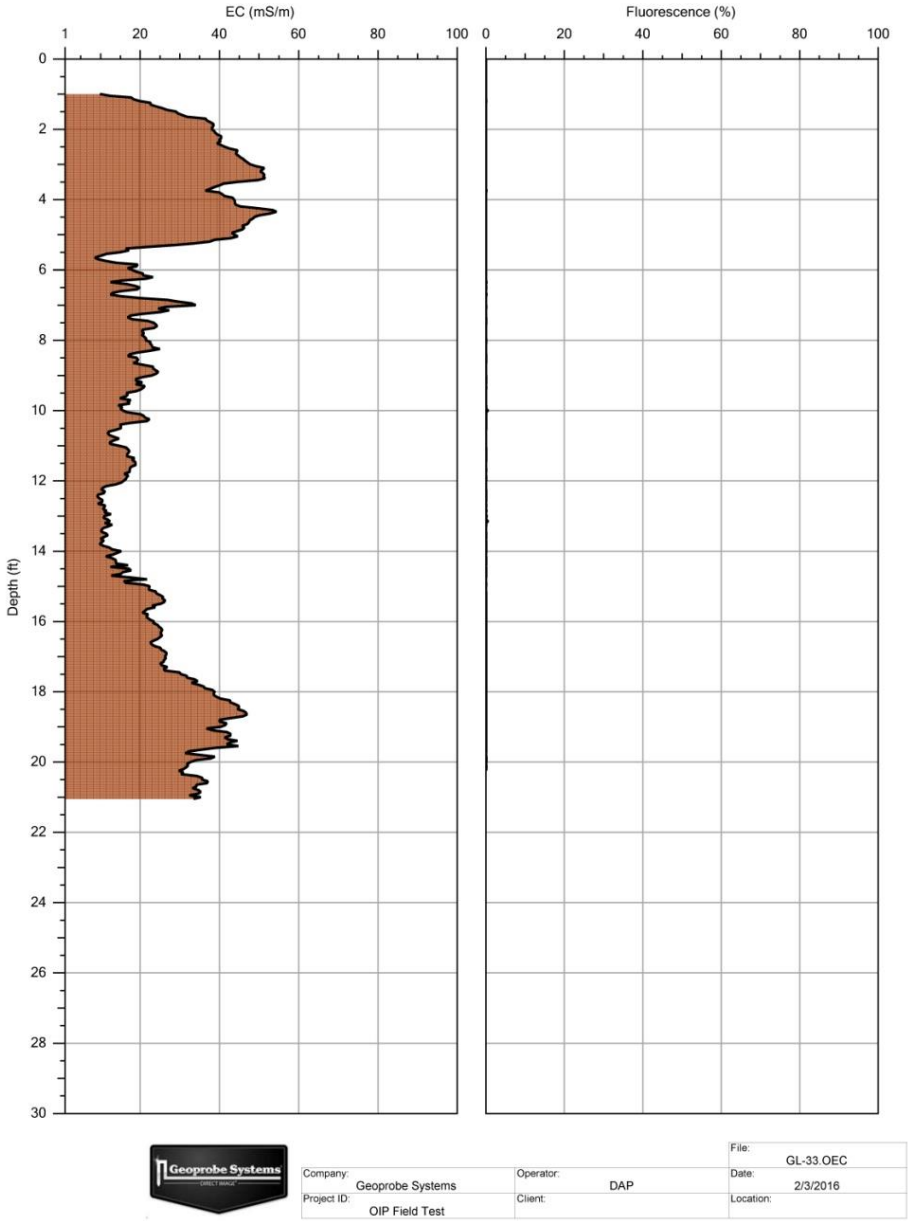

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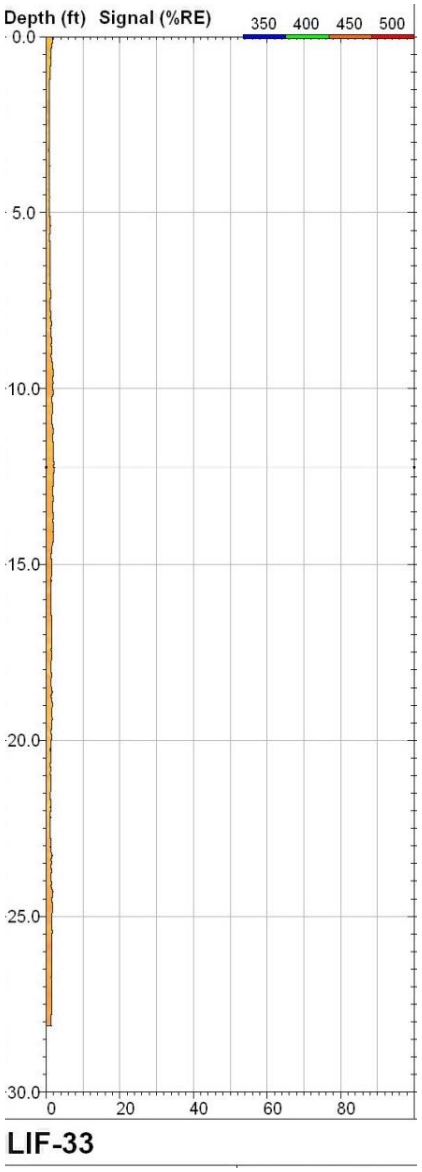

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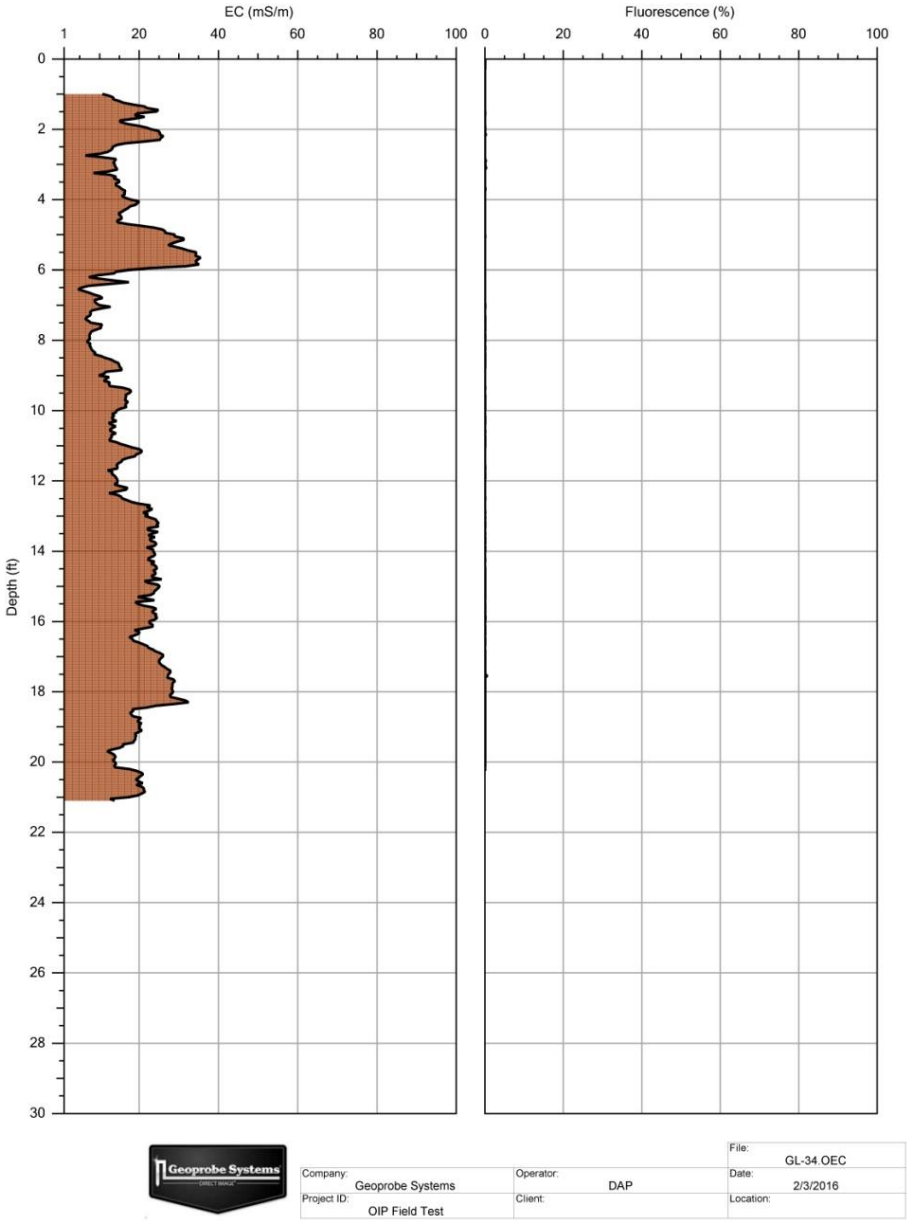

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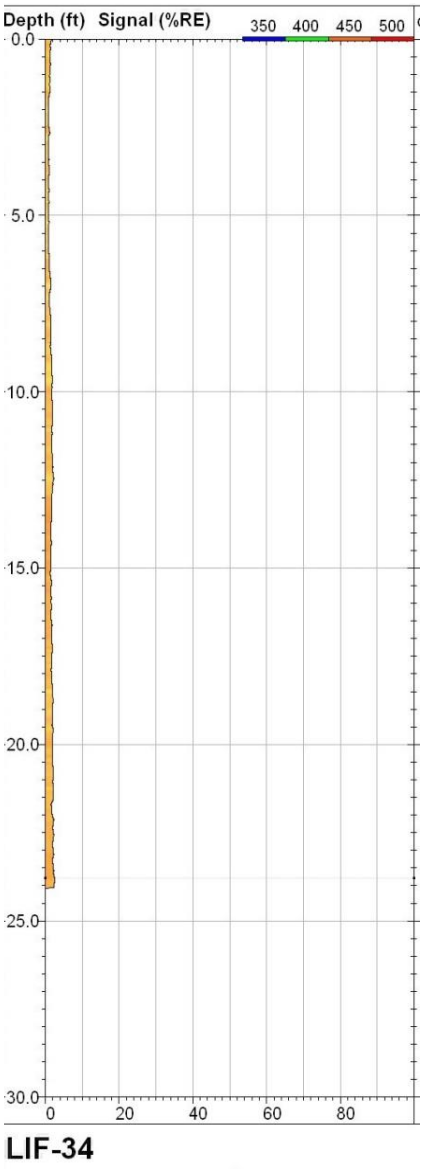

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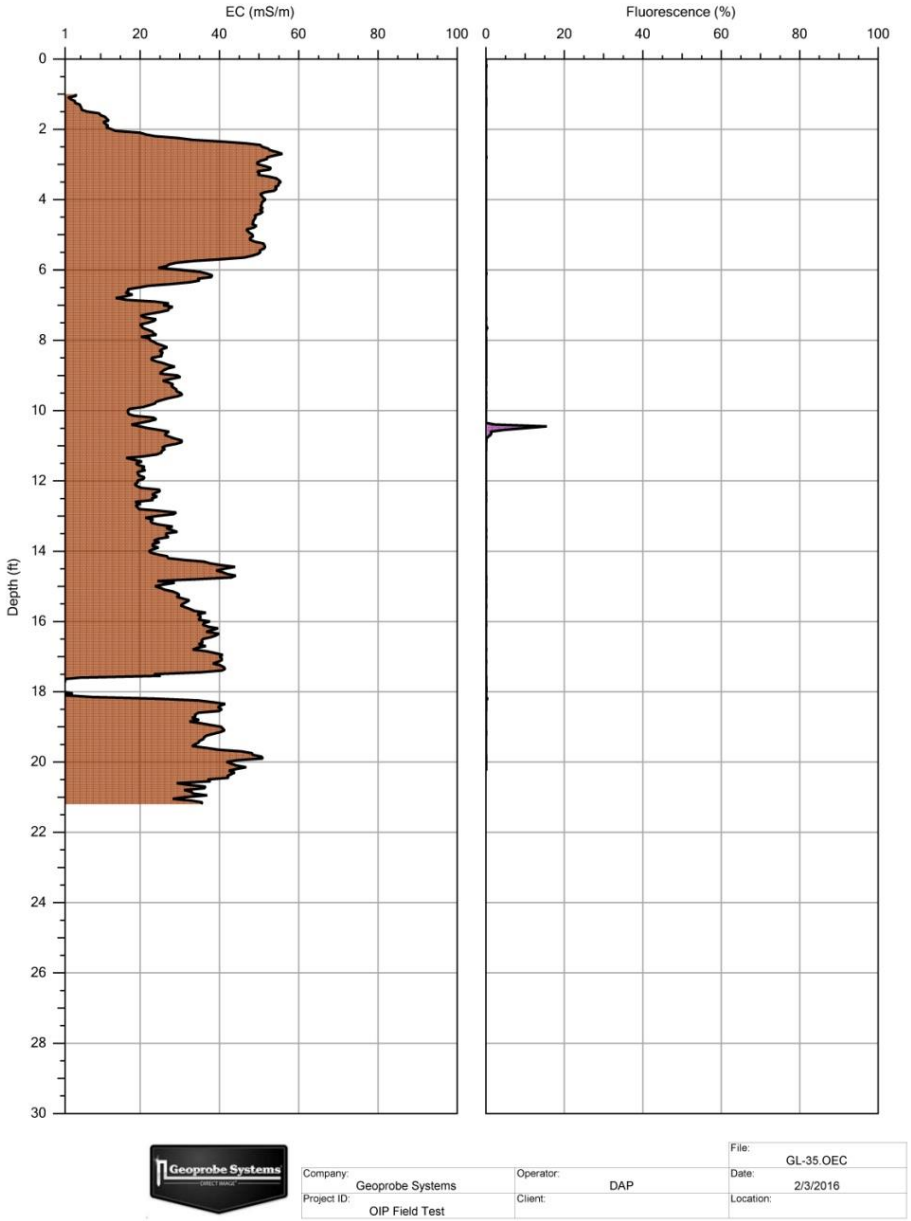

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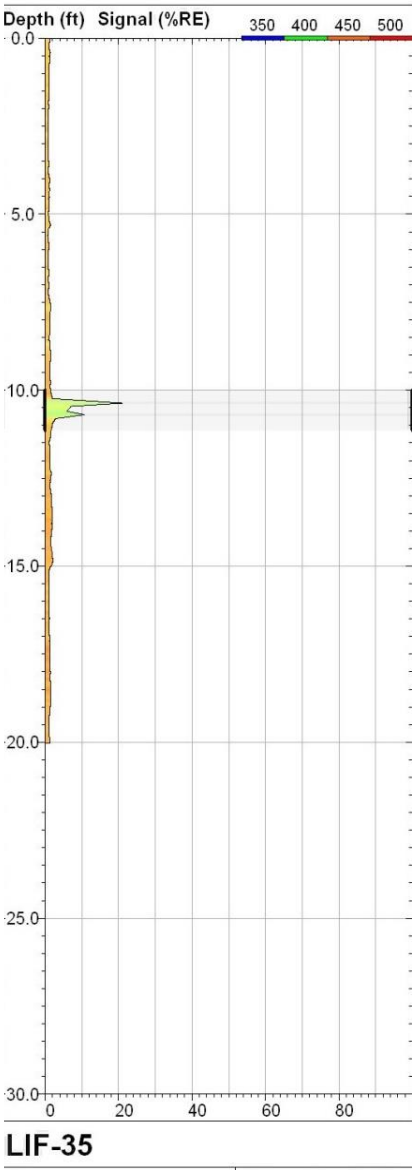

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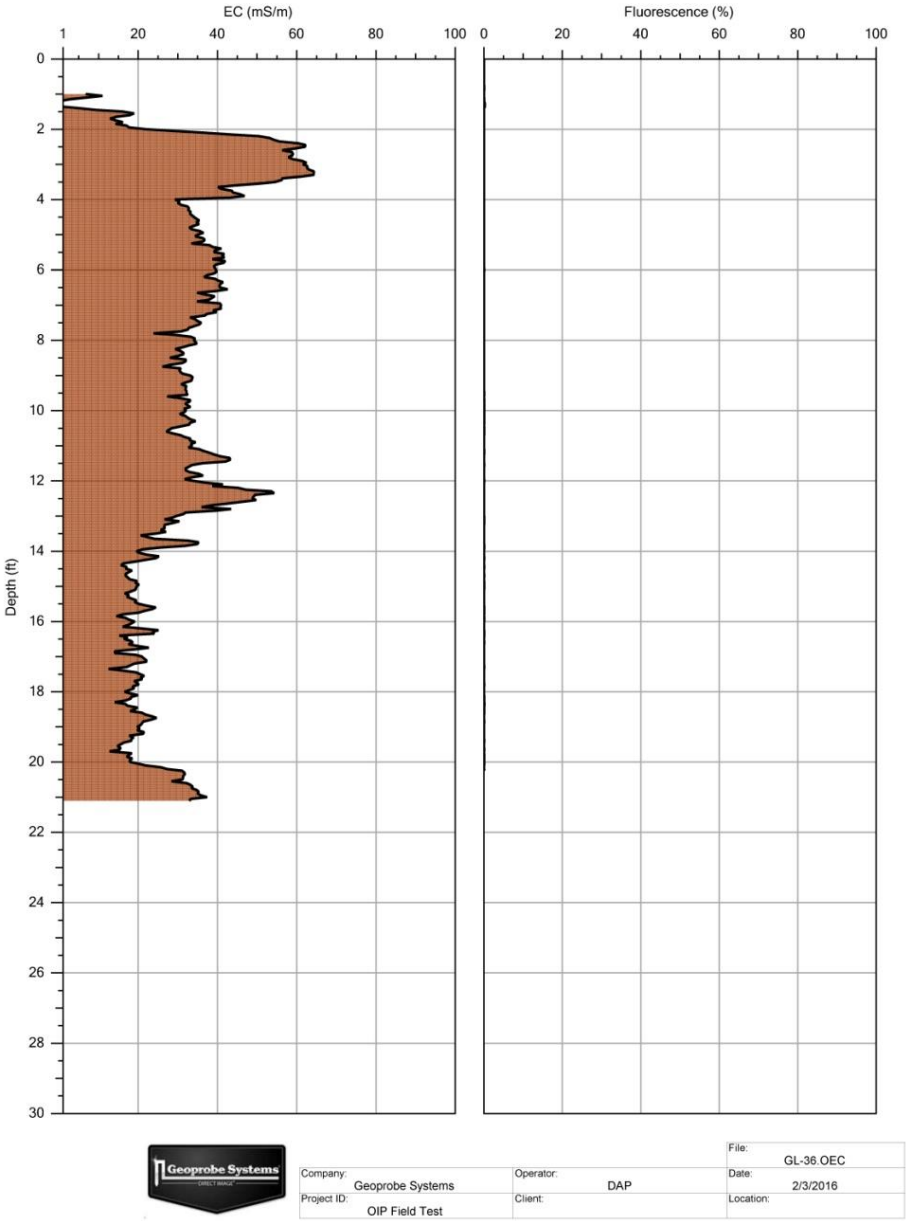

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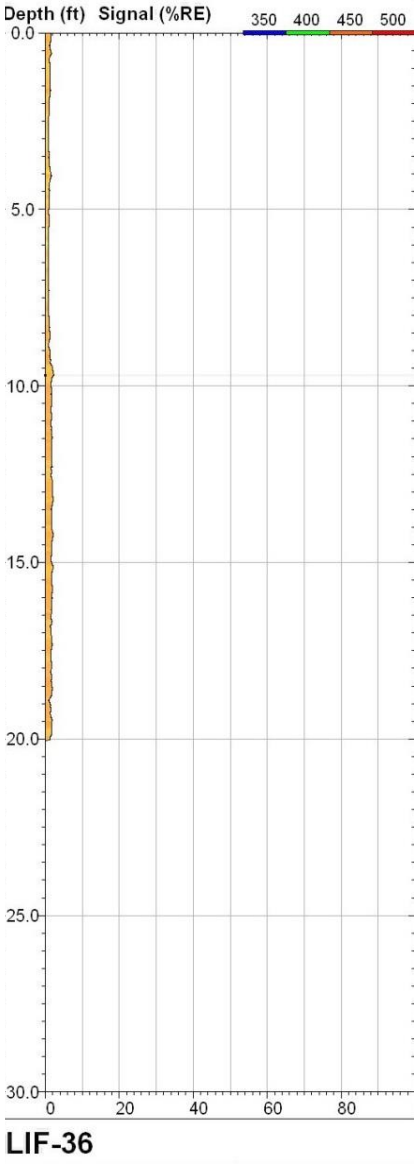

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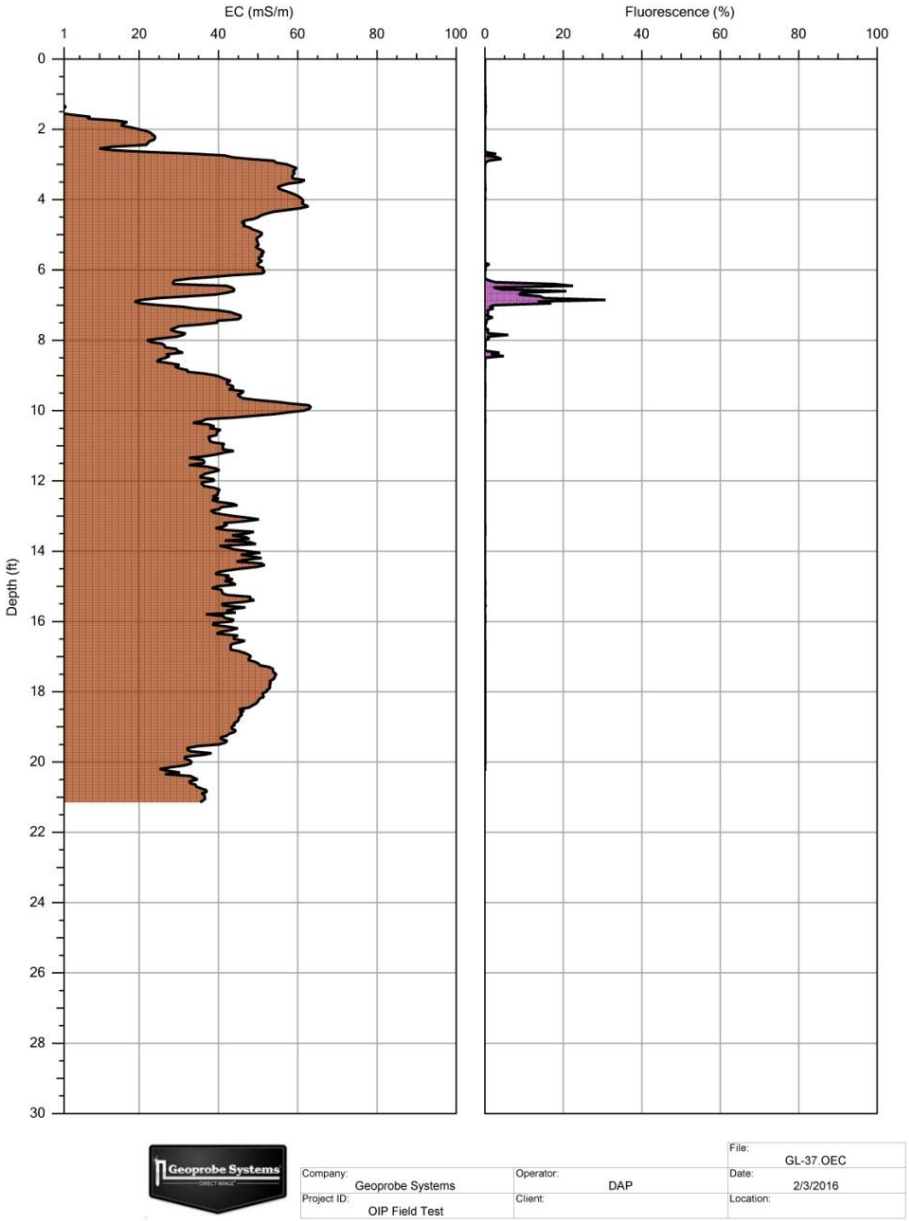

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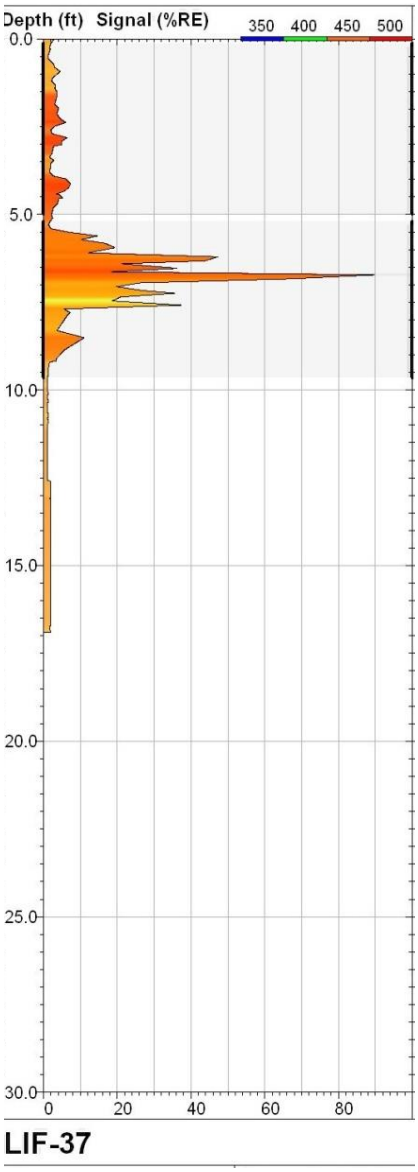

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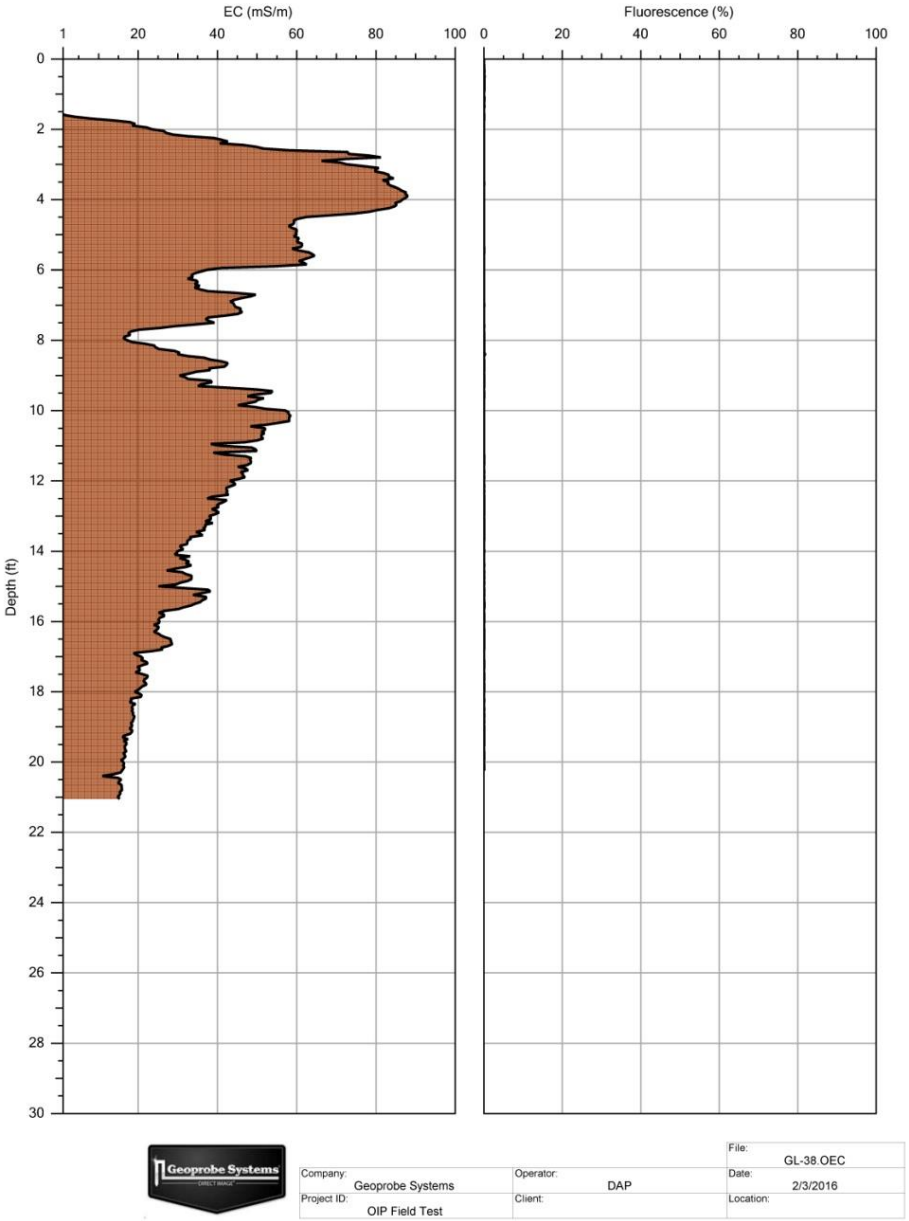

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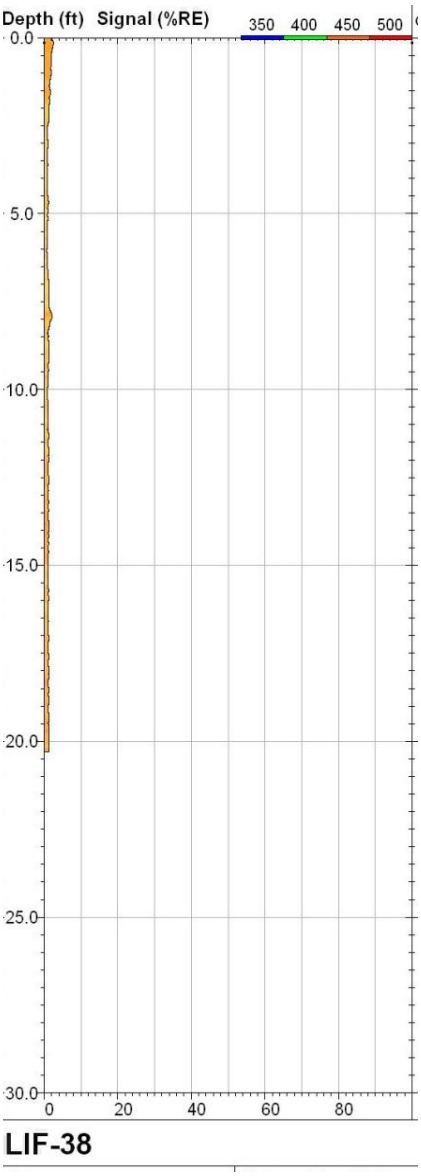

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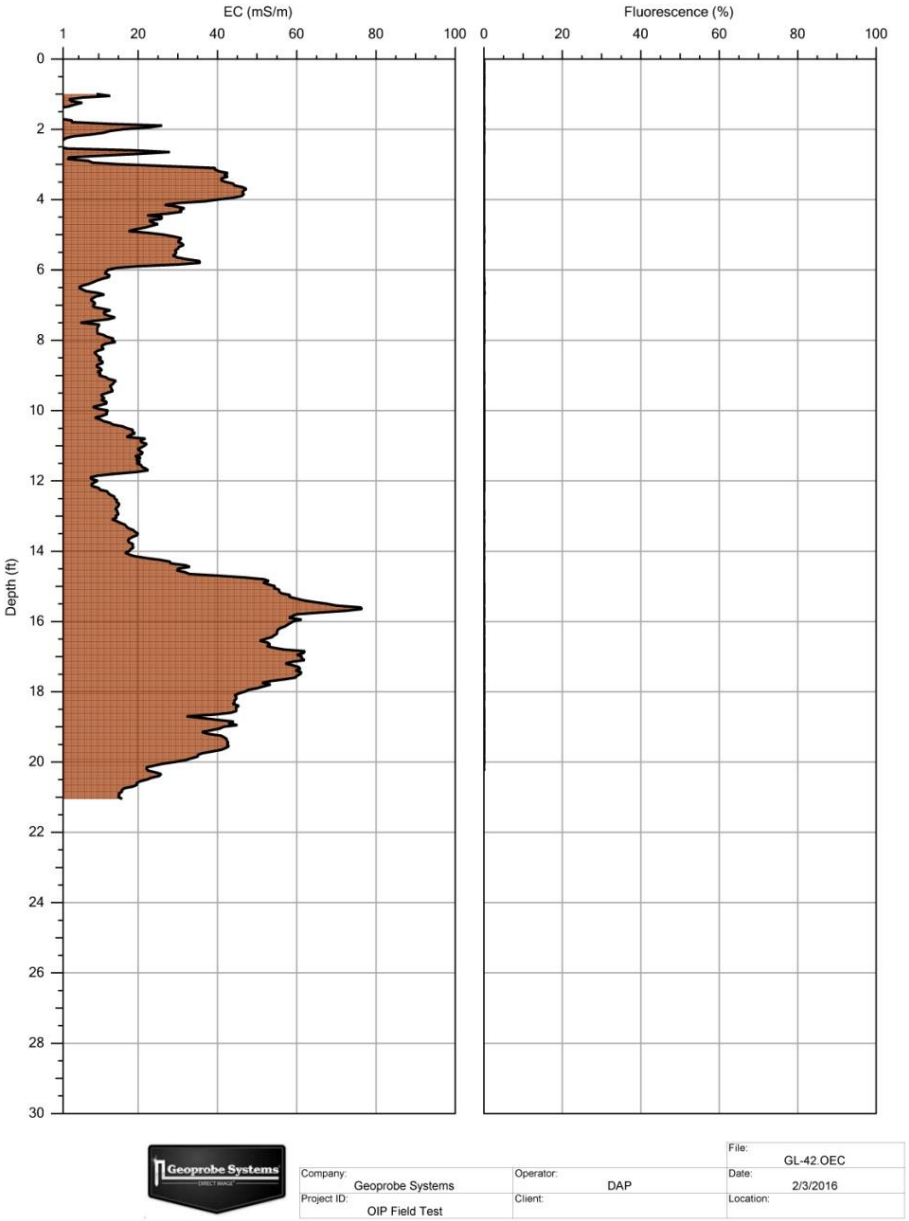

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