

# Fuel Fluorescence Logging using the Optical Image Profiler (OIP)



Note: A Patent is Pending for this System.



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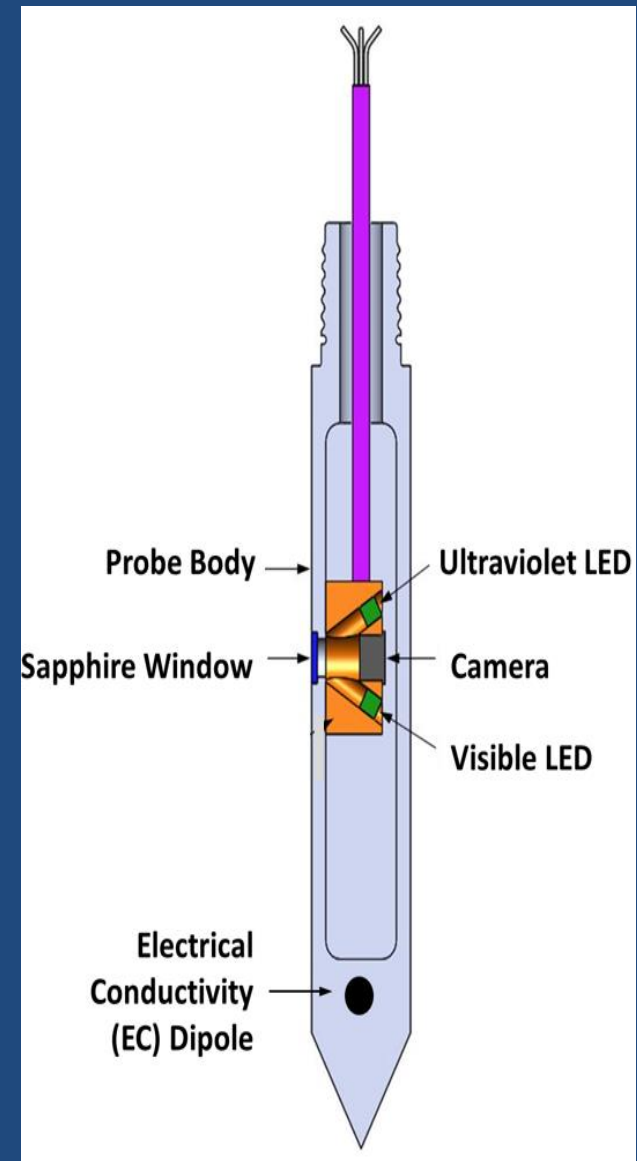
# Outline

- Tool Description and Instrumentation
- Basics of Fluorescence
- Image Analysis
- Field Site Data and Comparisons to other Technologies
- Log Review
- Summary

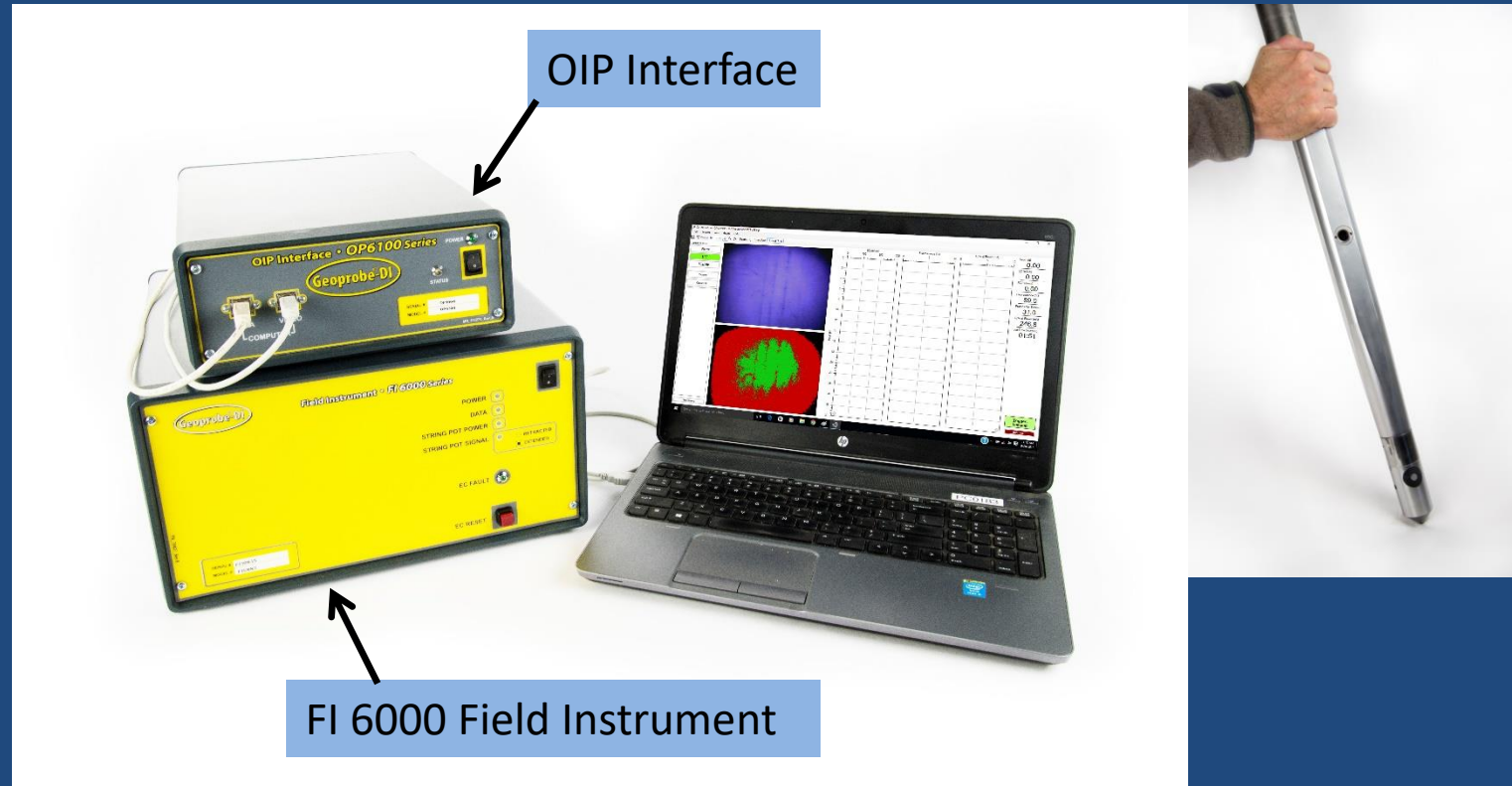
# OIP Probe Description

- **Purpose:** Detecting UV induced fluorescence of light non aqueous phase liquids (LNAPL) in soil. Primarily petroleum hydrocarbons.
- **Method:** A 275nm UV LED directed at the soil causes components of the LNAPL to fluoresce. A CMOS camera situated behind the sapphire window takes images of the soil. The image is analyzed for fluorescent color indicative of fuel fluorescence.

Visible light images of the soil may also be obtained.

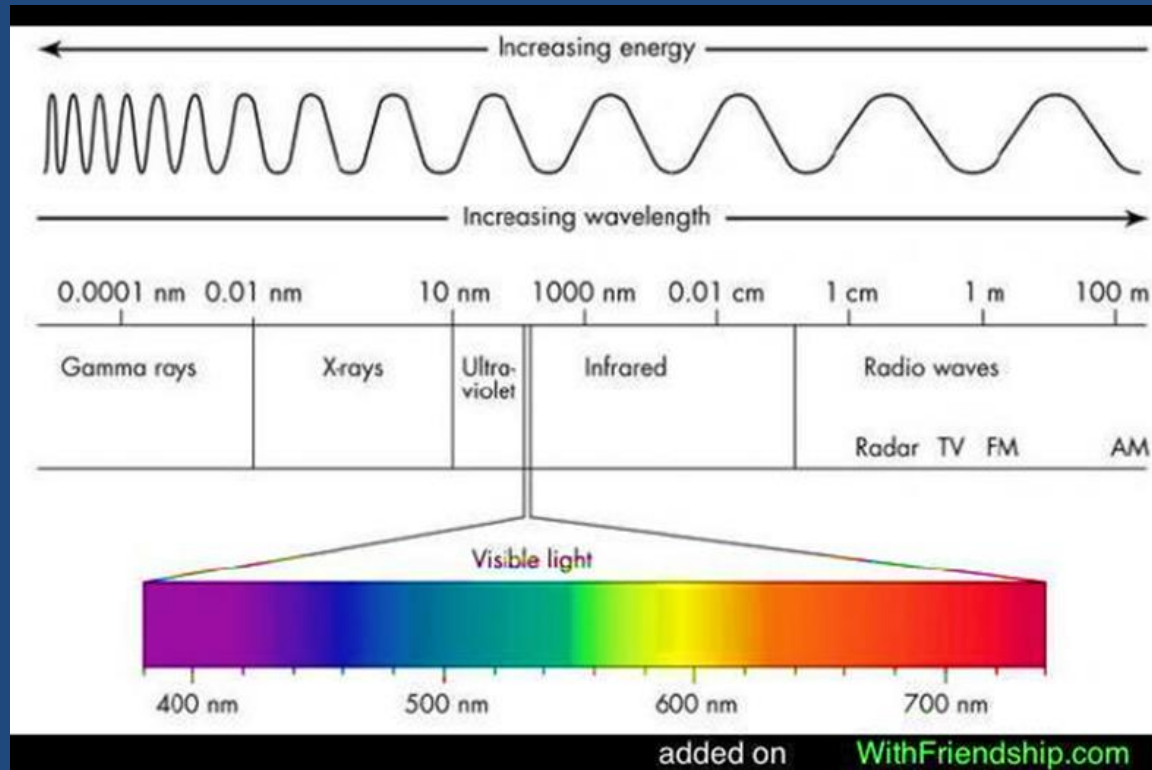


# OIP Instrumentation



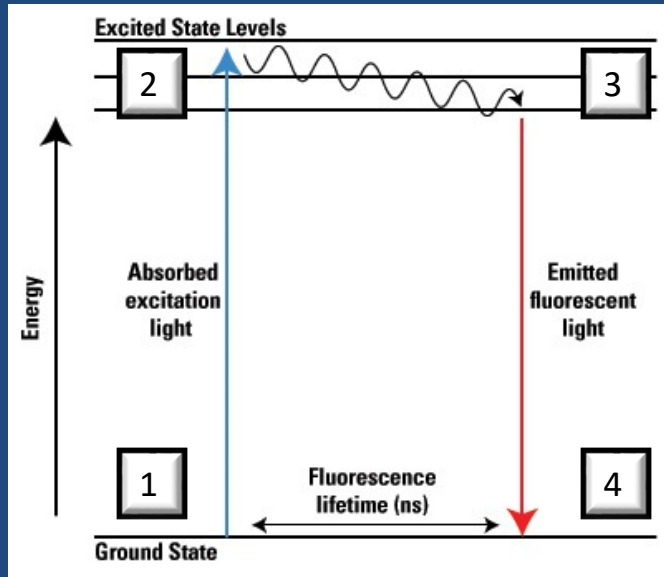
Instrumentation to run optical logs includes the FI6000 and the OIP Interface. A laptop computer is also required.

# Light Wavelengths



The human eye only sees a tiny portion of the entire electromagnetic (light) spectrum. Typically we see from about 380nm to 750nm wavelengths. The OIP UV LED emits light at 275nm.

# Fluorescence

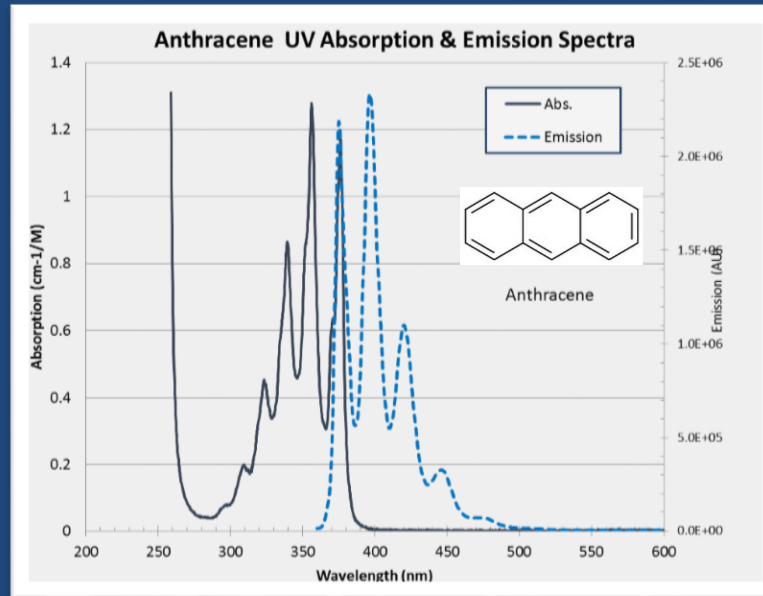


Jablonski Energy  
Diagram of  
Fluorescence

<https://www.thermofisher.com/>

Electrons in a fluorescent molecule (called a fluorophore) are normally in the ground state energy level (1). Incident UV radiation excites the electrons and they jump to an excited state (2). By a process called internal conversion the excited electrons lose some energy (squiggly line)(3). From this slightly reduced energy state the excited electron then releases a light photon (fluorescence) and returns to the ground state (4). This entire process occurs in about 1 nanosecond.

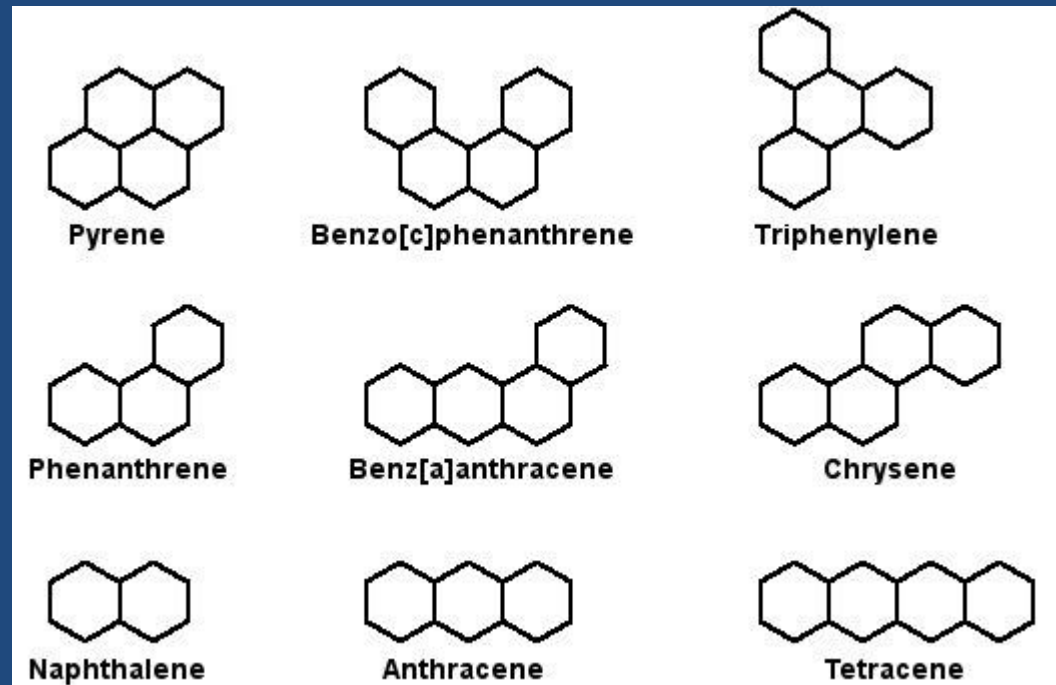
# Fluorescence



This is a plot of the absorption and emission spectra for Anthracene. The spectra display a mirror-like symmetry for some molecules, as seen here. Note that most of the absorption range is in the UV while most of the emitted light (fluorescence) is in the visible range for anthracene. Again, it is important to note that the wavelengths of light absorbed are at shorter wavelength (higher energy) than the wavelengths emitted.

# Polycyclic Aromatic Hydrocarbon (PAH) Fluorescence

- Smaller PAH Compounds
  - Gas and Diesel
  - UV Detectable
- Larger PAH Compounds
  - Coal tar, Heavy Fuels
  - Not UV Detectable
- Chlorinated VOCs
  - Typically Not UV Detectable
- Dissolved Contaminants
  - Typically Not UV Detectable





# Polycyclic Aromatic Hydrocarbon (PAH) Fluorescence

Smaller PAH Compounds (naphthalene, anthracene, etc.) are commonly found in gasoline and diesel. These molecules make the fuels detectable by UV induced fluorescence.

BTEX compounds are not detectable as their fluorescence absorption and emission is below the range OIP operates.

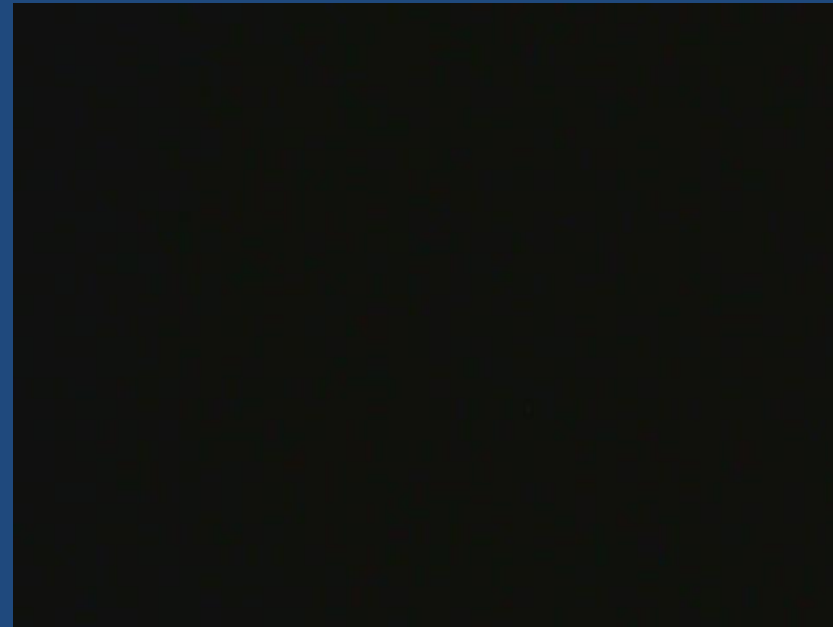
Dissolved fuel hydrocarbons are not typically UV detectable due to lower concentrations in solution, quenching and other effects.

Coal tar and heavy fuels are not reliably UV detectable due to quenching effects.

Pure Chlorinated VOC DNAPLs do not fluoresce under UV light. However if contaminated with oils, fuels or dyes they may fluoresce. <sup>9</sup>

# OIP UV Image

9.5 mm



7 mm



The CMOS camera captures images at 30 frames per second

Typical OIP background image with no fluorescence using the UV light source.

# OIP UV Image

9.5 mm



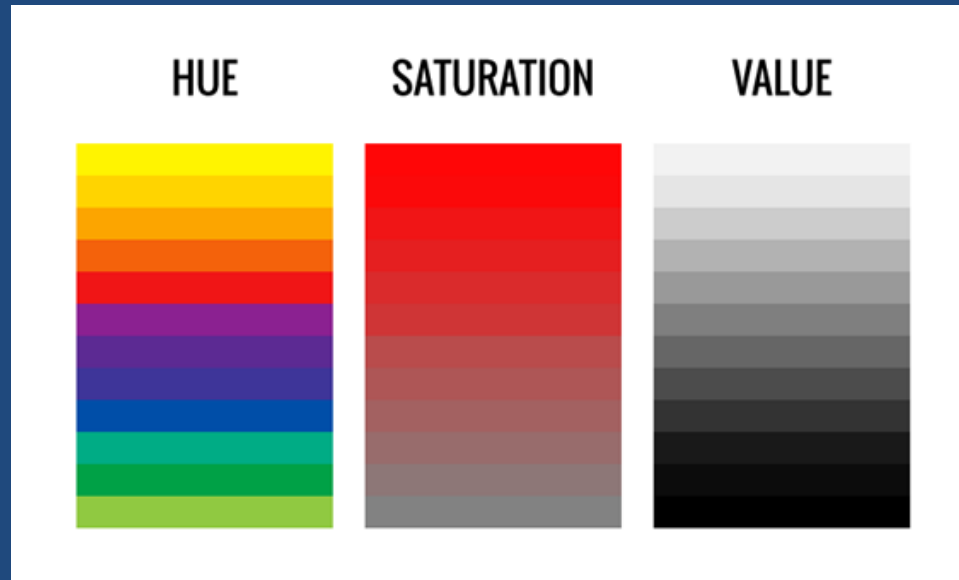
7 mm



OIP Fluorescence response is equal to the % area of the image (max 100%) displaying fluorescence.

Typical OIP image of hydrocarbon fluorescence using the UV light source.

# Software Color Analysis



Color defined by Hue, Saturation and Value (HSV)

Hue represents the color – 360degree color wheel.

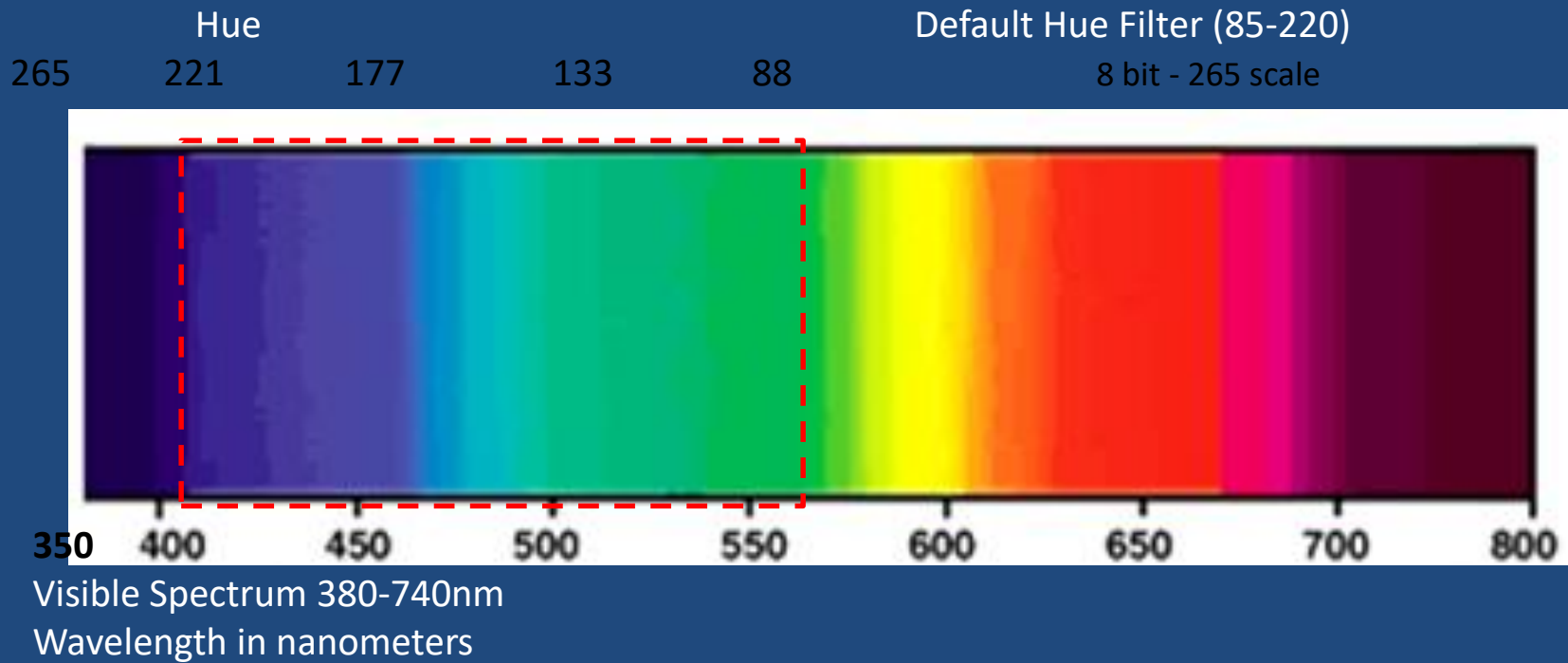
Saturation amount of color from full color to grey scale.

Faded color has lower color saturation. 0-100%

Value is the level of brightness. 0-100%

# Color Analysis

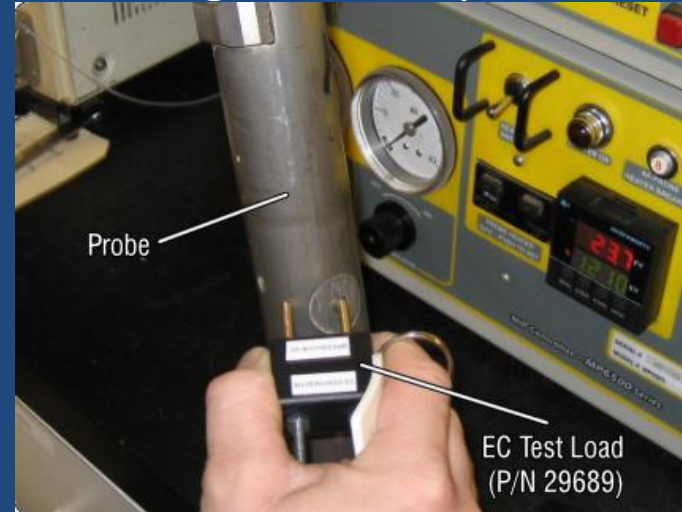
Approximate Conversion, Hue to Wavelength



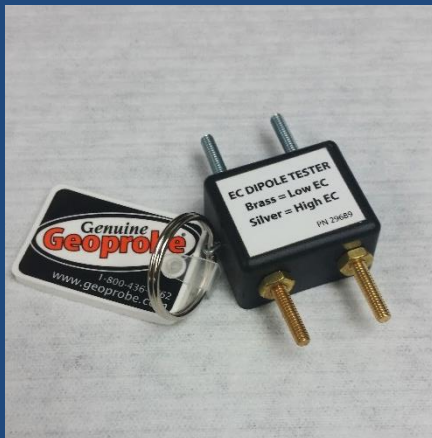
# OIP QA Testing

- QA Tests are performed before and after each log
- EC Dipole Test
- Optical Test

## Testing the EC Dipole



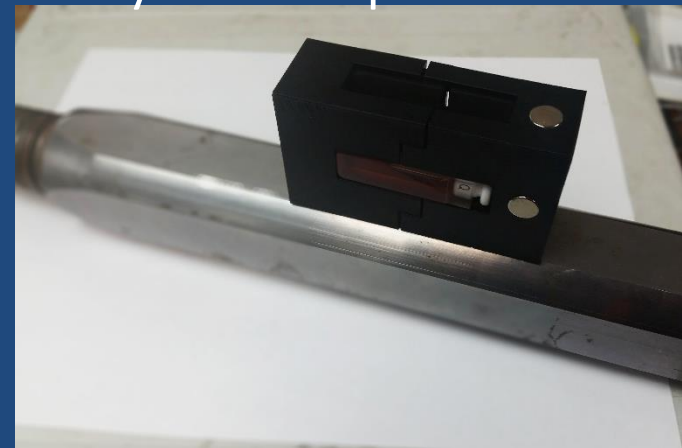
## EC Test Load



## OIP Cuvette Holder



## Testing the Optical Components and System Response



# Optical QA Test

- Image Assessment
  - Visible Target
- Background Assessment
  - Black Box
- Fluorescence Assessment
  - Diesel
  - Motor Oil



Visible Target



Black Box

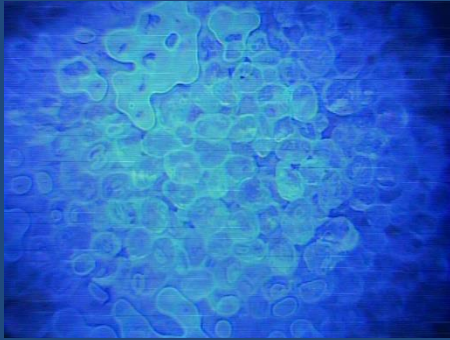


Diesel Fuel Cuvette

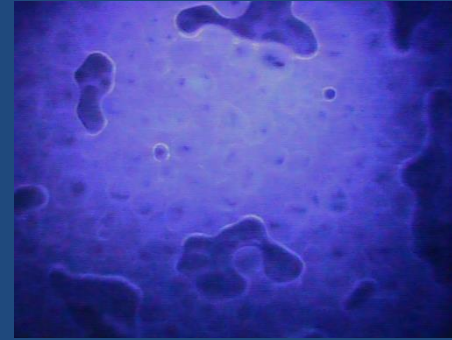


Motor Oil Cuvette

# Color Analysis



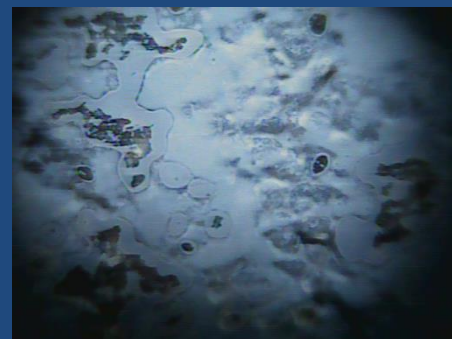
Motor Oil SAE 30



Diesel



Unleaded Gas



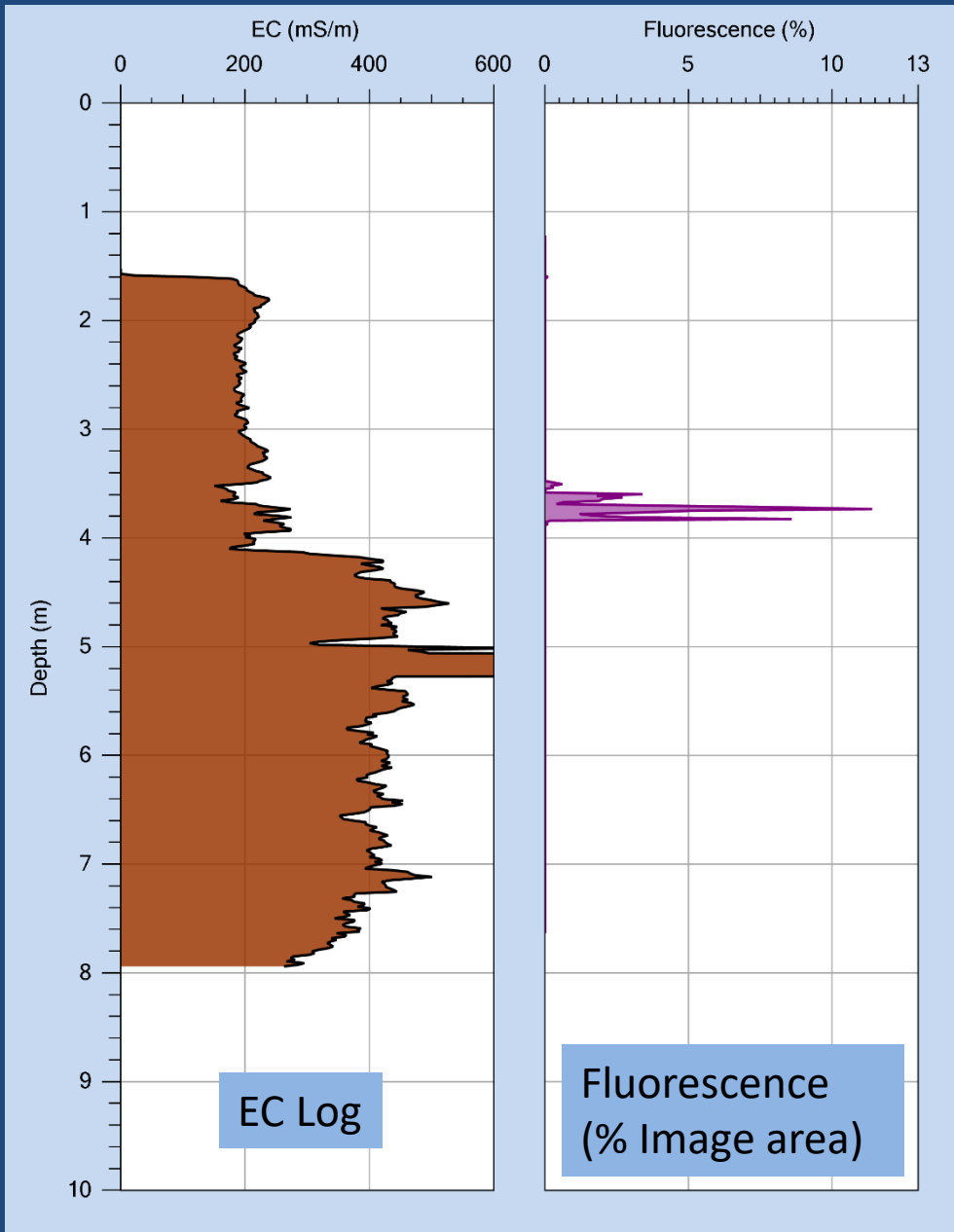
Crude Oil

Examples of some primary fuels and their fluorescent colors.  
Crude oil is a blue-green color that has low saturation  
We do not provide an indication in the log of fuel type.



# The OIP Log

- Images captured every 15mm (.05 ft.).
- Images are analyzed for fluorescence in real time.
- The average percent of the image area representing fuel fluorescence for every 0.05ft is recorded on the log.



3.0m  
0% detected



3.73m  
12% detected

# Field Site OIP Investigation Former Truck Stop in Michigan

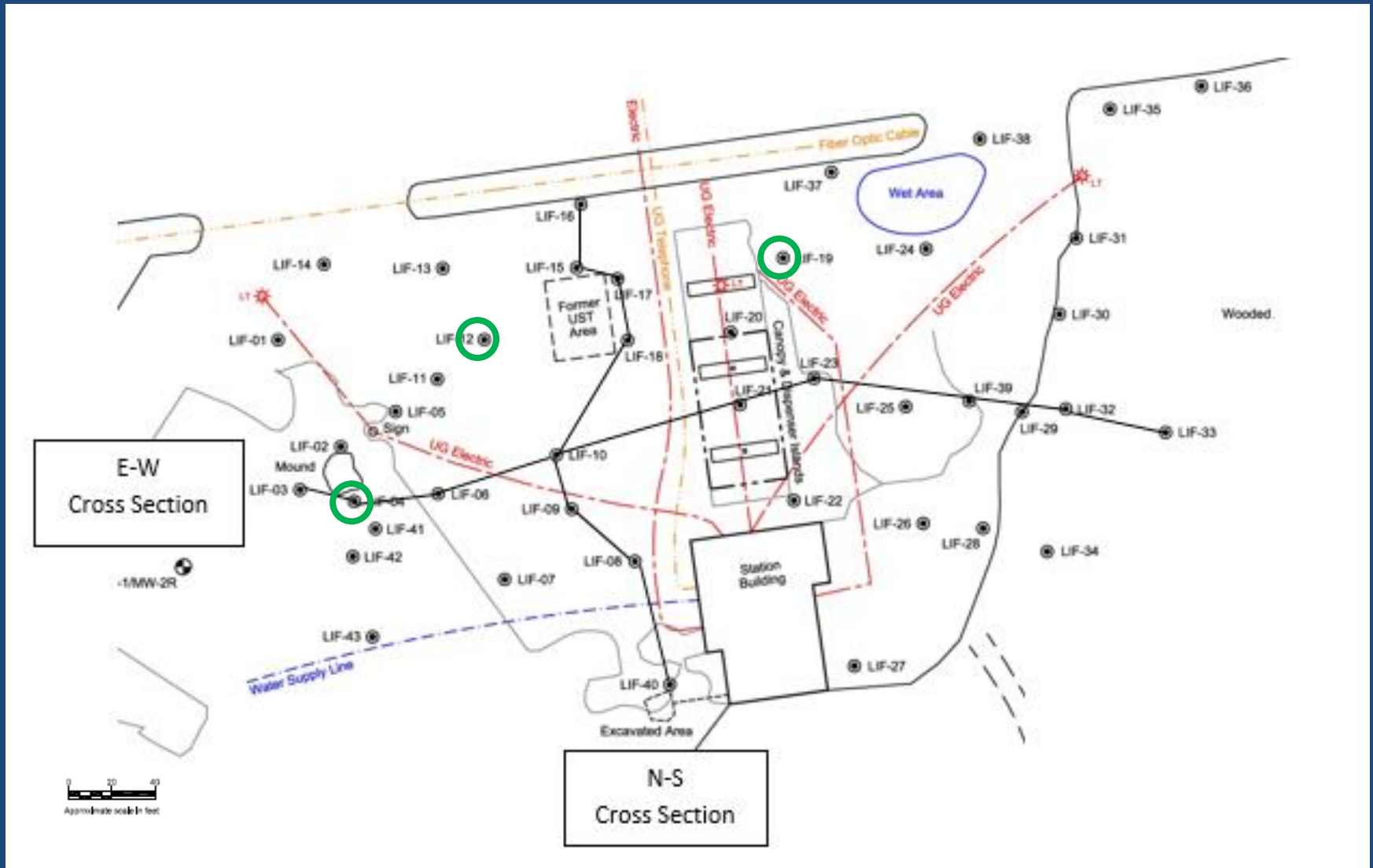


Site Plan: Map LNAPL with LIF – UVOST ~40 locations

We were invited to run OIP at these locations and completed 37 locations co-locating the UVOST logs within 1m.

# Field Site Map

## Former Truck Stop in Michigan



# Field Site Data

## Gasoline Fluorescence

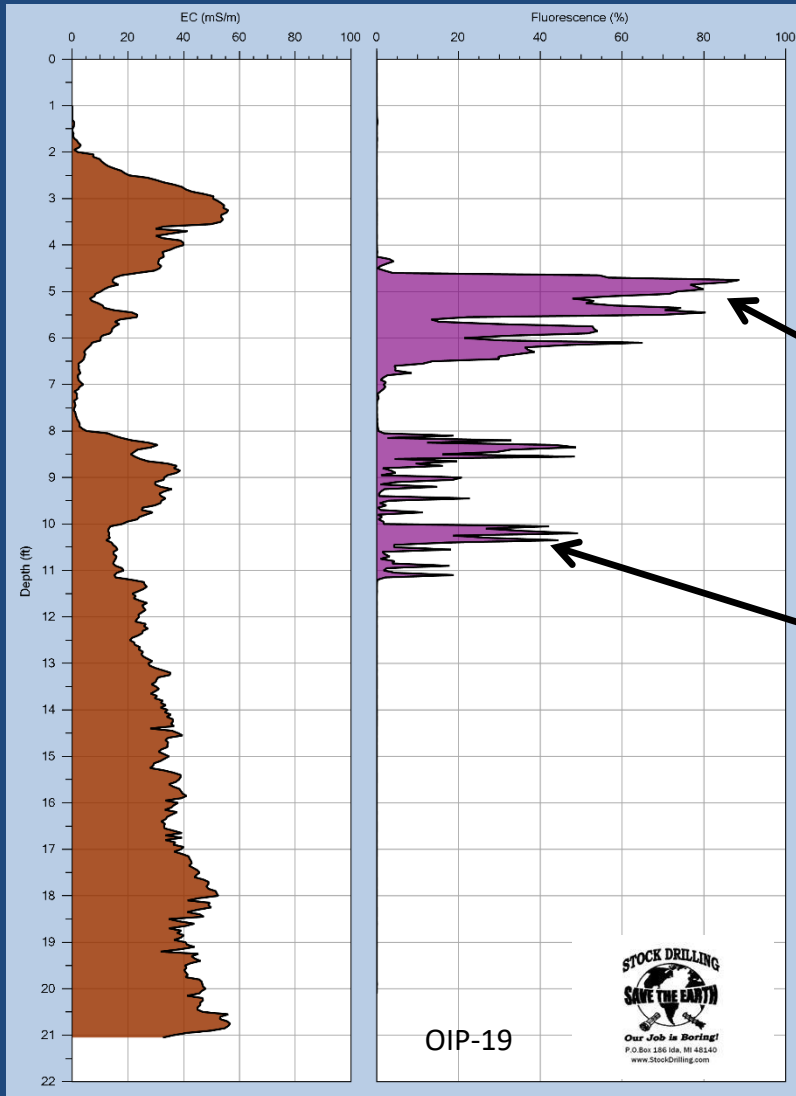


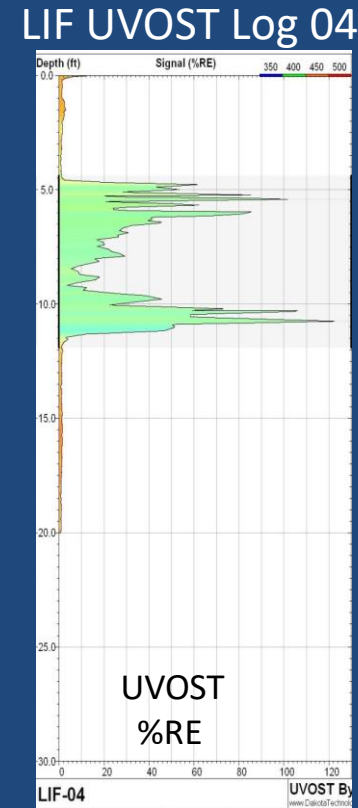
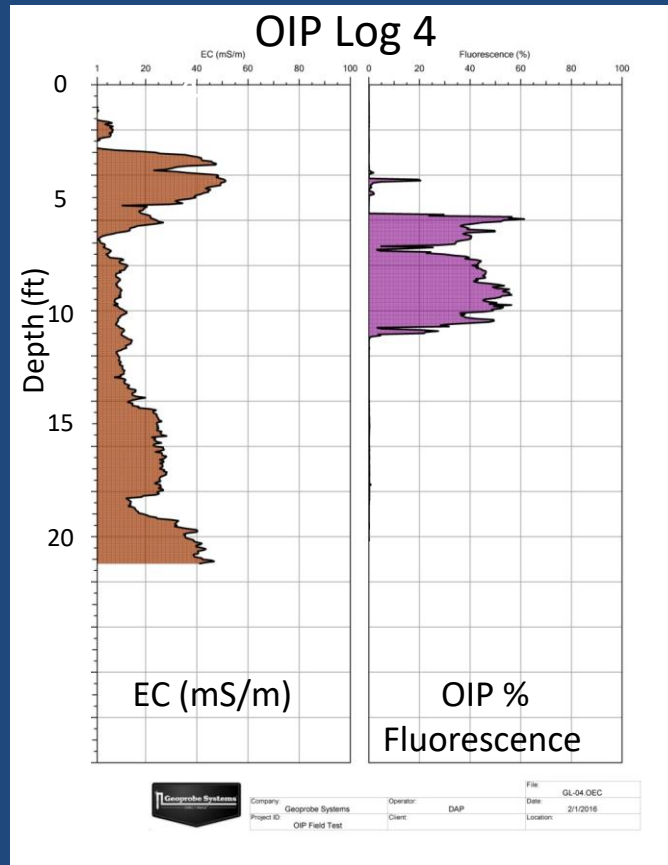
Image at  
5.0ft



Image at  
10.20ft

# Field Site Data

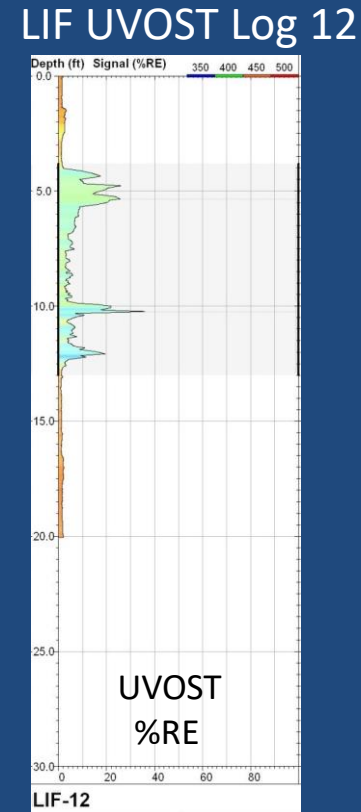
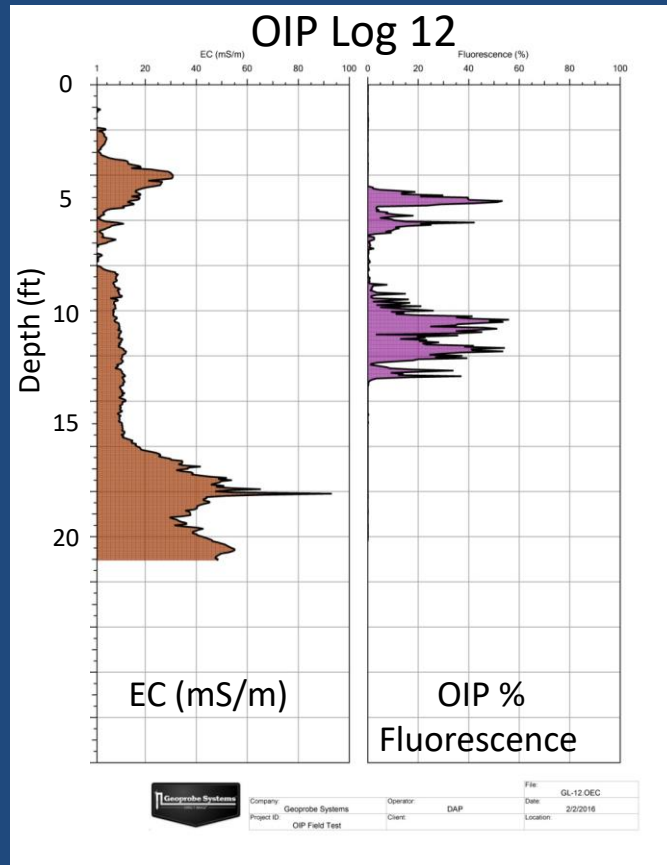
## OIP-EC to UVOST Comparison



The vertical distribution of fluorescence in both the OIP and UVOST logs are similar. The EC log indicates the LNAPL is present primarily in sandy materials at this location (lower EC).

# Field Site Data

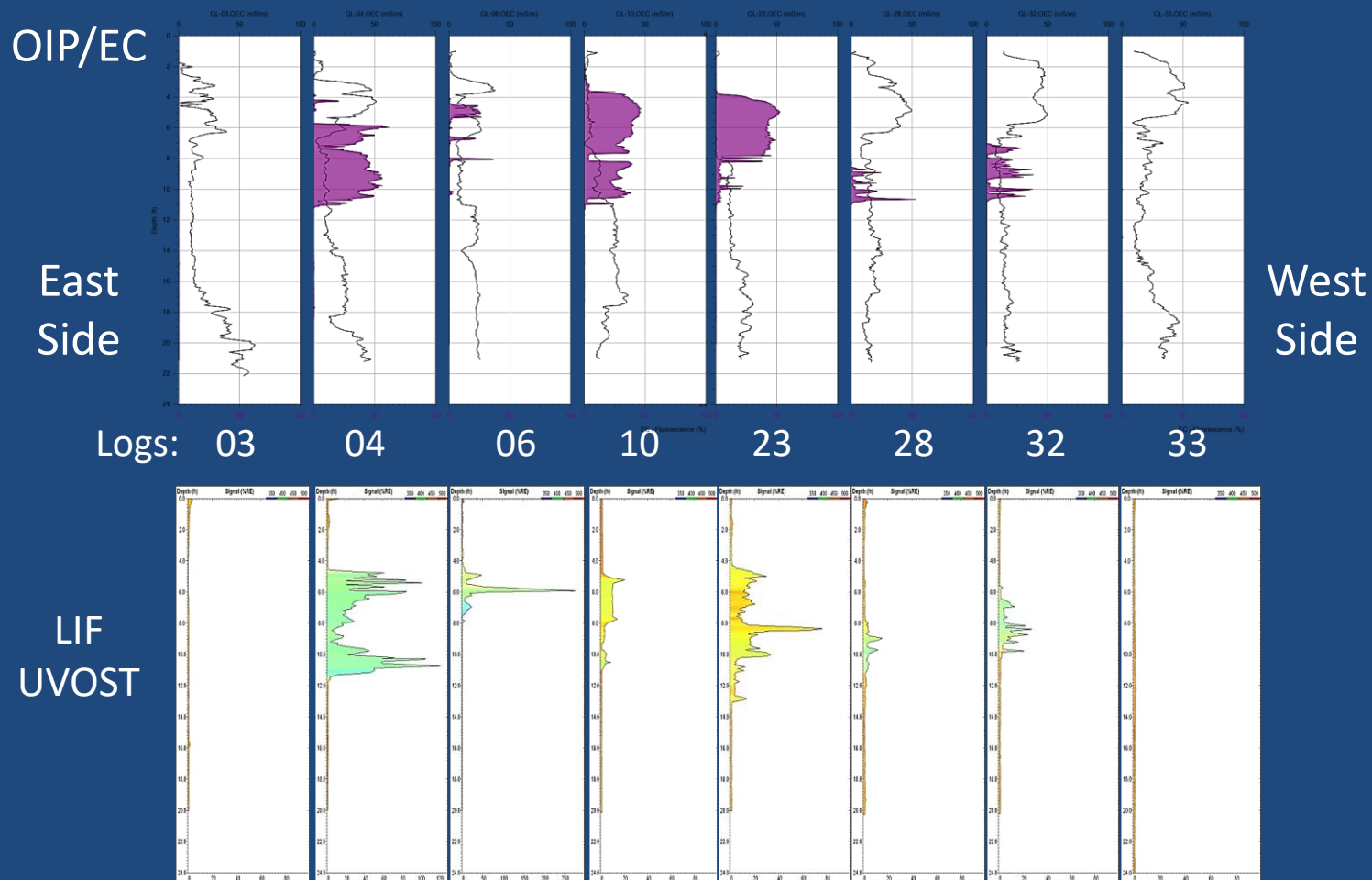
## OIP-EC to UVOST Comparison



The log 12 comparison also shows very similar vertical distribution of fluorescence in both the OIP and UVOST technologies.

# Field Site Data

## OIP/EC to UVOST Comparison



Both technologies display similar vertical and horizontal contaminant distribution.  
**Note:** Logs are displayed with equal spacing in the simplified cross sections, not equally spaced on the ground: not to scale.

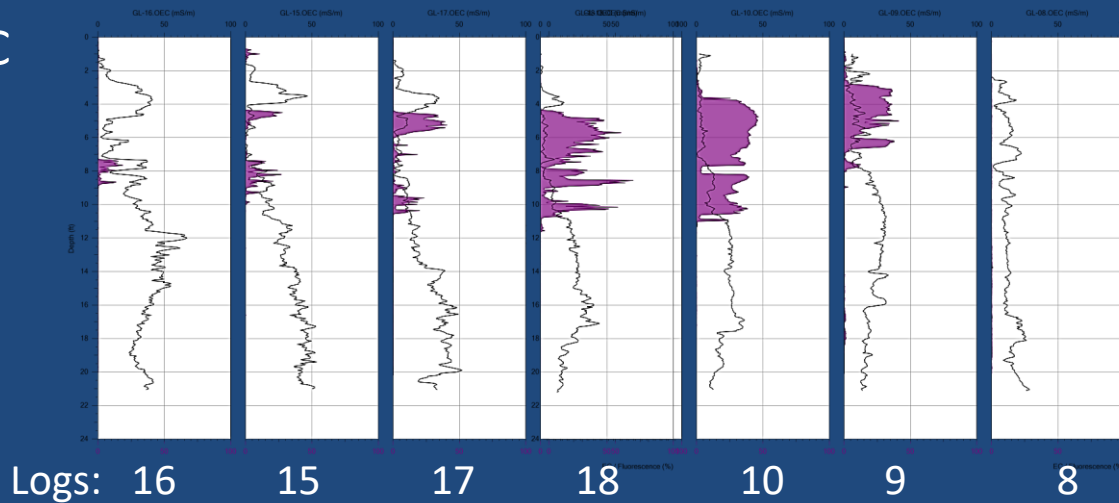
# Field Site Data

## OIP/EC to UVOST Comparison

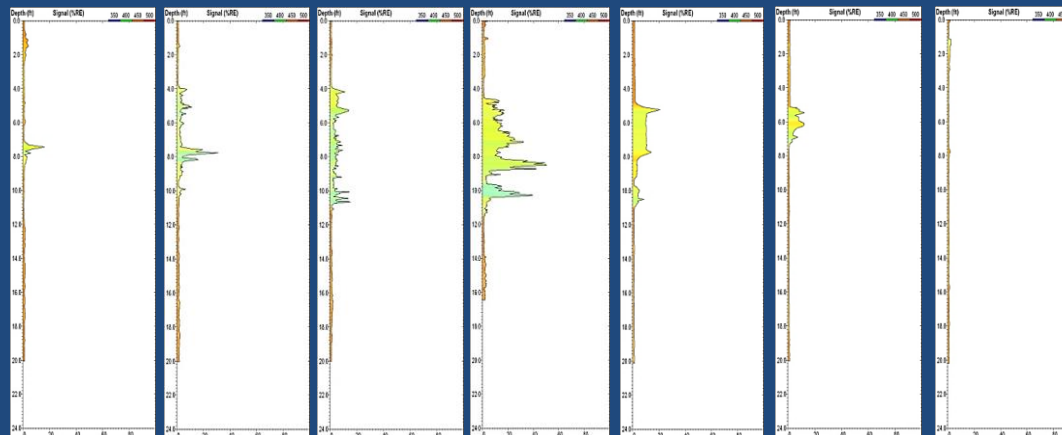
OIP/EC

North Side

South Side



LIF  
UVOST



Where UVOST is non-detect the OIP is non-detect. Where there is fuel to fluoresce both technologies detect it and with similar profiles.



# Field Site OIP Investigation

## Former Service Station

### Grand Junction, CO



# Field Site Map

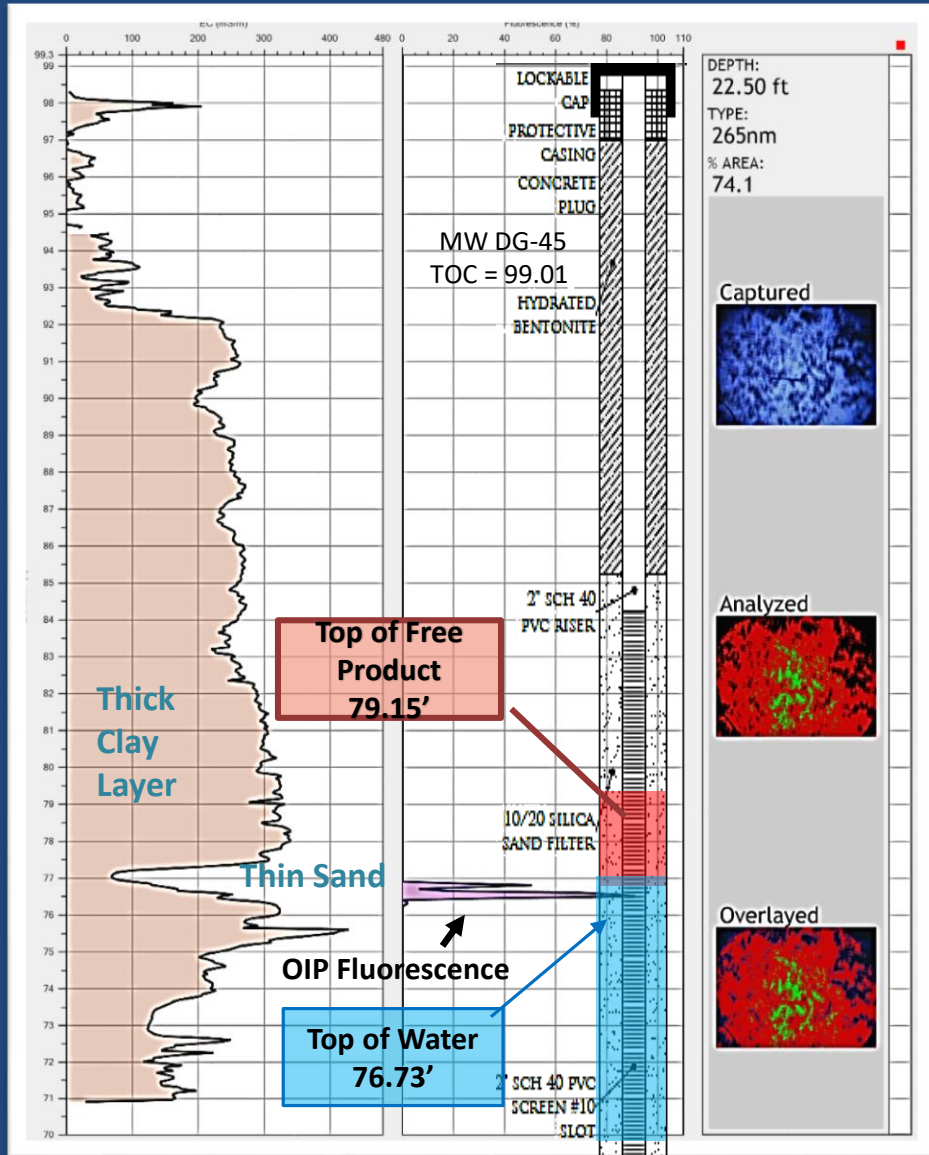
## Former Service Station

### Grand Junction, CO



Site map showing the "A" and "B" groups of OIP logs.  
The solid orange line = Cross Section.

# Field Site: Former Service Station Grand Junction, CO



OIP Log: OIP-A07

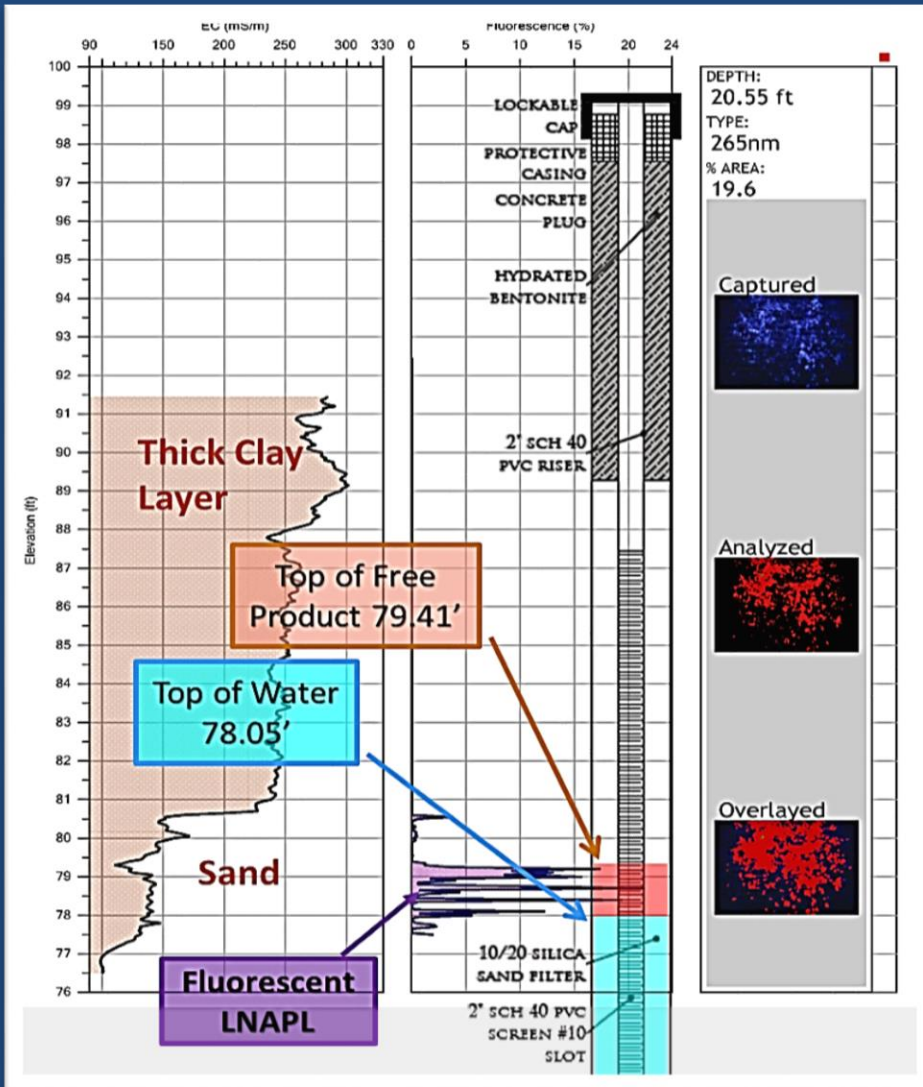
Elev. = 99.31'

(Based upon locale elevation marker = 100')

- This OIP log was 20ft from DG-45 well.
- MW-45 indicates 2.4ft of fuel on top of water.
- EC graph from OIP log indicates thick clay layer containing a narrow 6in sand seam.
- This sand seam is 2ft below the static water level.
- OIP fluorescence is only from this 6in sand seam.

# Field Site: Former Service Station Grand Junction, CO

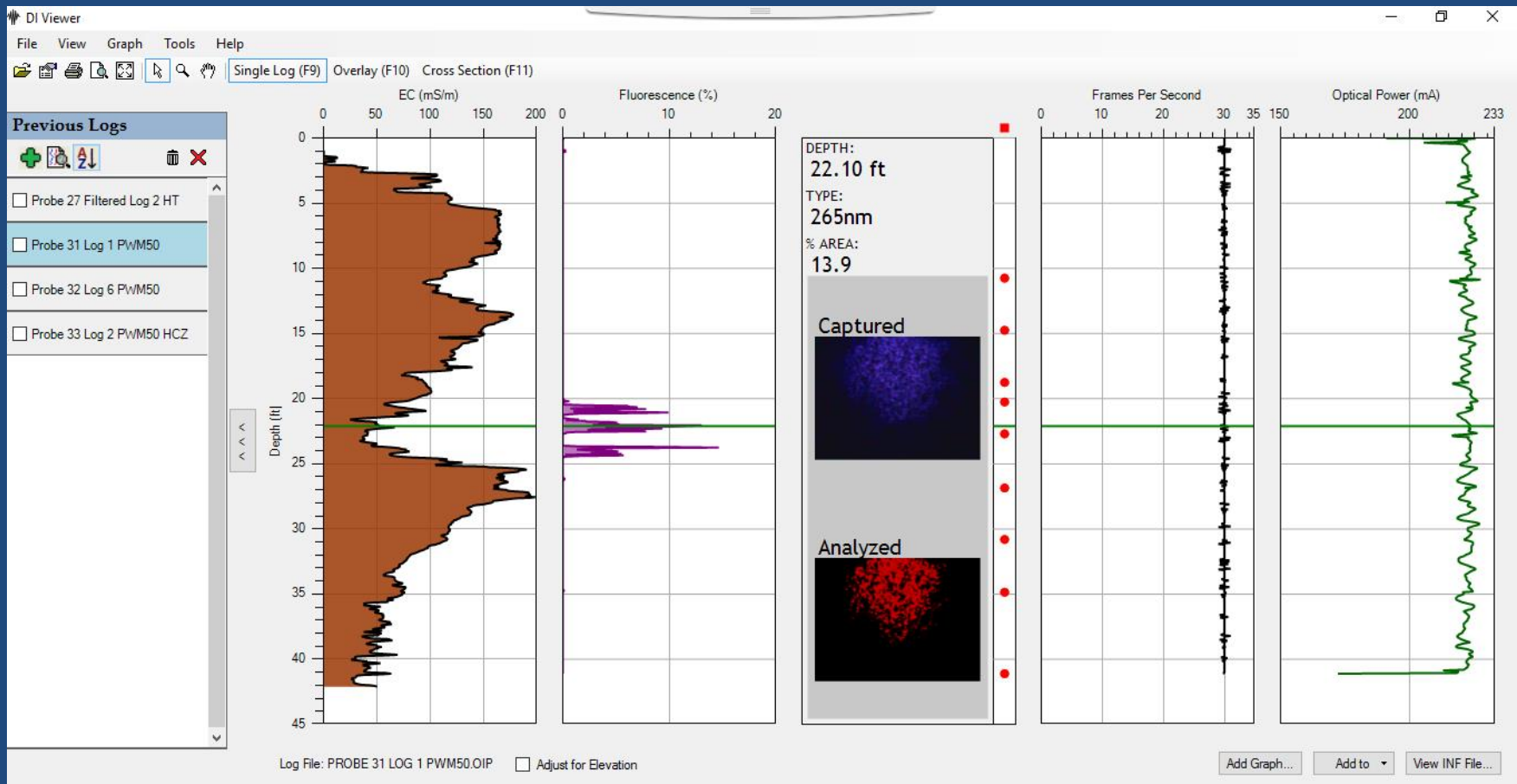
## OIP Log: OIP-B03



- This OIP log was 10ft from MW DG-28.
- MW DG-28 indicates 1.4ft of fuel on top of water.
- EC graph from OIP log indicates a clay layer overlying a wider sandy zone.
- The static water level is within the sand zone.
- OIP fluorescence is representative of the product seen in the MW.



# Viewing OIP Logs



OIP Logs can be opened using Geoprobe's DI Viewer V. 3.0 software. The user can view OIP optical images at any selected interval in the log. The DI Viewer also displays log cross sections and overlays.

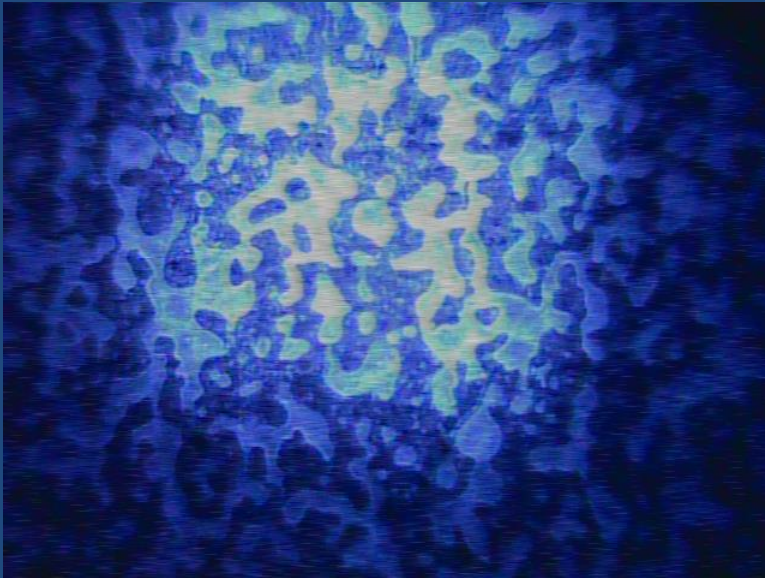
# Viewing OIP Logs

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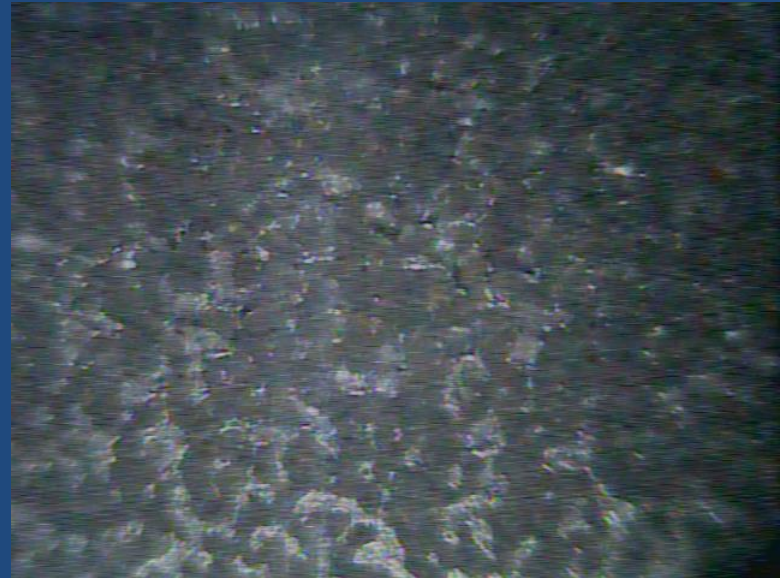
- The green depth line indicates the depth and corresponding saved images from that depth in the file.
- Saved still images (both UV and visible) are indicated by the red dots on the right side panel of the Image display graph and can be viewed by clicking on the red dots.
- Create log overlays and cross sections.
- See a demonstration of OIP log viewing under the video tab at:  
<http://geoprobe.com/oip-optical-image-profiler>

Obtain a copy of DI Viewer software at:  
<http://geoprobe.com/downloads/direct-image-viewer-31>

# OIP Visible Images



Fluorescence images of  
fuel globules in soil.



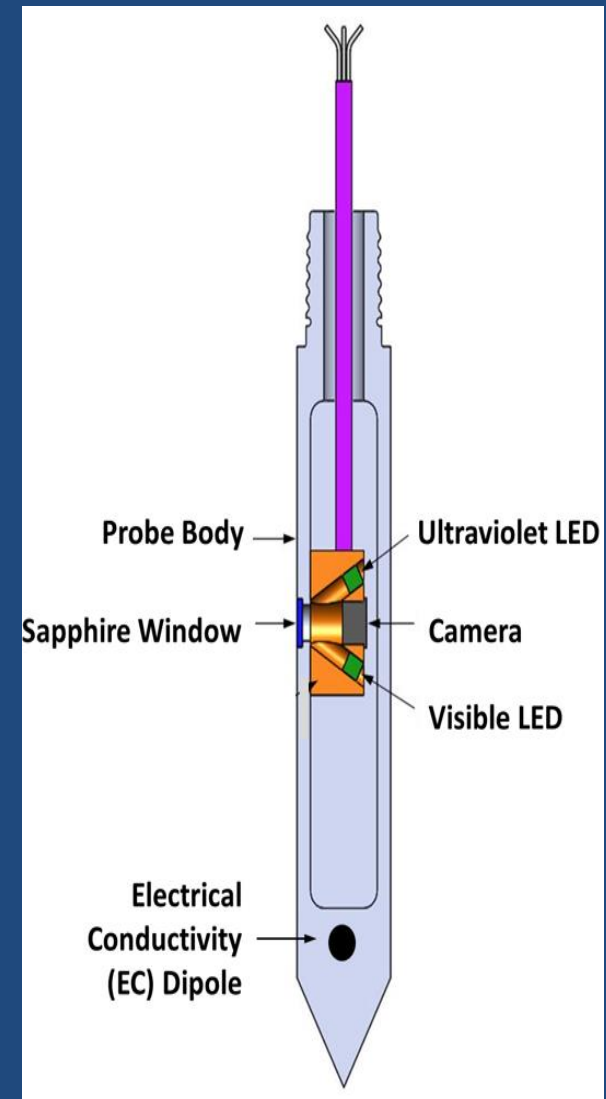
Visible image of  
Sand matrix.

Visible images of the soil may be obtained by stopping the probe and switching to the visible light source. The above images are of the same soil made with the two different light sources. Visible light images are useful for assessing the soil type, color, grain size and can be a confirmation of hydrocarbon product.



# OIP Summary

- Capable of capturing UV induced fluorescence and visible light images of soil
- Provides % Area fluorescence log of LNAPL hydrocarbons with depth
- Image analysis to identify fuel fluorescence in images
- Images can show spatial distribution of hydrocarbons in the soil matrix
- Images are saved and can be visually examined after the log has been completed
- Typically, neither dissolved phase hydrocarbons nor chlorinated VOC DNAPLS are detectable



# OIP Summary

- Visible light images of the soil may be captured and examined to identify soil texture and color
- EC logs help identify soil types/lithology in many settings (but not always)
- Fluorescence logs in cross section help to define LNAPL distribution in the subsurface
- Combine Fluorescence logs and EC logs to define migration pathways
- May be percussion driven using GH60 series (or smaller) hydraulic hammers
- For logging only in soils and unconsolidated formations, not for advancement into competent rock



# Acknowledgements

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