Field Tests with the OIP-Green DP Photo-Logging System for Detection of Coal Tars

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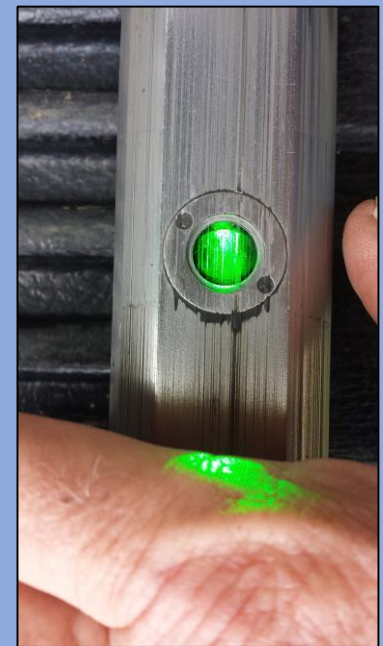Rick Bean[2], Ian Smith[2], Gary Richards[3], and Jonathan Stevenson[3]
1)Geoprobe Systems, Salina, KS 2)GSI Engineering, Wichita, KS 3)Kansas Dept. Health & Env., Topeka, KS
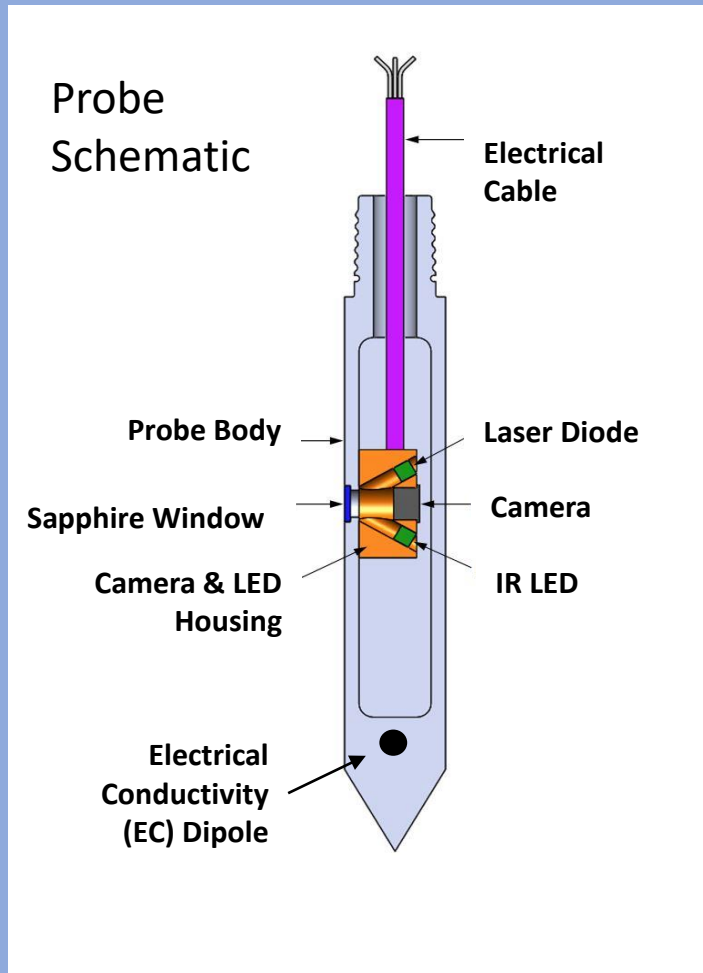* mccallw@Geoprobe.com

The Wellington, KS Manufactured Gas Plant (MGP) under construction (circa 1886) gas holder in foreground

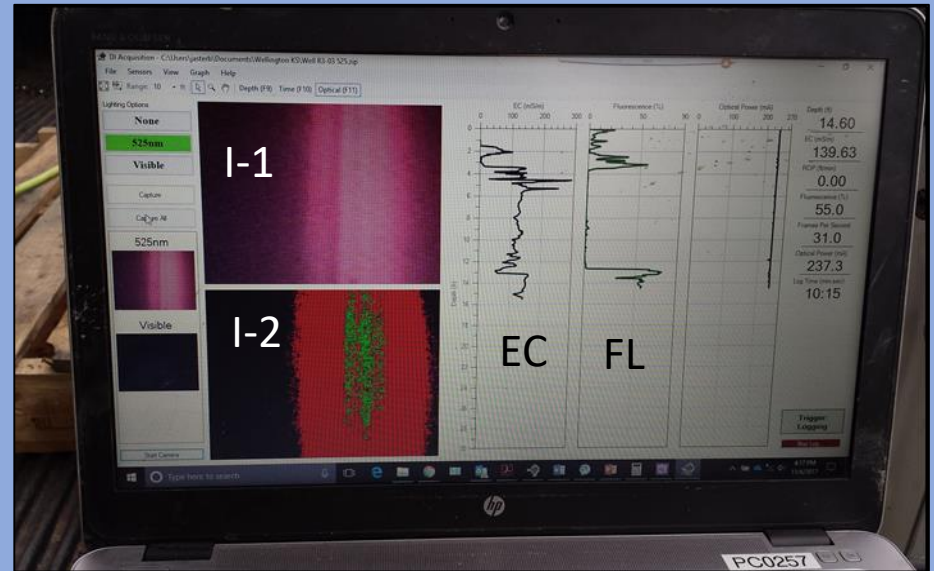Optical Image Profiler (OIP) with Green (520nm) laser diode

This presentation is based on a poster presented at the Battelle conference in April, 2018.

The OIP-G Probe

Probe Schematic

- **Electrical Cable**
- **Probe Body**
- **Laser Diode**
- **Sapphire Window**
- **Camera**
- **Camera & LED Housing**
- **IR LED**
- **Electrical Conductivity (EC) Dipole**

- The green laser diode (520nm) illuminates the formation outside of the sapphire window while logging.
- Nonaqueous phase contaminants like coal tar, creosote and some heavy fuels will fluoresce in the red wavelength range.
- The CMOS* camera captures images at 30 frames per second (fps) for analysis by the program software to identify fluorescence.
- The infrared (IR) light emitting diode (LED) is used at desired depths to observe formation texture and grain size.
- The EC dipole provides a log of bulk formation electrical conductivity which may help define lithology.

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* CMOS: complimentary metal oxide semiconductor

Instrumentation & Images of Coal Tar Fluorescence

A) laptop computer with Acquisition software
B) OIP Interface (OIP6100)
C) Field Instrument (FI6000)

Portable generator (not shown) powers the system

The logs of fluorescence (FL) and electrical conductivity (EC) are viewed live time along with the images of fluorescence as the probe is advanced.

Images of in-situ fluorescence (I-1) are displayed live time along with the software analysis (I-2) of the image. A 2-stage digital filter is used to define the percent area exhibiting fluorescence.

OIP Logging in the Field

- A direct push machine is used to advance the probe into the subsurface at 2 to 4ft/min.
- A trunkline, pre-strung through the drive rods, connects the downhole probe to the up-hole electronics.
- Rods are added incrementally to the tool string as the probe is advanced.
- A still image of fluorescence and IR image of the formation is automatically captured at each rod change.

Use of drive cushion recommended for OIP logging.

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System Quality Assurance Testing
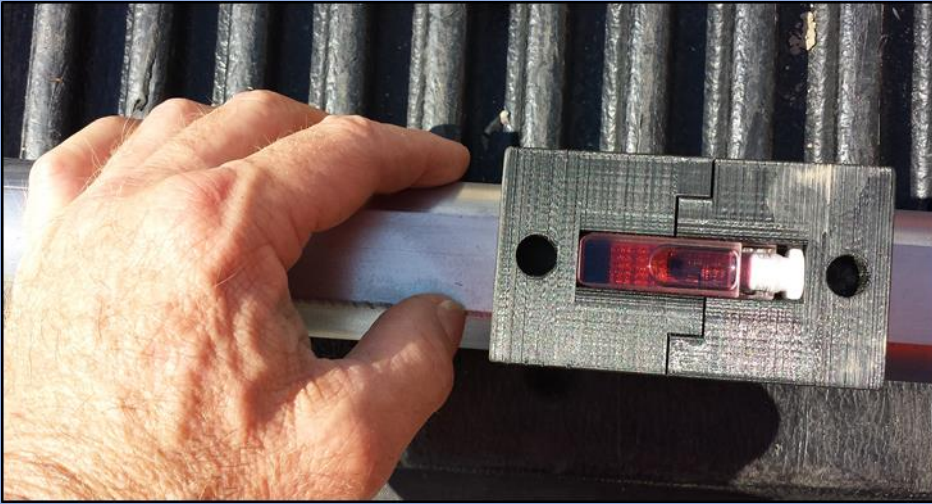
Cuvettes of know standards, typically diesel fuel and 30wt motor oil, are run before and after each log to verify performance of the optical system.

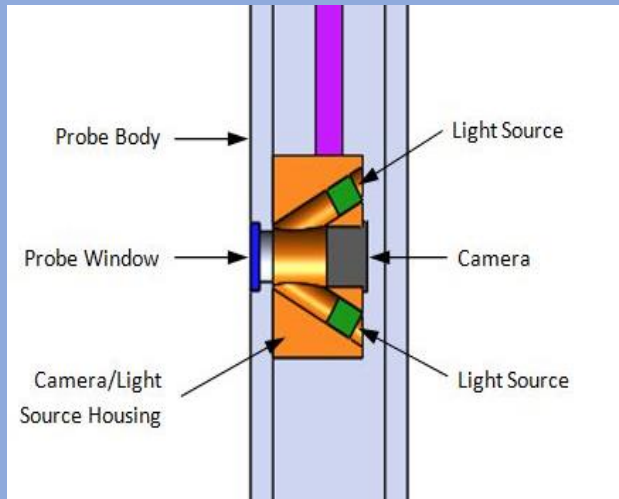Cuvettes of site specific products may be tested.

A "black box" test is run to verify the optical cavity and window are clean and free of potential contaminants.

A visual standard is run to verify accurate color and camera focus.

A test jig with two know conductance values is used to test and verify performance of the EC dipole and hardware before and after each log.

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Basics of Fluorescence Detection & Image Analysis

The OIP software uses a 2-stage digital filter (patent pending) to analyze the fluorescent light and determine if it falls in the correct color (hue) range above a specified brightness (value) level to be defined as fluorescence for the product under investigation. Coal tars and creosote typically fluoresce in the red-orange wavelength range.

The green laser diode illuminates the formation outside the sapphire window. The CMOS camera captures images of induced fluorescence in the visible light range. The camera is the detector. One image is saved to file for every 0.05ft (~ 15mm) of log depth.
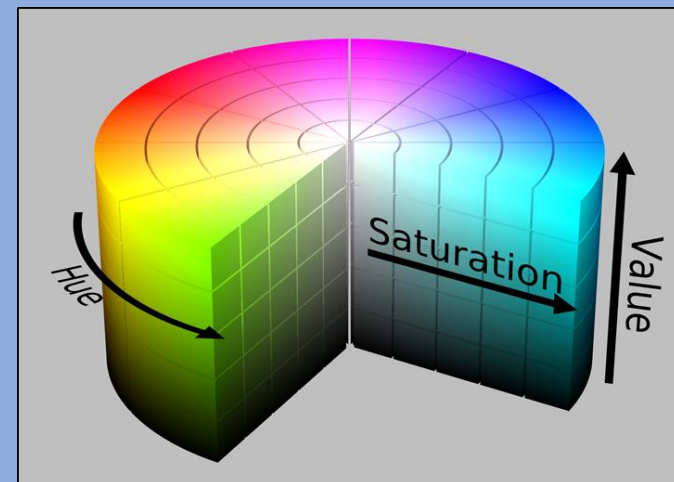
Hue, Saturation, Value (HSV) color space
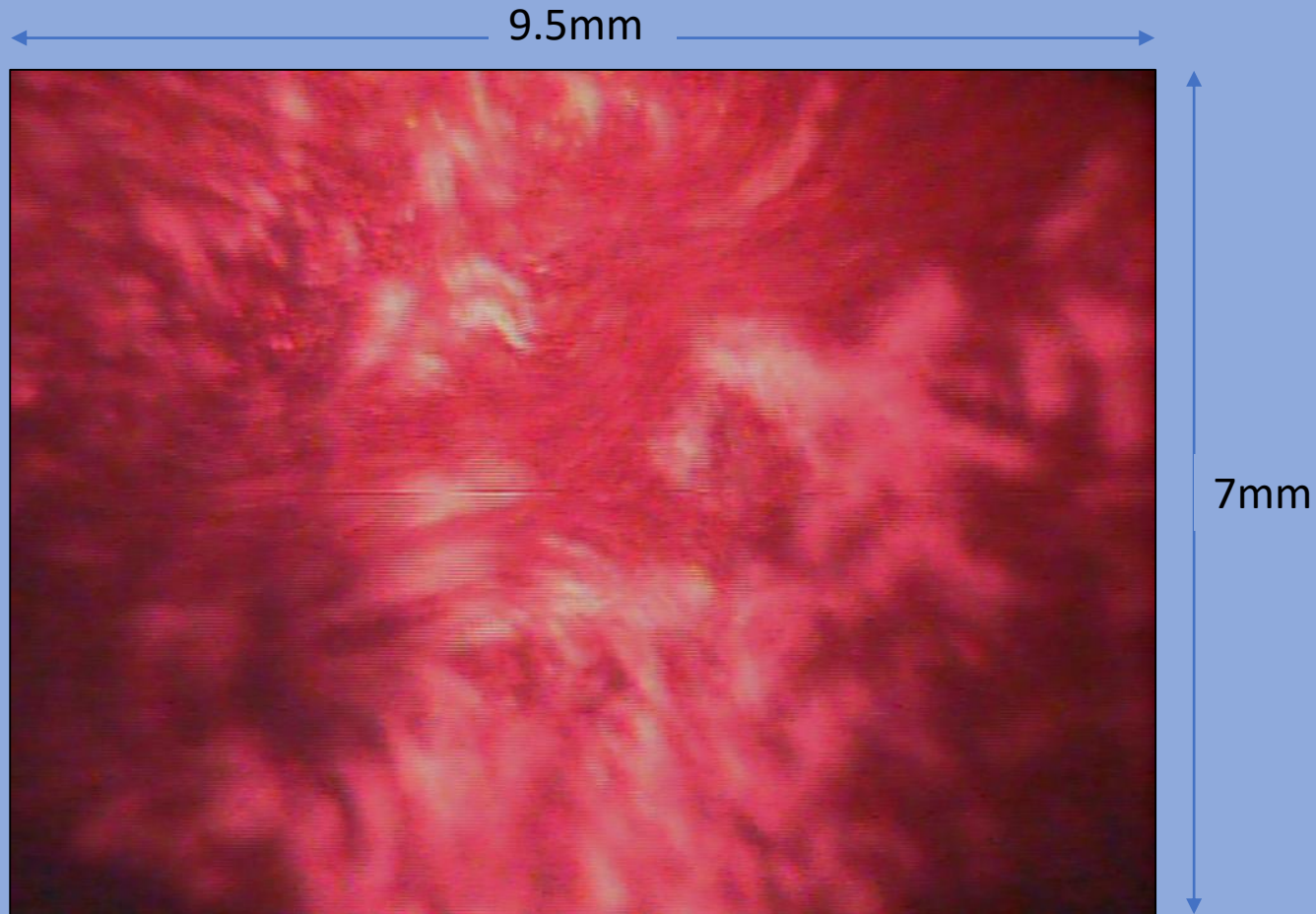
Image Specifications
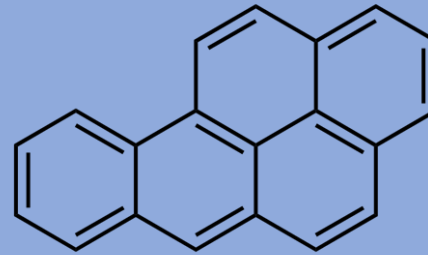
9.5mm

Image Resolution is approx. 0.3 megapixels

(640 X 480 pixels)

7mm

OIP-G image of coal tar fluorescence under the 520nm green laser diode at Wellington, KS. Location 23, 9.65 ft depth. 76.8% Area of fluorescence. Soil = 2724 mg/kg total PAH.

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What is Detected?
Polynuclear Aromatic Hydrocarbons

Chemical Structure of Benzo(a)Pyrene

Benzo(a)Pyrene is a polynuclear aromatic hydrocarbon (PAH) that is present in coal tar. It is a carcinogen. Coal tars contain many other PAHs including naphthalene, anthracene and pyrene. In all 14 PAHs are on the standard EPA analytical list. Many PAHs fluoresce under the green 520nm wavelength light.

Creosote is a wood preservative consisting of 75% to 90% PAHs along with some phenolic compounds and small amounts of other organic chemicals. The OIP-G system may be used to detect nonaqueous phase creosote.

See also: https://en.wikipedia.org/wiki/Benzo(a)pyrene
https://ec.europa.eu/jrc/sites/jrcsh/files/Factsheet%20PAH_0.pdf
https://en.wikipedia.org/wiki/Creosote

Viewing Software & OIP-G Log Interpretation
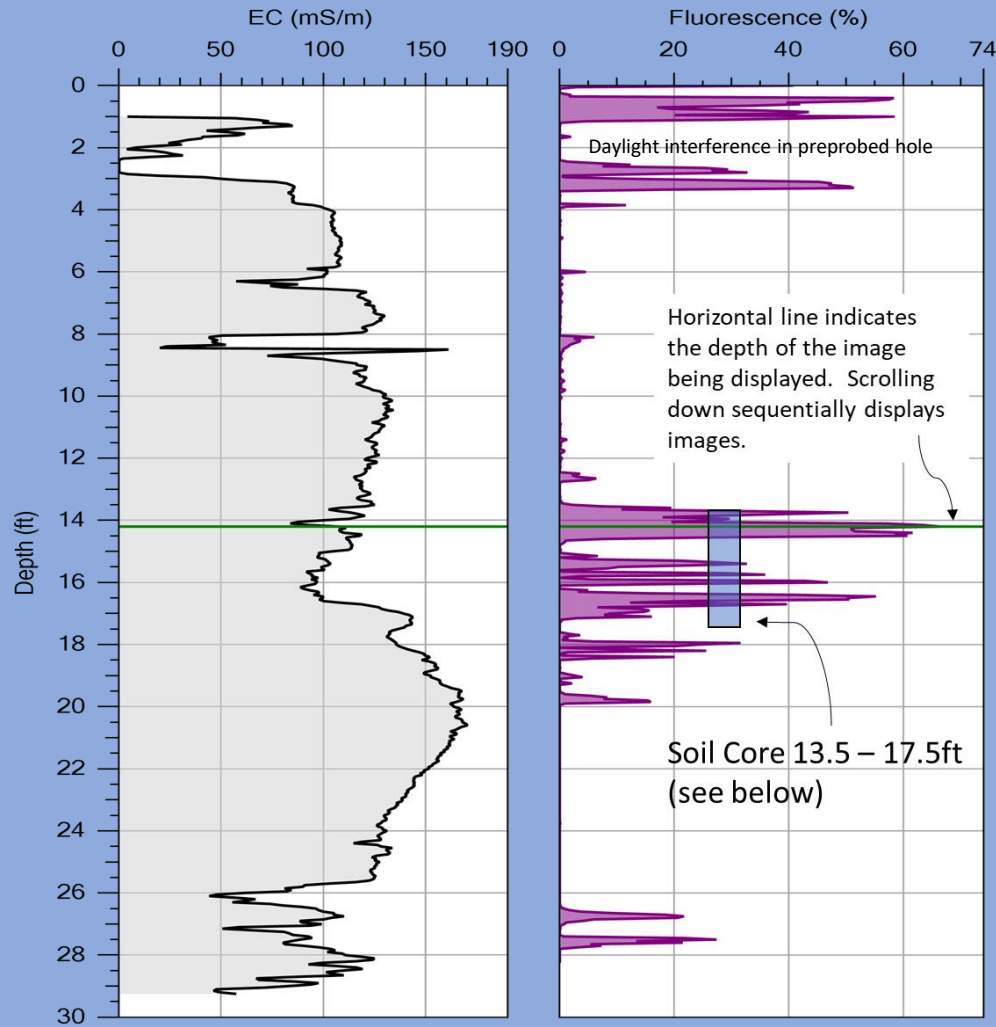
Soil cores confirmed that higher EC correlated with silty clays at this site while lower EC (8-9ft, 15-17ft and 25-28ft) indicated the presence of sand and/or gravel, often in a fine grained matrix.

Elevated fluorescence readings indicate the presence of coal tar products. Daylight "interference" occurred near surface in pre-probed holes.
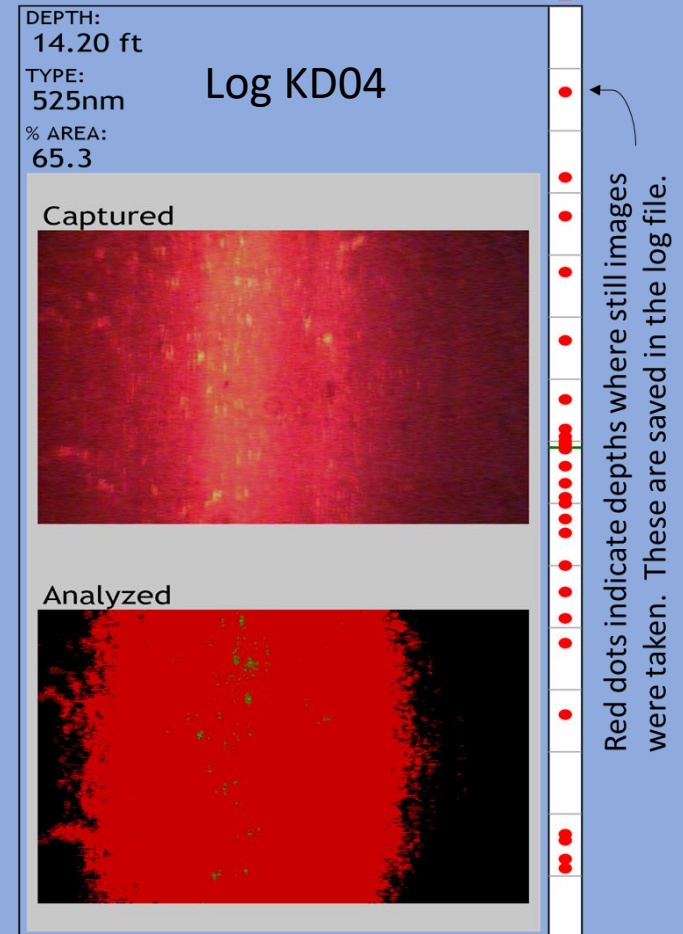
The image of fluorescence (upper) is the insitu image captured during logging. The analyzed image (lower) shows the area of image exhibiting fluorescence based on the software digital filter parameters

Soil Core: 13.5-17.5ft: KD04 Location

Black fluid drained from soil core in the field.

Visible coal tar fluid remains in pores of the core after fluid drained. Sand and gravel in fine matrix at about 15-16ft below grade. Confirms EC and fluorescence log and image. Lab Analysis of soil sample = 6015mg/kg total PAH.

Transition from coal tar saturated coarser grained material (right) to fine grained, dark green silt-clay (left) from about 17 to 17.5ft below grade. Confirms EC and fluorescence logs.

Coal tar DNAPL separated from water after sitting over night.

False Positive Interferences

Interferences

Some natural minerals (e.g. calcite) and natural organics as well as man-made materials (e.g. paper) fluoresce. At the site in Wellington we discovered that caliche nodules and limestone clasts in the formation as well as limestone gravel fill exhibited fluorescence in the same wavelength range as the coal tars under the green laser diode. Targeted sampling with the DT22 coring system quickly confirmed if the observed fluorescence was due to the presence of calcite bearing minerals or coal tar contamination.

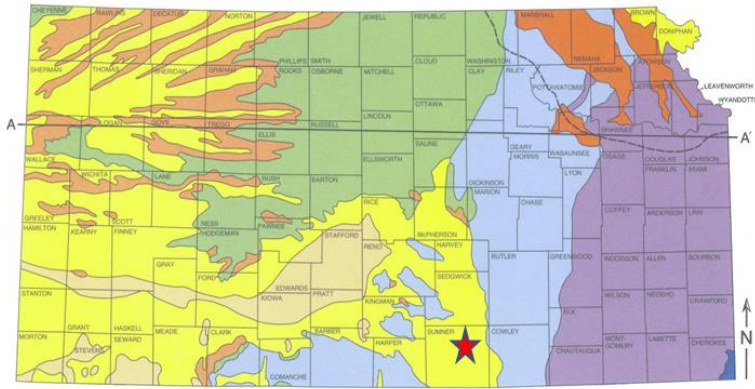DT22 soil core from location exhibiting false positive response due to limestone clasts and caliche nodules.
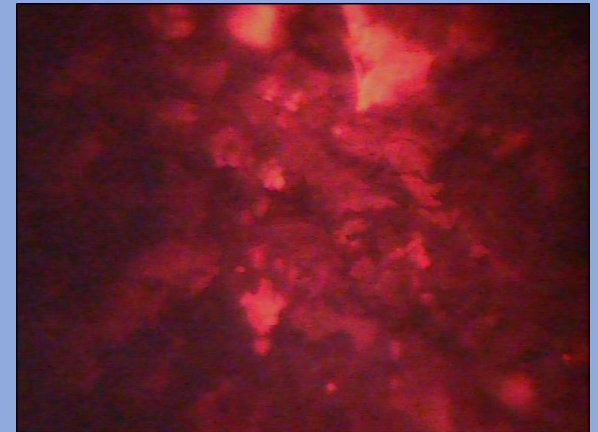
Fluorescence observed from the sample placed on the OIP window, up to 40% area of fluorescence was observed.

Wellington, KS fMGP Facility & Location

Site Location Maps

Generalized Geologic Map of Kansas

Under Construction circa 1886

Wellington is in Sumner County , Kansas. The local stream deposits are underlain by Permian Age (blue) Ninnescah shale.
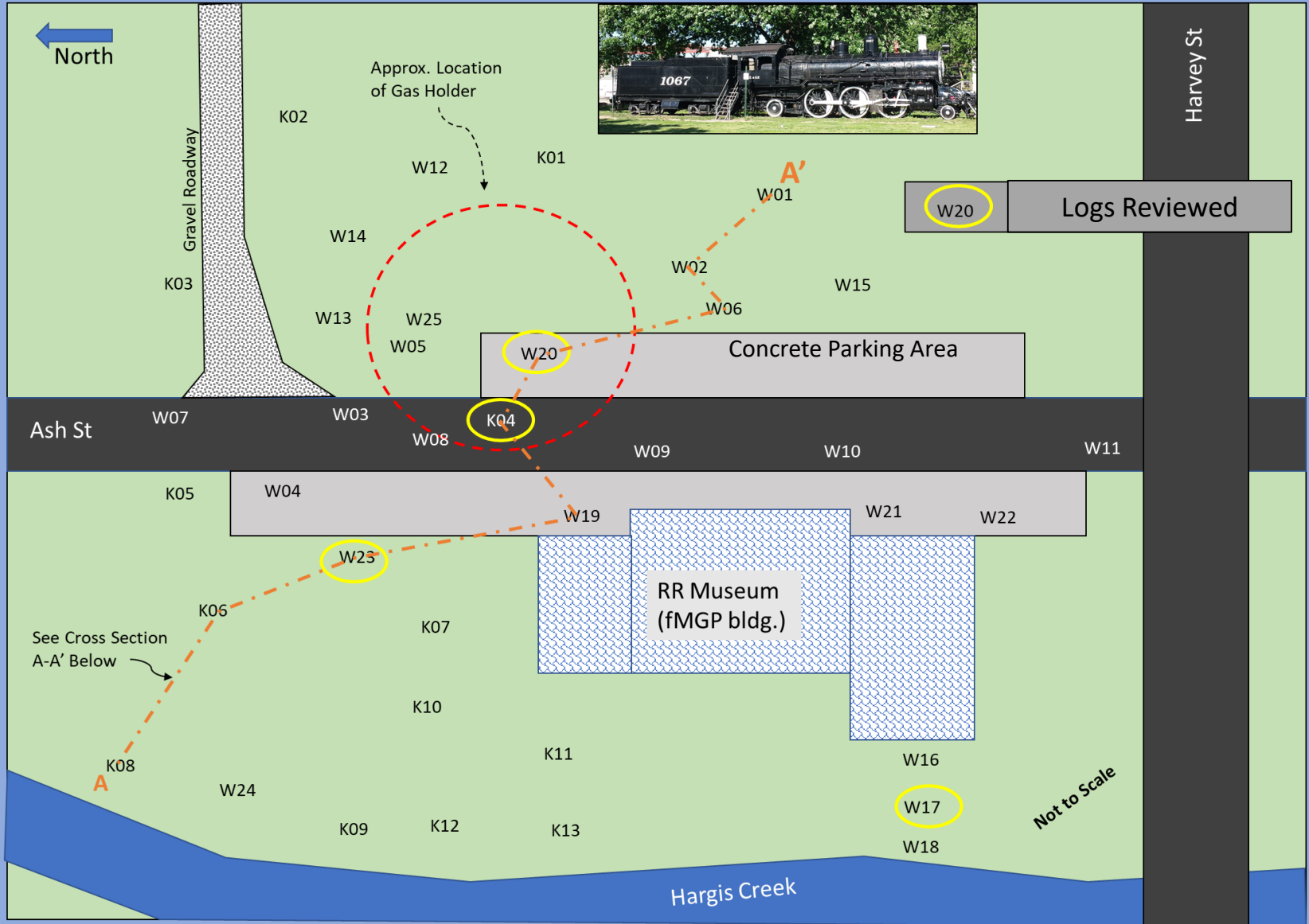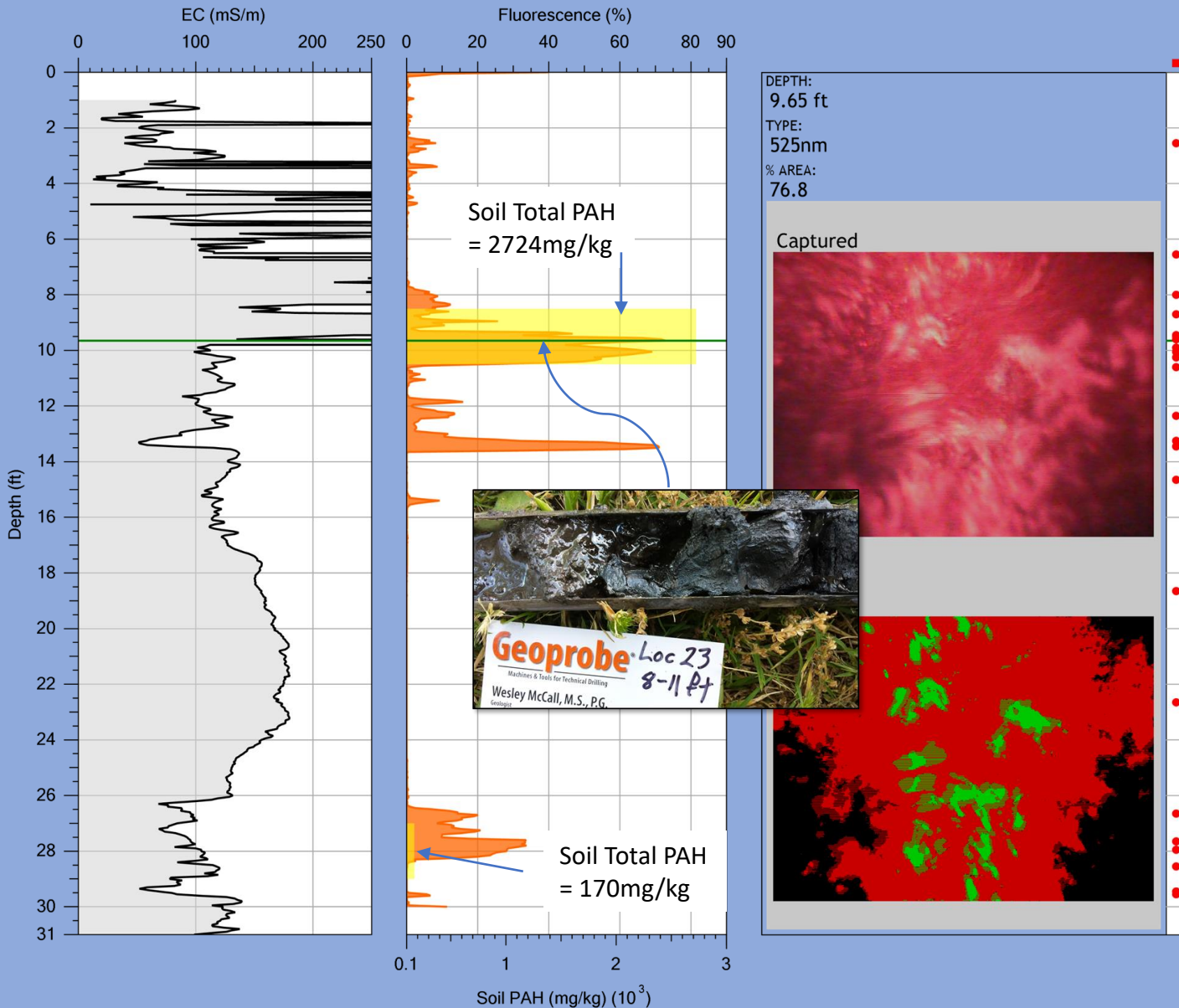
Today the building is used as a railroad museum visited by school children and RR buffs.

Site Sketch Map with Log Locations

North

Gravel Roadway

Approx. Location of Gas Holder

1067

Logs Reviewed

W20

K02

W12

K01

W01

W02

W06

W14

W15

K03

W13

W25

W05

W20

Concrete Parking Area

A'

W07

W03

W08

K04

W09

W10

W11

Ash St

K05

W04

W19

W21

W22

W23

RR Museum (fMGP bldg.)

K06

K07

See Cross Section A-A' Below

K10

K08

A

W24

K11

W16

W17

Not to Scale

K09

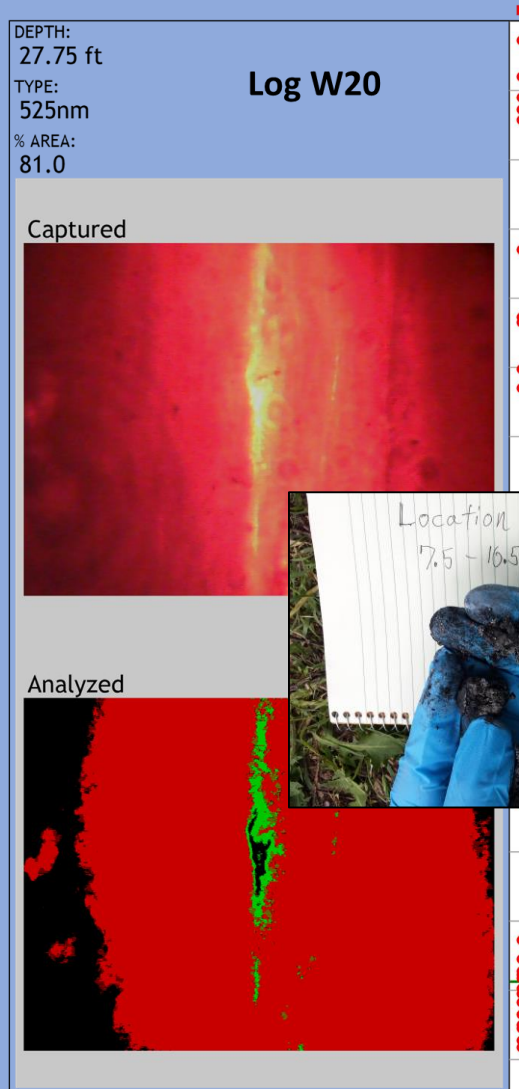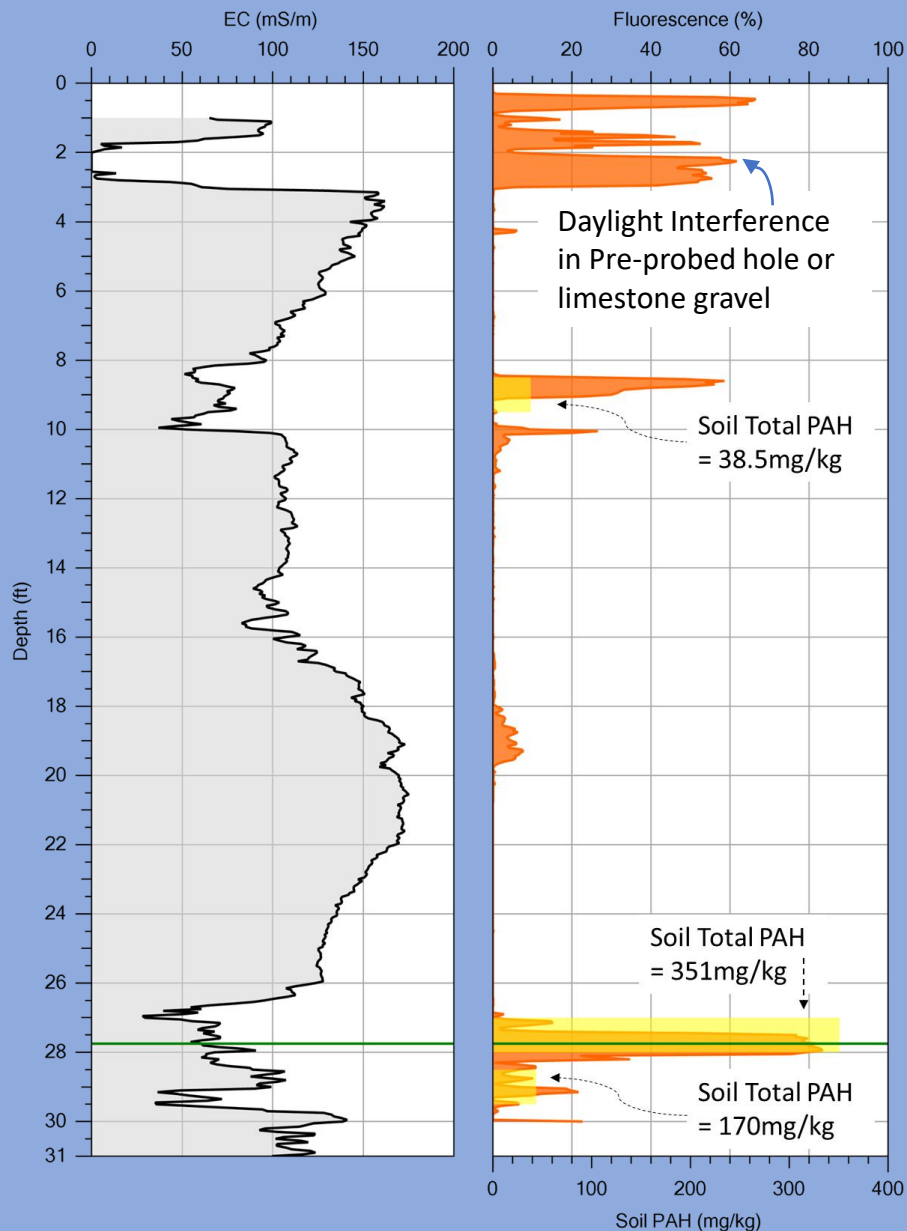K12

K13

W18

Hargis Creek

Harvey St

Log 23 and Sample Results

Soil samples from two depth intervals were collected and analyzed to verify the OIP fluorescence response. A photo of the 8-11ft sample shows black tarry gooh observed in the fluorescence image.
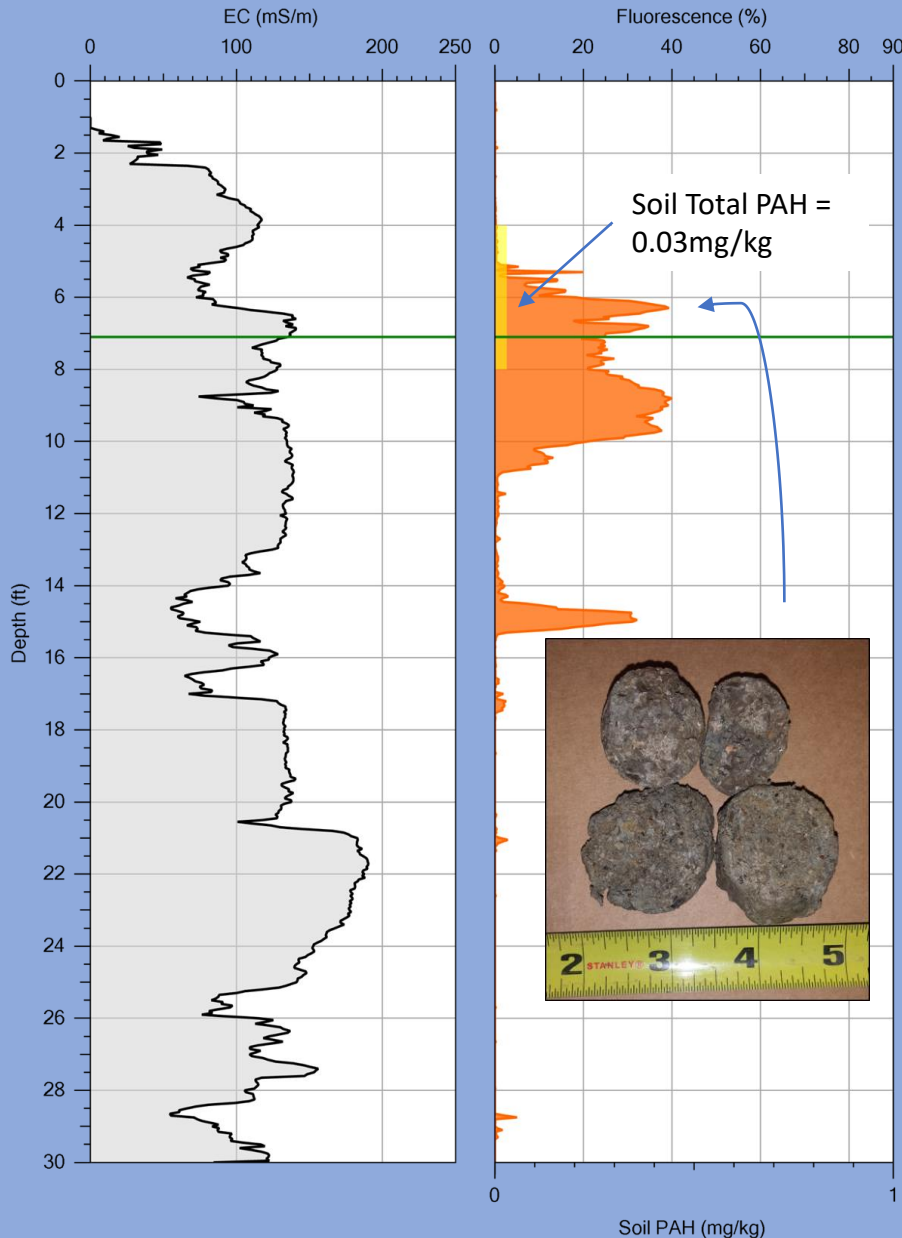
Log 20 and Sample Results

Daylight Interference in Pre-probed hole or limestone gravel

Soil Total PAH = 38.5mg/kg

Soil Total PAH = 351mg/kg

Soil Total PAH = 170mg/kg

DEPTH:
27.75 ft
TYPE:
525nm
% AREA:
81.0

Log W20

Captured

Analyzed

Location # 20
7.5 - 16.5 ft

Analysis of soil samples confirm log fluorescence at three depth intervals.

Tar laden sample material from 7.5 to 10.5ft interval

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Log 17 and Sample Results: False Positive

Soil Total PAH = 0.03mg/kg

DEPTH:
7.10 ft
TYPE:
525nm
% AREA:
27.9

Captured

Analyzed

Soil core from the 4-8ft interval displayed no visual or olfactory evidence of coal tar contamination. Lab analysis of sample for PAHs also very low.
Spotty texture in captured image typical of false positive response at this site.

Cross Section A-A' Based on EC and Fluorescence Logs
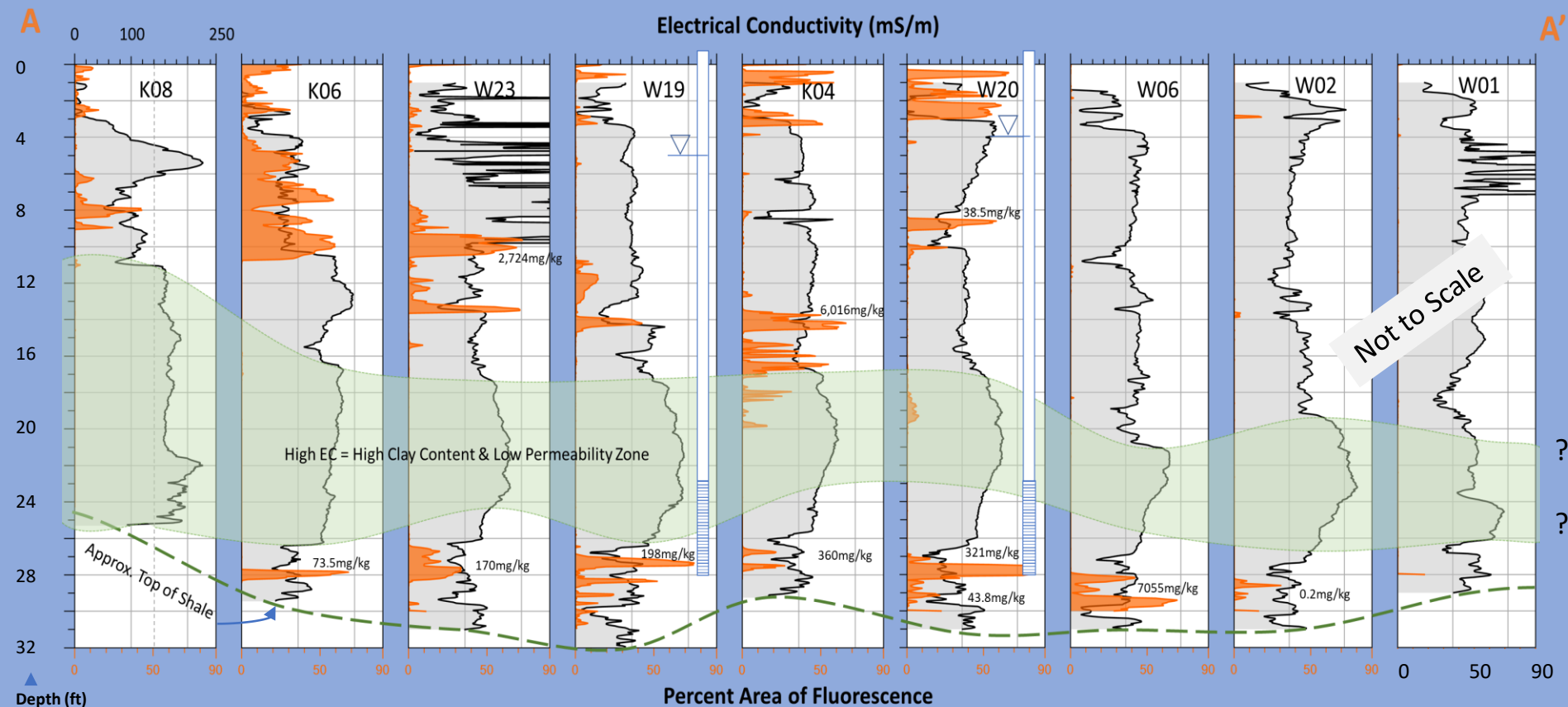
Cross section A-A' is labeled on the site map above and shown here with EC shaded in gray and the % Area of Fluorence (%AF) shaded in orange. The logs are spaced evenly in the simplified cross section here but not so on the ground (not to scale). Logs plotted at depth, not elevation corrected. Analytical results for Total PAHs from several soil samples are plotted adjacent to the depth/location where collected. Light green shading has been applied to outline a zone of elevated EC (≥ 140mS/m) in the local formation. Several samples across the site from this zone showed it consisted of a firm, dark green-gray silt-clay with low permeability. This low permeability zone was observed in all logs obtained at the site, with some variation in thickness and vertical extent. With few exceptions the coal tar contamination was found to be present either above or below this low permeability zone. No obvious pathway across the low permeability zone was observed in any of the OIP-G logs.
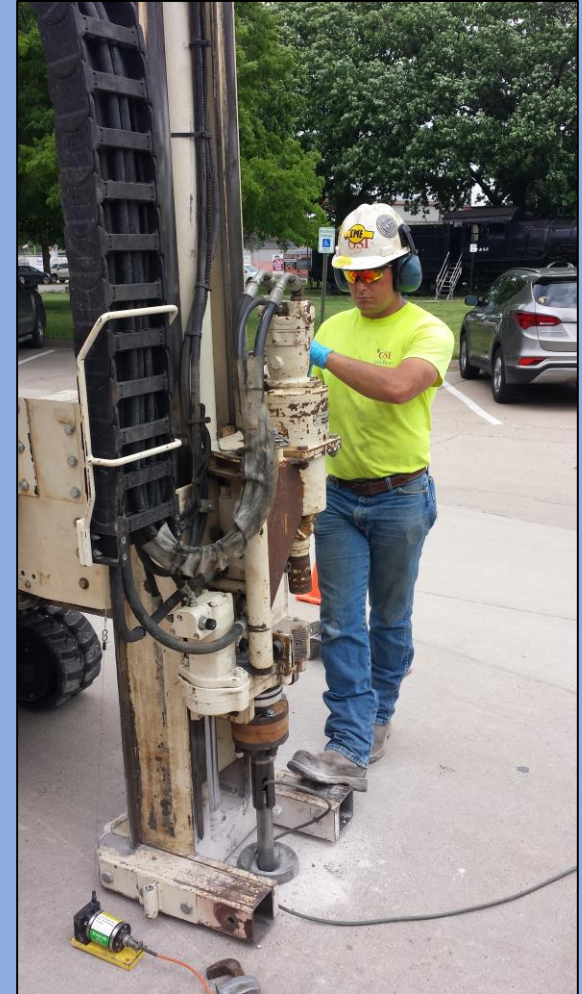
Summary and Conclusions

The OIP-G/IR probe is advanced with percussion probing methods (DP) into soils & unconsolidated formations

The Green (525nm) laser diode induces fluorescence of coal tars and creosote

False positive due to calcareous minerals may occur at some sites

Targeted soil coring guided by logs can quickly confirm presence or absence of coal tar contamination

Images of fluorescence provide powerful visual data for confirmation

OIP-G logging at Wellington

Summary and Conclusions

IR images help define soil-formation texture

EC logs assist with lithologic identification with a minimum of sampling at many sites

Cross sections of EC and %AF help define contaminant migration pathways and barriers

Site characterization with OIP-G/IR is quick and effective compared to traditional sampling or excavation methods

For more information about the OIP system visit:
https://geoprobe.com/oip-optical-image-profiler
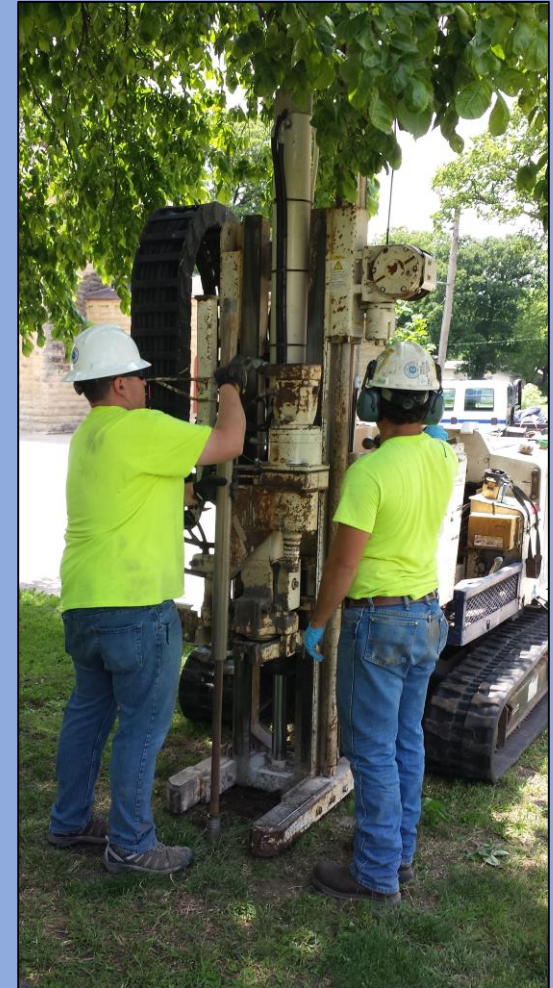
DT22 soil coring for confirmation sampling