

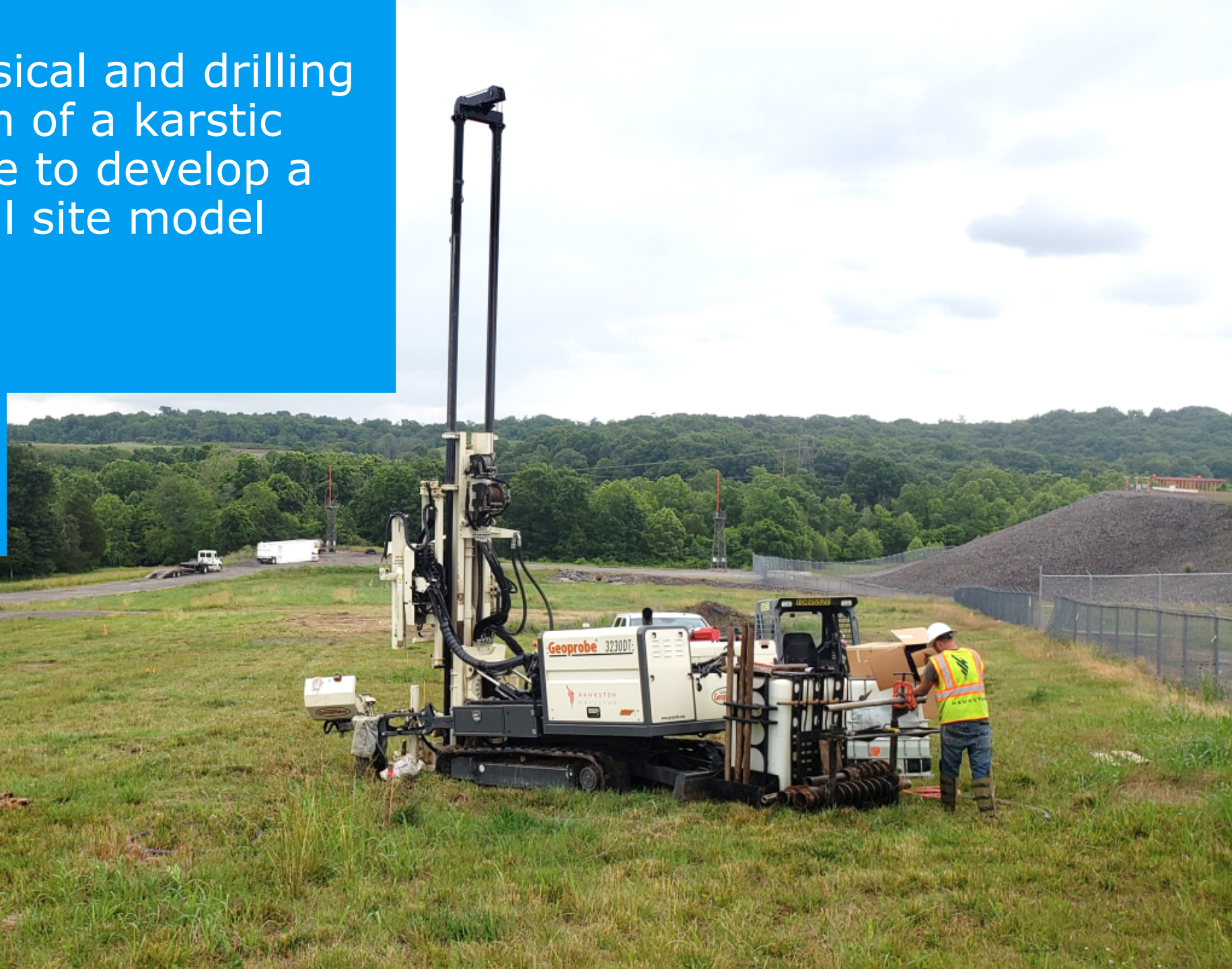
Expediated geophysical and drilling site characterization of a karstic gasoline release site to develop a coherent conceptual site model

2023 Bioremediation Symposium
Battelle Conference
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Presented By: Kit Carson
David Heidlauf, CPG

RAMBOLL

Bright ideas.
Sustainable change.



Agenda

01

Background

02

Previous site investigations

03

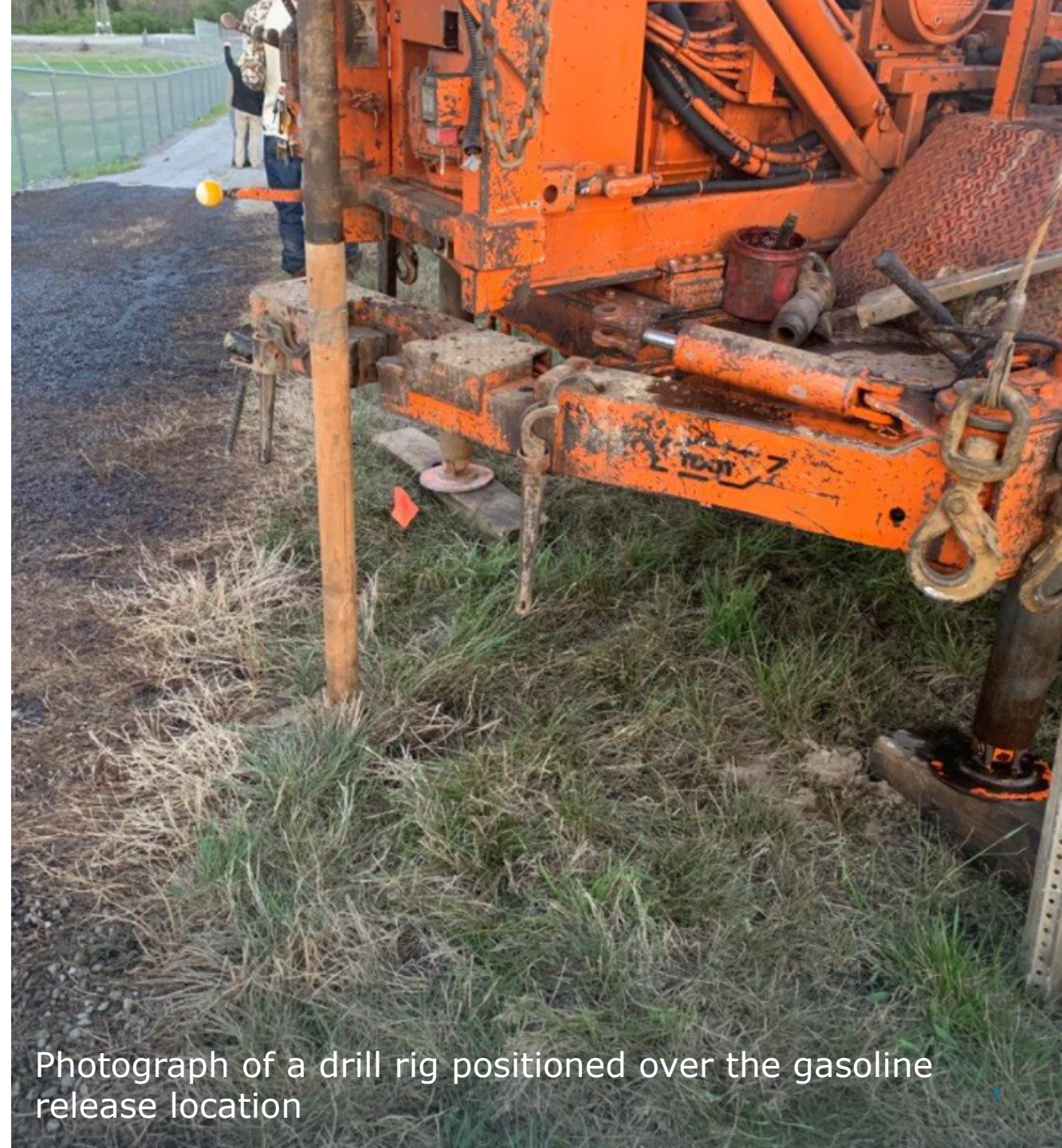
Phase 1 – geophysical surveys

04

Phase 2/3 – drilling investigation & water sampling

05

Summary and conclusions



Photograph of a drill rig positioned over the gasoline release location

Project Overview

- Litigation delaying critical parts of a multi-billion dollar airport expansion project
- In 2021, Ramboll conducted an expedited three-phase, three-month long *high-resolution site characterization*, as follows:
 - Phase 1: Geophysical survey (May)
 - Phase 2: Drilling investigation (June)
 - Phase 3: Well and surface water sampling (July)
- Integrating data resulted in coherent Conceptual Site Model (CSM)



Photograph of the gasoline surface flow path along a drainage ditch along an airport roadway



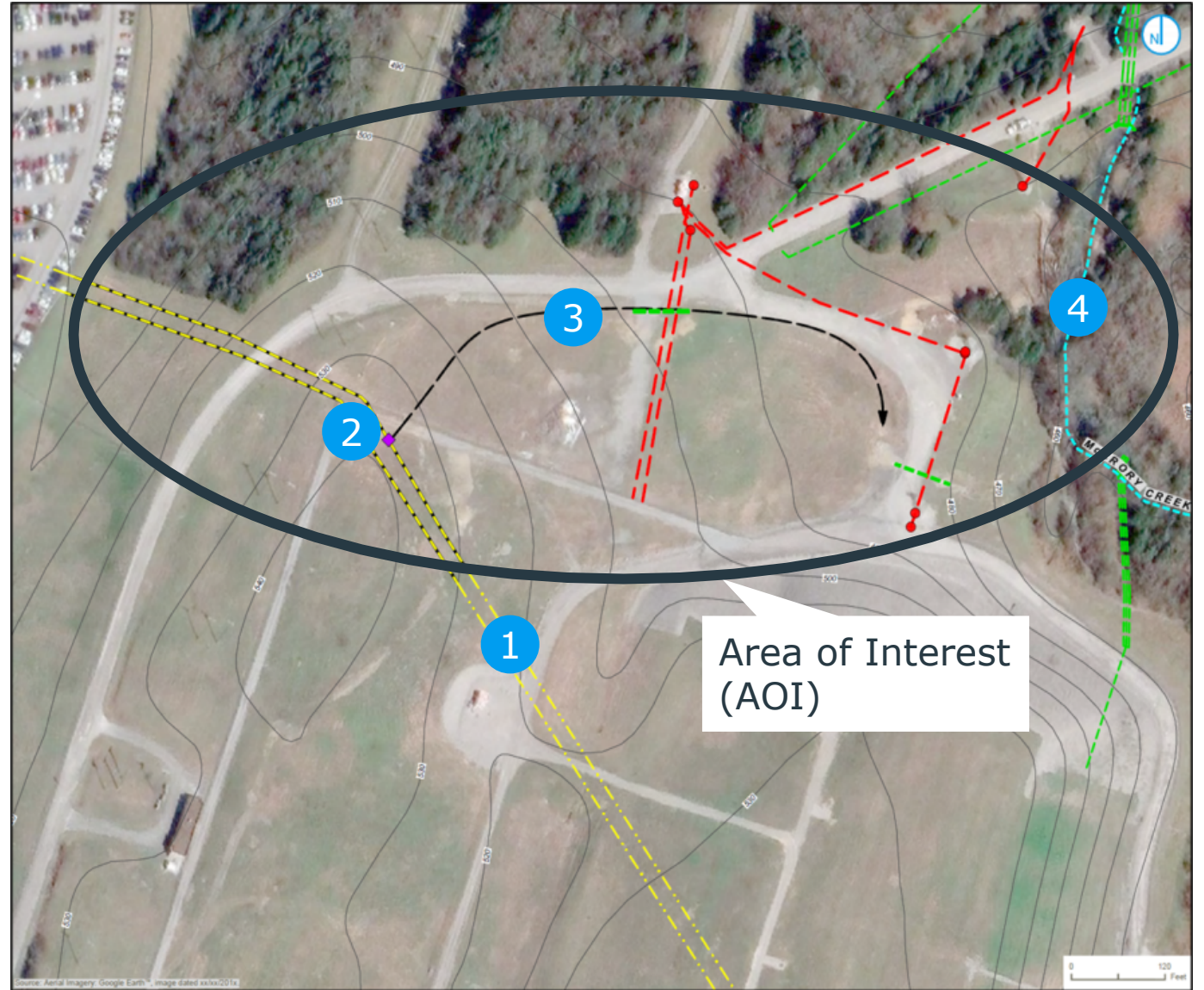
Project Background

- An underground gasoline pipeline was struck by others during an April 2019 drilling operation
- Estimated 14,000 gallons of gasoline released
- Within two days of the gasoline release, a petroleum sheen was observed in the western stream bank of McCrory Creek
- Temporary containment system (TCS) was installed within McCrory Creek to mitigate surface water impacts

Photograph of the gasoline release located on a karstic carbonate bedrock topographic high

Site Layout and Features

- 1 Gasoline pipeline
- 2 Gasoline release location
- 3 Gasoline surface flow path
- 4 Primary receptor (McCrary Creek)

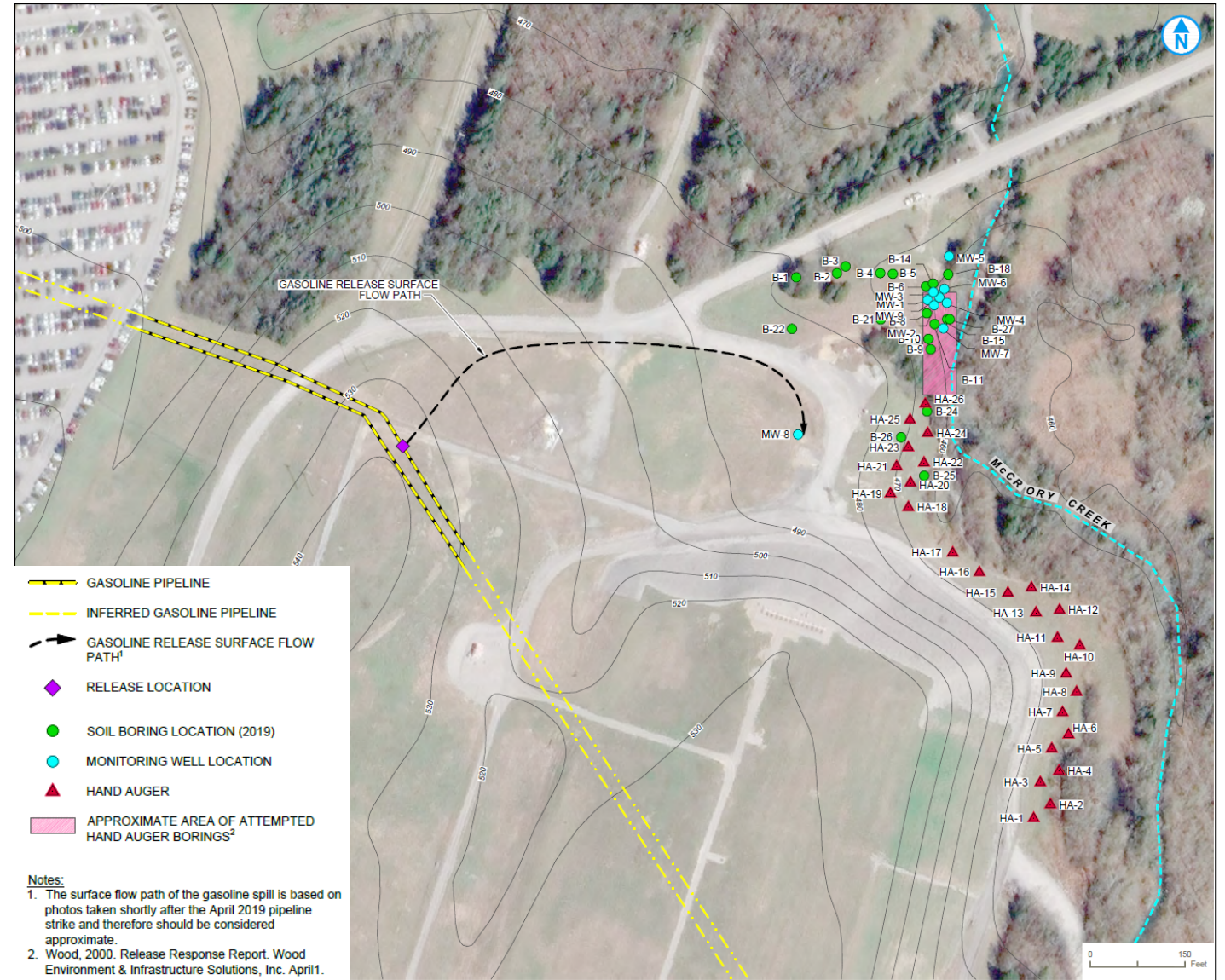


Previous Site Characterization Investigation(s)

Limited to areas along McCrory Creek; the closest ecological receptor to the gasoline release

Data gaps include:

- 1 Source zone characterization not defined
- 2 Migration pathways not defined to the north and west
- 3 Further define impacts along McCrory Creek



Ramboll Site Characterization Investigation

Geophysical methods employed
(in the following order):

- 1 Electromagnetic (EM) terrain conductivity
- 2 Electrical resistivity imaging (ERI)
- 3 Multichannel analysis of surface waves (MASW)

Phase 1: Geophysical Surveys

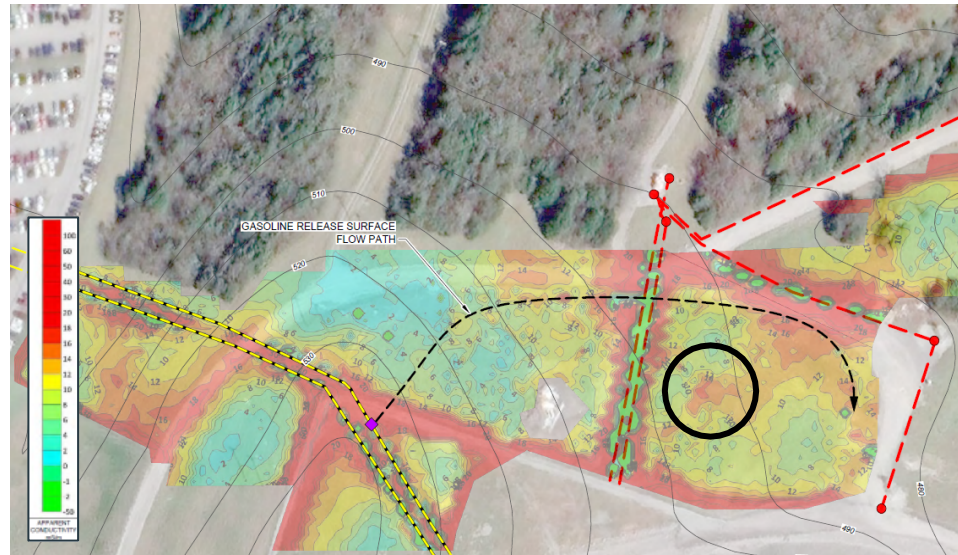


Legend:

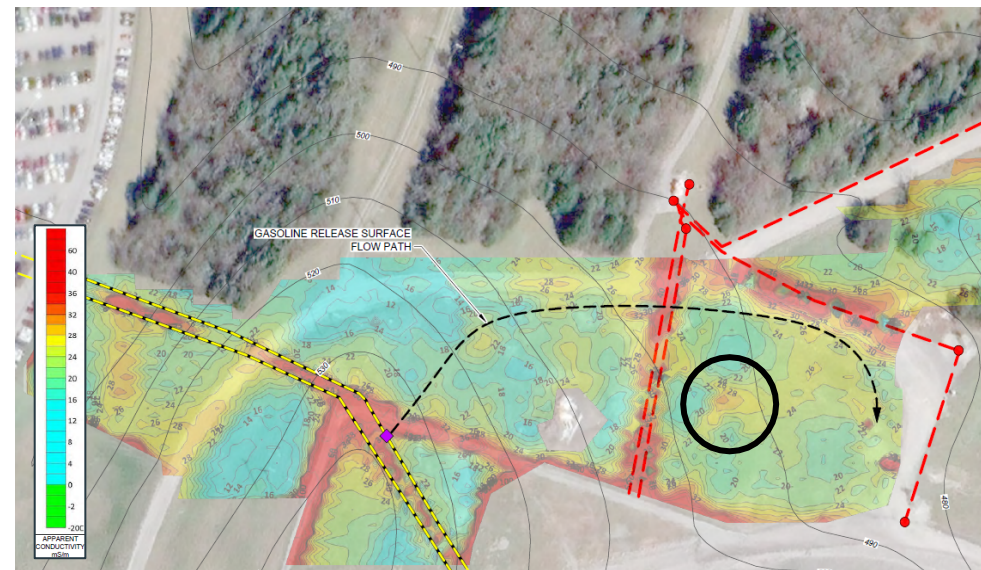
Yellow = EM31
Red = ERI
Blue = MASW
Pink = Surface features (e.g., fence or berms)

EM-31 Geophysical Results

- **BLUE:** Low apparent conductivity is indicative of **competent bedrock**
- **ORANGE:** High apparent conductivity is indicative of **clay-rich zones, fracturing, faulting, weathering, and/or karst activity**
- **RED:** Notable instances of very high apparent conductivity is indicative of interference from **underground utilities and chain-link fence**



EM-31 Normal
Depth of investigation
between 15 to 18 feet

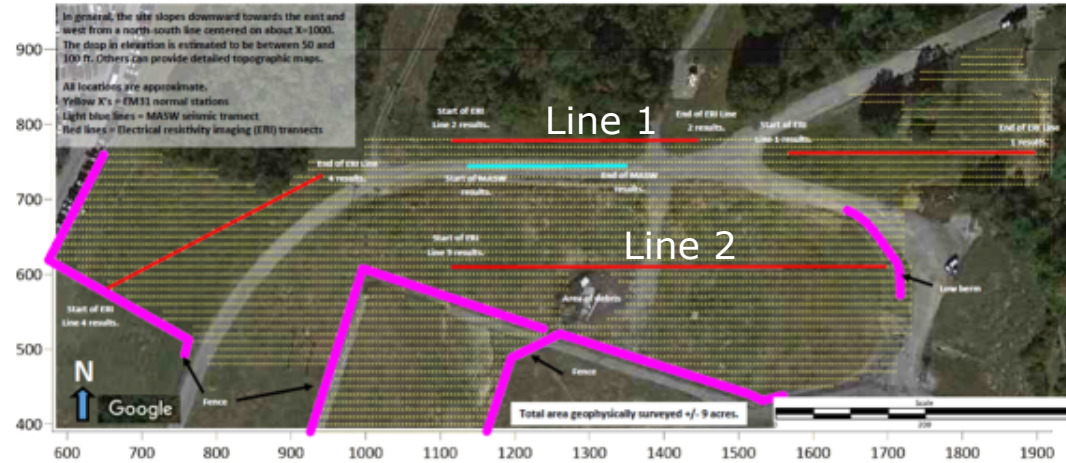


EM-31 Short
Depth of investigation
approximately 10 feet

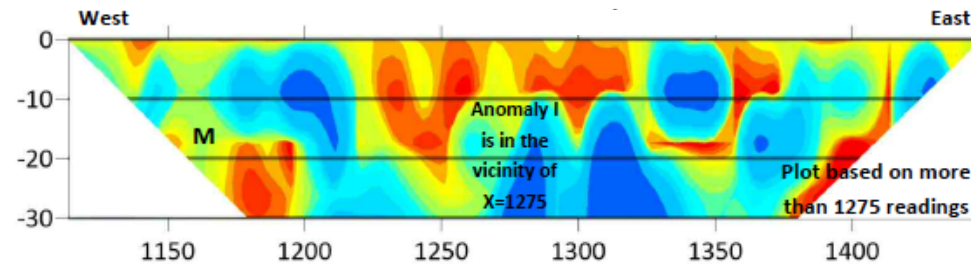
ERI Geophysical Results

Uneven bedrock surface, clay-filled voids and/or fracture zones

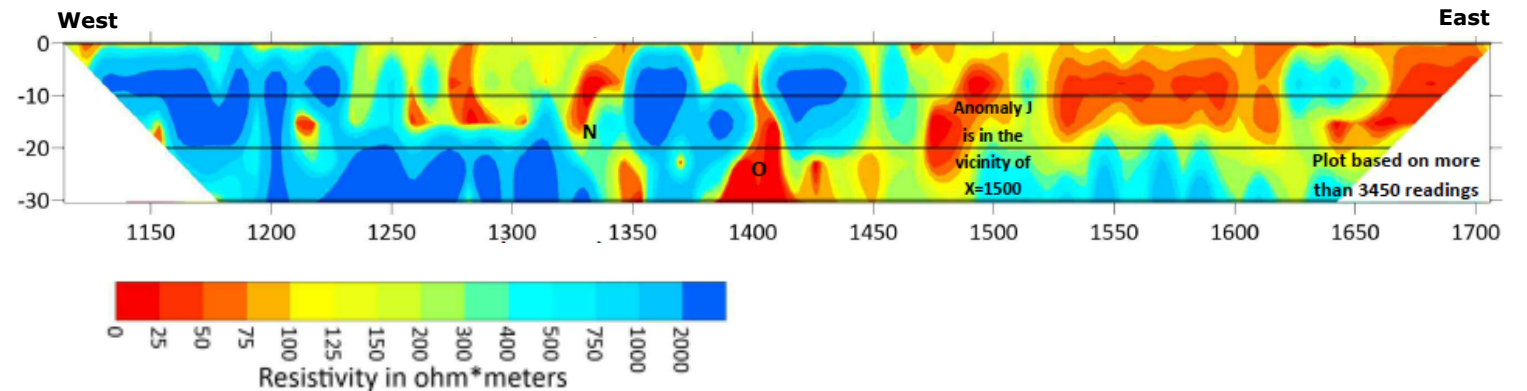
- High resistivity values are indicative of **competent bedrock**
- Low resistivity values are indicative of **moist to saturated clay-rich zones**



Line 1



Line 2

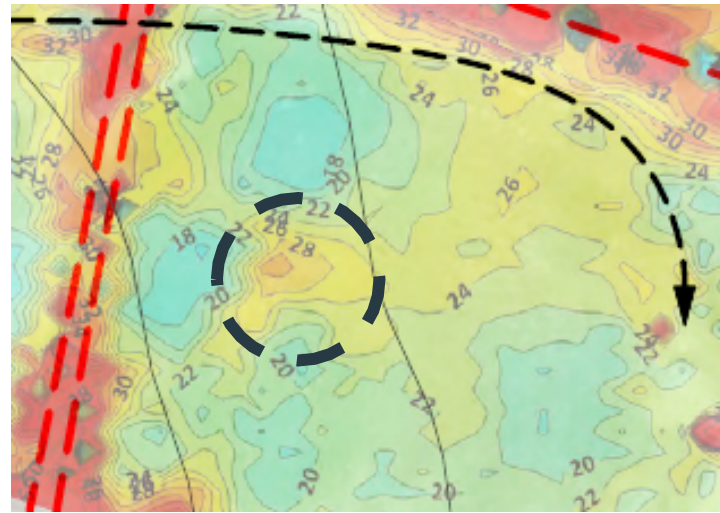


Integration of EM-31 and ERI Results

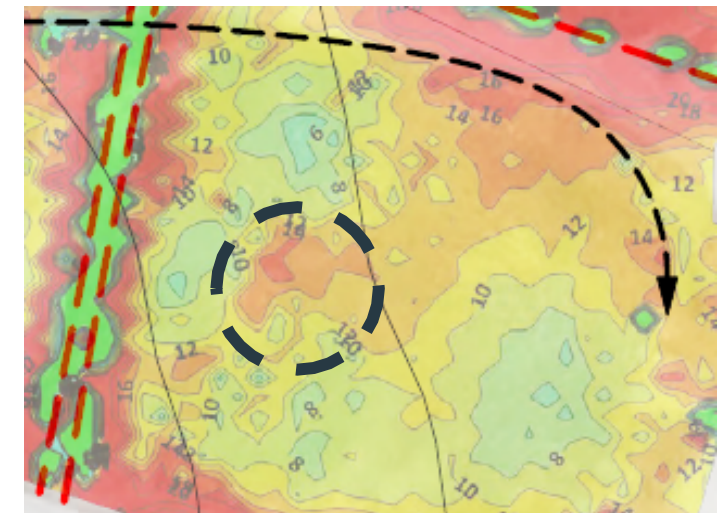
Identification of an anomalous zones, indicating potential vertical preferential pathways within a previously unexplored area

Black dashed circle is the location of temporary monitoring well TW-113

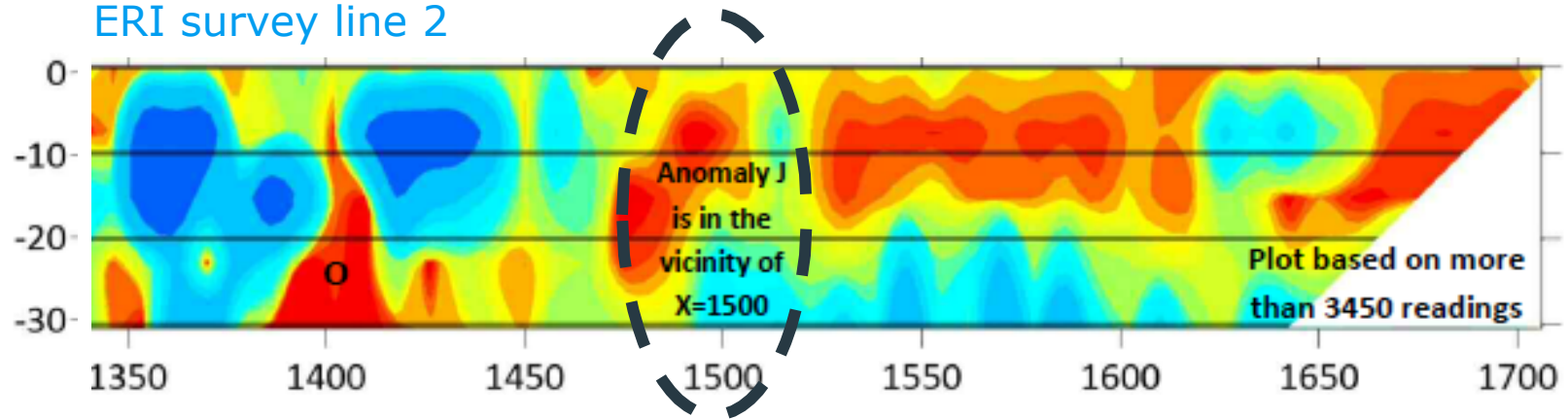
EM-31 short survey



EM-31 normal survey



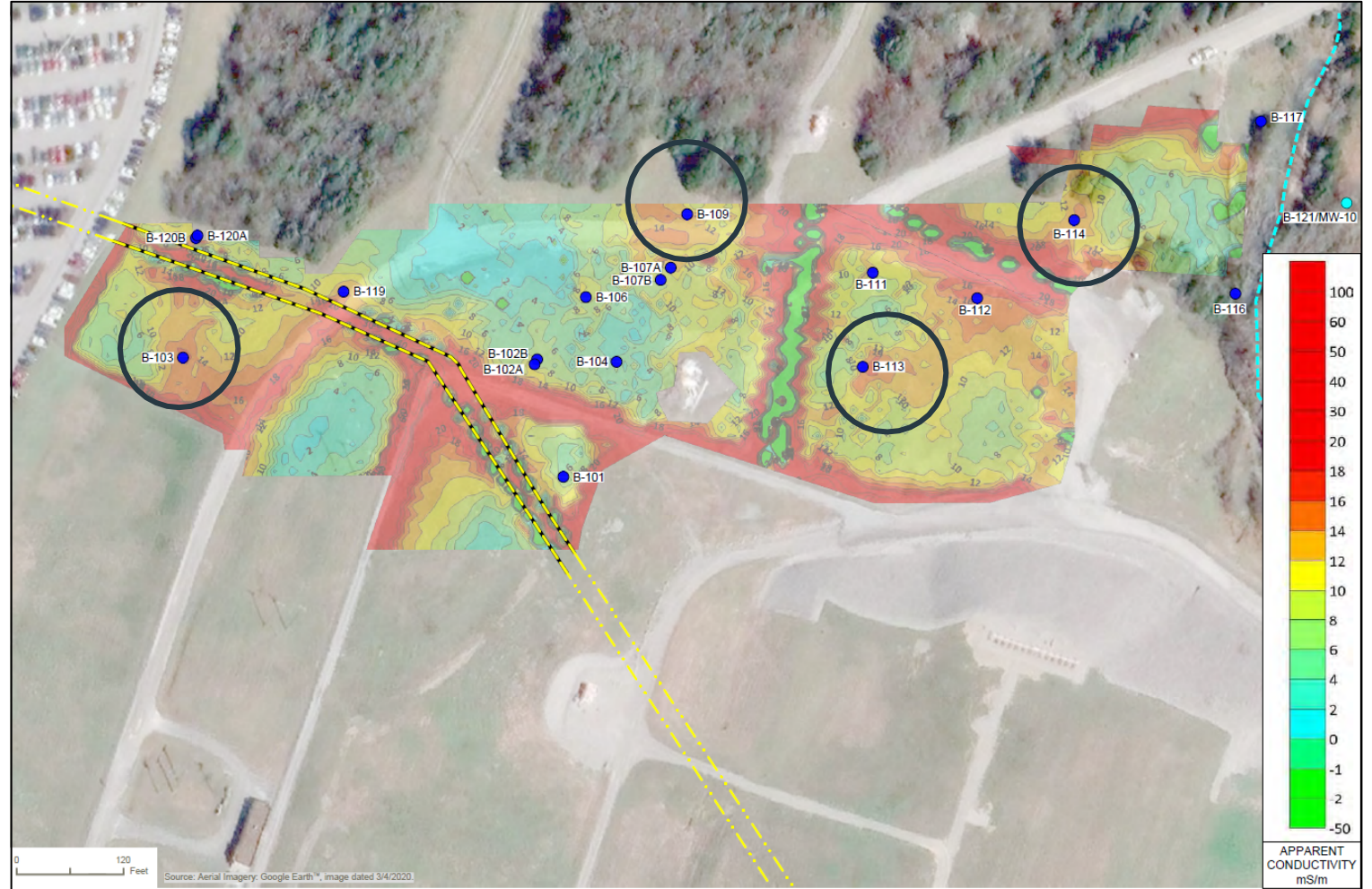
ERI survey line 2



Selection of soil boring locations

Sixteen (16) boring locations were selected based on the following criteria:

- Electromagnetic (EM) anomalies
- Other considerations include:
 - Gasoline surface flow path
 - Existing gasoline pipeline
 - Proposed pipeline
 - Data gaps along McCrory Creek



Note: EM anomalies indicated by black circle(s)



HAWKSTON
DRILLING



Phase 2: Drilling Investigation



Multiple drilling techniques employed at the Site including, direct-push technology (DPT), rock coring, and air rotary. One rig employed!



Karstic bedrock primarily drilled via rock coring, which provided technical benefits compared with other drilling techniques (e.g., sonic)



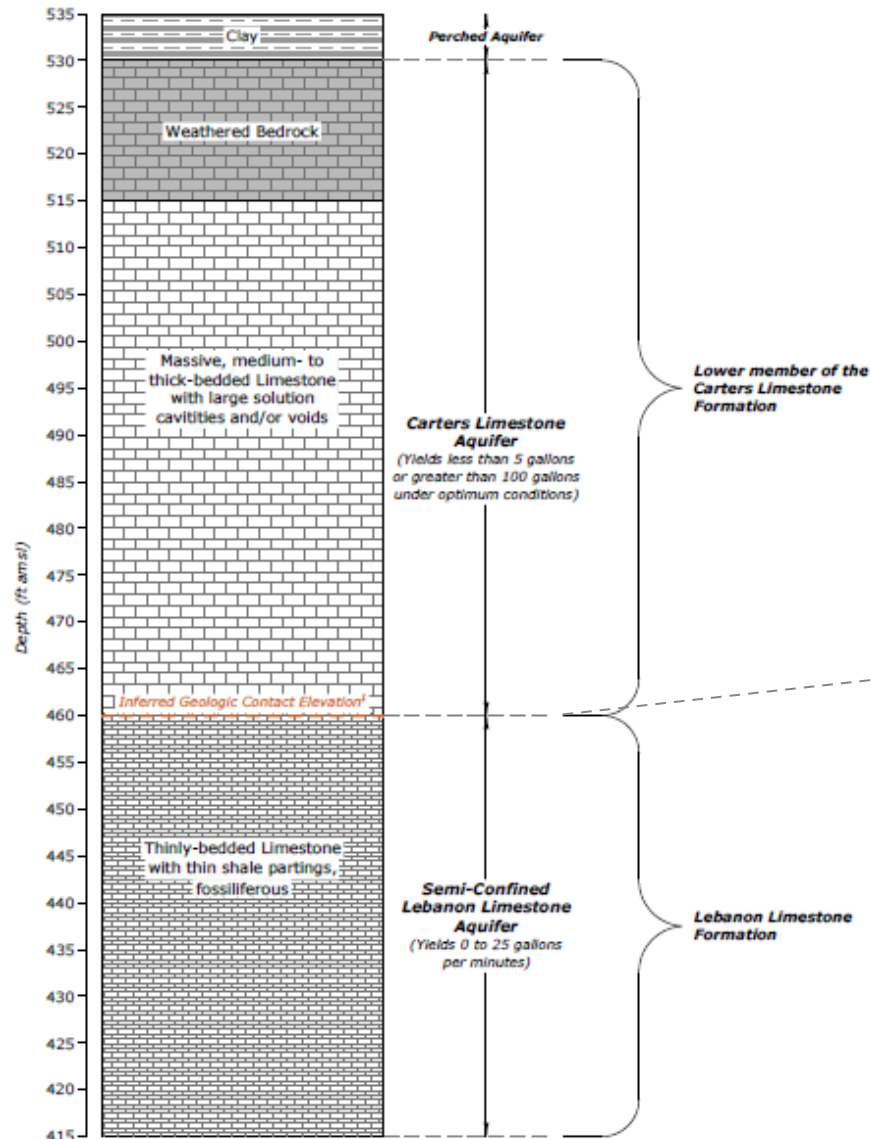
Improved geologic/hydrogeologic CSM

Track-mounted Geoprobe 3230DT drill rig

Geologic Field Observations

- Clay: Negligible hydrocarbon impacts except along gasoline surface flow path
- Carters Fm: Abundant vertical fractures and voids
- Lebanon Fm: Overall increase in black-stained fractures, hydrocarbon odor, and increasing PID results

Stratigraphic column



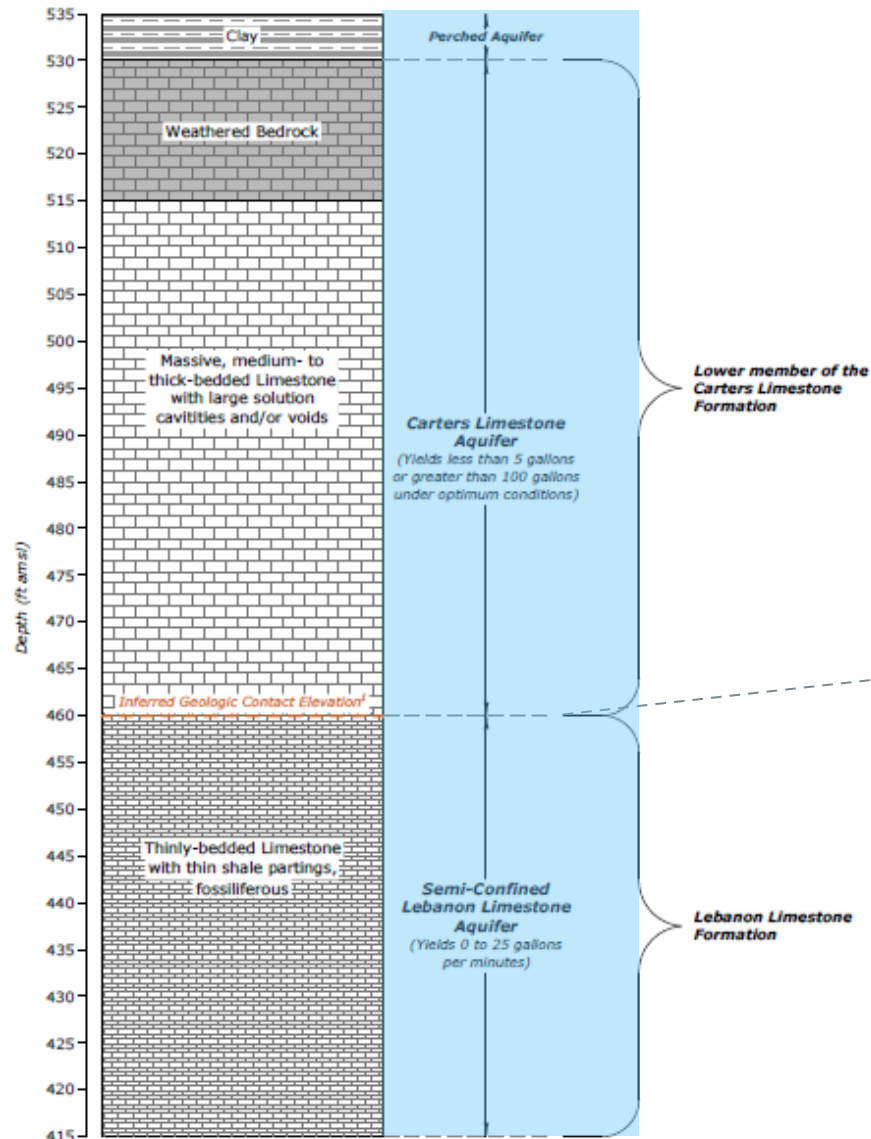
Photo(s)



Hydrogeologic Field Observations

- Perched: very low yield and discontinuous
- Carters Fm: Water-bearing zones uncommon. When present, observed within void spaces. (e.g., 0.3-foot void at TW-113)
- Lebanon Fm: Water-bearing zones often occurred in groups of natural breaks over a short interval.

Stratigraphic column

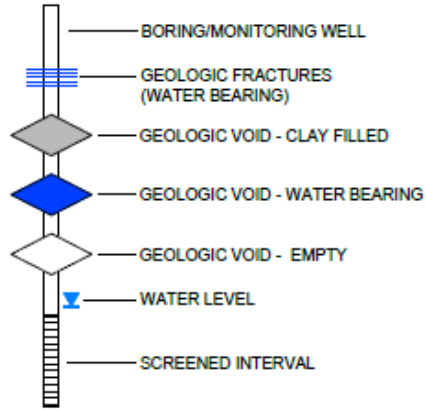
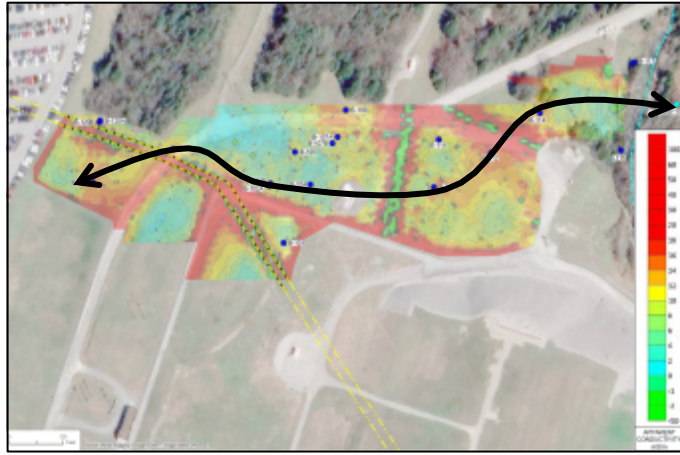


Photo(s)



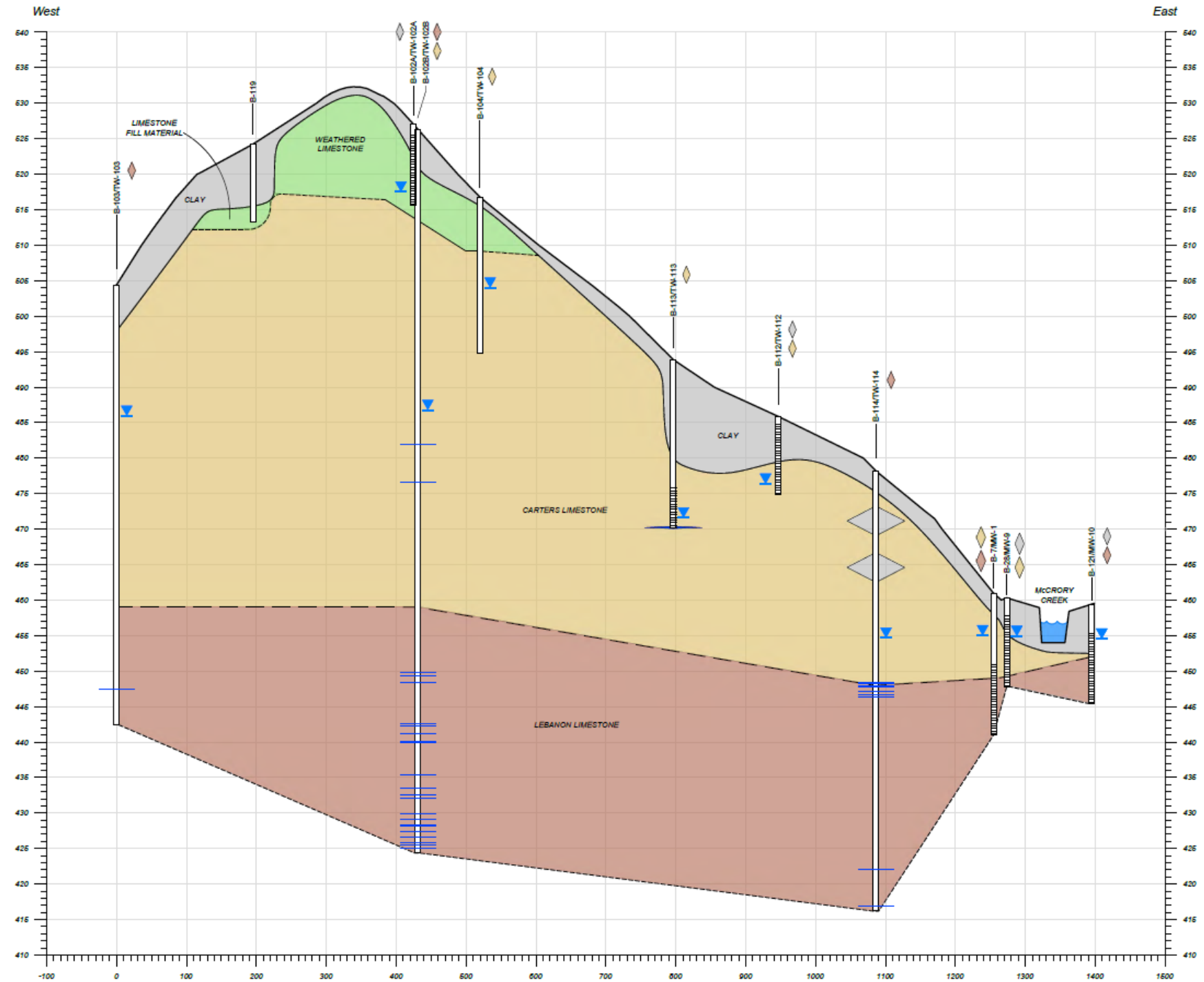
Cross Section

Vertical Exaggeration = 10x



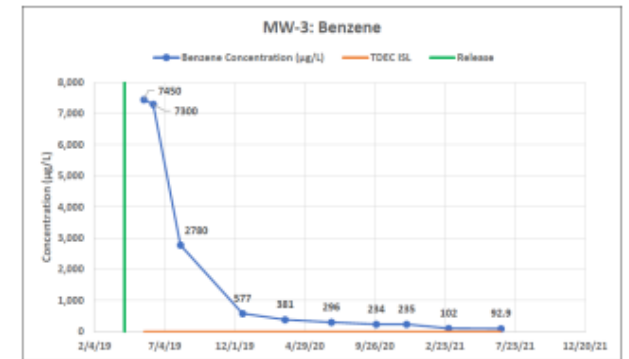
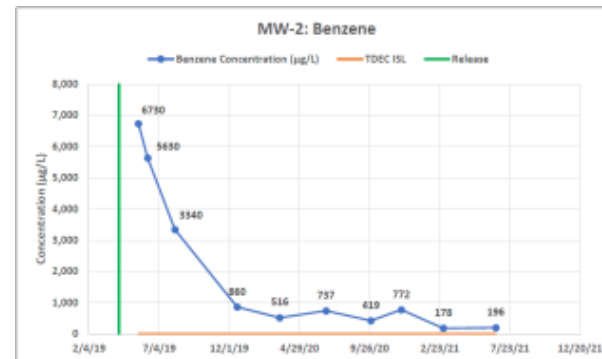
HYDROSTRATIGRAPHIC UNIT (OR WATER BEARING ZONES):

- PERCHED UNCONFINED SATURATED ZONE
- CARTERS LIMESTONE AQUIFER
- SEMI-CONFINED LEBANON LIMESTONE AQUIFER



Phase 3: Sampling and Monitoring Results

- LNAPL was **not** present in the groundwater, and only very low residual petroleum constituents were detected in groundwater and surface water
- Over a two-year period, benzene (primary COC) decreased by 89–99%, depending on the monitoring well location.



- Surface water has periodic sheen and low-level exceedances above applicable screening levels.

Field geologist providing oversight during the installation of boring location B-117 along McCrory Creek.

Project Summary

- High-resolution site characterization using (1) geophysical surveys, (2) drilling observations, and (3) analytical datasets resulted in the development of a coherent and defensible CSM
 - Natural flushing and natural source-zone depletion (NSZD) in source area and underlying bedrock
- **Outstanding litigation settled** – no active remediation necessary prior to airport expansion projects
 - Periodic McCrory Creek surface water monitoring to continue until the remaining residual petroleum impacts mitigated.
 - **2022-23 Updates:** Very intermittent sheen and low-level exceedances above applicable standards. No exceedances downstream!



Temporary Containment System along the western bank of McCrory Creek following a recent rainstorm in April 2022

Questions and acknowledgements

David Heidlauf (Principal)
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Caroline Chavers (Field Team)
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Hawkston, LLC (Geotechnical Drilling)
GPRS (Private Utility Locating)

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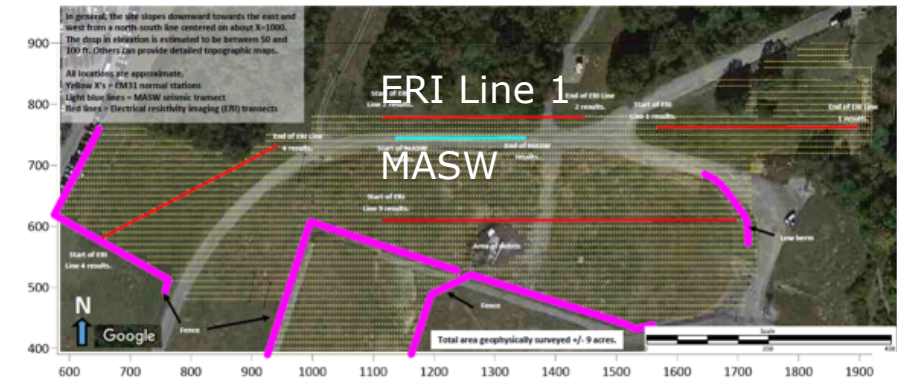
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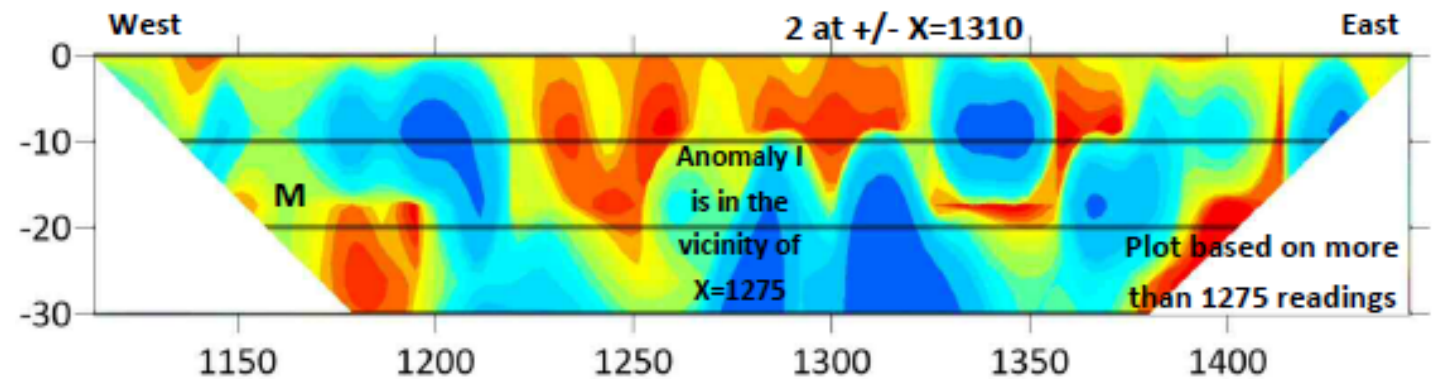
Comparison of ERI and MASW geophysical data

Uneven competent bedrock surface, identification of anomalous zones

- 0-10 ft: Soil and/or fill materials (velocity below 500 ft/sec)
- >10ft: clay/fill materials to less competent bedrock (velocities between 500-1000 ft/sec)
- >15 ft: Most competent bedrock (velocities greater than 1,000 ft/sec)



ERI Survey Line 1



MASW Survey Line

