U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

CATALOG Program: Integration and Best Practices
FWP 1025006

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2024 NETL Resource Sustainability Project Review Meeting

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Project Overview

- BIL Funded, Multi-laboratory program
- Performance Dates: 5-year program initiated in 2022
- Participants: LANL, LBNL, LLNL, NETL, and SNL
- Integration and Best Practices Objectives:

  Provide integrated and standardized data for use by Federal, State, and Tribal agencies. Develop a framework/best practice for well finding, emissions measurements, and characterization methodologies for use by Federal, State, and Tribal agencies.

  - Activity 1: Develop tools and techniques to standardize data and records for integration into a common framework.
  - Activity 2: Establish field sites for testing and demonstration of integrated well finding and characterization technologies from various platforms: aerial, ground surveys, direct measurements, etc.
  - Activity 3: Review and recommendation of best practices for well finding, emissions measurements, and well integrity testing.

  This presentation will describe five CATALOG research activities that are ready or near-ready for transfer of the technology to our stakeholders

Best practices: Use of downwind methane concentrations measurements and wind field measurements to model and estimate orphaned well methane emissions

- Motivation and Background
  - Survey of IOGCC participants as well as other communications with state agencies identified **inexpensive** and **rapid** methodologies for detection and measurement of methane emissions from orphaned wells as a major challenge
  - Many inexpensive and field-portable methane concentration measurement instruments are on the market
  - Coupling wind field measurements and methane concentration measurements made at several distances downwind of a well with an inverse plume dispersion model could provide estimates of methane emission rate from the well
  - Although the methodology does not provide the same high level of accuracy of flux chambers or high flow sampling, it allows for easy identification and classification of wells that are not leaking, leaking at low or mid-rates, or high emitters that may warrant additional investigation

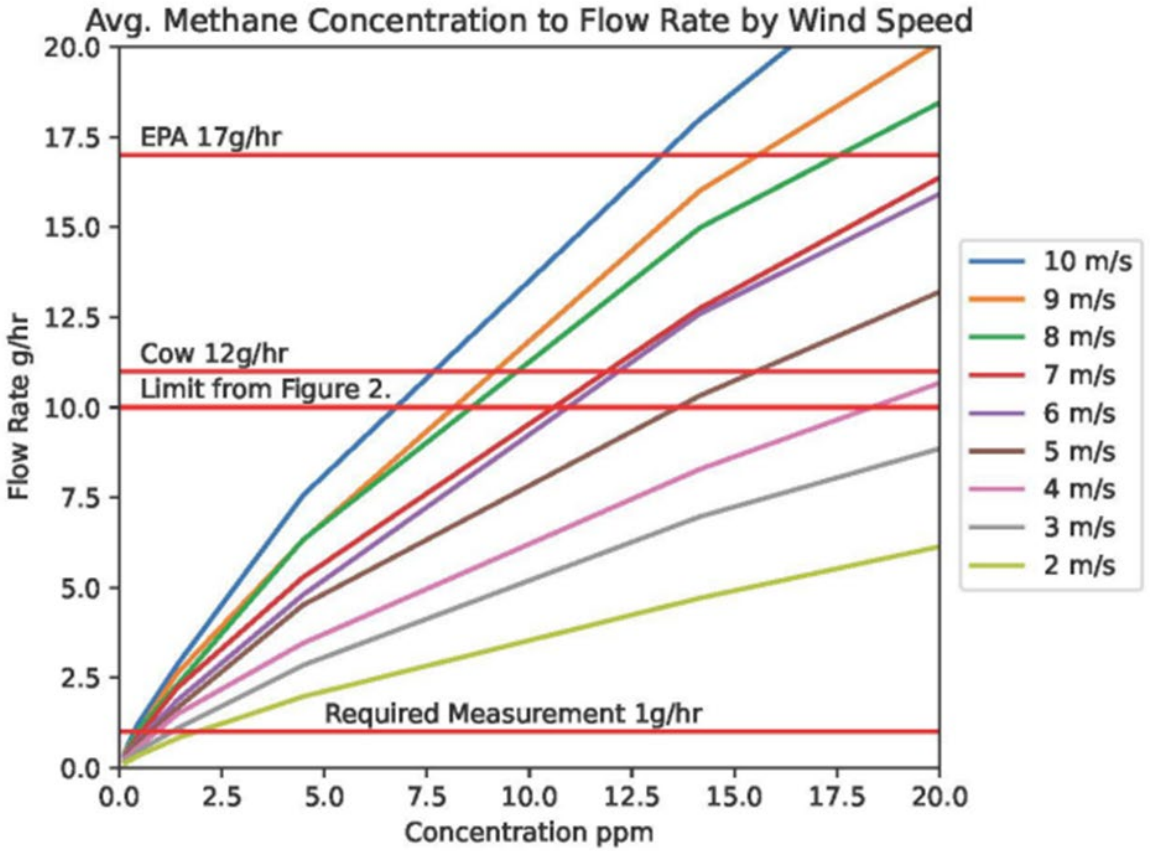
With this methodology, wells that should be high priority for plugging due to high methane emissions can be quickly and inexpensively identified.

Best practices: Use of downwind methane concentrations measurements and wind field measurements to model and estimate orphaned well methane emissions

- Data Section/Methodology
  - A Gaussian plume dispersion model was developed using a variety of atmospheric stability classes and wind speeds to estimate the expected methane concentration up to 10m downwind of a well emitting methane at a rate of 1 g/hr.
  - The model was then tested via controlled releases and at several wells in New Mexico where methane emission rates were known and could be compared to modeled estimates.

Best practices: Use of downwind methane concentrations measurements and wind field measurements to model and estimate orphaned well methane emissions

- Learnings/Accomplishments
  - Figure at right shows modeled methane emission rate as a function of wind speed and methane concentration measured 2m downwind of the source under stable atmospheric conditions.
  - The graph illustrates how this approach can be used by operators to roughly estimate methane emission rate from an orphaned well by simple collection of wind speed data and downwind methane concentration, which is less time consuming and expensive than some alternative approaches.



Dubey, M.; Meyer, A.; Dubey, M.; Pekney, N.; O'Malley, D.; Viswanathan, H.; Govert, A.; Biraud, S. (2023). How to estimate O&G well leak rates from near field concentration and wind observation. 20230103-OrphanWellLeakQuantificationFECM22.pdf (energy.gov)

Best practices: Use of downwind methane concentrations measurements and wind field measurements to model and estimate orphaned well methane emissions

- Future Work
  - Testing and demonstration of methodology are ongoing
  - Integration and Best Practices team is working with the developers of the methodology to determine how to build out the methodology into a user-friendly tool that will be publicly accessible.

Best practices: Procedure for locating oil and gas wells in the Appalachian Basin that utilizes a compilation of publicly available digital resources

- Motivation and Background
  - The top data gap or need as reported by the states through a CATALOG team-administered IOGCC survey is locating orphaned wells
  - The CATALOG team has reported a methodology for systematically compiling publicly available digital data at progressively smaller scales prior to embarking on field campaigns.
  - Geographical Information System (GIS) technology is used to analyze digital data and create maps to guide field work activities based on the goals of a specific project.
  - This workflow was developed in the Appalachian region and although certain aspects may be unique, the general process should be applicable to locating undocumented wells in other regions.

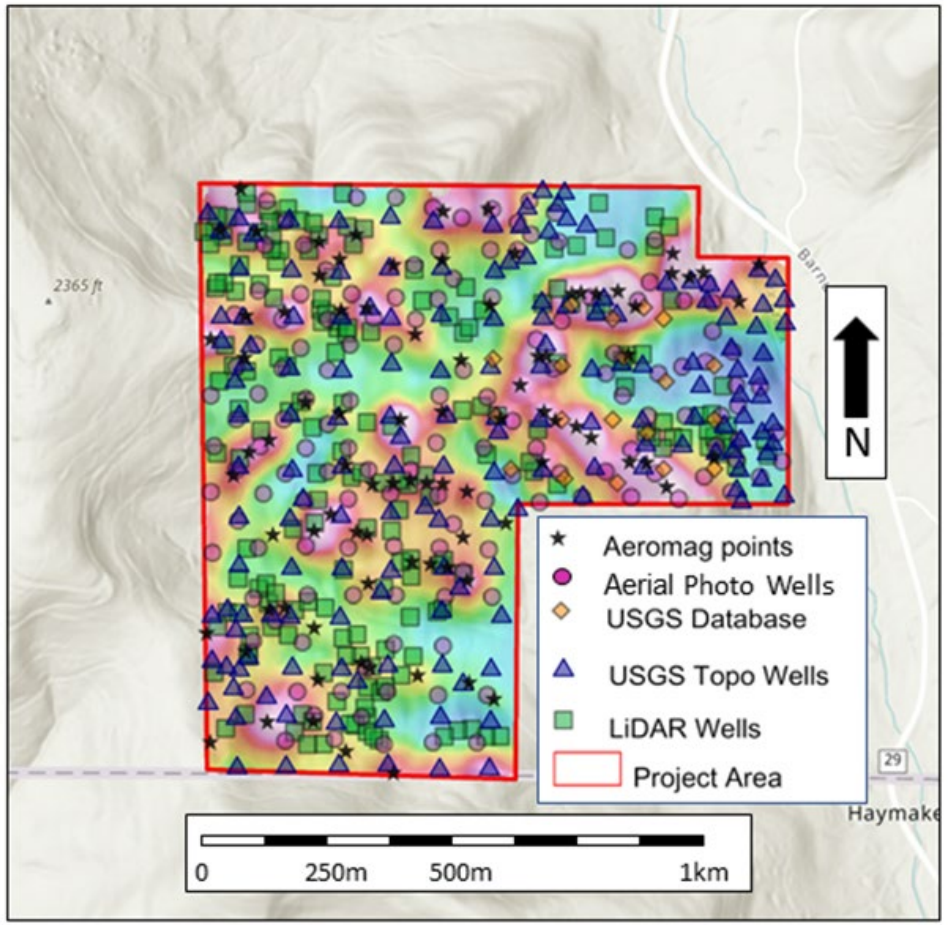
The report of the methodology was designed to assist states, particularly in the Appalachian Basin, in their initial investigations of well locations for an identified area of interest.

Best practices: Procedure for locating oil and gas wells in the Appalachian Basin that utilizes a compilation of publicly available digital resources

- Data Section/Methodology
  - Data sources and links are provided in the report and include:
    - Well location/production databases for each state
    - National databases curated by USGS as well as three privately owned databases
    - USGS topographical maps
    - USDA Aerial photographs
    - Historical mine maps from Office of Surface Mining Reclamation and Enforcement
    - State LiDAR surveys
  - The methodology for compiling the digital data involves using GIS software to develop a map application that layers well site location information from each of the data sources.

Best practices: Procedure for locating oil and gas wells in the Appalachian Basin that utilizes a compilation of publicly available digital resources

- Learnings/Accomplishments
  - An example layered map was developed for a project area in New York
  - All digital resources were compiled as well as the results of an aerial magnetic survey
  - Comparison of well locations do not always show agreement between various digital resources, but good agreement indicates high confidence of finding a well at that location
  - This approach can be used as a first step in identifying potential well sites in an area of interest to improve efficiency in conducting ground-based field verification of well locations



Reeder, M.; Sams, J.; Gorantla, V.R.; Pekney, N. Procedure for locating oil and gas wells in the Appalachian Basin. The Leading Edge Special Section: Orphaned and Abandoned Wells, December 2023. https://doi.org/10.1190/tle42120828.1

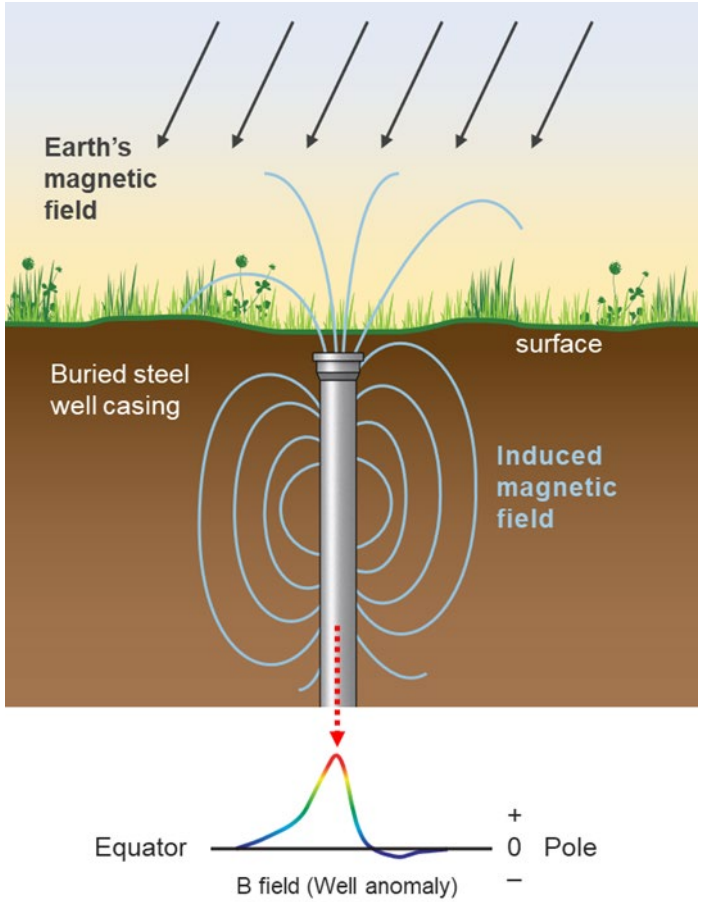
Best practices: Procedure for locating oil and gas wells in the Appalachian Basin that utilizes a compilation of publicly available digital resources

- Future Work
  - The methodology, originally targeted for the Appalachian Basin, will continue to be tested and expanded for other regions of the U.S.
  - From application of the methodology, we will be developing a tool that assigns a confidence value to indicate level of certainty of well location based on agreement between multiple digital data sources

Best practices: Aerial magnetic surveys to find well sites

- Motivation and Background
  - Over the past decade, NETL has shown that airborne magnetic field surveys are able to detect and locate oil and gas wells, including undocumented orphaned wells.
  - When areas are surveyed with a magnetometer, well casing and other infrastructure containing high amounts of ferromagnetic alloys appear as strong magnetic field anomalies compared against the Earth's inducing field.
  - The use of aerial magnetic surveying provides accurate locations for metallic-cased wells, which is of particular interest in areas where documented well locations are expected to be inaccurate or there is potential for the presence of undocumented wells.

The sharing of a best practices report will allow stakeholders to benefit from the decade of experience that NETL has in testing and demonstrating this technique.



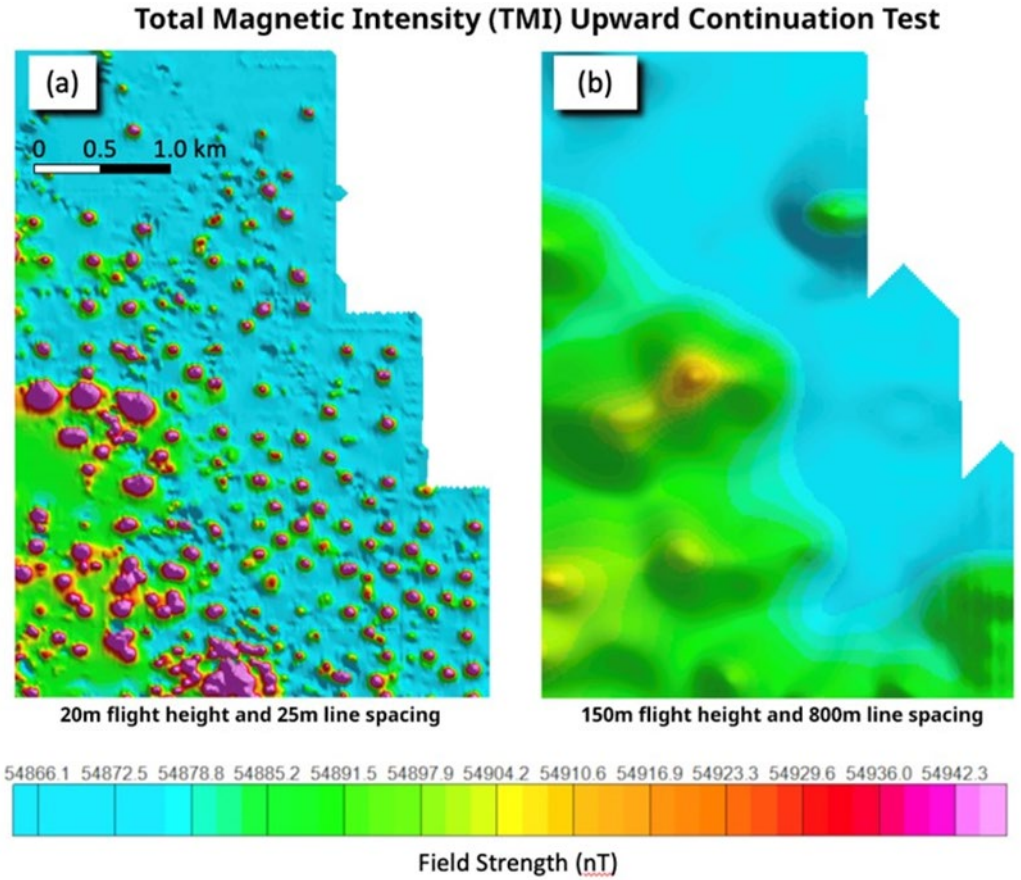
Best practices: Aerial magnetic surveys to find well sites

- Data Section/Methodology
  - Aerial survey design recommendations are based on empirical testing through field campaigns conducted at several locations over the course of over a decade:
    - Hillman State Park, PA
    - Oil Creek State Park, PA
    - Ole Bull State Park, PA
    - MCC Partners Well Pad, PA
    - Salt Creek Oil Field, WY
    - Teapot Dome Oil Field, WY
  - Recommendations for data processing, analysis, and filtering as well as common sources of error are shared in the best practices report

Best practices: Aerial magnetic surveys to find well sites

- Learnings/Accomplishments
  - Tighter grid spacing and lower elevations give the best resolution of the magnetic data but have higher cost
  - From empirical testing, NETL has determined that a maximum flight height of 45 m and an inline spacing of 40 m can be used without significant degradation to the detection success rate

  Experience and science-based justification for survey planning and execution are necessary for successful application of aerial magnetic surveying technology
- Future Work:
  - Continue to provide support to our stakeholders as advisors
  - Test aerial surveying techniques in challenging areas (i.e., rugged and hilly/mountainous terrain)

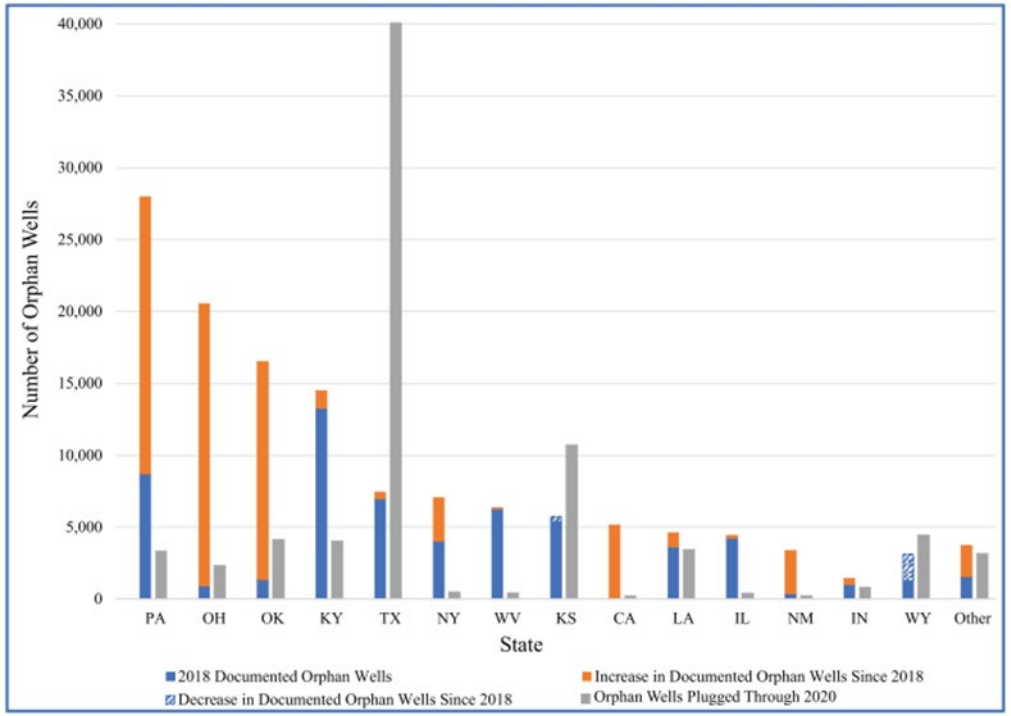


Richard Hammack, Garret Veloski, James Sams, and Colton Kohnke Aeromagnetic surveys for the location of undocumented orphaned wells. The Leading Edge 2023 42:12, 798-807.

Selection of field testing and demonstration sites

- Motivation and Background
  - Some research activities conducted under work packages in the CATALOG program will require the field testing and demonstration of various technologies and methodologies to verify their performance
  - To ensure that field testing and demonstration can be effectively conducted, the Integration and Best Practices team has focused on (1) assigning coverage of sites across the U.S. such that technologies and methodologies are relevant and successful in a variety of settings (different geology, topography, land use and cover, etc.) and (2) matching the needs of specific technology field tests and demonstrations with an available site.

Selection of field testing and demonstration sites

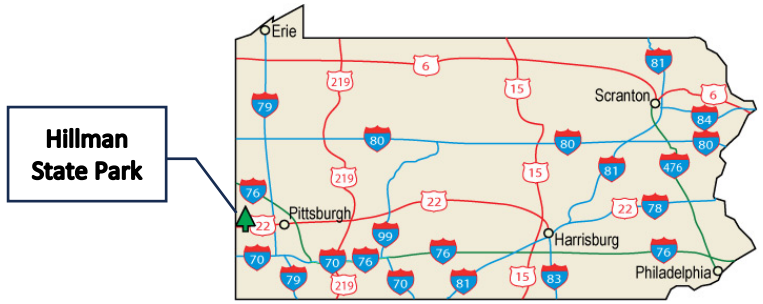


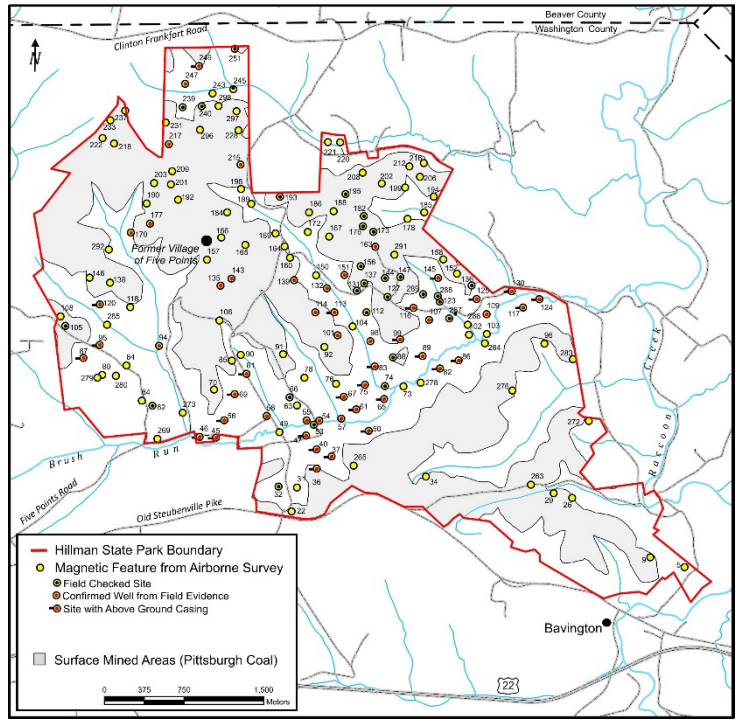
Documented orphaned wells as of IIJA enactment, from IOGCC Idle and Orphan Oil and Gas Wells: State and Provincial Regulatory Strategies (2021). States with the highest populations were targeted for field testing and demonstration sites.

Matching of states/regions with labs that either had a proximal advantage or had prior experience in working with the state agency or state oil and gas data. The assigned states/regions would then be the focus of that laboratory's field testing and demonstration activities.

Selection of field testing and demonstration sites

- Learnings/Accomplishments
  - To match the needs of specific technology field tests and demonstrations with an available site, a questionnaire was distributed to PIs of distinct CATALOG research projects that would require field testing and/or demonstration
  - PIs were asked about needs related to:
    - Well configuration (presence of a wellhead, casing type)
    - Well characteristics (leaking or not, produced water storage)
    - Geology (depth, type of well, density of wells)
    - Geography (U.S. basin/region, terrain, vegetation type, ability to fly a drone)
  - Hillman State Park, PA was identified as a field testing and demonstration site that meets the needs indicated by several of the PIs for various CATALOG research projects
  - The Well Done Foundation (https://welldonefoundation.org/) has been identified as a collaborator in providing well sites for emissions measurement collection and testing. They have had and will continue to have field sites across the country.
- Future Work: Continue to communicate with PIs to ensure field testing and demonstration sites are available to match their needs





Defining key terms for the CATALOG project

- Motivation and Background
  - Various terminology may be used to describe the disposition of non-producing oil and gas wells depending on state.
  - Use of differing terms and definitions can hinder communication understanding of state and project needs.
  - The Integration and Best Practices team created a glossary (“Key Terminology for the CATALOG Project”) summarizing key, relevant terms and associated generalized definitions – noting certain synonymous terms parsed out by state – to help streamline discussions and ensure consistent understanding across the project.

Defining key terms for the CATALOG project

- Data/Methodology
  - Multiple peer-reviewed journal articles, shared project resources, and governmental reports were consulted to assemble the glossary.
- Learnings/Accomplishments
  - A quick-guide glossary of important terms used to categorize non-producing oil and gas wells facilitates common understanding and aids the project in engaging with state agencies that may use different terms

Defining key terms for the CATALOG project

Term	Key nuances	Notes
Abandoned	Non-producing well that is either plugged or unplugged.	Regional Synonyms: Deserted, dormant, idle, inactive, long-term idle, shut-in, suspended, temporarily abandoned, orphaned
Orphaned Well	An unplugged abandoned well with an unknown/insolvent operator such that a governmental agency is responsible for decommissioning and remediation.	Regional Synonyms: Abandoned, forfeited, revoked, shut-in, unknown CA: deserted, potential orphan NY: unknown, unknown located, unknown not located PA: DEP orphan, DEP abandoned UT: orphan-no responsible operator
Documented Orphaned Well	An orphaned well whose details (location and characterization) can be found in federal inventories or in a state database after undergoing a verification process, which can vary by state.	
Undocumented Orphaned Well	An orphaned well that has an unknown or unverified location and lacks formal documentation (e.g., drilling, completion, or inspection reports) establishing the existence and properties of the well.	Regional Synonyms: None; Lost; Unknown
Uncharacterized Orphaned Well	An orphaned well whose location is known, but well has unknown properties or characteristics.	Term introduced by CATALOG project

Integration and Best Practices: Other Future Work

- To make research products consumable on multiple levels, the team will communicate with PIs, collect information and results, and share them in a format that is appropriate for our stakeholders on the CATALOG website.
- Automation of the procedure for locating oil and gas wells that utilizes a compilation of publicly available digital resources: There are opportunities to automate this process using machine learning techniques. A CATALOG team has initiated efforts to pick well features from topographical maps using ML. Results will be shared via journal articles (in development) and on the CATALOG website.
- A procedure for assigning a probability or risk factor to potential well sites will be developed as a follow-up to the process for compiling digital resources to find well locations. Based on agreement between various resources, potential well sites will be assigned a higher or lower confidence in the accuracy of the location.
- Field testing and demonstration of deploying drones with a multi-sensor payload, will continue. Ultimately the results of the testing will be shared in best practices guidance in a future year.