

Methods for Locating Wells in Urban Areas - A Summary of Case Studies

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Case Studies

Midwest, Wyoming (Salt Creek Oil Field)

Naval Petroleum Reserve No. 3 (Teapot Dome Oil Field)

- Locate Unmarked Abandoned Wells
- Evaluate Effectiveness of Well Finding Technologies
- Verify Wells Database

Versailles Borough, Pennsylvania

- Locate Unmarked Abandoned Wells

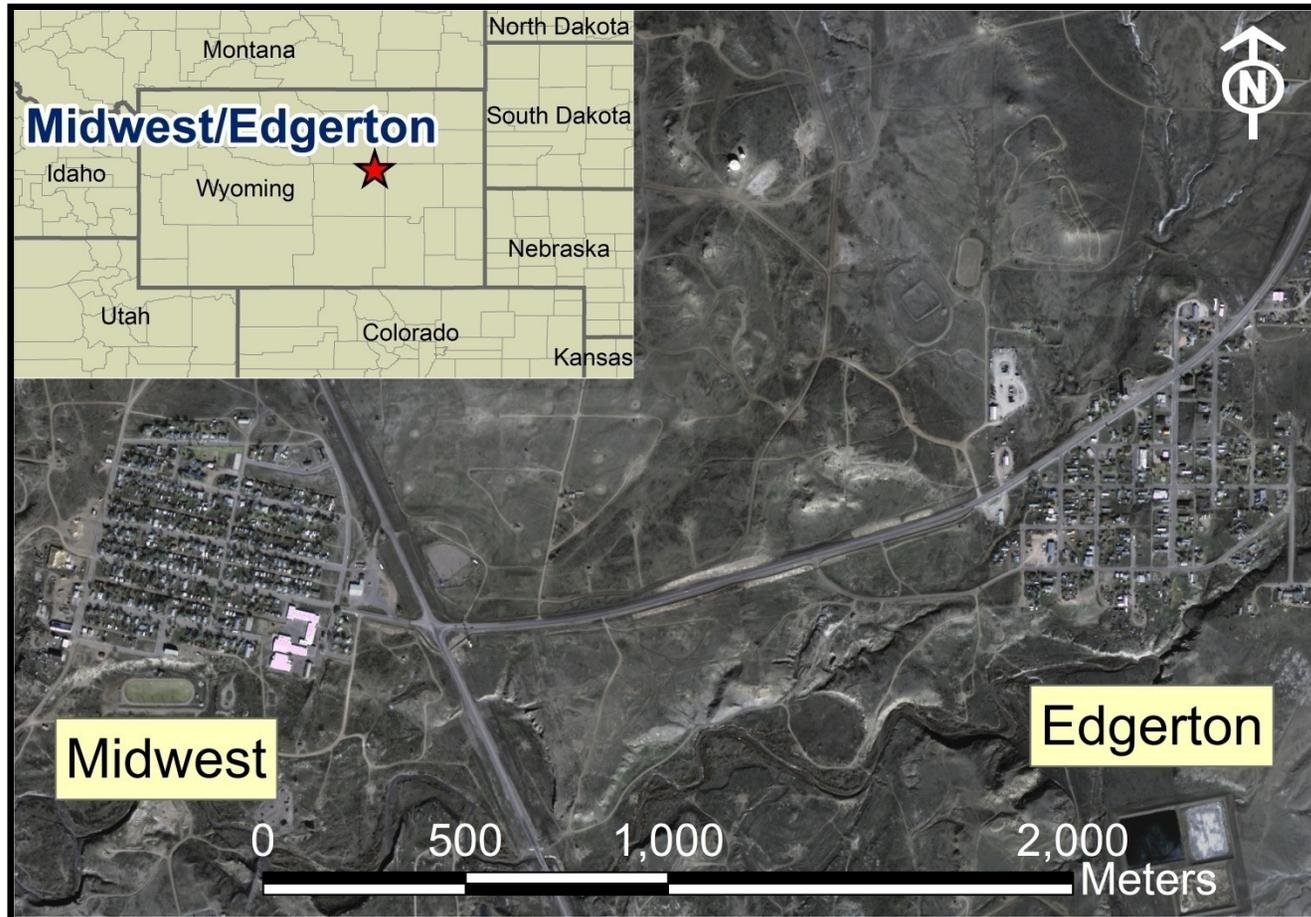


Methods for Locating Abandoned Wells

- **Geophysical Methods**
 - Airborne Magnetometry
 - Ground Magnetometry
- **Spectroscopic Methods**
 - Portable Infrared Spectrophotometer (Apogee LDS)
 - Differential Absorption Lidar (LaSEN)

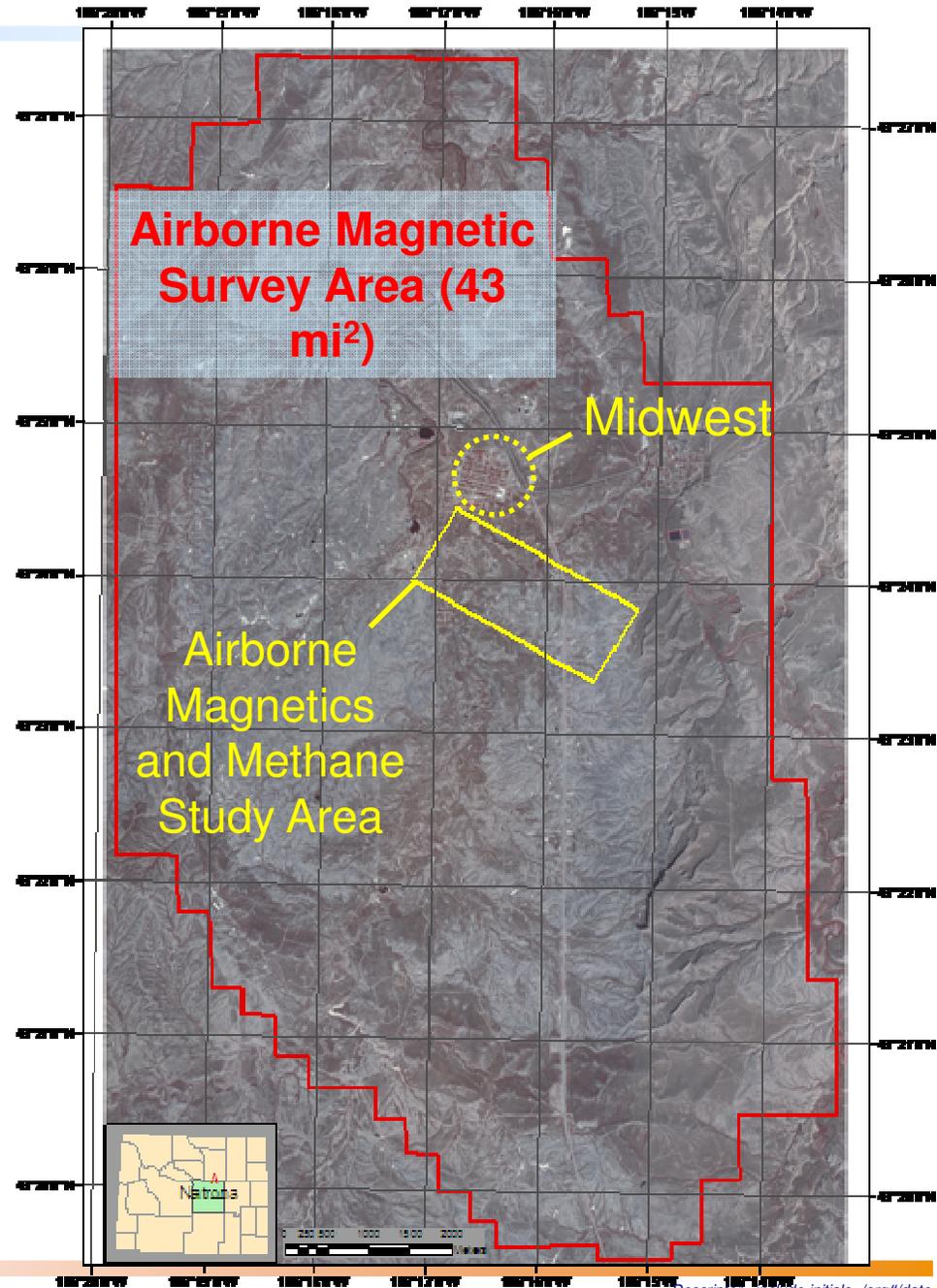


Midwest, Wyoming Location Map

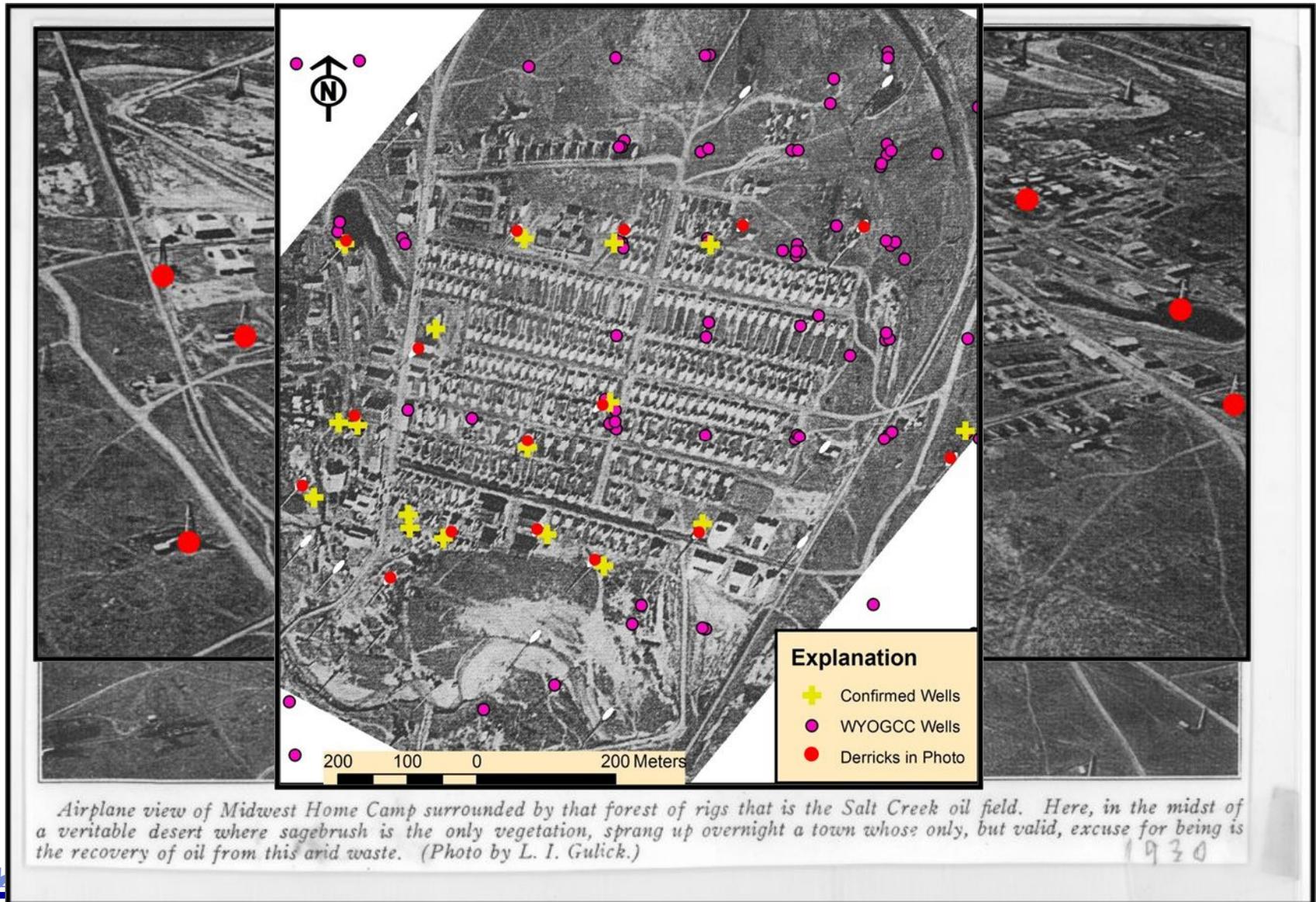


Salt Creek Oil Field Midwest, Wyoming

- Study Area Selection Criteria
 - 1 mi²
 - Accessible
 - Wells inventory/database
 - “Friendly” terrain
 - Selected for CO₂ flood



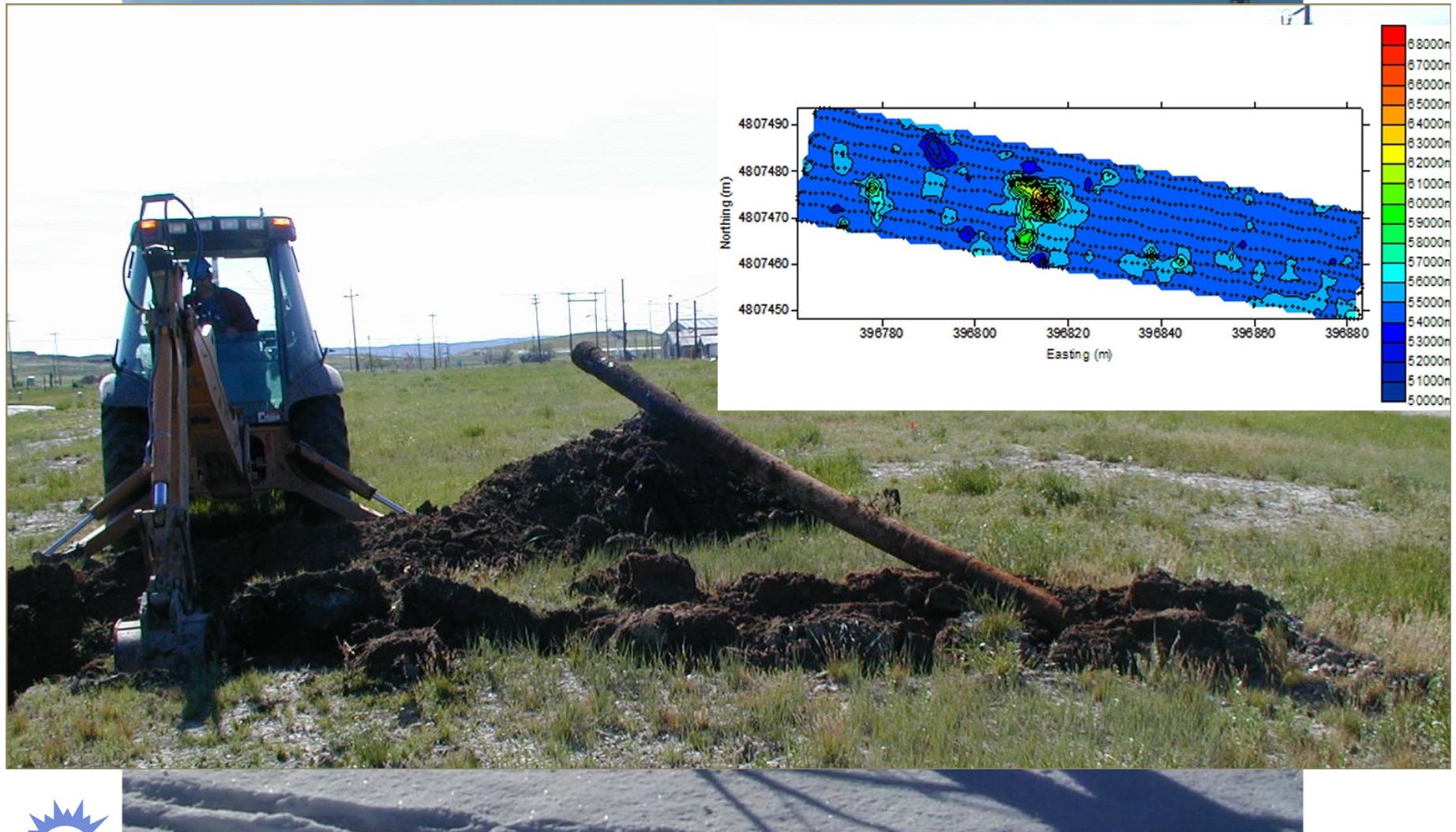
Locating Wells in Midwest



Use of Historical Photos for Well Finding - Example



Ground Magnetic Surveys in Midwest, WY



Wells Located by Ground Magnetometry in Midwest, WY



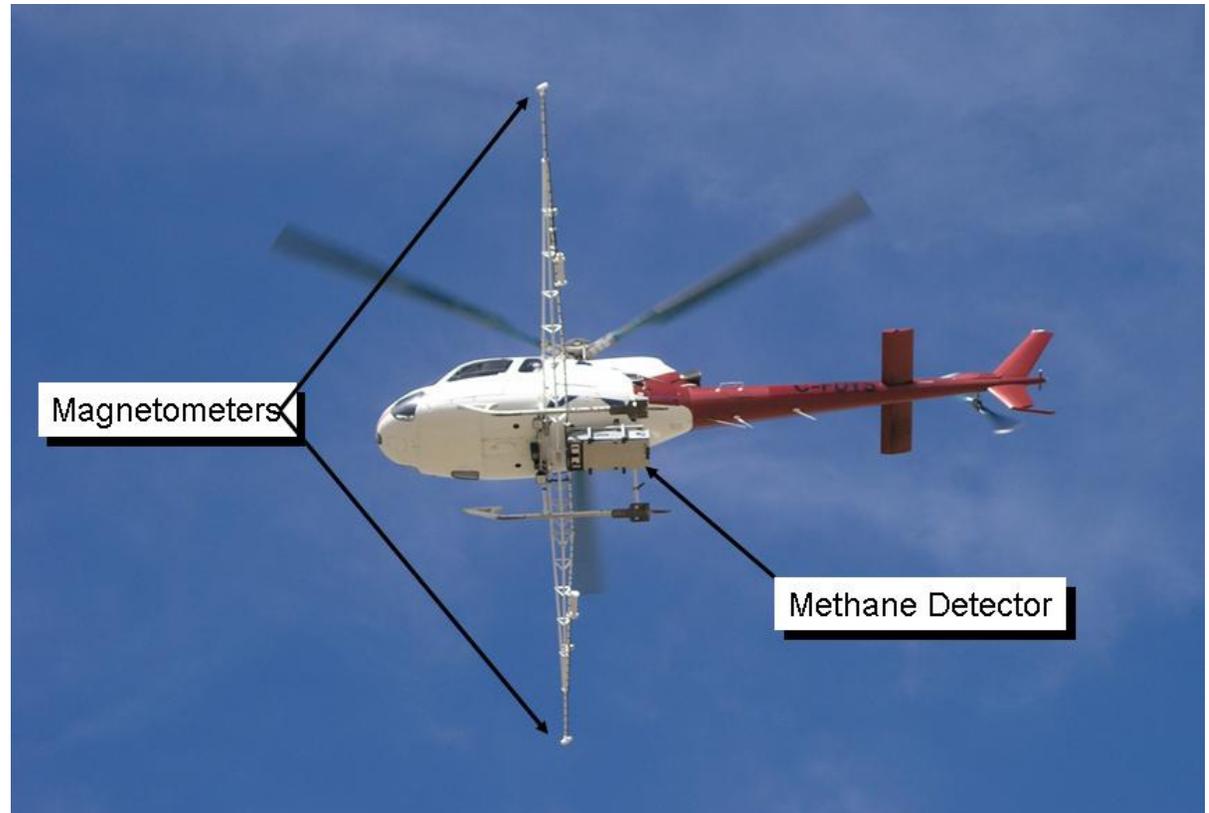
Results from Ground Magnetic Survey in Midwest, Wyoming

- 25 excavations
- 23 wells located
- Horizontal accuracy of <0.6 m (<2 ft)
- One 0.2 m x 3.7 m vertically oriented steel pipe
- One repository of buried truck parts
- Success rate = 96%
- All documented wells found

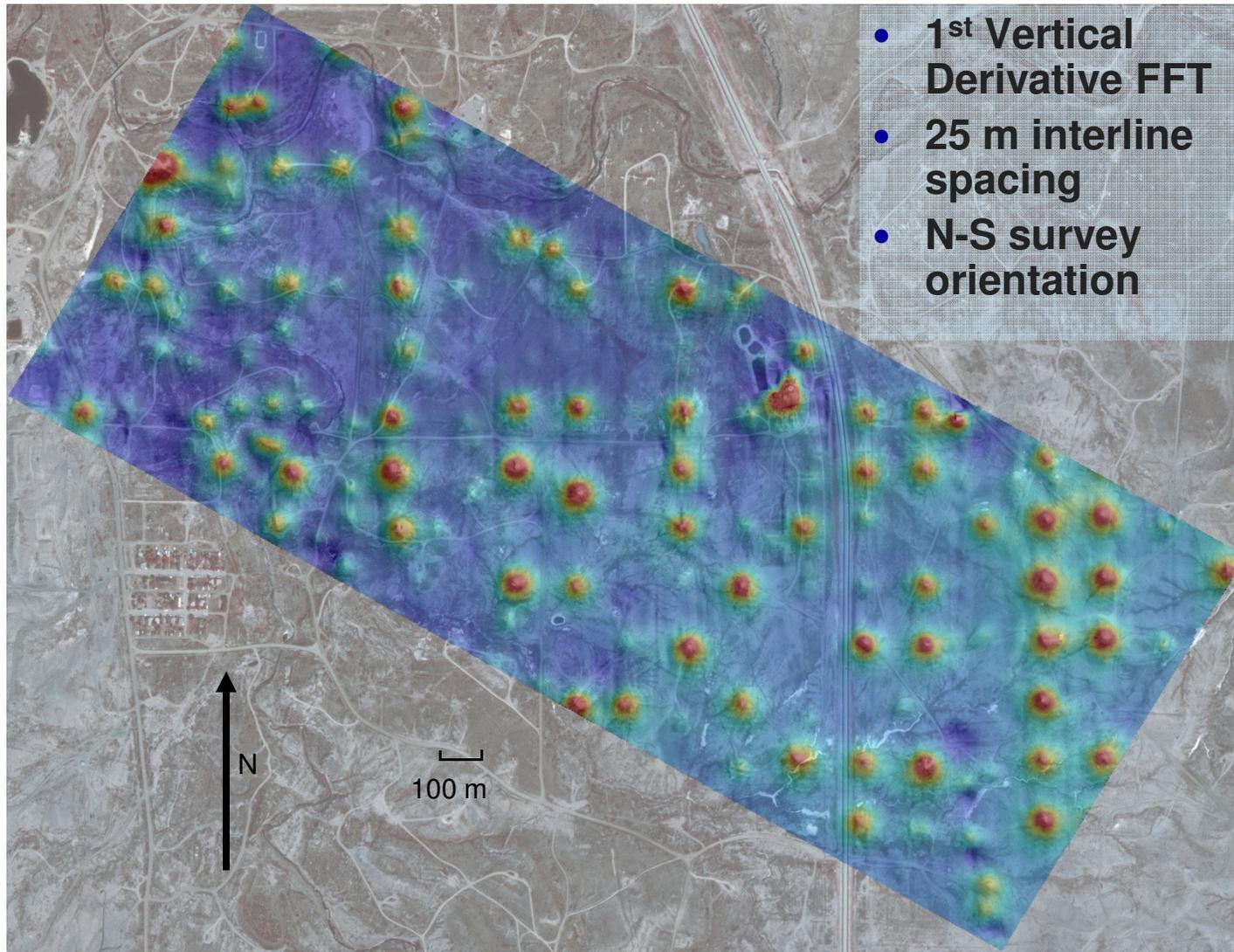


Airborne Survey - Salt Creek Oil Field

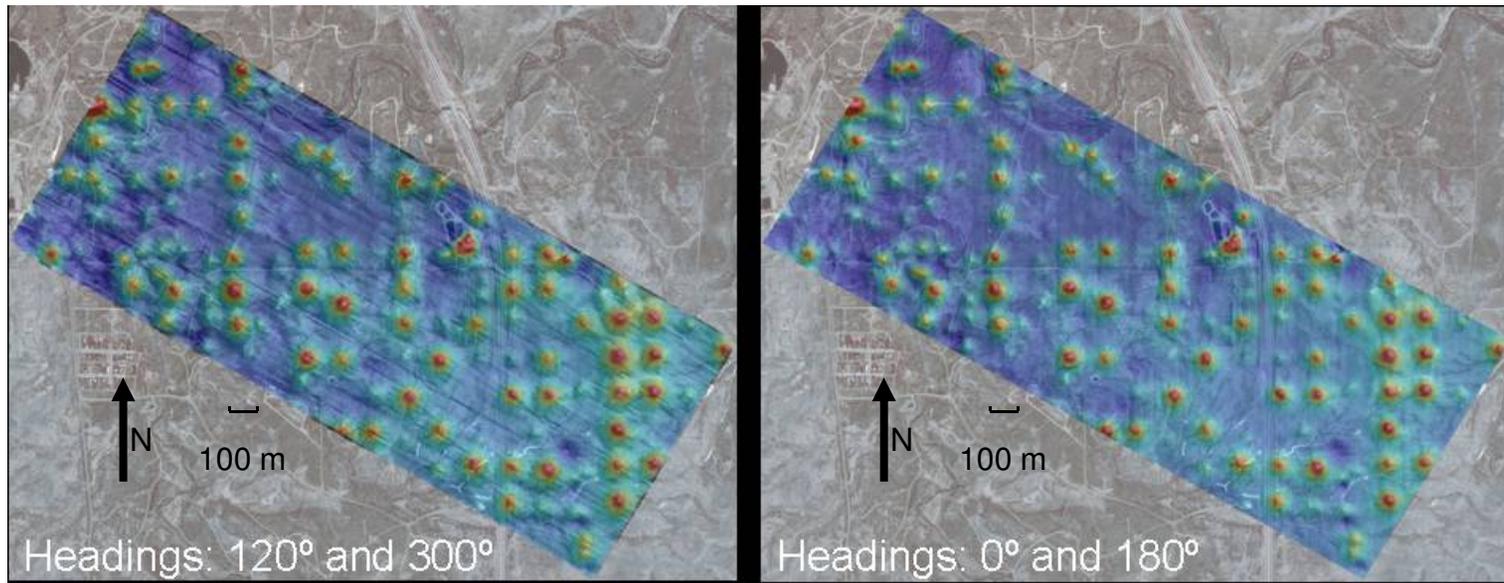
- Midas horizontal boom dual sensor (cesium)
- On-the-fly-data compensation (flux gate sensors inboard of main sensors)



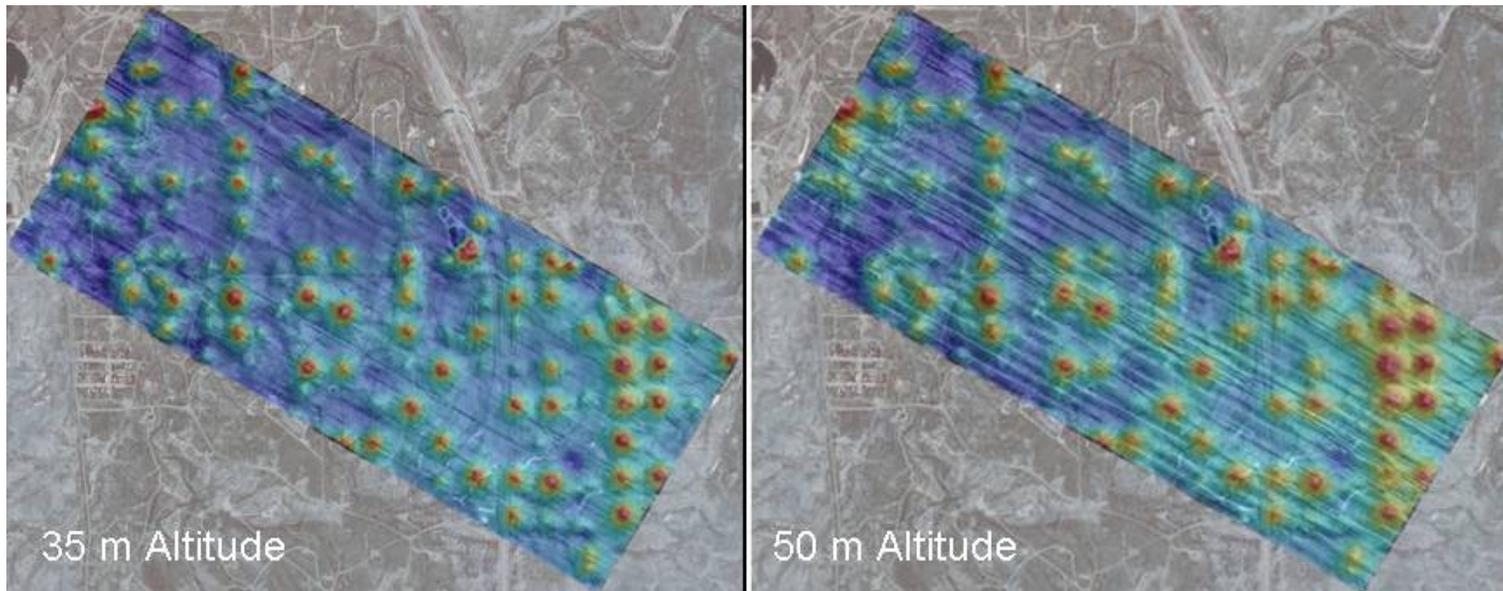
Results from Airborne Magnetic Survey



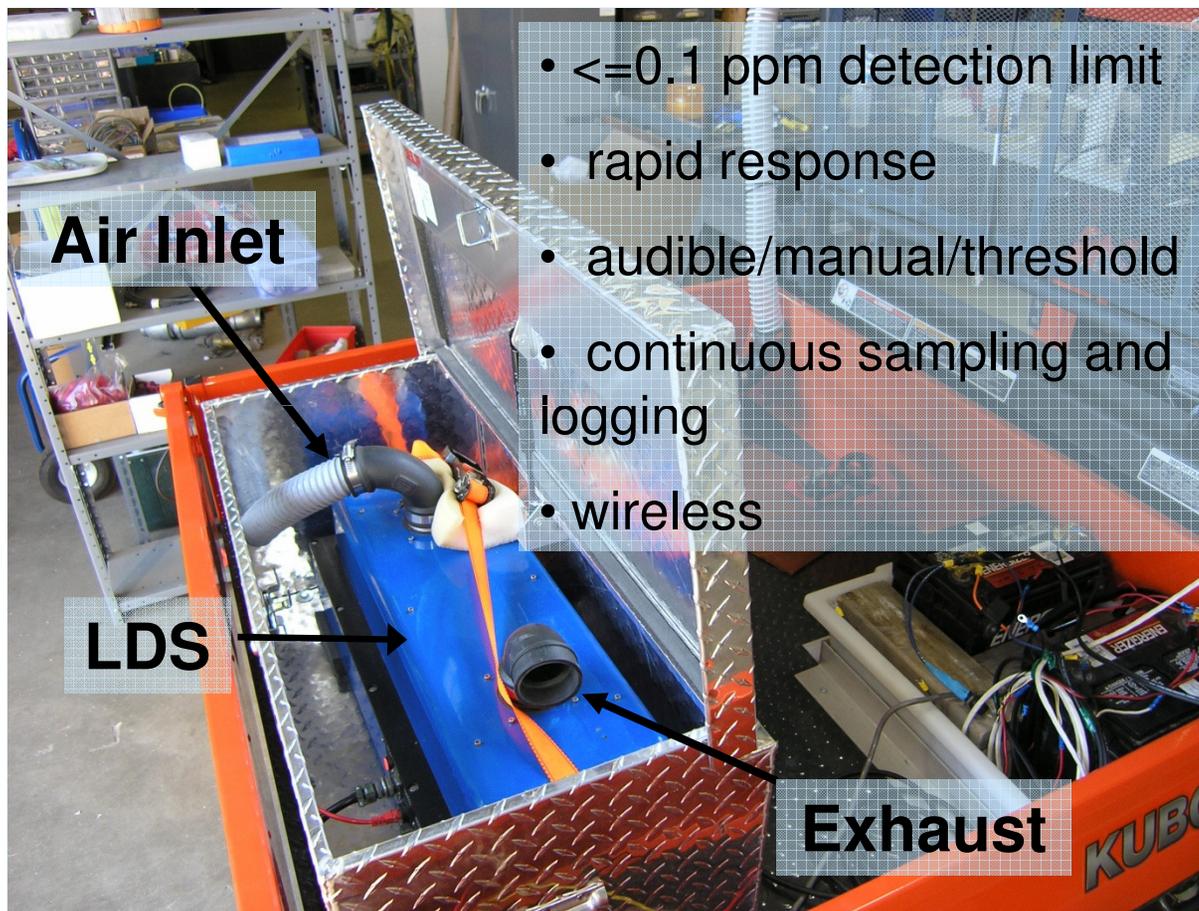
Airborne Magnetometry- Effect of Survey Heading



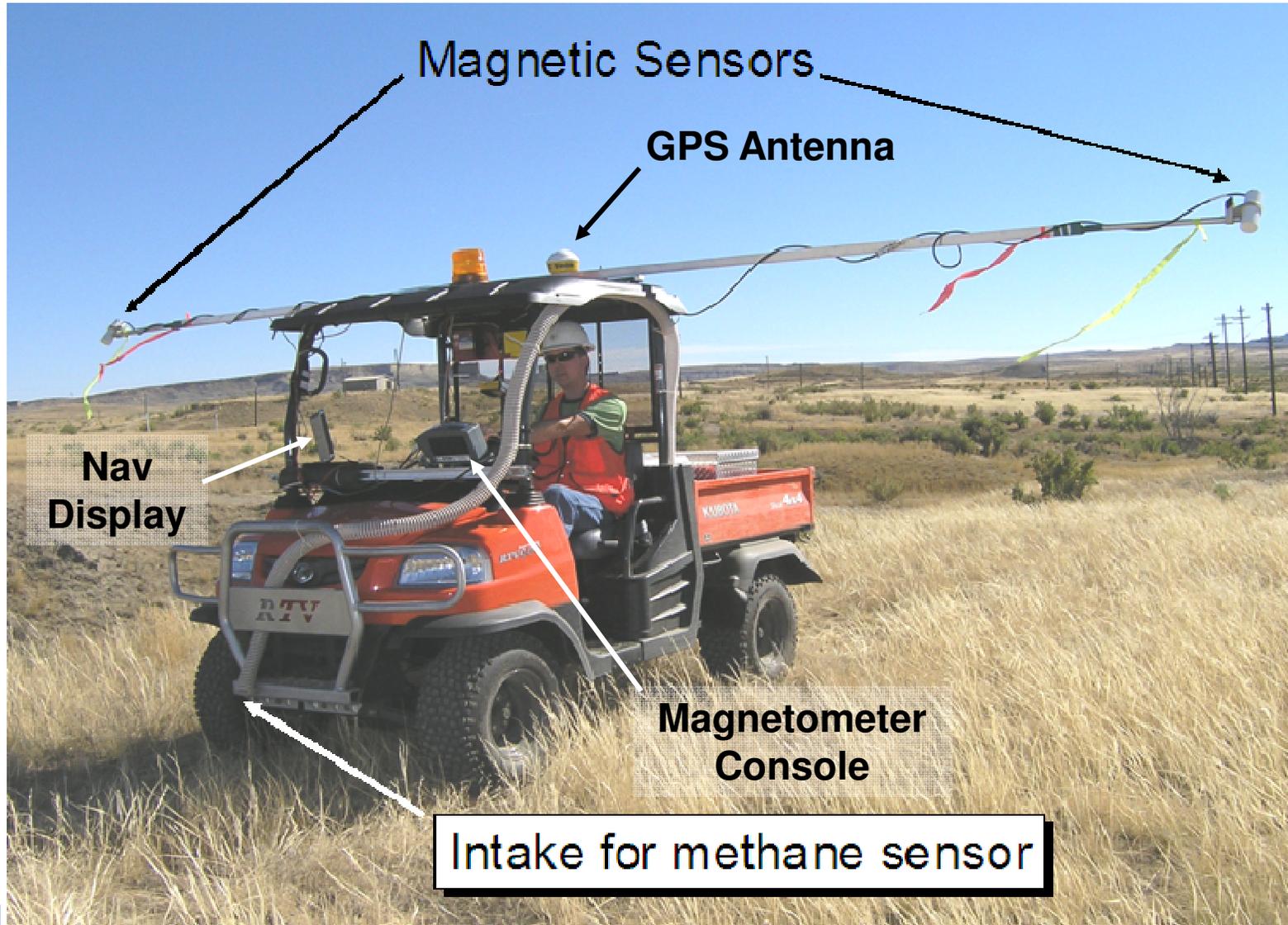
Airborne Magnetometry – Effect of Altitude



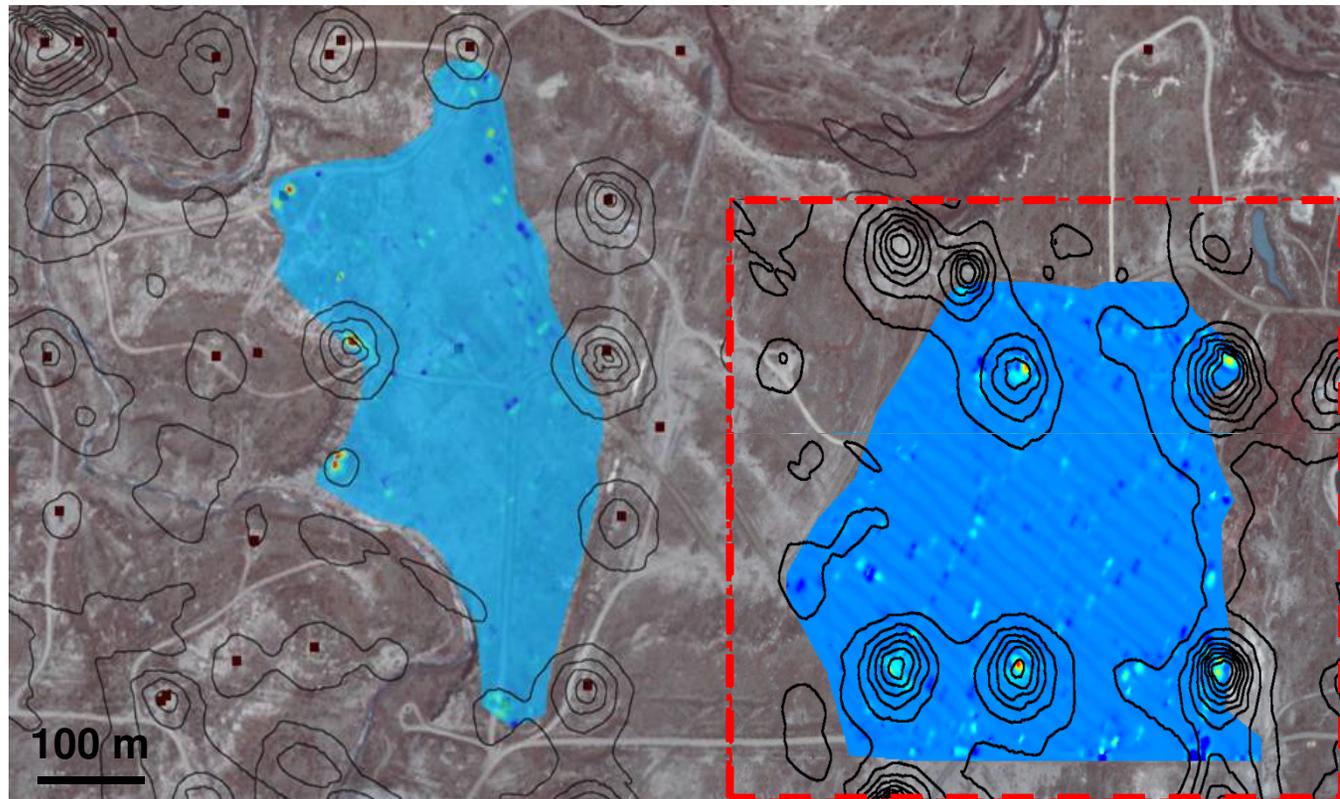
Apogee LDS Infrared Spectrophotometer for CH₄, CO₂, and HC



Ground Survey Vehicle



Utility Vehicle Magnetometer Surveys



Contours:
Airborne
Magnetic
Anomalies

- Wells

Survey Parameters:
10 m line spacing
0.1 second sampling interval

Sensor spacing = 6 m
Sensor Height = 2.1 m
Survey Direction = NW-SE

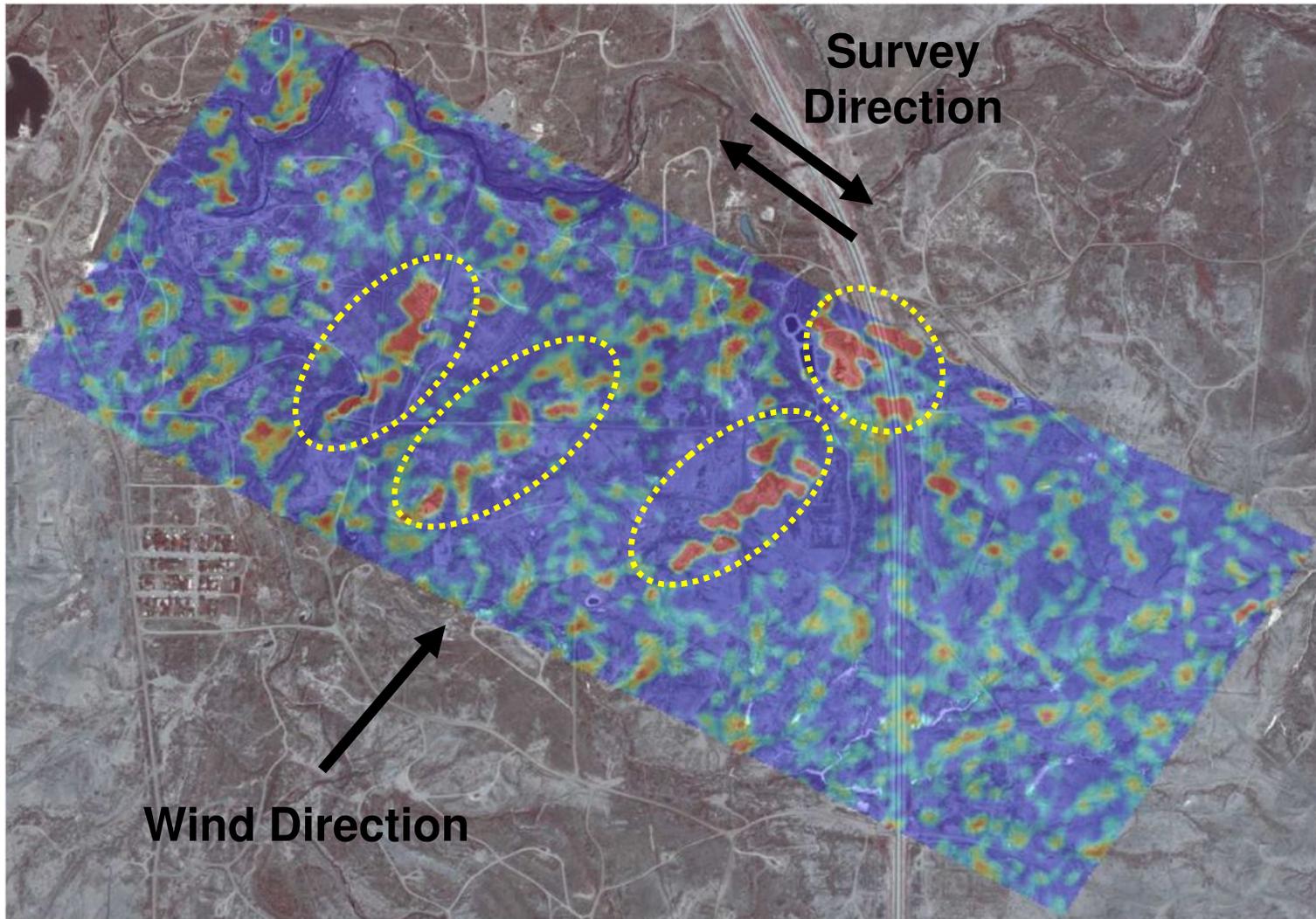


Summary of Results for NETL 1 mi² Survey Area

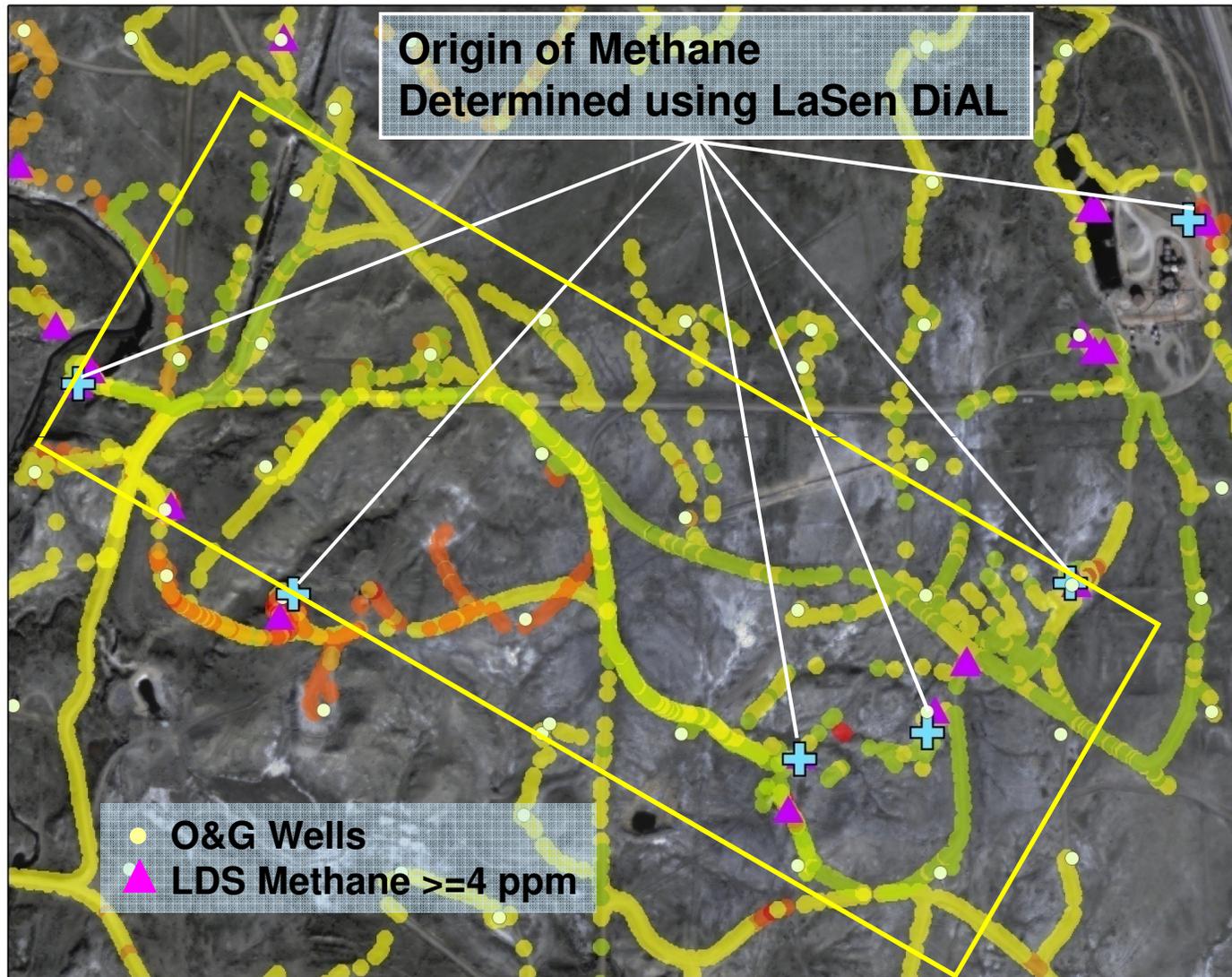
- 129 Wells in Database
- 10 Database Wells not Detected
- 120 Targets detected in Helicopter Survey
- 34 Targets detected in Helicopter Survey NOT in Database
- 1 Target Located only in Ground Survey



LaSen Methane Data



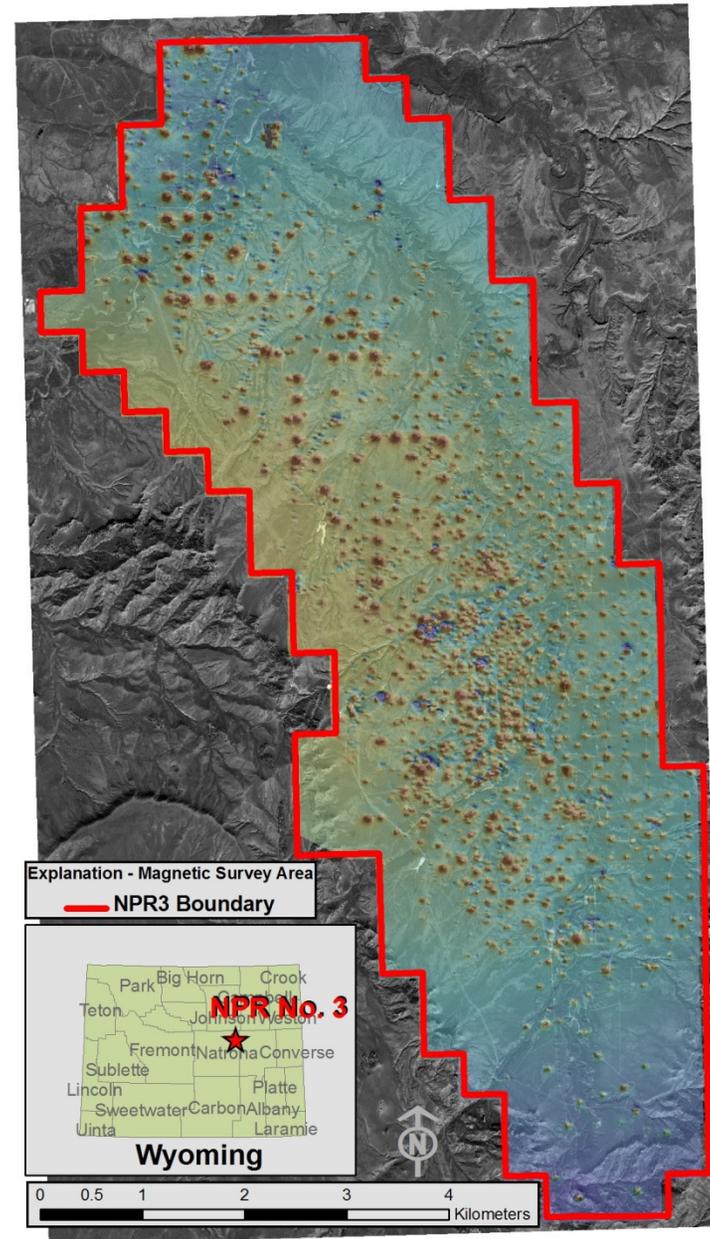
Comparison of Apogee and LaSen Data



Location Map – NPR No.3 Airborne Magnetic/Methane Survey

Rocky Mountain Oilfield Testing Center (RMOTC), Naval Petroleum Reserve No.3

- 40 miles northeast of Casper, WY
- Gov't owned (est. 1915)
- 40.5 km² (9600 acres)
- ~2200 (+/-) oil/gas/injection wells
- produces Oil, NG and NGL



Purpose of Magnetic Survey at RMOTC

- **Locate existing wells**
- **Locate undocumented wells**
- **Reconcile database**
- **Evaluate effectiveness of methane survey**
- **Make improvements**



Airborne Survey Parameters – RMOTC



- Midas II System
- 2- Scintrex CS-2 cesium vapor magnetometers
- In-flight sensitivity of 0.01 nT, 13.4 m apart
- Speed ~70 kts, 10 Hz (3.6 m sampling interval)
- Absolute Altitude (AGL) 20 m
- Interline spacing 25 m
- N–S survey direction

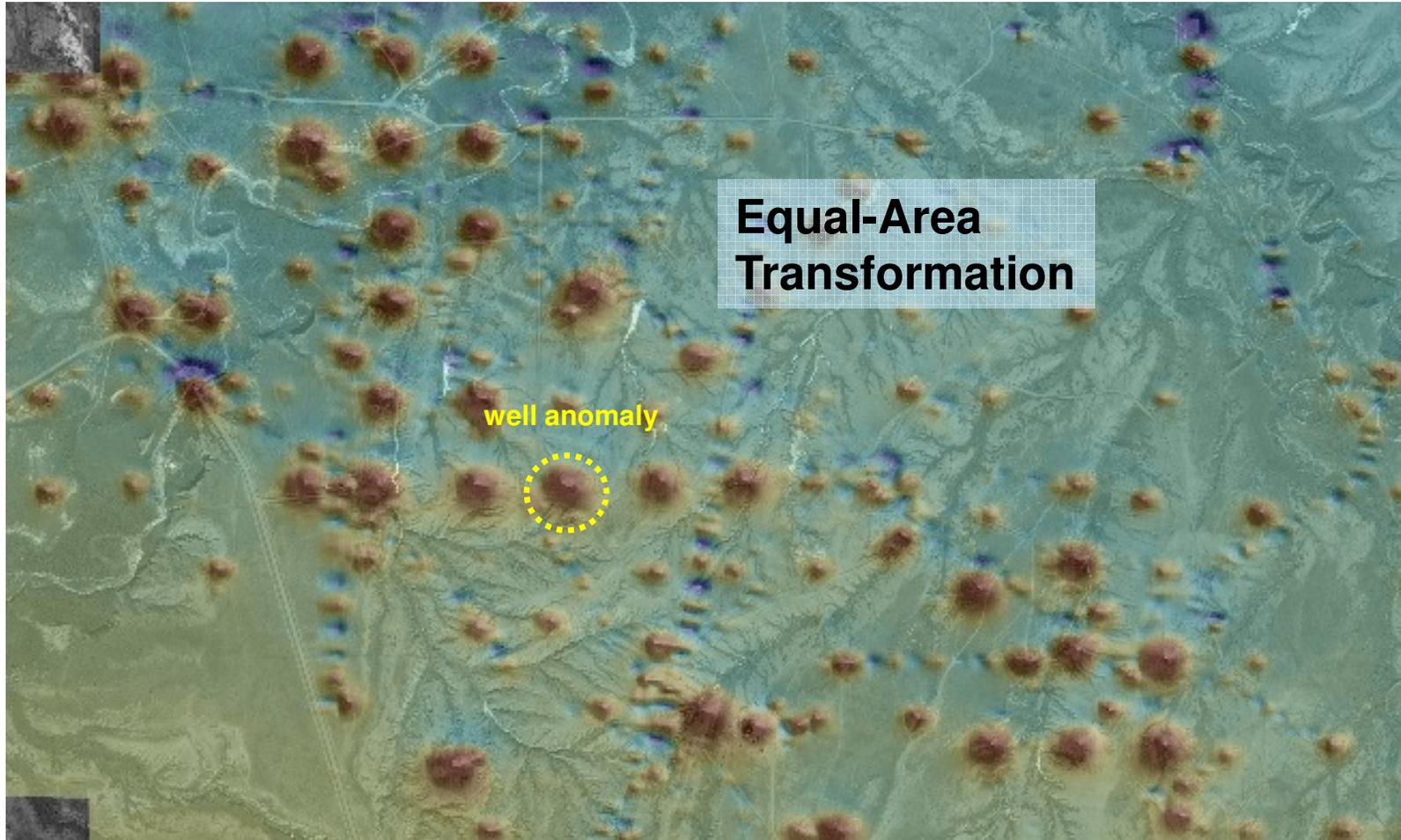


Schema for Processing Magnetic Data

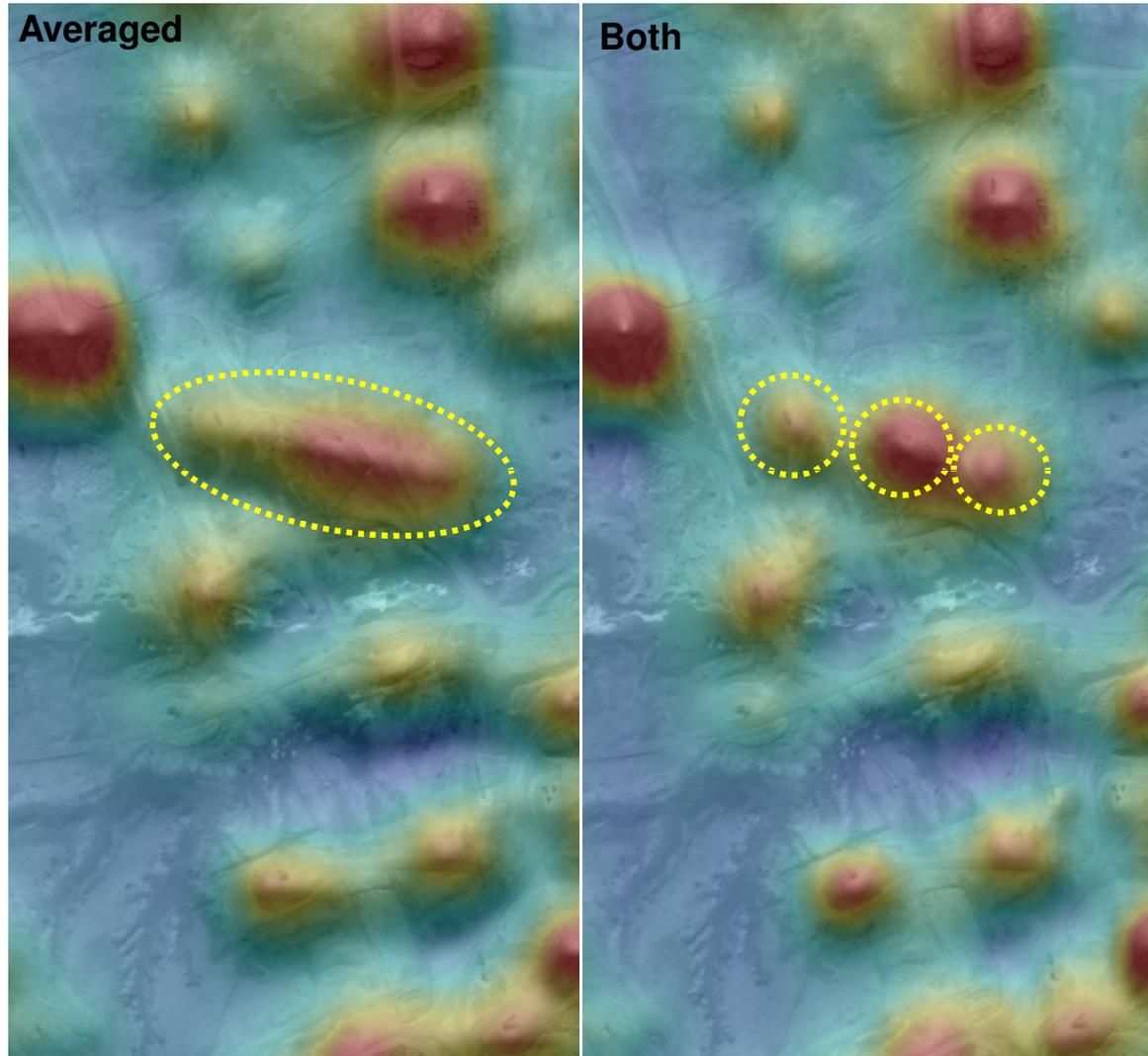
- **Import xyz data file into Geosoft as line database**
- **Apply Corrections**
- **Generate grids**
- **Apply color schemes, filter, shaded image**
- **Overlay imagery, CAD, shapefile layers**
- **De-trend**
- **Automated target selection from grid**
- **Perform spatial analysis in GIS**
- **Verify/Reconnaissance/Excavate**



Processing Magnetic Data - Feature Enhancement



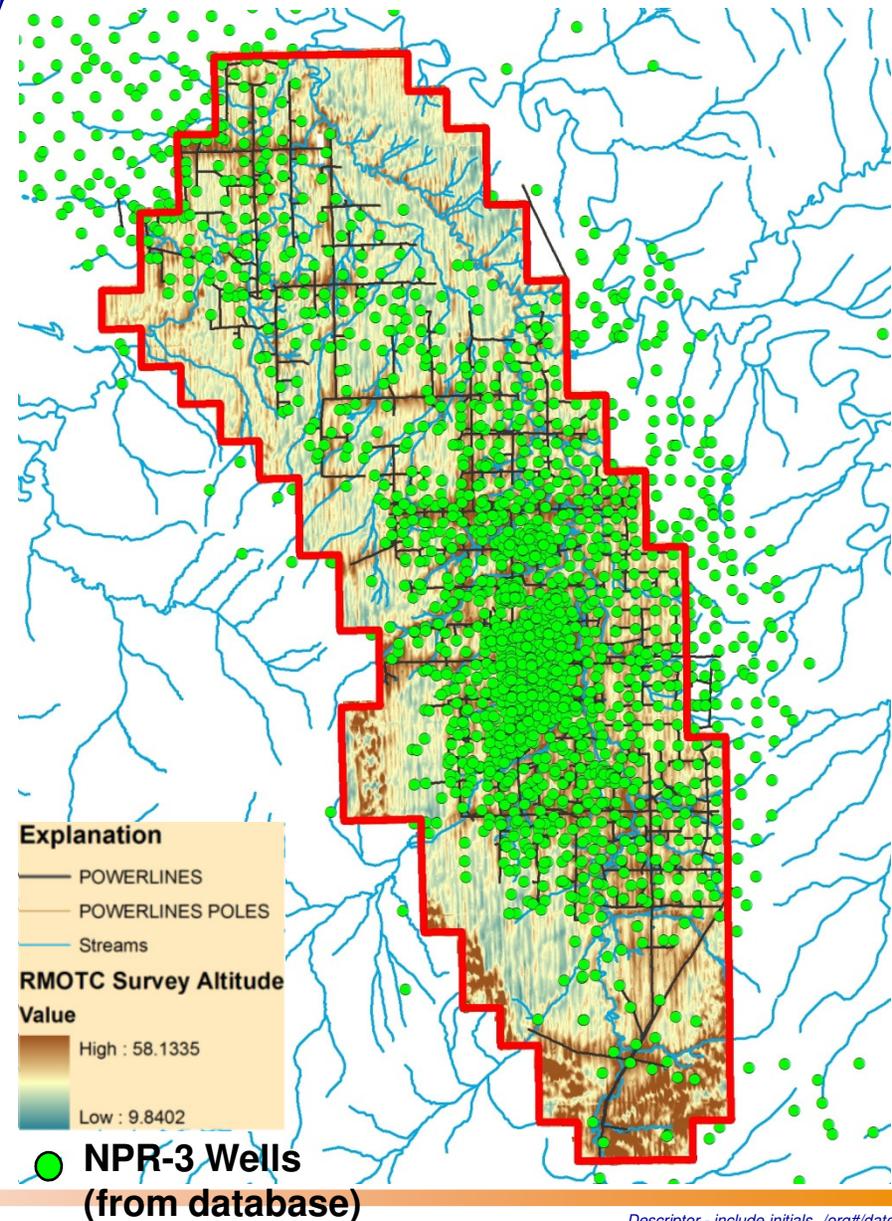
Averaged Response vs. Both Sensors



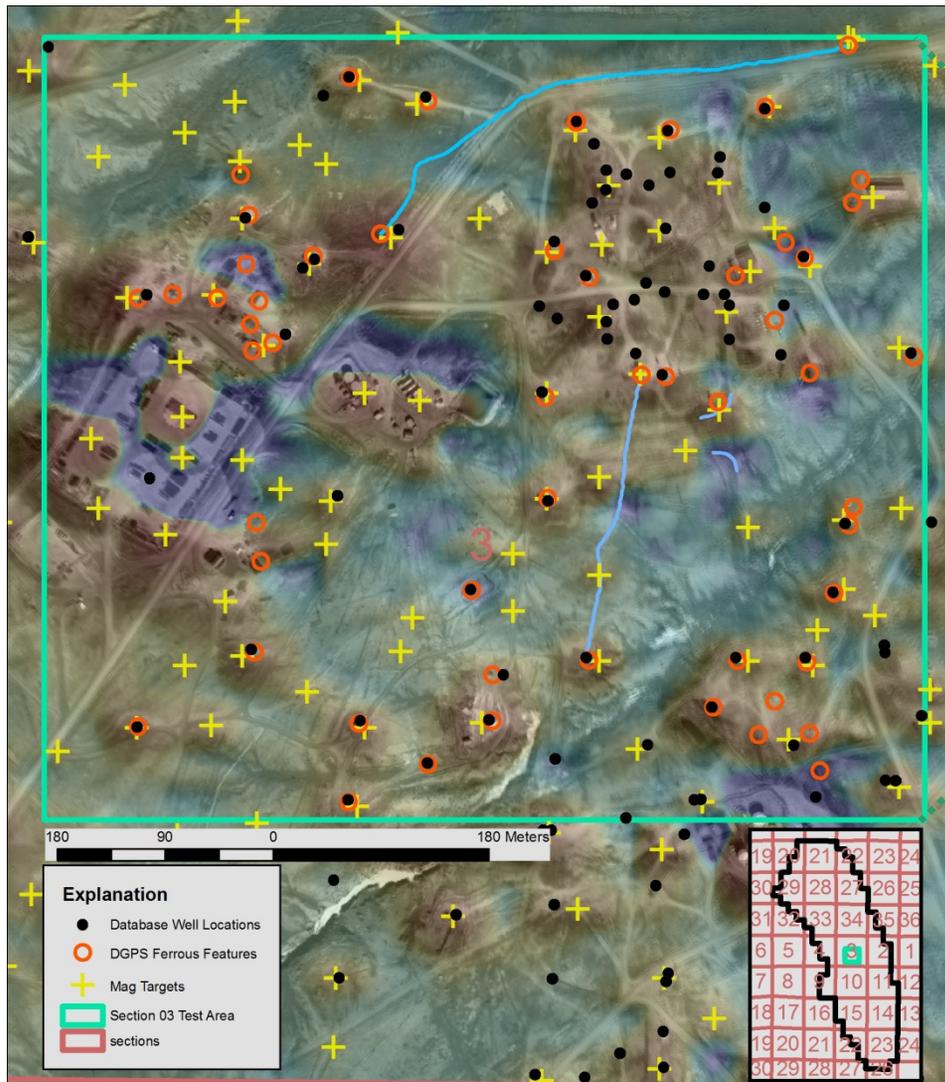
**Sensors treated
as independent
measurements**

Airborne Magnetic Survey Terrain Compliance at RMOTC

- Obstructions
(Power lines, poles)
- Rising terrain
- Falling terrain



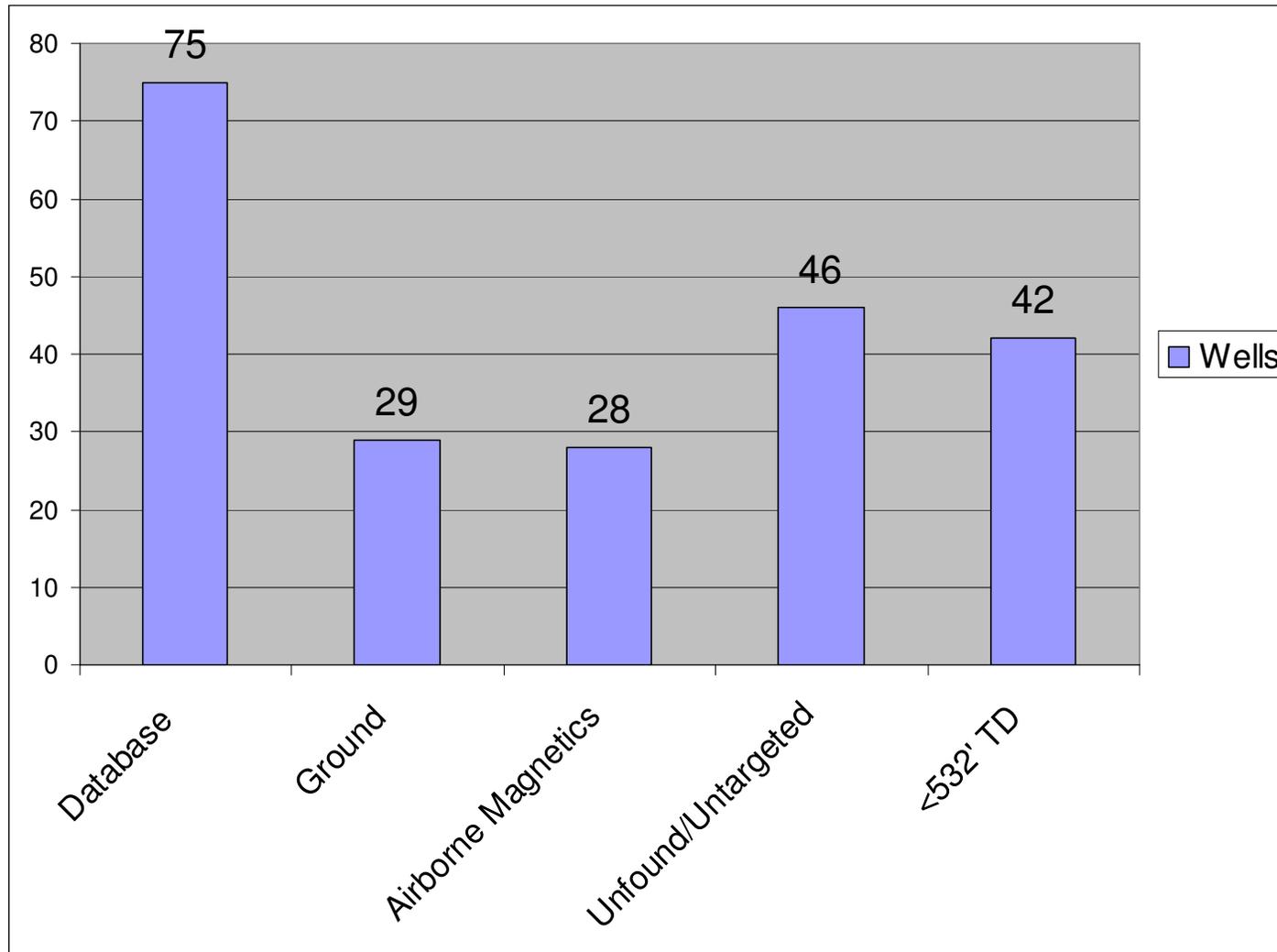
RMOTC Airborne Magnetics Validation Area



Area = 0.5 km²



RMOTC Validation Area Summary



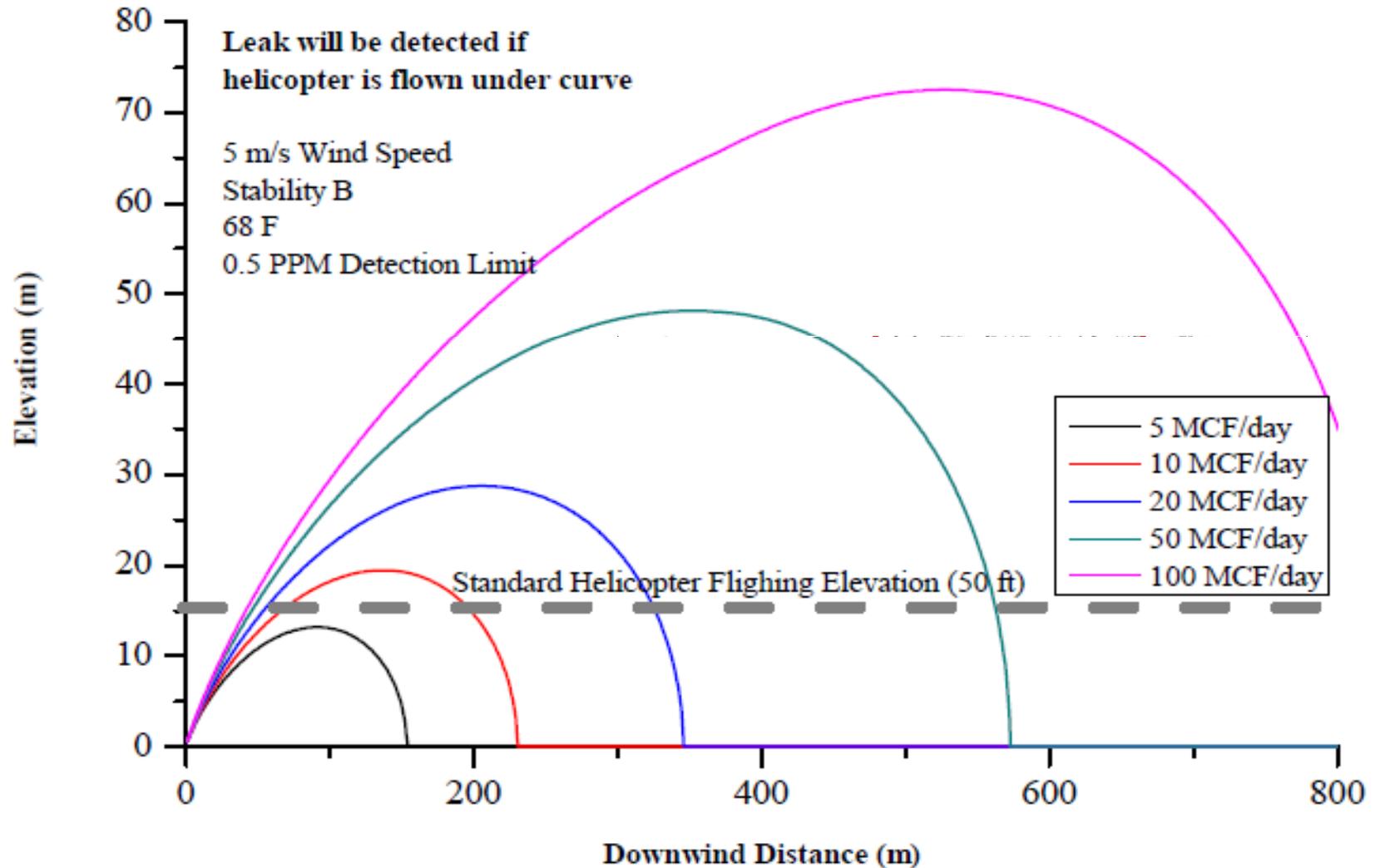
RMOTC Magnetic Survey Results (general)

- Airborne magnetics could not detect all steel-cased wells at NPR-3
- Wells closer than ~15 m apart not resolved
- Most undetected wells at NPR-3 were shallow (<500 ft) and relatively recent (after 1970).
- Cable tool wells (before 1930) strongly magnetic



Airborne Detection of Methane at RMOTC

Modeled Methane Plume Characteristics



Tools for Analysis of Methane Survey Data

The screenshot shows the Google Earth interface with a satellite view of a landscape. Several yellow waypoints are placed on the terrain, each labeled with a date and time, such as "08/04/07-33", "08/04/07-36", "08/04/07-41", "08/04/07-35", "08/04/07-42", "08/04/07-38", and "08/04/07-44". A text box overlaid on the map reads: "Leaks appear in Google Earth as waypoints along with anemometer data".

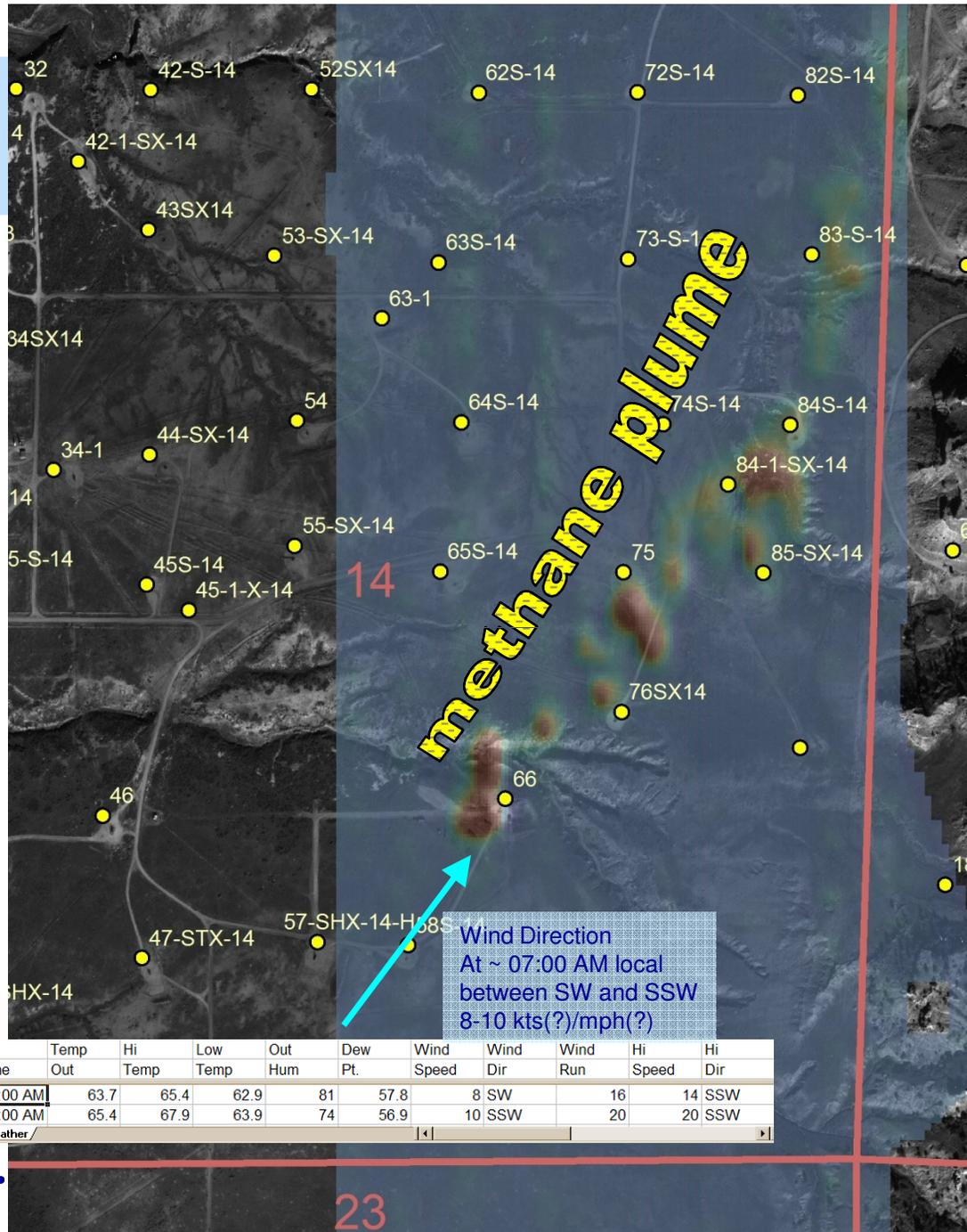
In the bottom-left pane, a table of survey data is displayed. The table has columns for sample number, longitude, latitude, northing, easting, elevation, concentration (ppm), type, date, and time. The row for sample 70 is highlighted in red.

	A	B	C	D	E	F	G	H	I	J
1	sample_no	long	lat	northing	easting	elev_ft	conc_ppm	type	date	time
64	83763	-106.178276	43.287167	4793378.95	404408.71	5438	0.71	0	8/4/2007	9:15:33 AM
65	83785	-106.178268	43.286625	4793318.78	404408.48	5438	1.06	0	8/4/2007	9:15:35 AM
66	87936	-106.178275	43.287167	4793378.95	404408.71	5438	0.71	0	8/4/2007	9:22:28 AM
67	88001	-106.178268	43.286625	4793318.78	404408.48	5438	0.43	0	8/4/2007	9:22:35 AM
68	88934	-106.178268	43.286625	4793318.78	404408.48	5438	0.43	0	8/4/2007	9:24:08 AM
69	89974	-106.178261	43.260895	4790461.31	404368.81	5437	1.15	0	8/4/2007	9:25:51 AM
70	89995	-106.178238	43.260323	4790397.74	404369.78	5437	1.81	0	8/4/2007	9:25:53 AM
71	92118	-106.178658	43.260216	4790386.36	404335.55	5437	0.67	0	8/4/2007	9:29:25 AM
72	93001	-106.179207	43.289917	4793685.46	404337.51	5437	0.45	0	8/4/2007	9:30:53 AM
73	93048	-106.17923	43.291504	4793861.72	404338.14	5437	0.26	0	8/4/2007	9:30:57 AM
74	93123	-106.179268	43.294010	4794140.10	404338.97	5437	0.92	0	8/4/2007	9:31:05 AM
75	93796	-106.179665	43.294121	4794152.84	404306.96	5437	0.36	0	8/4/2007	9:32:12 AM
76	93886	-106.179649	43.291878	4793903.72	404304.68	5437	1.17	0	8/4/2007	9:32:21 AM
77	93906	-106.179657	43.291321	4793841.87	404303.19	5436	0.92	0	8/4/2007	9:32:23 AM

Another text box overlaid on the table reads: "Leaks exported to CSV, Shapefile and GPX file for reconnaissance".

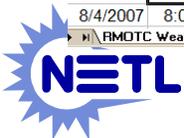


Example of Methane “plume” found by Apogee LDS downwind of Well 66 in Section 14

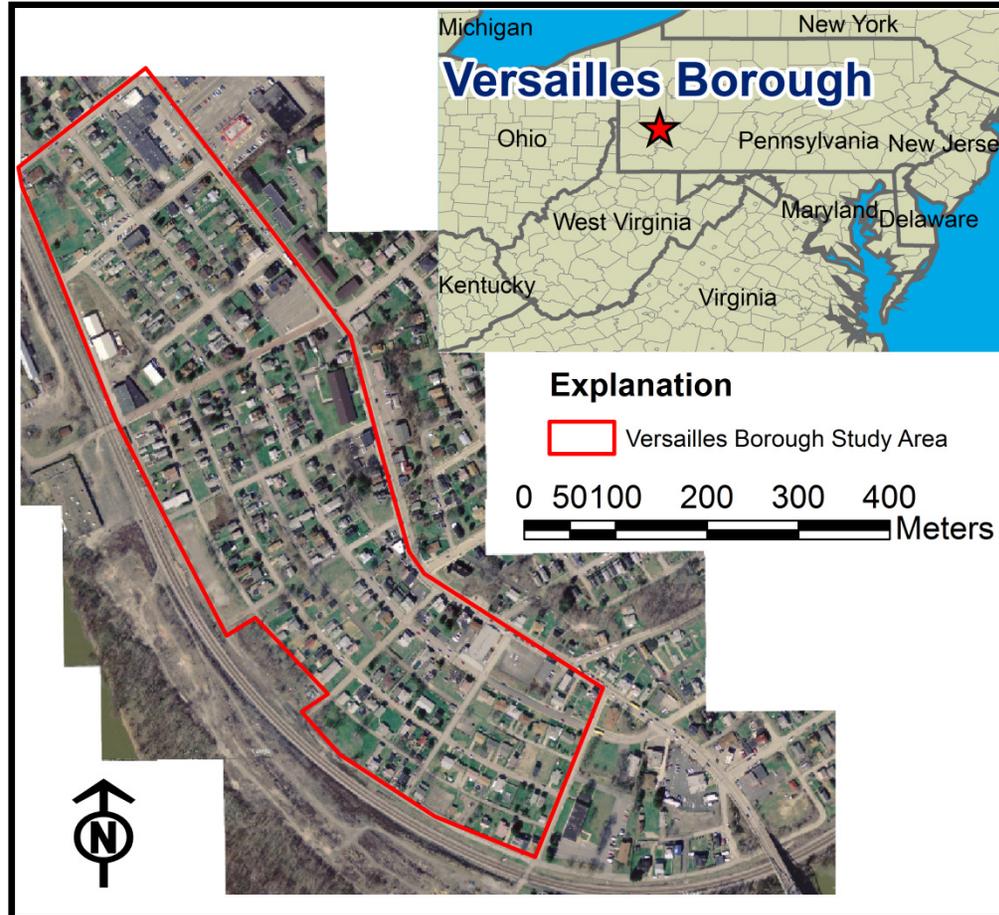


Date	Time	Temp Out	Hi Temp	Low Temp	Out Hum	Dew Pt.	Wind Speed	Wind Dir	Wind Run	Hi Speed	Hi Dir
8/4/2007	6:00 AM	63.7	65.4	62.9	81	57.8	8	SW	16	14	SSW
8/4/2007	8:00 AM	65.4	67.9	63.9	74	56.9	10	SSW	20	20	SSW

FMOTC Weather



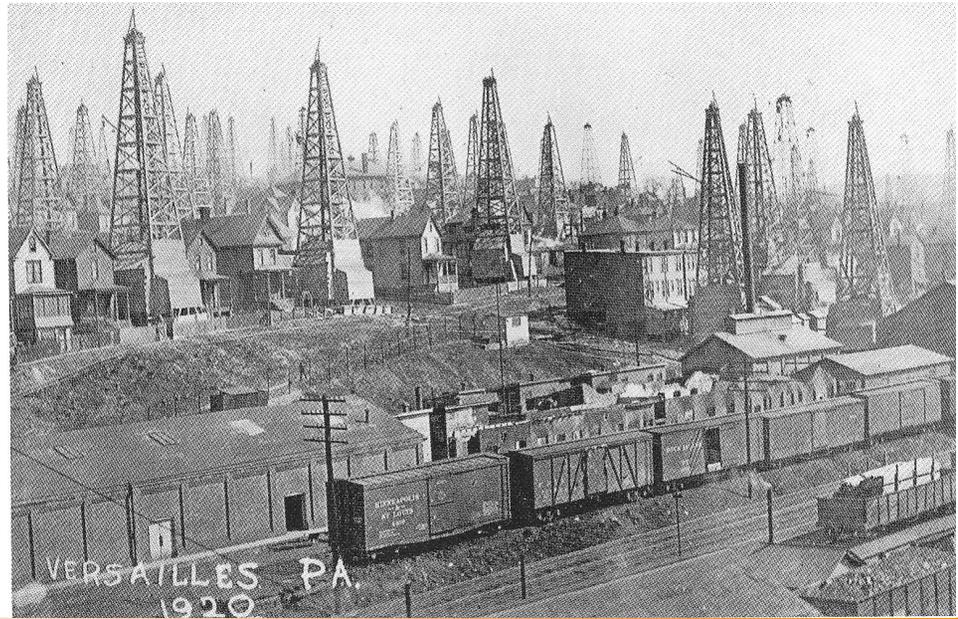
Versailles Borough, PA



Legacy of Gas Wells in Versailles Borough



**“Over 600 wells were drilled in an area that could have been drained by ten”
(Johnson, 1929)**



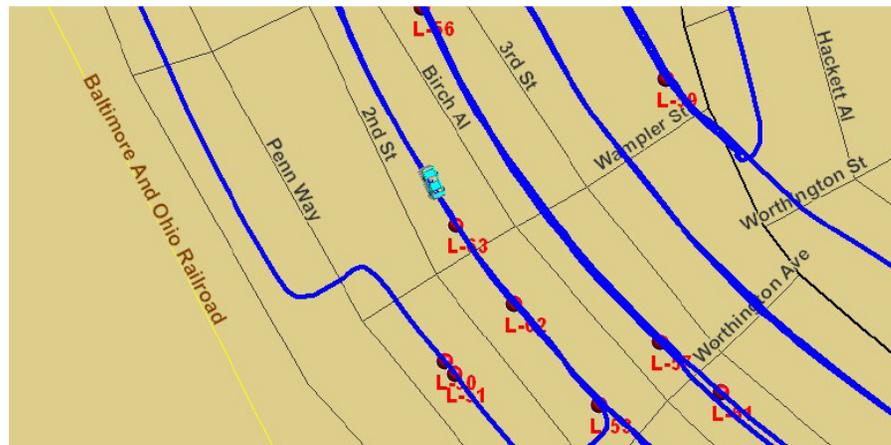
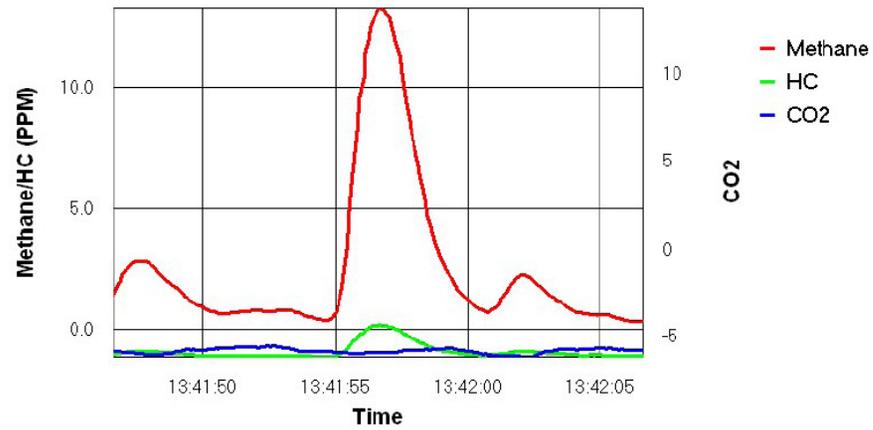
Truck-Mounted Apogee LDS System



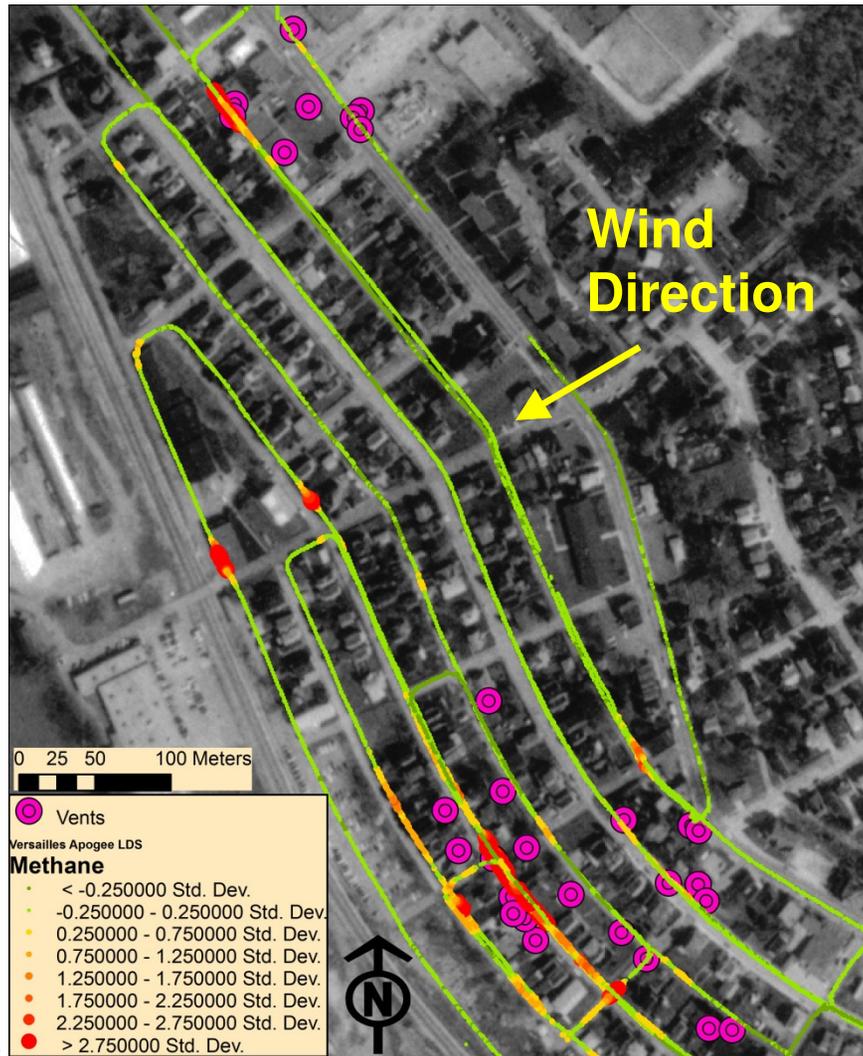
LDS Leak Report

Leak ID: L-63
Project Name:
Date/Time Found: 05/31/06 13:41
Max Methane Conc. (PPM): 13.3
HC:CH4 Ratio: 0.10 R2=1.00
Address: 217 Wampler St
McKeesport, PA 15132

Latitude: 40.316386
Longitude: -79.835124
Altitude (ft.): 748
Vehicle Speed (mph): 6
Operator: gv
Comments:



Versailles Borough Methane Street Survey Results

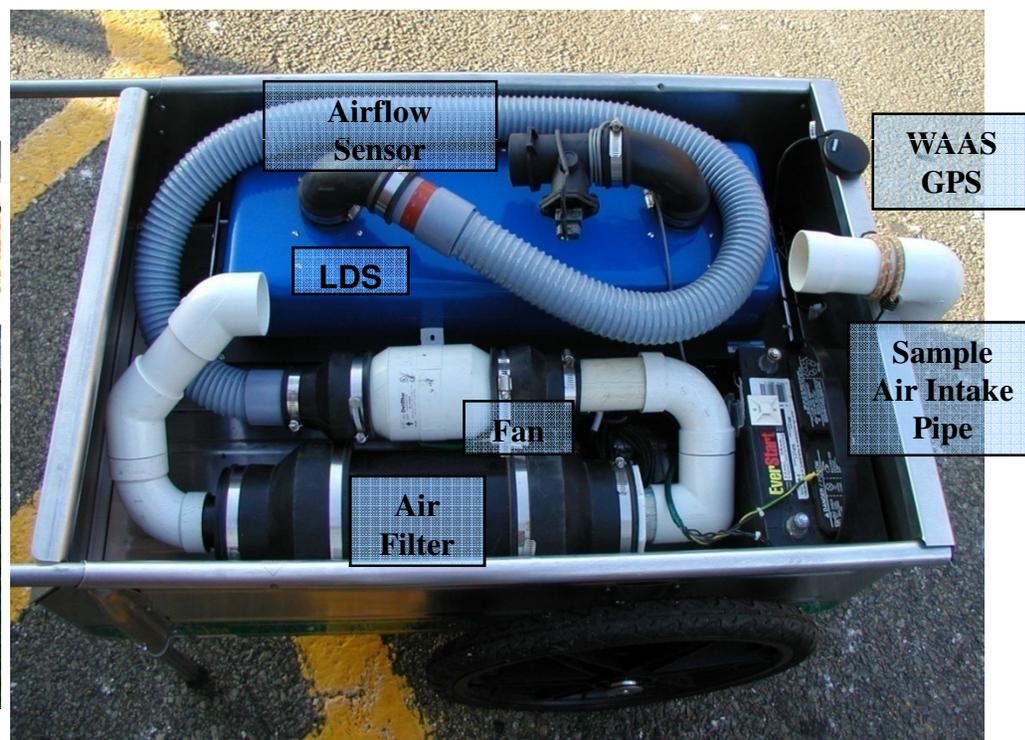


Elevated methane levels found in vicinity of vents

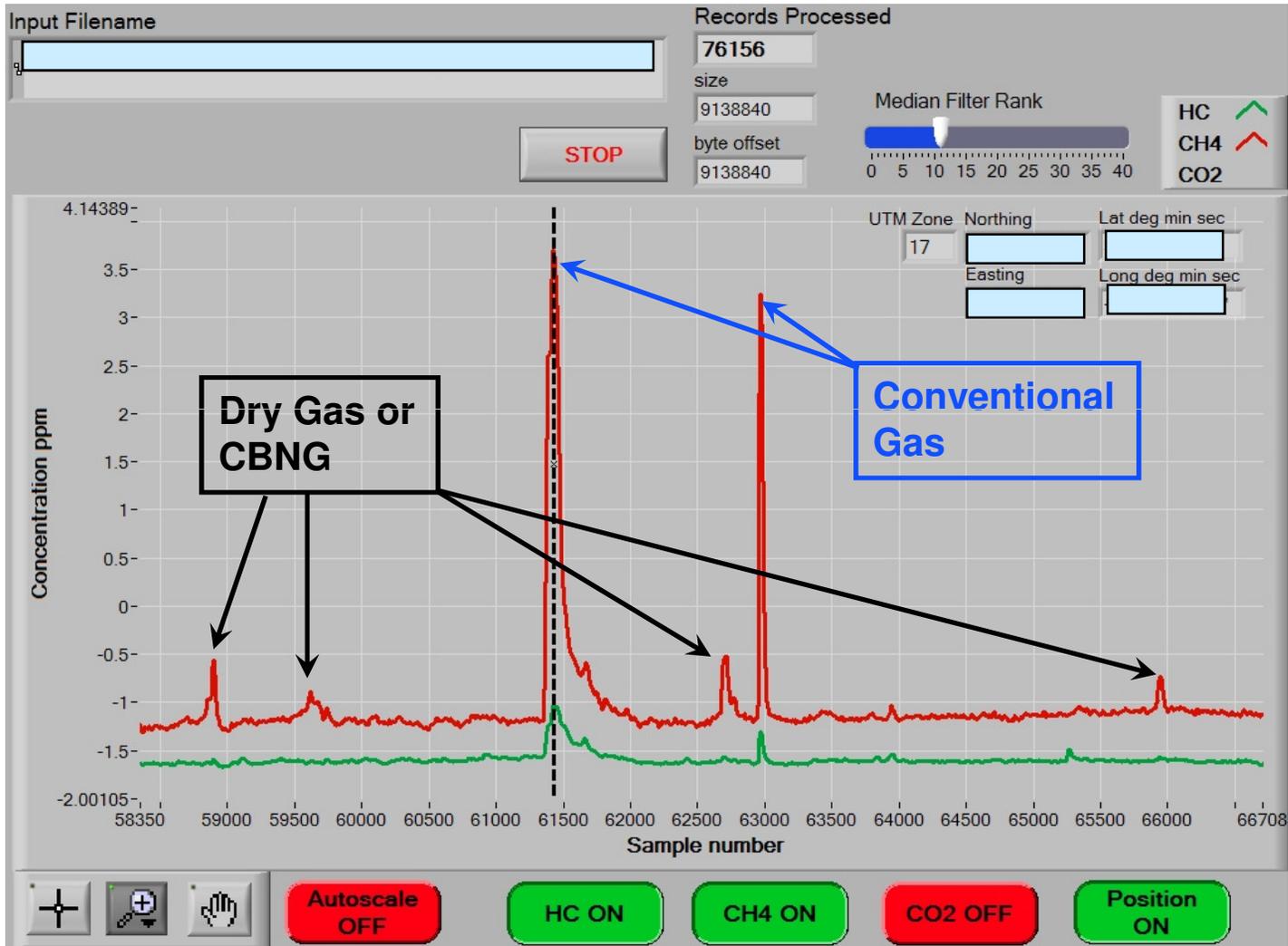


Detection of Hydrocarbons

An Apogee LDS Instrument was deployed in a lightweight cart to detect trace amounts of methane emanating from leaking wells.



Apogee LDS as a Prospecting Tool

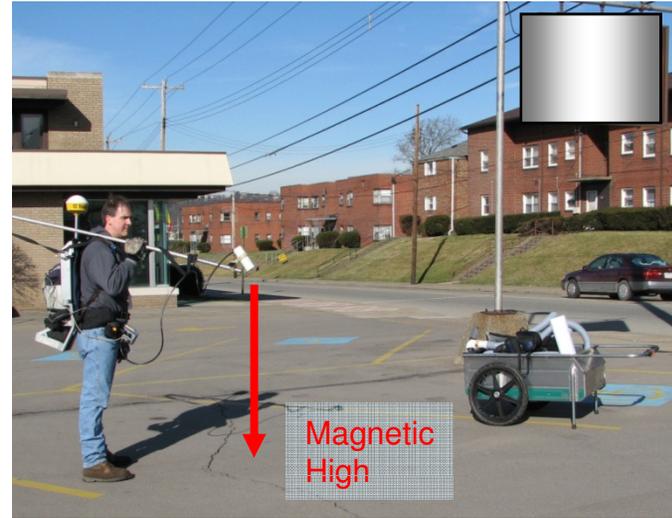
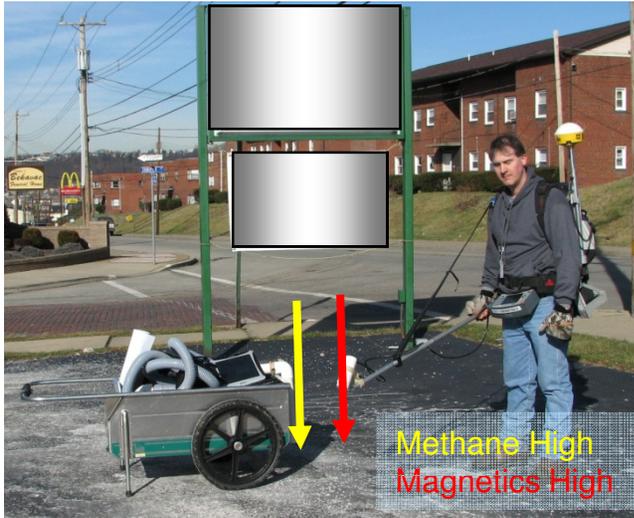


Magnetic Surveys to Locate Wells in Versailles Borough, PA

- Geometrics G858 Magnetometer
- DGPS-linked data acquisition
- Bull's-eye shaped anomalies - High magnetic gradients
- No base station required
- Lag correction not necessary



Well Finding Activities in Versailles Borough



Significant Anomalies Located in Versailles Borough, PA

- 52 suspected wells
- 14 methane anomalies collocated with magnetic anomalies
- 3 wells confirmed



Conducting Magnetic Surveys for Unmarked, Abandoned Wells in Urban Environments – Tips and Tricks

- **Construct a GIS project**
- **Be skeptical of State Oil & Gas databases**
- **Obtain permission from landowner**
- **Explain what you are doing**
- **Arrange for removal of parked cars and other ferrous metal objects**
- **Anecdotal information often unreliable**
- **Conduct surveys in N-S direction**
- **Raise the sensor (shoulder height)**
- **Refine dig location with magnetic compass**
- **Beware of dog**

