Discovery of Undocumented Oil and Gas Wells using Historical Topographic Maps

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Ciulla et al., A Deep Learning Approach to the Discovery of Undocumented Orphaned Oil and Gas Wells at Regional Scales (in preparation)

BERKELEY LAB

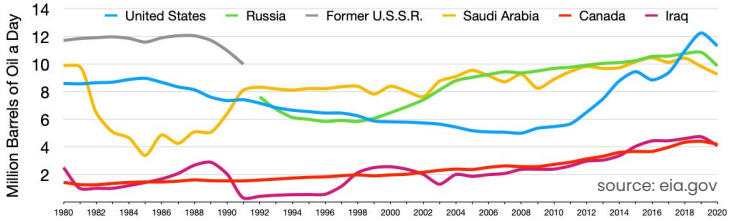
NERSC

U.S. DEPARTMENT OF ENERGY

Consortium Advancing Technology for Assessment of Lost Oil & Gas Wells.

Introduction

The United States has a long history of hydrocarbon extraction with about **3.7 million oil and gas wells** drilled **starting from the 1850s**.



When a well reaches the end of its useful life, the operator is required to **properly plug and abandon** it.


photos by CalGEM

Undocumented Orphaned Wells (**UOWs**) are wells with **no responsible party** for proper abandonment and **no or limited documentation** with the regulatory agency.

"For 2020, the total number of undocumented orphan wells estimated by participating states is between **310,000 and 800,000**."

IOGCC (2021) Idle and orphan oil and gas wells: state and provincial regulatory strategies

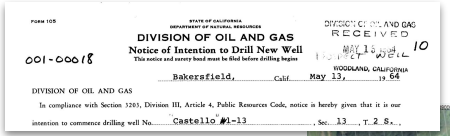
Motivation

UOWS are more likely to be unplugged or improperly plugged which can cause the release of **methane**, **hydrogen sulfide** and **VOC** into the **atmosphere**, and **contamination of freshwater aquifers**.

photo by Earthworks/Reuters

photo by CalGEM

Previous studies attempted to find UOWs using **historical records**, **photographs**, **lease or farmline maps**, in-the-field and remote sensing employing **LiDAR**, **magnetometers**, **gas sensors** or **metal detectors**.



STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF OIL AND GAS
Notice of Intention to Drill New Well
This notice and survey boad must be filed before drilling begins

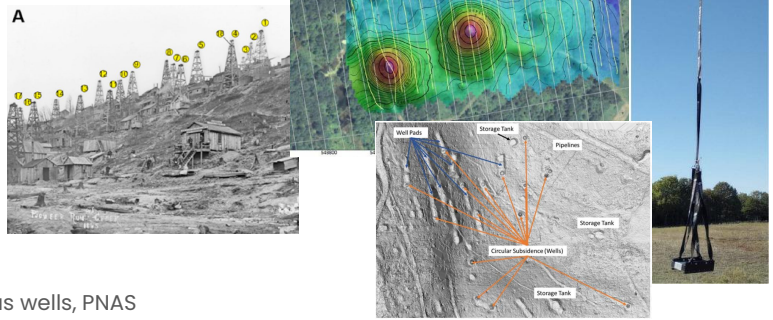
001-00018

RECEIVED
MAY 16 1964
WOODLAND, CALIFORNIA

Bakersfield, Calif. May 13, 1964

DIVISION OF OIL AND GAS

In compliance with Section 3203, Division III, Article 4, Public Resources Code, notice is hereby given that it is our intention to commence drilling well No. Castello #1-13, Sec. 13, T. 2 S.,



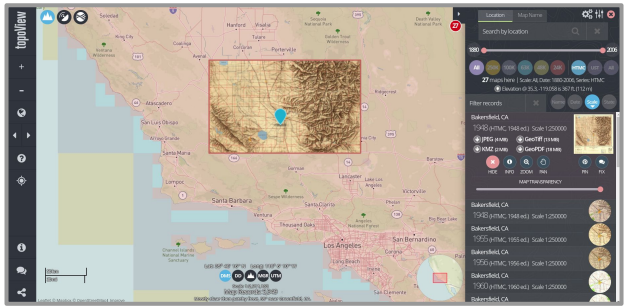
To date no methods have been developed to identify the **precise location** of UOWs at **regional to continental scales**.

Kang et al., (2016) Identification and characterization of high methane-emitting abandoned oil and gas wells, PNAS
Hammack et al., (2020) Using Drone-Mounted Geophysical Sensors to Map Legacy Oil and Gas Infrastructure, URTeC
Saint-Vincent et al., (2020) Historic and modern approaches for discovery of abandoned wells for methane emissions mitigation in Oil Creek State Park, Pennsylvania, JEM
Saneiyan et al., (2023) Locating undocumented orphaned oil and gas wells with smartphones, Journal of Applied Geophysics

Method - dataset

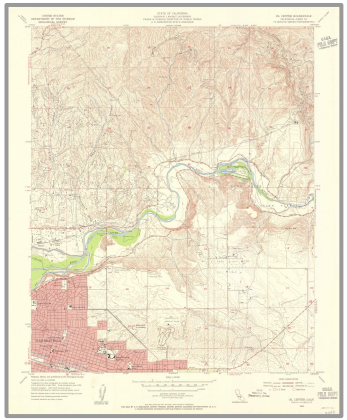
Framework for **automated identification** and **accurate location** of UOWs at **regional scales** using **publicly available data**

Historical Topographic Maps Collection: set of 190,000 **georeferenced** raster maps covering the **entire US** published by the USGS **since 1884**.

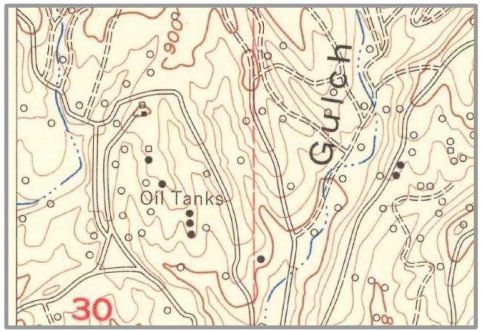


https://ngmdb.usgs.gov/topoview/

Quadrangles (1947 - 1992) focus on **consistency** of **colors** and **symbols**



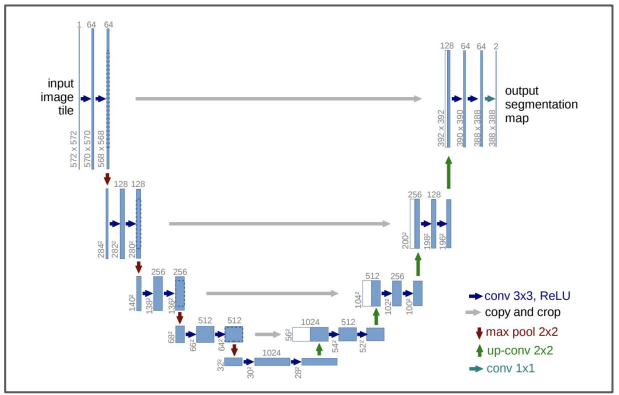
Oil and gas wells consistently represented as **black circles**



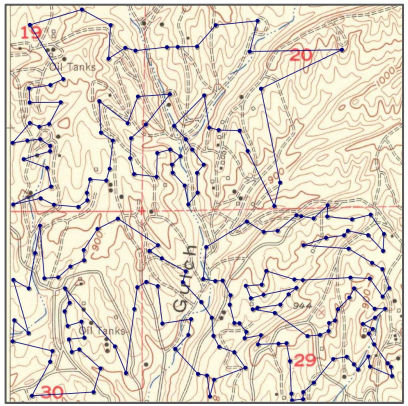
Challenge: symbols must be detected!

Method - algorithm

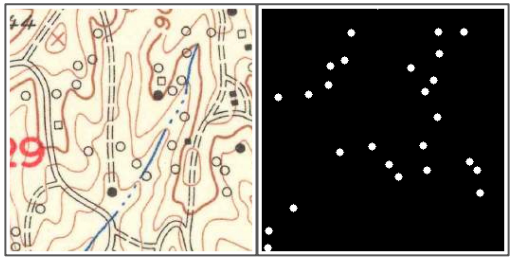
The convolutional neural network algorithm **U-Net** for image segmentation



We **labeled** more than **11,000 well symbols** from **56 different maps**



Total of **7040 unique image/mask** pairs for training purposes



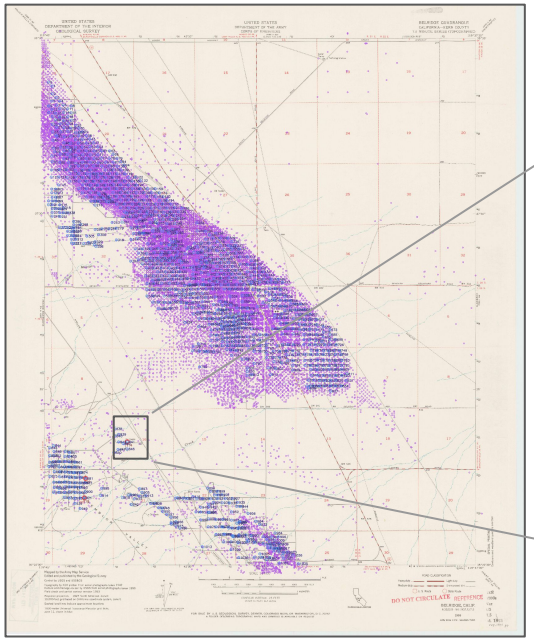
Precision: 0.98
Recall: 0.88

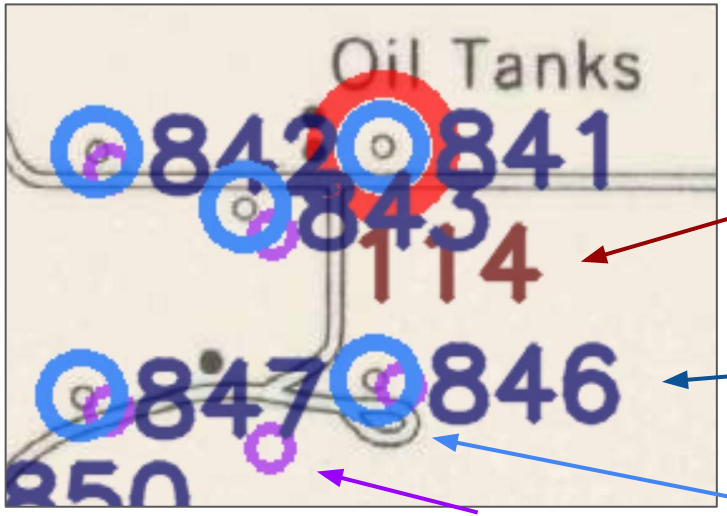
Ronnerberger et al., (2015) U-Net: Convolutional Networks for Biomedical Image Segmentation. arXiv

Method - detection

Each map gets **enriched** with geographical information of the detected wells

Detected wells **further than 100m** from the closest documented well are flagged as **potential UOWs**





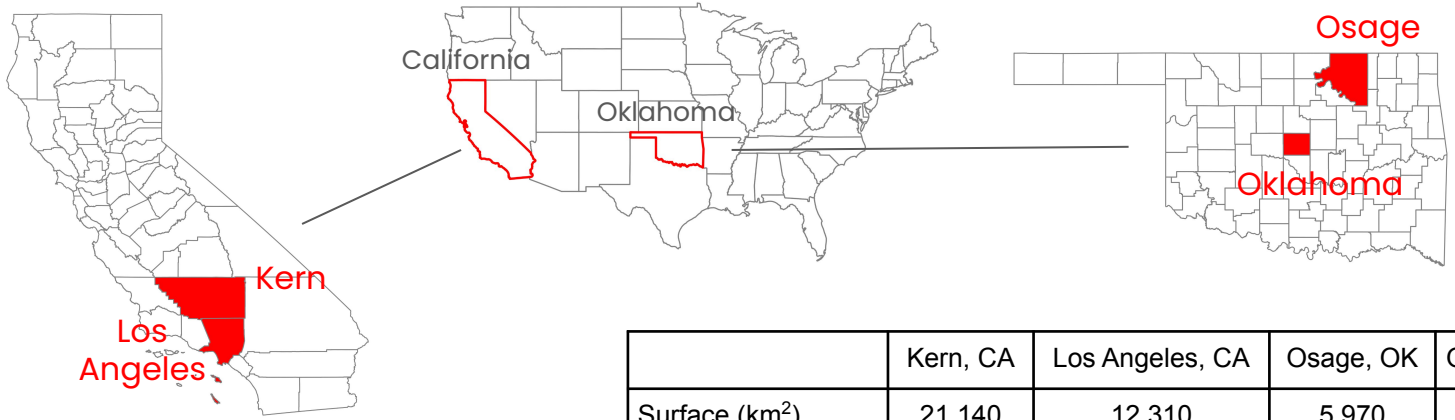
distance to nearest documented well

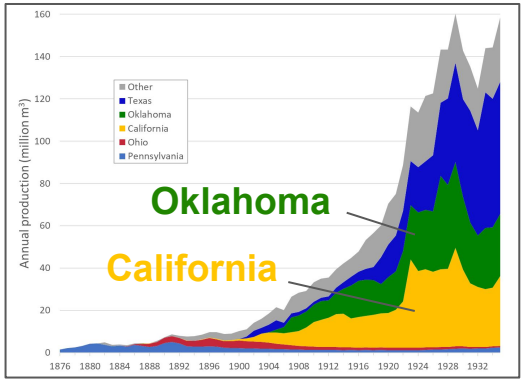
unique ID

detected well

documented well

Results - study areas





	Kern, CA	Los Angeles, CA	Osage, OK	Oklahoma, OK	Total**
Surface (km^2)	21,140	12,310	5,970	1,860	**41,280**
Total maps	564	513	96	60	1,233
Documented wells	156,445	23,034	43,962	6,314	229,755
Detected wells	59,438	61,314	15,382	4,263	140,397
Potential UOWs*	**304 (298)**	**237 (181)**	**487 (261)**	**275 (204)**	**1301 (944)**
Potential UOWs per 1,000 km^2	**14.1**	**14.7**	**43.7**	**109.7**	–
Potential UOWs to doc. wells ratio	**$1.9x10^{-3}$**	**$7.9x10^{-3}$**	**$5.9x10^{-3}$**	**$3.2x10^{-2}$**	–

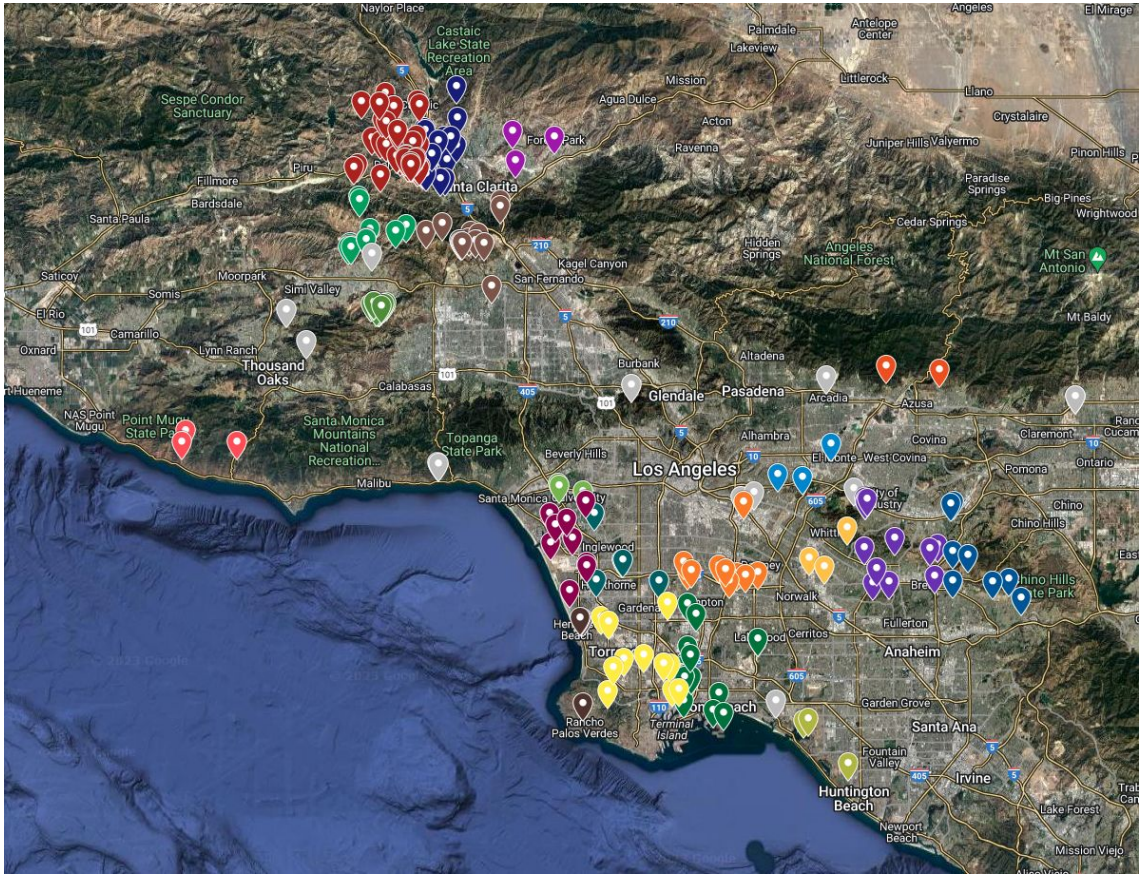
*In parenthesis values strictly within countylines. **Total UOWs account for possible overlaps

White et al., (1937). Crude petroleum and petroleum products. In U.S. Department of the Interior Bureau of Mines, Statistical appendix to minerals yearbook 1937.

Results - Los Angeles County

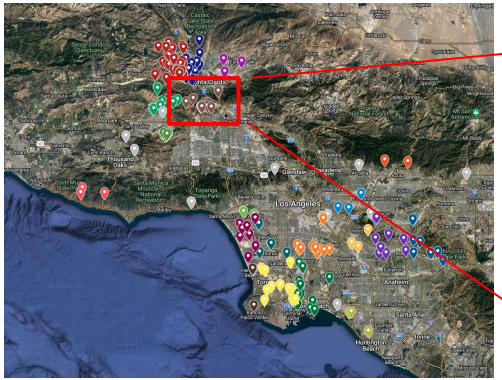
Surface (km^2)	12,310
Potential UOWs*	**237 (181)**
UOWs per 1,000 km^2	14.7
Ratio UOWs to documented wells	$7.9x10^{-3}$

*In parenthesis values strictly within countylines



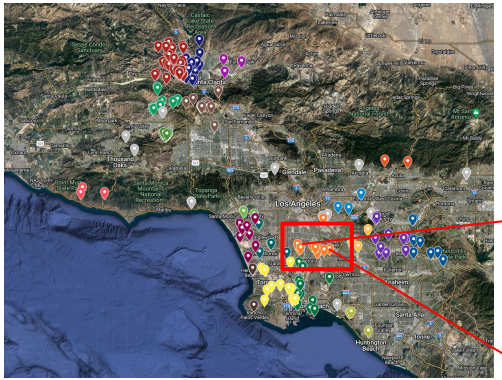
credits: Google Maps

Results - Los Angeles County



11 potential UOWs in proximity of the Aliso Canyon gas storage facility

Results - Los Angeles County



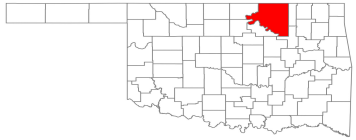
Proximity to **hospitals**, **schools**, **apartment buildings**

California Lagged in Capping Century-old Oil Wells Leaking Under Homes of LA Residents Plagued by Illness and Odors

By **Marissa Pianko** on Feb 13, 2020 @ 17:12 PST
11 min read

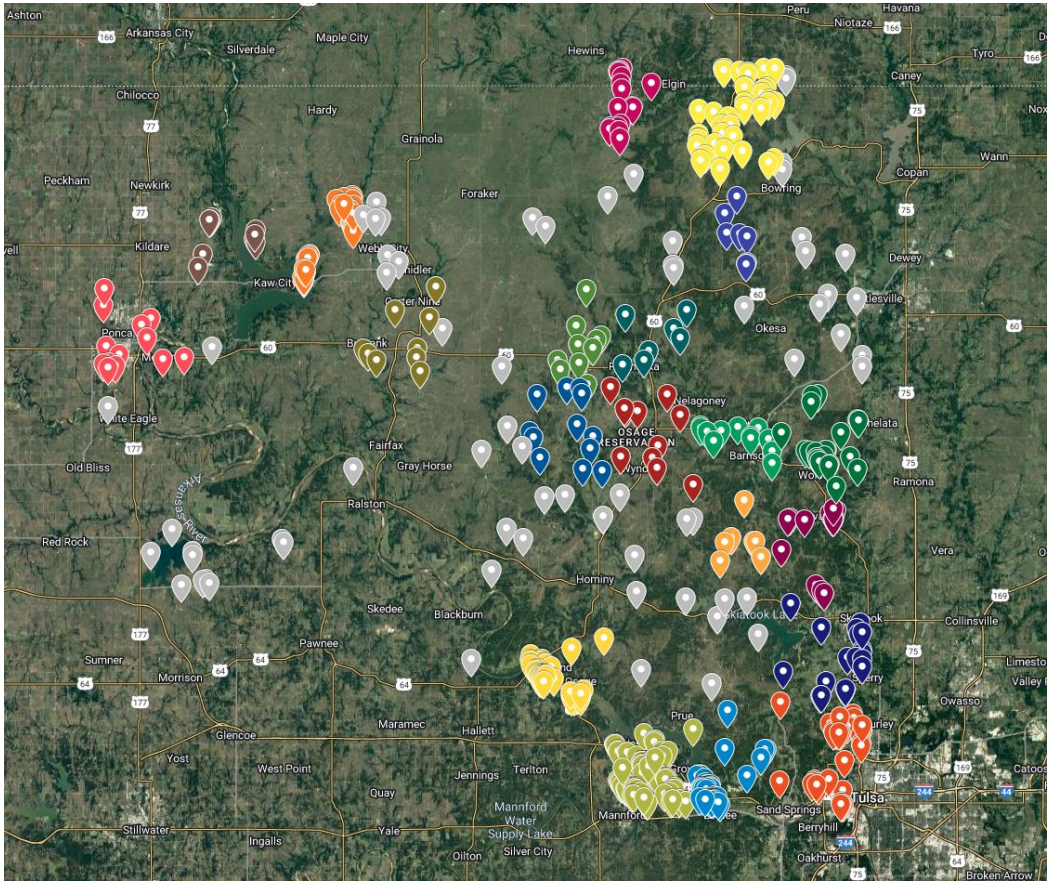
In private residence **backyards**

Results - Osage County



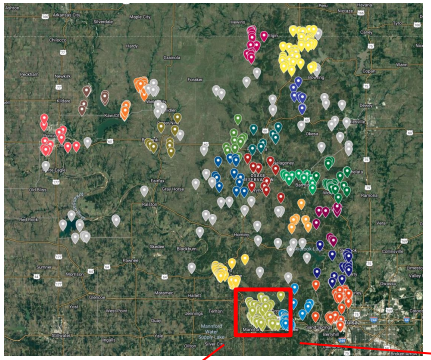
Surface (km^2)	5,970
Potential UOWs*	**487 (261)**
UOWs per 1,000 km^2	43.7
Ratio UOWs to documented wells	$5.9x10^{-3}$

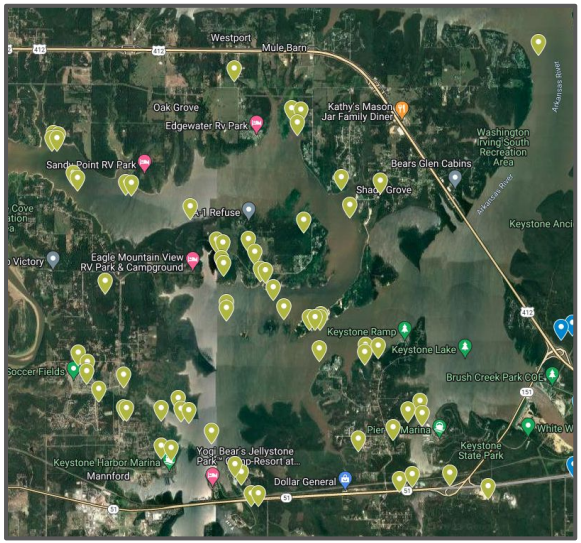
*In parenthesis values strictly within countylines



credits: Google Maps

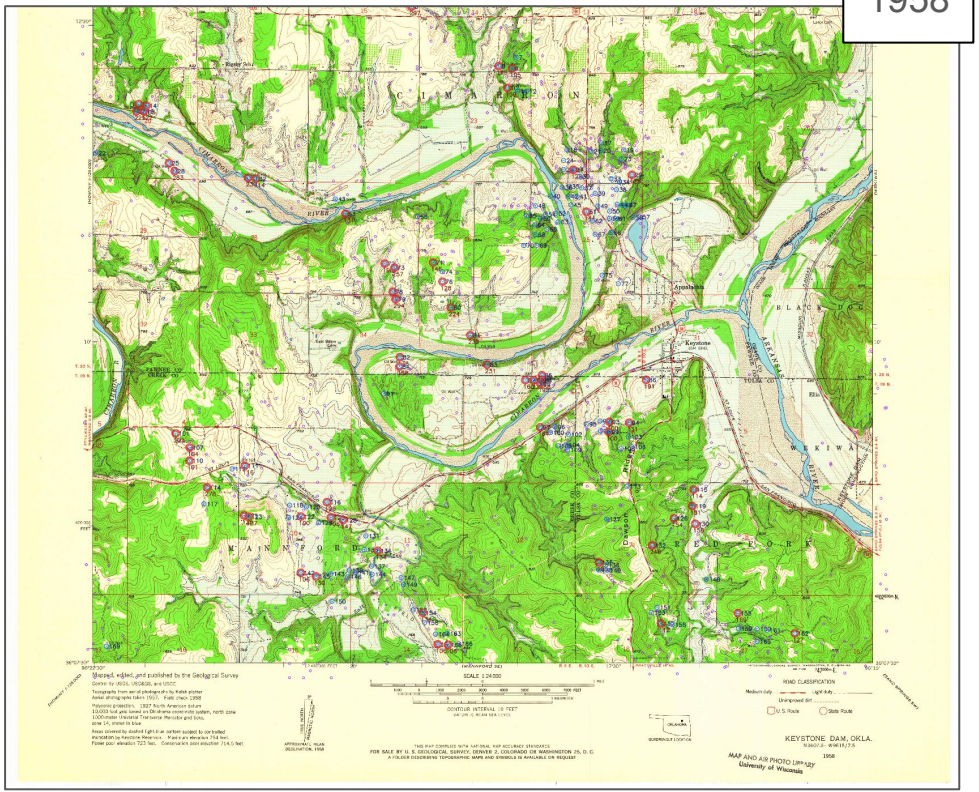
Results - Osage County



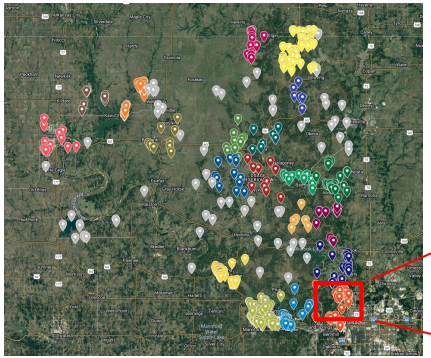


Potential UOWs now **submerged** due to the construction of the **Keystone Dam** on the **Arkansas River**.

1958

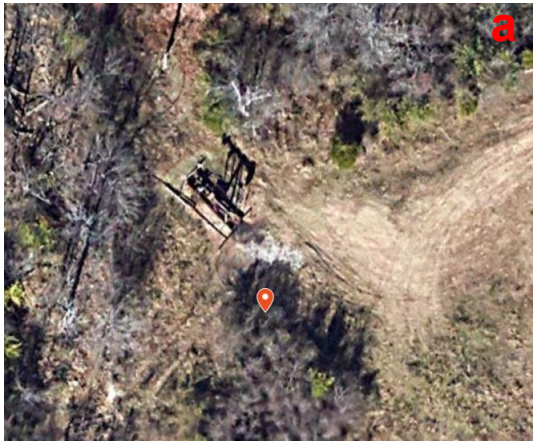


Results - Osage County



Potential UOWs visible from **current satellite imagery**

Documented wells in blue in this image for reference



Field Investigation - Kern and Osage campaign

11 potential UOWs visited

7 in Kern County on June 2023

4 in Osage County on October 2023

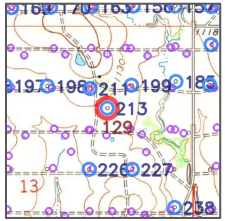
Average distance from detected locations in maps: **12.5m**

Small methane leak from **only one UOW: 1.7445 ± 0.3429 g/hr**

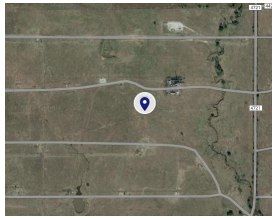
The discovery process

Remote

1. Detection



2. Geolocalization



3. Validation

Field

4. Localization

5. Measurement

Conclusions

Historical Topographic Maps **valuable source** for UOWs detection

Identification of **1,301 UOWs** in **4 counties** in **2 states**

Spatial accuracy of **O(10) meters**

Variability in UOW density: 14.1 - 109.7 UOWs per 1,000km^2

UOWs to documents wells ratio ≤ O(10^{-2}): **"Needle in the haystack" problem**

No new oil fields discovered

Only **one site** with small methane leak

Underestimation: limited time window 1947 - 1992

contact: fciulla@lbl.gov

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Consortium Advancing Technology for Assessment of Lost Oil & Gas Wells.

Thanks

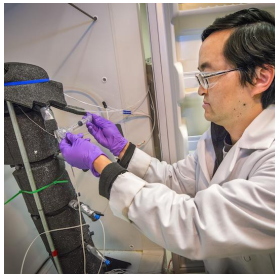
Charuleka Varadharajan

Preston Jordan

Timothy Kneafsey

Sebastien Biraud

André Santos



Yuxin Wu

contact: fciulla@lbl.gov

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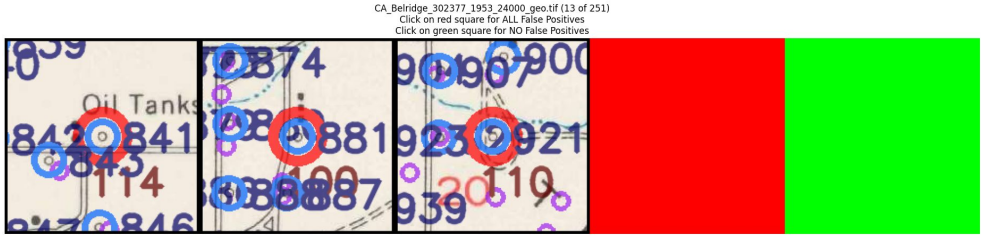
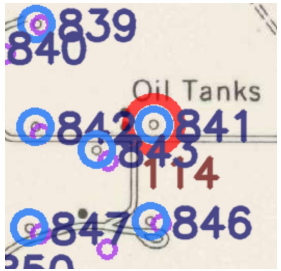
DATALOG Consortium Advancing Technology for Assessment of Lost Oil & Gas Wells.

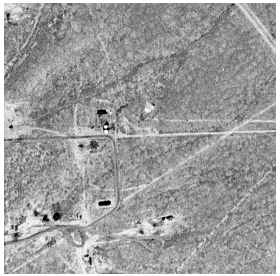
Method - validation

Custom script for fast validation



Historical aerial photos





Satellite imagery