Using Thermal/IR and Multispectral Sensors on Drones to Find the Origin of and Extent of Contamination from Saltwater Spills from Producing Wells*

Susan Nash[1]

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[1]AAPG, Tulsa, OK, United States (snash@aapg.org)

Abstract

This presentation discusses how new drone-based technologies using thermal / infrared and multispectral sensors can help quickly and efficiently locate the source of a saltwater spill as well as the extent of contamination. We review the workflow, which includes identifying the first indication of a spill, collecting the necessary data to plan the mission, identifying the proper types of drones and sensors, and planning the mission. We discuss the types of sensors and software needed to capture and analyze the data. In addition to reviewing several case studies, we will look in-depth at the case of Black Bear Creek in Pawnee, Oklahoma, and also at Bird Creek in Osage County, Oklahoma, to discuss how drones complemented existing efforts to solve the problem of contamination coming from an unidentified source, and how the combined analytics provided more insight not only of the health of the ecosystem, but also in finding wells and suggesting new ways optimize EOR efforts in a mature field.

Websites Cited

https://www.analistgroup.com/en/new-solutions-with-drones/phantom-mapir. Website accessed August 2018.

https://gisgeography.com/ndvi-normalized-difference-vegetation-index/. Website accessed August 2018.

http://www.mdpi.com/2072-4292/10/2/204/html. Website accessed August 2018.

Using Thermal / IR and Multispectral Sensors on Drones to Find the Origin of and Extent of Contamination from Saltwater Spills from Producing Wells

Susan Nash, Ph.D.
AAPG

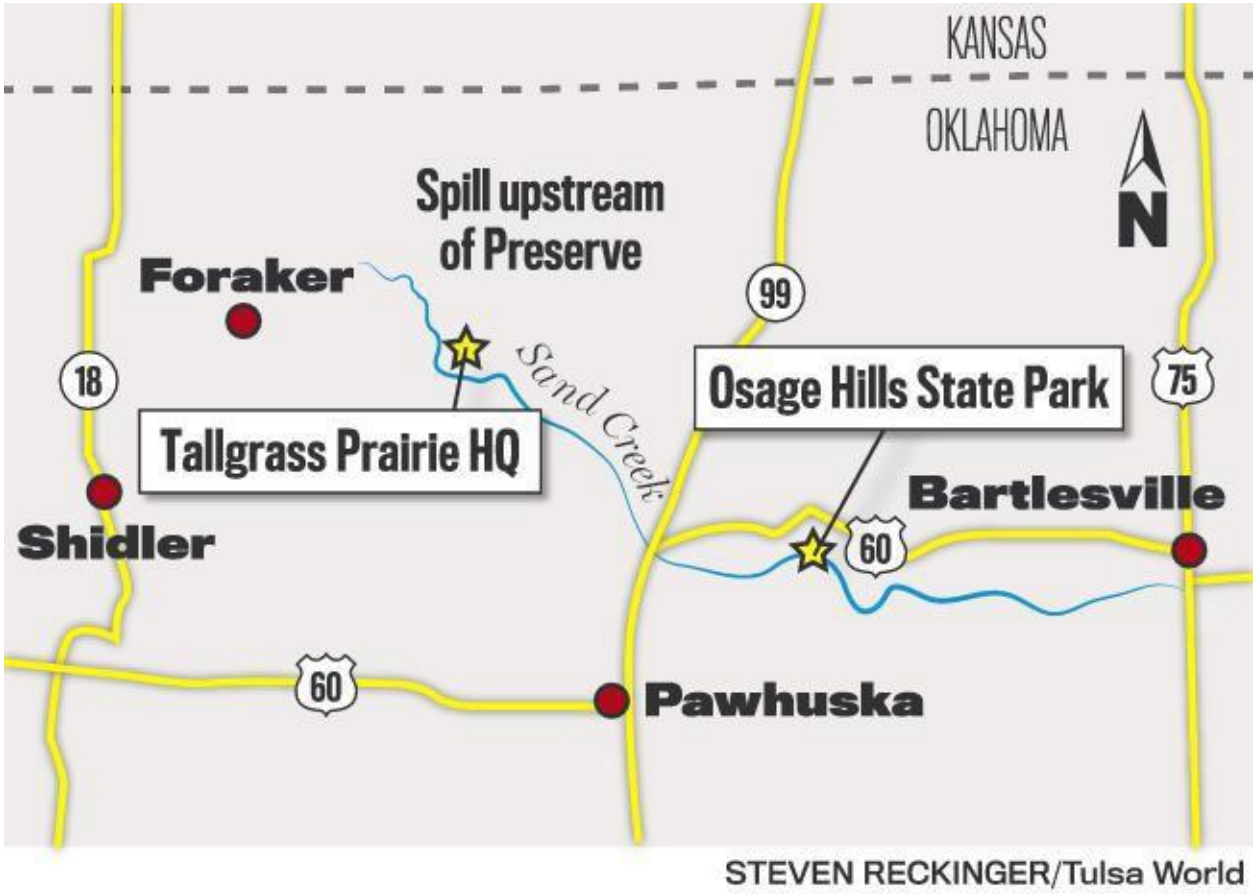
Problem: Bird Creek Contamination

Location: Osage County, on Osage Tribal Land

August 2016:
Oily sheen on water, accompanied by dead fish and turtles

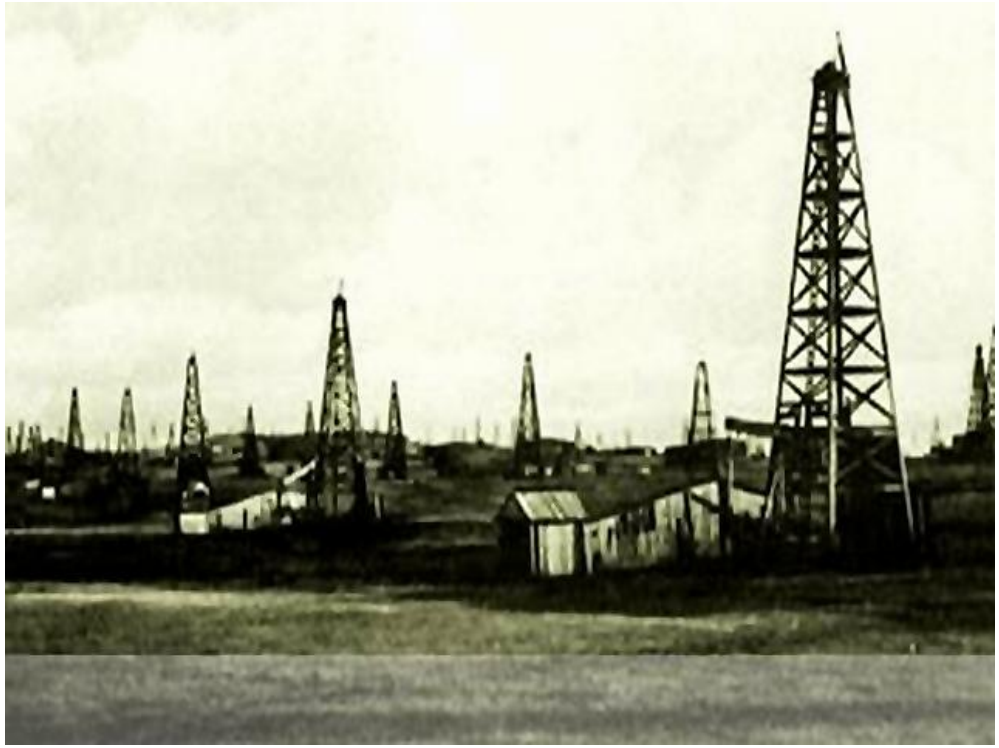
In a pool of the upper creek tributary on the Chapman Ranch, just west of the Tall Grass Prairie Preserve, Osage County
(source: Tulsa World)

The Bird Creek Watershed



Environmentally sensitive area: watershed to Catoosa and also in the Tallgrass Prairie

History of Oil in Osage County



Location: Osage County, on Osage Tribal Land
And subject to many overlapping agency jurisdictions

1920
Marland Oil drilled its discovery well, Bertha Hickman #1

Burbank Sand
2,900 ft

Burbank Field

Continuously developed since then

Contamination? Who's to blame?

Location: Osage County, Oklahoma

The EPA blames the operators.
The operators disagree.

File suit to fight EPA order to shut in 7 producing oil wells in the upper tributary of Bird Creek (January 2018)

--Jireh Resources, LLC
--Warren American Oil, LLC
--Novy Oil and Gas

Conflict #1

- EPA claims ongoing contamination and increasing salinity. Operators and independent environmental testing agents say it is decreasing.
- **Drone solution: Use sensors to do drone-based aerial surveys to determine salinity over time. Hyperspectral sensors.**

Conflict #2

- Solution: Run a log to test the surface casing integrity. Look at regional structures for possible conduit (fault).

- **Drone solution: Look for evidence of salt water spill in the topsoil. Are there distressed plants? Thermal infrared sensors can be used; also hyperspectral.**

DJI Phantom MAPIR for Precision Farming

https://www.analistgroup.com/en/new-solutions-with-drones/phantom-mapir

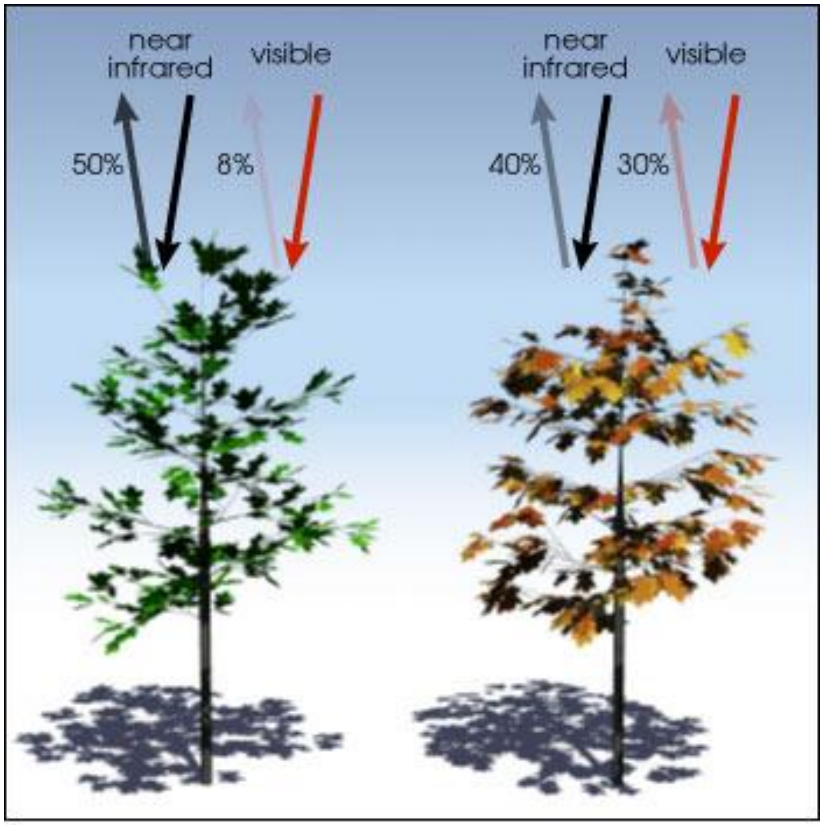
Normalized Difference Vegetation Index

--Most common index used in remote sensing
--Quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs)
--NDVI ranges from -1 to +1

$$\text{-- NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})}$$

https://gisgeography.com/ndvi-normalized-difference-vegetation-index/

NDVI for vegetation health determination



$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72$$

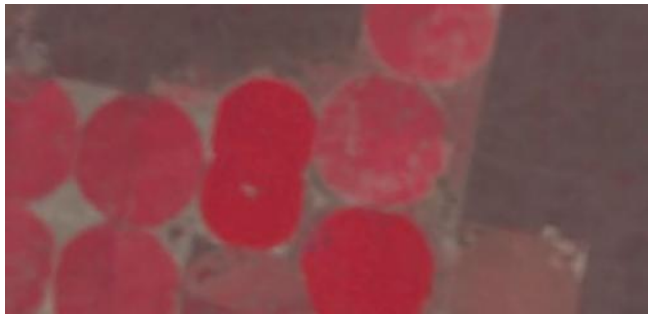
$$\frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

Near Infrared channel on the sensor

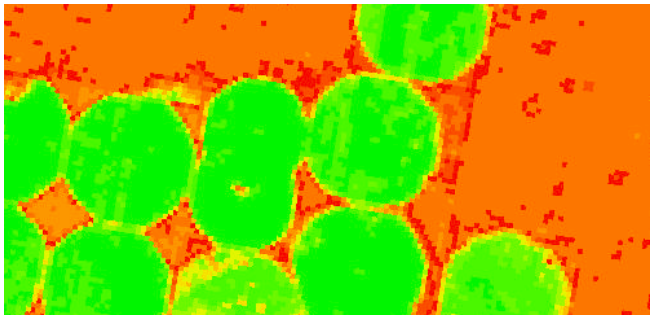
--High NDVI: healthy
--Low NDVI: less or no vegetation

NDVI Example: Agriculture

True color: looks for red, green, and blue

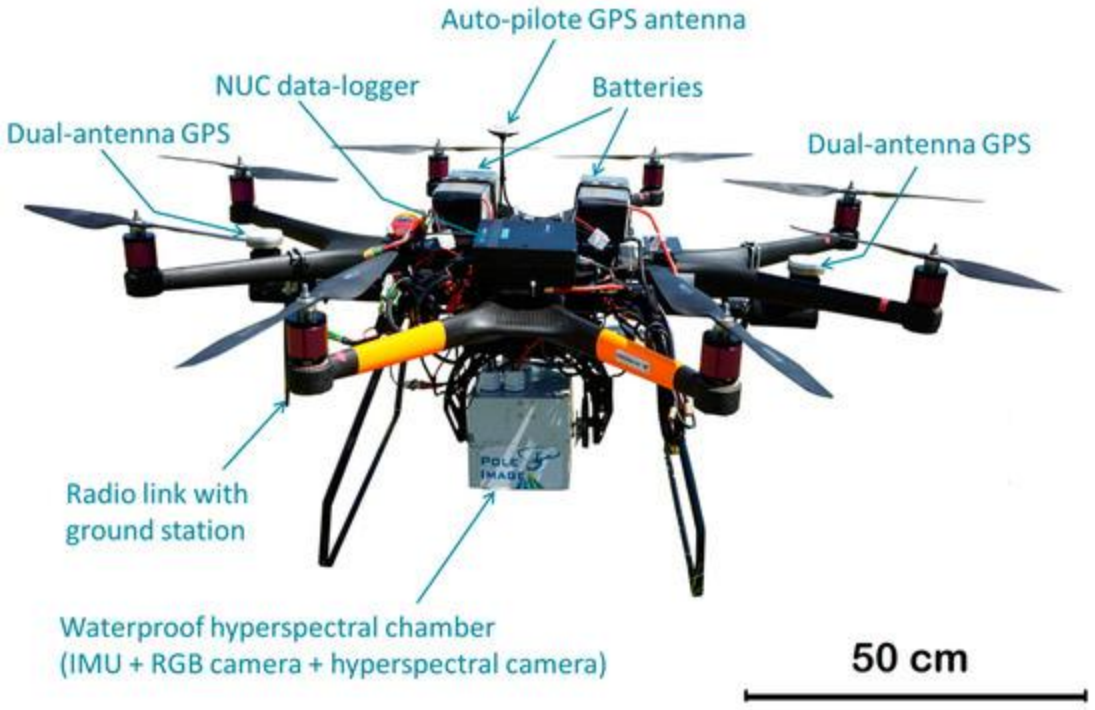


NIR band as red: we get color infrared (in the red channel) – bright red means “water me!”



Apply the formula: bright green means high NDVI

Hyperspectral Drone for Environmental and Littoral Observations



The onboard flight control system is composed of a GNSS and an autopilot. Ground station software is used to control the UAV flight parameters during the survey. The flight control is run by DJI® iOSD® software. Although Hyper-DRELIO is able to perform an autonomous flight, take-off and landing are manually controlled. http://www.mdpi.com/2072-4292/10/2/204/html

Typical Thermal Inspection Specifications

Model	**FLIR Aerial Home Inspection Kit**	**FLIR Aerial Building Inspection Kit**	**FLIR Aerial Building Inspection Kit** R (30 Hz)
Thermal Camera	DJI Zenmuse XT Thermal Camera & Stabilized Gimbal	DJI Zenmuse XT Thermal Camera & Stabilized Gimbal	
Thermal Camera Configuration	6.8 mm lens (45° × 35°), 336 × 256 resolution	13 mm lens (45° × 37°), 640 × 512 resolution	Radiometric 13 mm lens (45° × 37°), 640 × 512 resolution
Aircraft Type	DJI Inspire 1 (V 2.0)		

Can be used for tank batteries, compressors, gas gathering monitoring as well

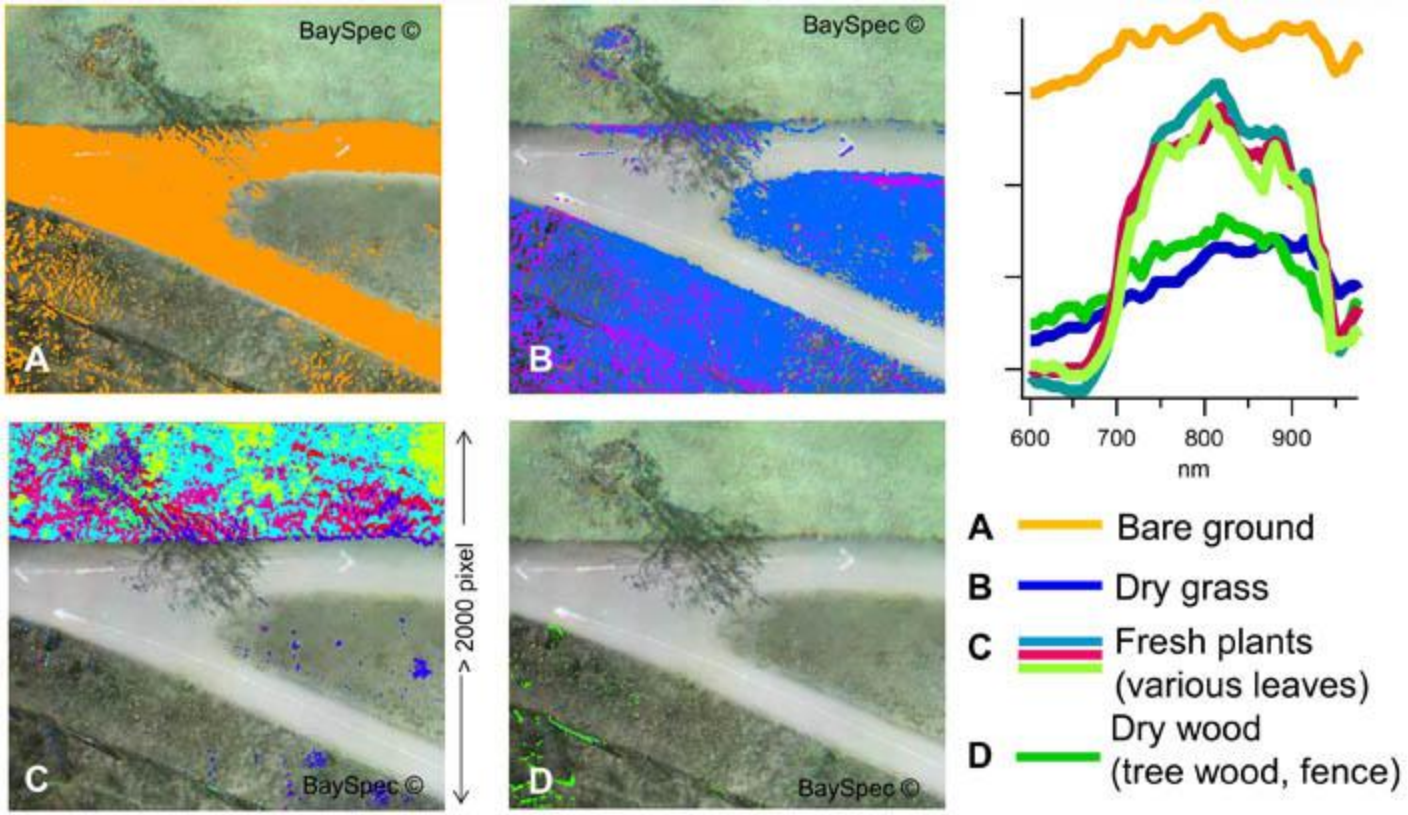
Hyperspectral sensors

BaySpec Hyperspectral Camera (OCI-UAV-1000) Imaging ***NDVI and ENDVI Vegetation Indexes Generation and Analysis -*** **Normalized Difference Vegetation Index (NDVI).**

FLIR Camera with DJI Zenmuse

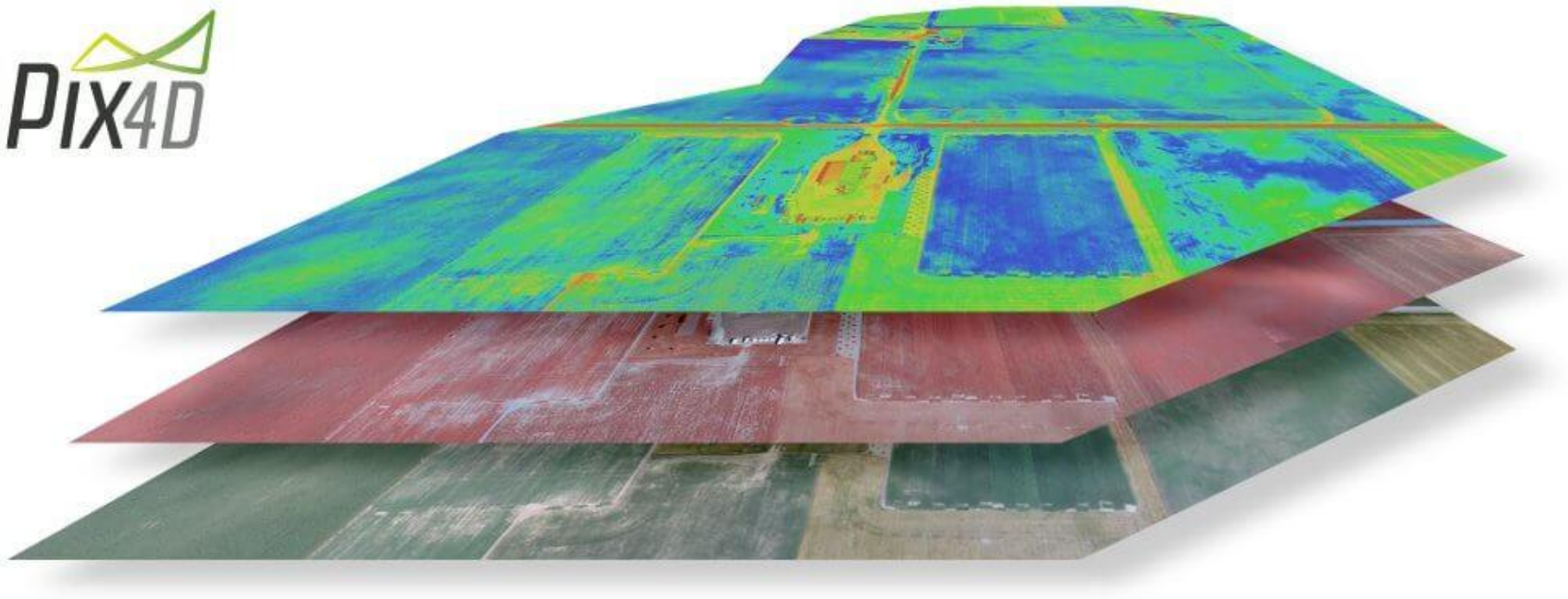
Infrared / Thermal Camera

Environmental Vegetation Imaging



OCI-UAV-1000 Flight Data Example (processed with pseudo-RGB color and material color based on spectral characteristics

Low-Cost Solution



DJI Phantom plus Pix4D – 3D models, Point Clouds, orthomosaics

Conclusions and Recommendations

- Fight finger-pointing with facts
- Use remote sensing for new insights
- Plan ahead and maintain a regular schedule of drone surveys
- Integrate your information
- Calibrate with “ground truth”
- Apply your findings to other locations
- Review “precision farming” and other agricultural applications for up-to-date software
- Low-cost solutions can work

TIMELINE (source: Kelly Bostian, Tulsa World)

August 2016: An oily sheen, dead fish and turtles are reported on a northern tributary of Bird Creek on the Chapman Ranch in Osage County. Osage Nation, Bureau of Indian Affairs and Environmental Protection Agency officials respond. Initially, it is assumed that production water was dumped from the roadside.

October 2016: After heavy rains swell the creek and the contamination remains and investigators find water temperatures near 100 degrees and salinity levels above 80,000 parts per million, far above the EPA acceptable level of 1,000 ppm. Out of "an abundance of caution" the City of Pawhuska switches its water supply to a source far removed from Bird Creek.

December 2016 and January 2017: Newspaper reports surface of residents complaining about inaction on the part of regulators.

May 2017: EPA Administrator Scott Pruitt visits the site. Close monitoring of the stream begins and producers are told they may be asked to do periodic shut downs of injection wells.

July 2017: The EPA announces it has found the source of contamination in Bird Creek, due to over-pressurized reservoirs below related to seven nearby wells. The wells will be asked to shut down and it is said a wider area may be examined in relation to the saltwater contamination.

August 2017: The EPA issues a formal request to shut down the wells. Some initially comply, but then resume pumping as their own experts doubt the EPA's conclusions.

October 2017: A public hearing is held in Tulsa for all parties to air their positions on the proposed shut-down order. Producers forward a plan to pump the heaviest saltwater concentrations out of the creek.

December 2017: Producers and Chapman Ranch owners take a first shot at pumping saltwater out of the creek and taking readings. On Dec. 20 the EPA finalizes its shutdown order.

January 2018: Producers file suit in federal court to fight the shutdown order. Negotiations to pump out the saltwater and monitor the creek continue.