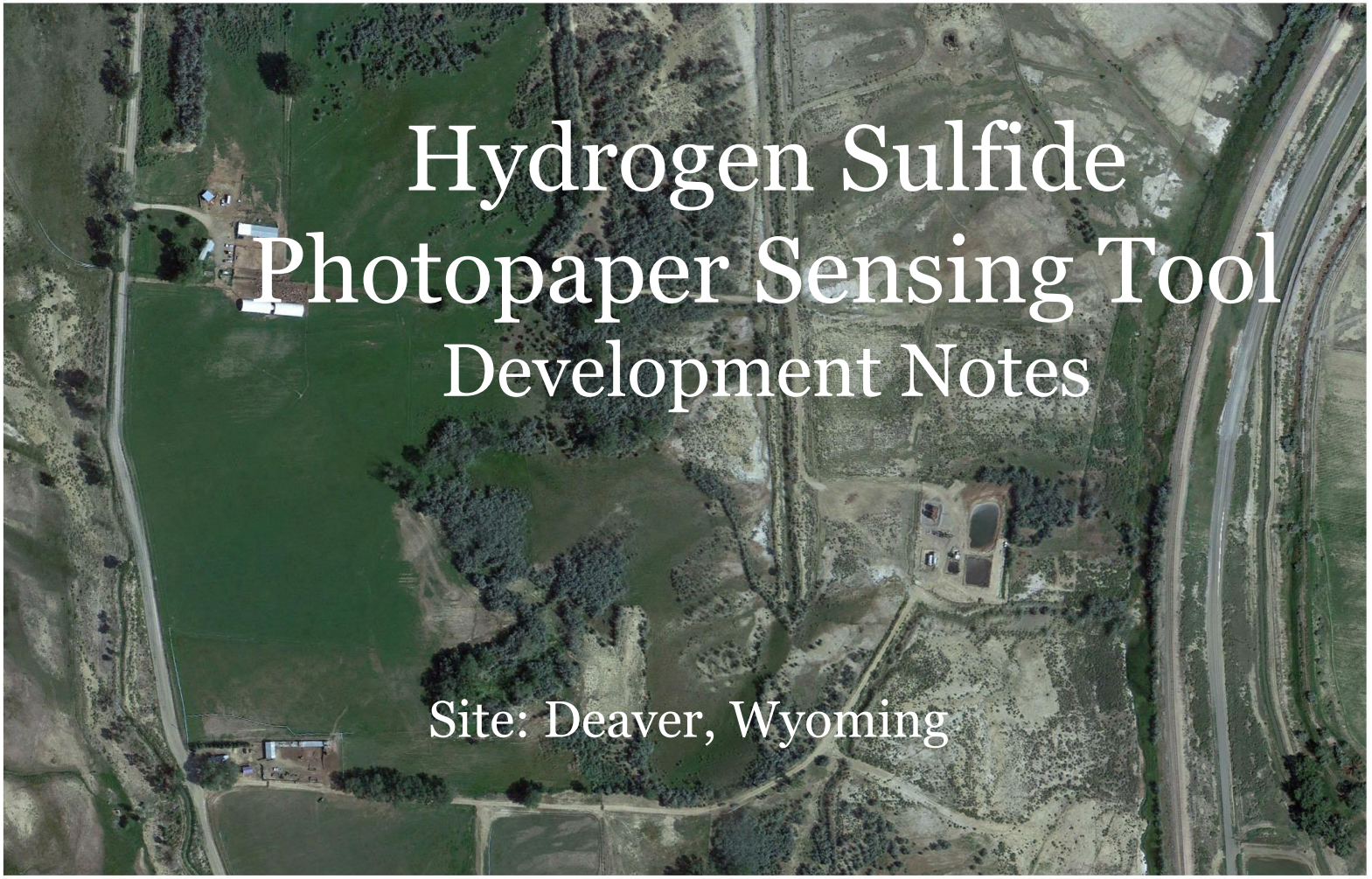


Hydrogen Sulfide Photopaper Sensing Tool
Development Notes

Site: Deaver, Wyoming

Contributors |

Caitlyn Kennedy, Megan McLaughlin,
Deborah Thomas, Elisabeth Wilder and Sara Wylie

Partner Organizations |

Powder River Basin Resource Council
Clark Resource Council
Pavillion Area Concerned Citizens

SSEHRI
Social Science Environmental Health Research Institute

publiclaboratory.org

Purpose of Research

- The purpose of this research was to test whether the photopaper sensing tool can be used to map hydrogen sulfide (H_2S) emissions around sites of oil and gas extraction.
- A general description of the tool and instructions for using it can be found here.

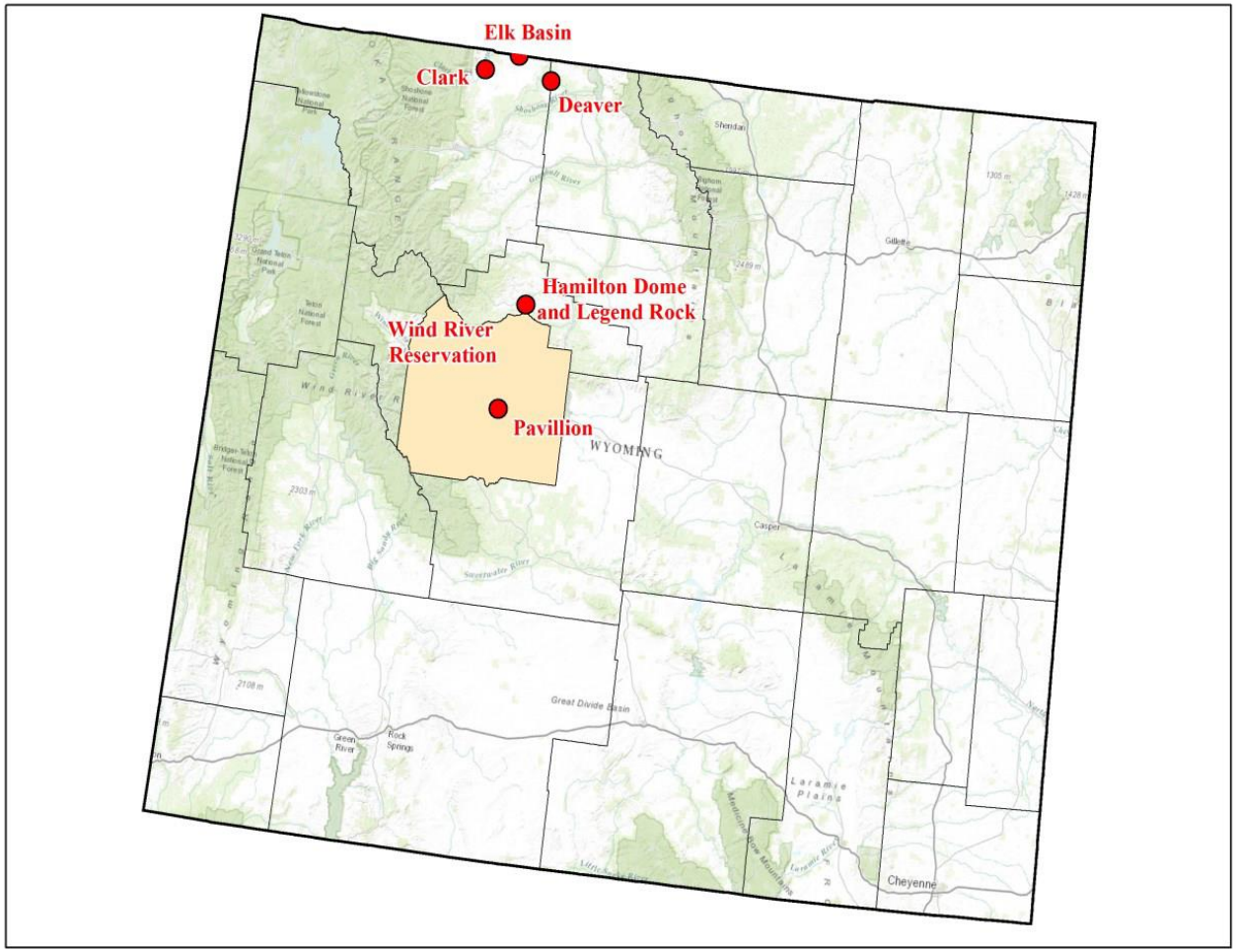
Purpose of Slideshow

- This slideshow describes the process of creating the final maps for this site. In the interest of improving the process next time, it highlights the challenges and problems that we encountered during each stage of the process.
- This was the first site that we tested and mapped; accordingly, we encountered many more problems during these three rounds than at the three other sites.

Meet the Research Team

- **Cait Kennedy** – Drew University GIS student
- **Megan McLaughlin** – landscape architect trained at Rhode Island School of Design
- **Deb Thomas** – Clark Resource Council, Powder River Basin Resource Council and Pavillion Area Concerned Citizens
- **Elisabeth Wilder** – sociology PhD student at Northeastern University
- **Dr. Sara Wylie** – co-founder of Public Lab and Assistant Professor at Northeastern University

Test Sites



The sites in this study (Deaver, Elk Basin, Hamilton Dome, and Legend Rock) are areas in which members of the community live, work, recreate, and travel through. They were chosen based on the concerns of Powder River Basin Resource Council members. The common factor in all of the areas sampled is oil and gas development.

Clark Resource Council & Pavillion Area Concerned Citizens. 2014. *Breathe at Your Own Risk*. Manuscript submitted for publication.

Deaver, WY

Deaver is located in the Bighorn Basin in north-central Wyoming along the Montana/Wyoming border.

Sampling points were located on private property northwest of Deaver, in Park County. Oil and gas has been developed in this area since the 1950s.

As in other places across Wyoming, hydrogen sulfide (H_2S) gas is released during oil and gas development in the Deaver area. Particularly noticeable is the pungent rotten egg smell often associated with H_2S.

Clark Resource Council & Pavillion Area Concerned Citizens. 2014. *Breathe at Your Own Risk*. Manuscript submitted for publication.

Background on Deaver Location

Clark Resource Council chose to conduct air sampling at this site because residents reported smelling rotten eggs and heavy hydrocarbon odors coming from the oil pads located on their property. Hydrogen Sulfide gas (H_2S) is suspected to be the source of some odors emitted from the oil development. Dizziness, breathing difficulties and headaches are among the symptoms the landowners experience while working their ranch fields and pastures in this area. Increased rates of miscarriage in livestock have also occurred in pastures adjoining this location.

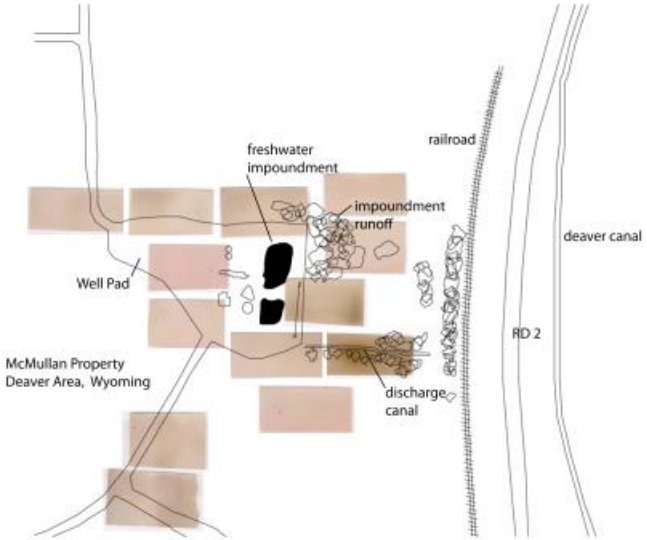
The well pad includes a pump jack, condensate tanks and produced water impoundments which discharge into a drainage canal. The discharge canal runs through pastures and into the irrigation system on the ranch.

The landowners have been in protracted negotiation with both the well's owners and Wyoming Department of Environmental Quality (WDEQ) to improve the condition of the unlined produced water impoundments and discharge canals, which have historically leaked into subsurface and surface soils. In 2013, the landowners were successful in negotiating with the State to close a short span of the discharge canal, but the produced water is still discharged in open canals across their property. Neither the state nor the operators have information about how much produced water is being held in the unlined pits or how much water is leaking into the adjacent pastures. When it spills into the pasture, livestock often drink the contaminated water.

We intended to begin testing at the Deaver location in the spring of 2013. However, the ranchers experienced a large spike in miscarriages in their goat herd and we had to reschedule testing to mid summer.

Community based research often has different rhythms than lab based work, as community organizers and residents have to fit work in around their daily lives. It is important that a testing method used by communities be flexible in terms of time. The photopaper test strips complement this research method, as they keep indefinitely as long as they aren't exposed to the air and can be set at any time.

Final Product: Maps of H_2S Exposure



Round B
7/31/2013 - 8/7/2013
Aerial Photograph Google Earth 8/3/2013

Round C
7/31/2013 - 8/22/2013
Aerial Photograph Google Earth 8/3/2013

Our final maps show increasing levels of H_2S after 1 week (Round B) and 3 weeks (Round C) of exposure.
Round B tests showed the most discoloration and therefore highest levels of H_2S where the produced water is discharged into the discharge canal. The findings were confirmed in Round C, where film canisters in the same locations showed the most discoloration. Air samples were taken at these points, and results were found to be above short term health based standards.

H_2S is not being monitored by WDEQ or Rael Resources, LLC, the company operating at this location. The dangerous levels of H_2S, found in our grab samples and indicated by the test strips show that monitoring at production pads and the associated produced water impoundments and discharge canals is needed.

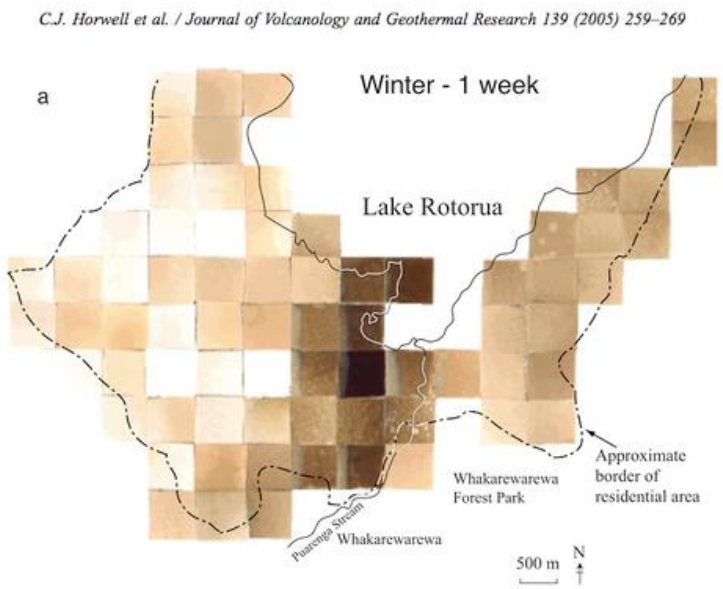
The photopaper sensing method helped to identify one of the sources of H_2S on the property and suggests further research and monitoring at this site should be done at the wellsite, produced water impoundments and discharge canals. Monitoring further away from the pad is also needed to identify how far H_2S is traveling. There is currently no data or information available to explain if H_2S is present in the landowners' home, or how it may be affecting their health.

Making the Canisters

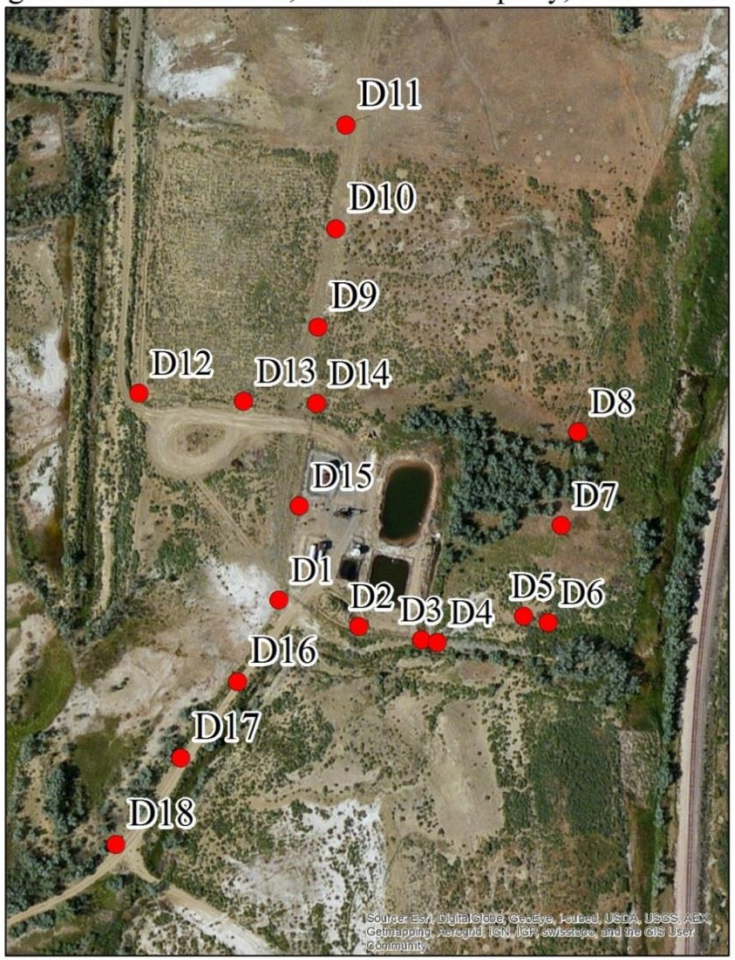
- In the darkroom at Northeastern University, we cut the photographic paper into strips and placed them in the glycerol solution.
- After they were dry, we placed them inside empty film canisters and capped them or inside black tubes and sealed the opening with duct tape.
- The canisters were duct taped to metal stakes.
- The canisters were then placed in light safe containers and mailed to Deb and Cait at the field site in Wyoming.

For more information see: Test Strip Assembly

Canister Locations



Hydrogen Sulfide Canisters, McMullan Property, Deaver Area, WY



Originally, we intended to lay out the canisters in a grid, following Horwell et. al's (above) example. However, it soon became clear that for these types of sites, a grid would not work for a number of reasons, including

- Roadways and fences
- Heavy use and animal traffic
- Geographic challenges: vegetation, uneven terrain, irrigation ditches, etc
- the fact that the site borders private lands (and we could not trespass)

The pattern that we chose is shown in the map to the right, with each red dot corresponding to the location of a canister.

Placing the Canisters in the Field

The canisters were taken out to the field, placed in the ground, and the cap removed on all containers once in place. The canisters were left in place for different amounts of time for each round.

Round A (test): 2 weeks
Round B: 1 week
Round C: 3 weeks

When picked up the canisters were capped or sealed with two layers of duct tape, placed in light safe bags, and mailed back to Northeastern.

Ideally, when each canister is placed in the field and its GPS location recorded, a photo would be taken. However, although photos were taken, they were not labelled right away and eventually became difficult to organize and manage. We are now testing photo labeling with the smartphone app Aviary in order to simplify this process.

Round A: What were we testing?

Question 1: Do the strips change color?

Question 2: Do two strips left in the same location for the same amount of time show the same degree of discoloration?

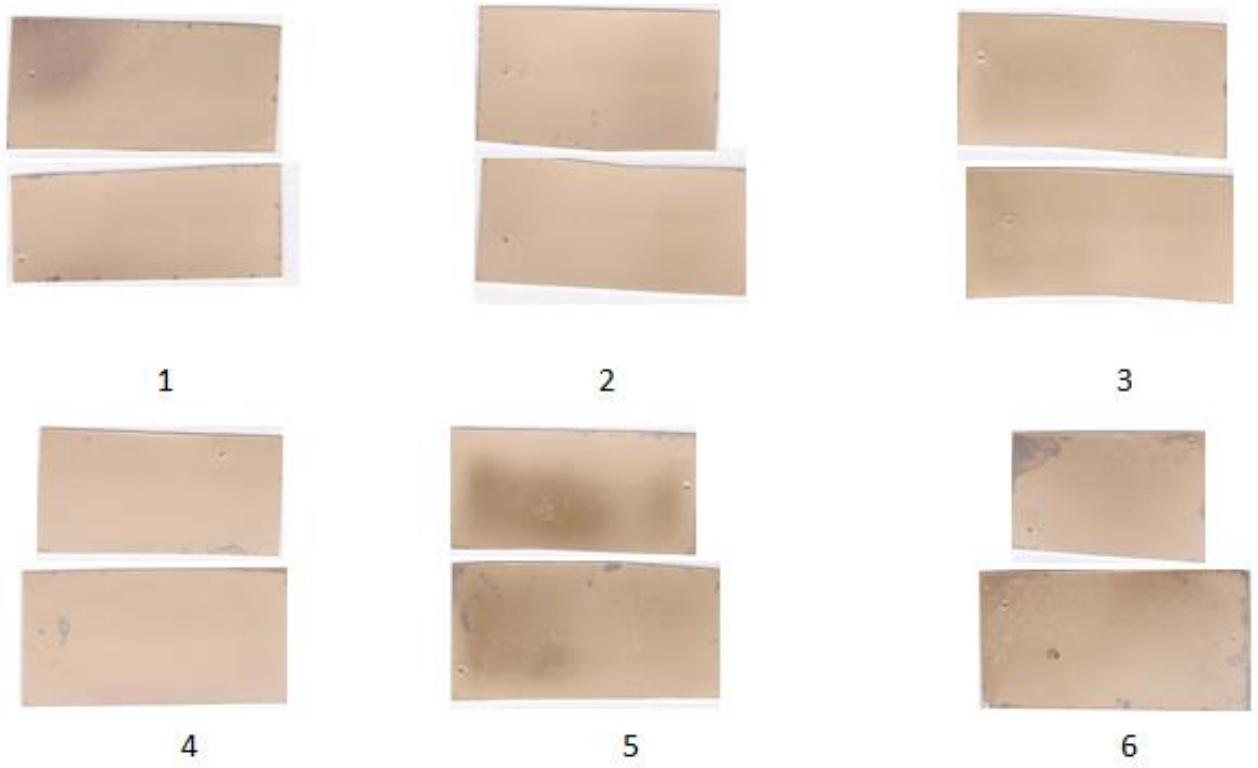
Developing the Strips: Round A

Round A canisters and light-safe bag as they were received, Northeastern darkroom.

Round A results on the drying rack, Northeastern darkroom.

- Once received at Northeastern, the canisters were taken to the darkroom. There were six pairs of strips set and developed during Round A.
- Plastic tubes and duct tape were used to house the strips. We wrote the label of each canister in large letters on a post-it (so it could be seen in the dim red-light of the darkroom safelight)
- Once the lights were off, we took the strips out of the canisters one by one, labeled the back in sharpie, and placed the strip in the fixer.
- We then used thumbtacks to secure the strips to drying racks under their corresponding label.

Deaver Round A Results



Q1: Do the strips change color?

Yes! But a control is needed in the future. Citizen science is a great way to learn the scientific method. In an experiment it is always important to include a control. A control is an experimental condition in which a positive or negative outcome is expected. In this experiment a control would be a strip that is left out in the field but not opened to the air. A strip that is not open to the air should be completely white. The control confirms that the color change is due to exposure to the air. Deb and Cait were new to this process and did not include a control. Hence while we hypothesize the color change in this round came from exposure to the air, we can't conclusively prove it. Controls were added for the following two rounds of testing.

Deaver Round A Results

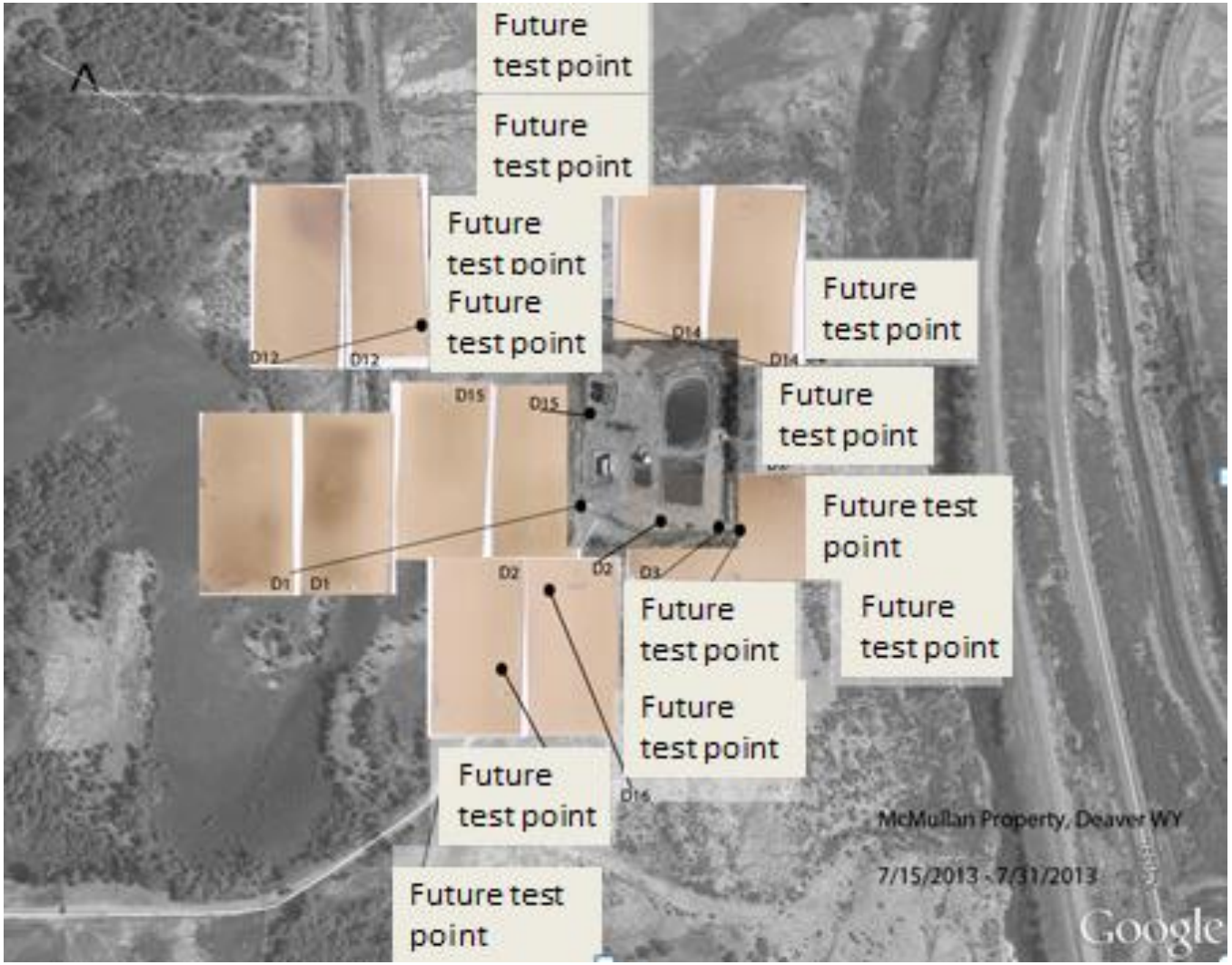
Q2: Do two strips left in the same location for the same amount of time show the same degree of discoloration?

Yes. The most exciting result from this round of testing is that two strips left in the same location are discolored to the same degree. This confirms that the method is internally consistent.

Lessons Learned:

Lessons Learned: *Don't put test strips only where you expect positive results!*
Deb and Cait had a very short window in which to start testing in Deaver and it was also their first time doing testing of this nature, so they placed testing strips where they knew H_2S to be present. Therefore, while the strips did show positive results, the relatively uniform coloration across strips shows the need to place strips in areas where H_2S is expected and not expected in order to show different levels H_2S coloration of and to indicate the direction in which H_2S is traveling. We also noted the importance of adding a control strip for comparison.

Initial Maps: Round A (test)



Our test map showed that using the satellite image as the background made the map a bit busy and difficult to read.

We decided to simplify the maps in Rounds B and C and use simple line drawings of the site as the background.

The test map also shows the points at which canisters will be placed in Rounds B and C.

Round B: What were we testing?

- We added 12 more points in this round in order to gain a more complete view of the area.

- Also added a control for comparison and to confirm that discoloration was due to H_2S infiltration of the canisters.

Developing the Strips: Round B

Round B canisters and drying rack, Northeastern darkroom.

Round B canisters and fixed strips on a drying rack, Northeastern darkroom.

In this round we added 12 new data points and a control. Two canisters were placed at each data point, and the first picked up after one week during Round B. Since Round A had confirmed the validity of our method, we used only one strip per test point.

Deaver Round B Results

Control

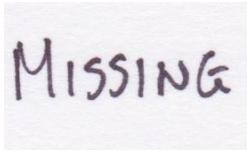
1

2

3

4

5



6

7

8

compromised

9

compromised

10

compromised

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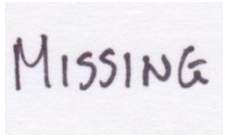


16

17

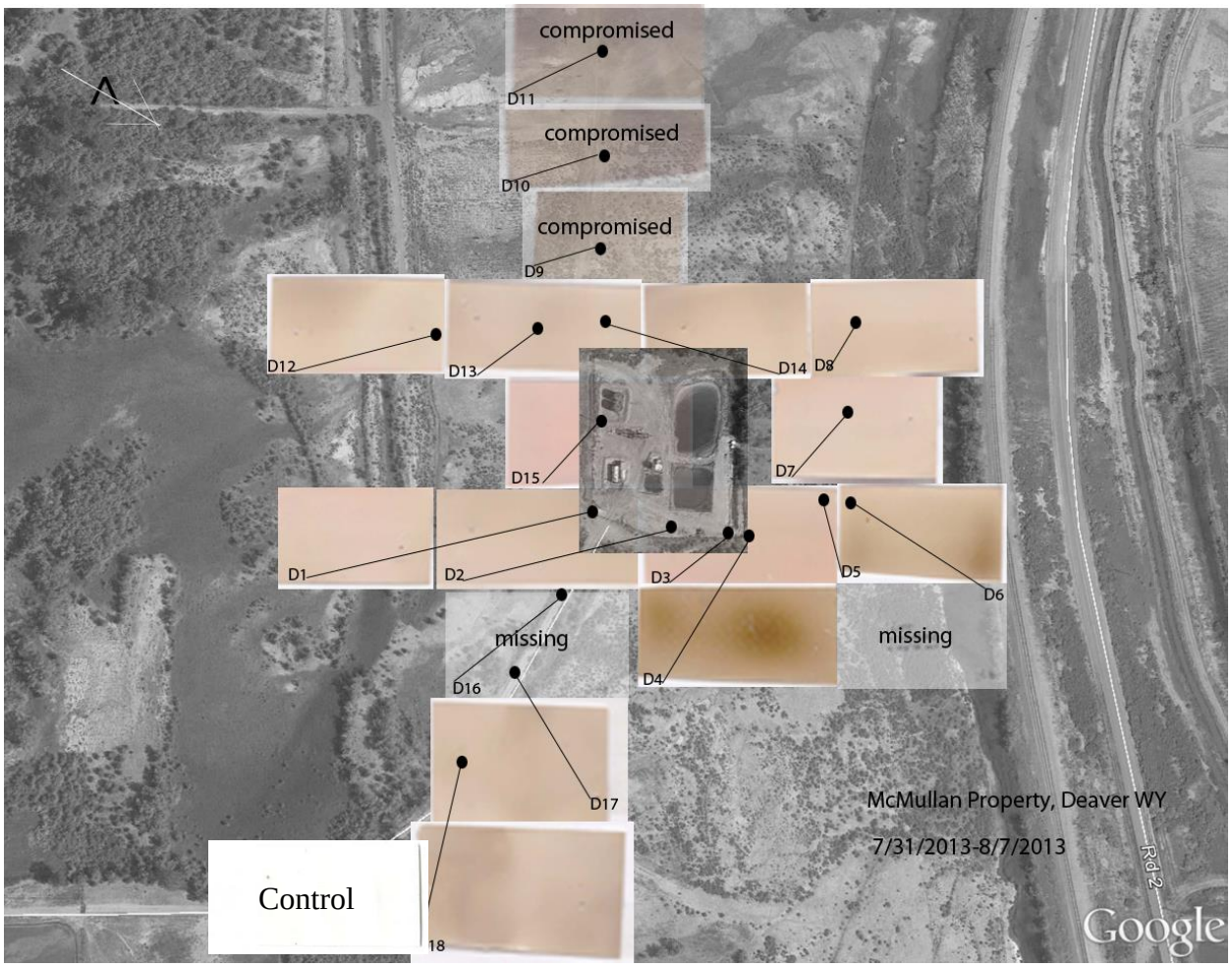
18

Deaver Round B Results

(Continued from previous slide)

- The control confirms that color change was due to exposure to the air.
- Test strips D4 and D5 show the greatest discoloration.
- The Round B test strips were left out for one week. They show more variation than the Round A results.
- Test Canisters D11, D12 and D13 were compromised (knocked out of their original location) and were both picked up during Round B. You can see these test strips show strange discoloration. The grey color is consistent light contamination which we hypothesize occurred when they were up turned which probably let light into the tube.
- Two canisters were missing.

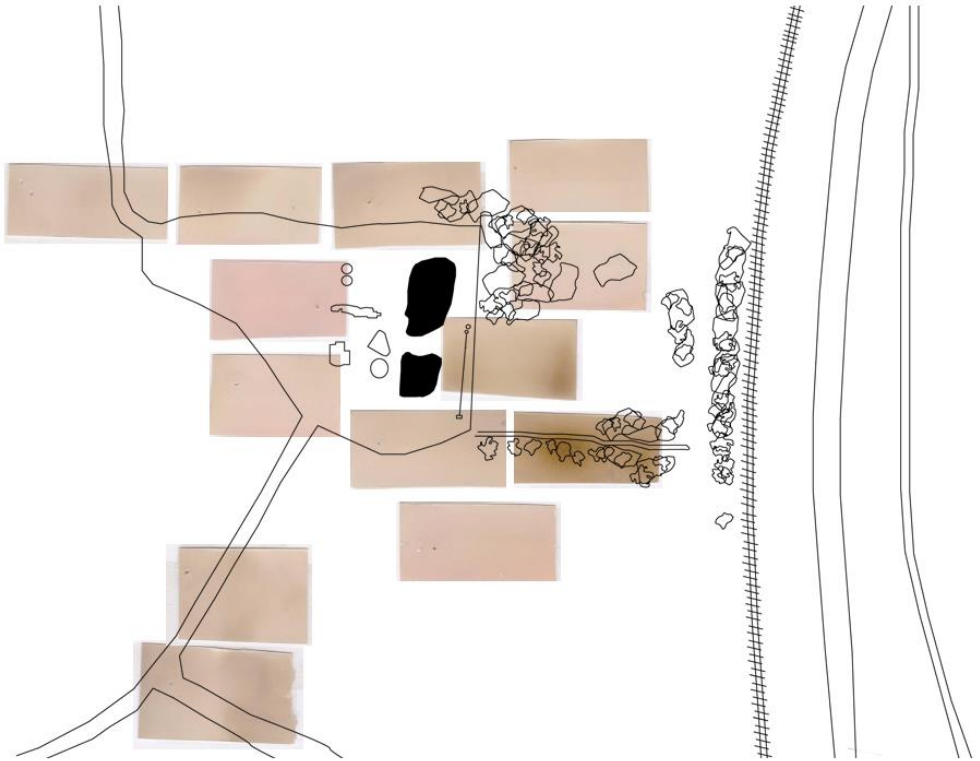
Initial Maps: Round B



Higher levels of H_2S are seen at testing Point D4 and D5. This is right along the discharge canal for produced water on from the well operations.

Two controls were placed during this round – a double canister at D12 and another at D18. Both controls were picked up during Round C.

Final Map: Round B



We chose to use basic line drawings as the background map in order to allow the results to stand out and be more easily interpreted. Our results indicate that the gas is heaviest near produced water impoundments and discharge canals.

Round B
7/31/2013 - 8/7/2013
Aerial Photograph Google Earth 8/3/2013

Developing the Strips: Round C

Round C drying rack, Northeastern darkroom.

Round C canisters, Northeastern darkroom.

In this round the canisters and controls were left out for three weeks.

Deaver Round C Results

1

2

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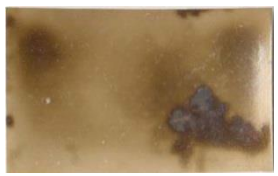
4

5



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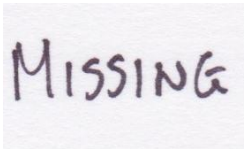

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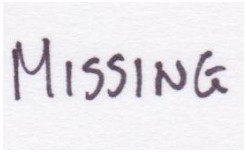

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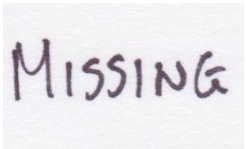

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Control

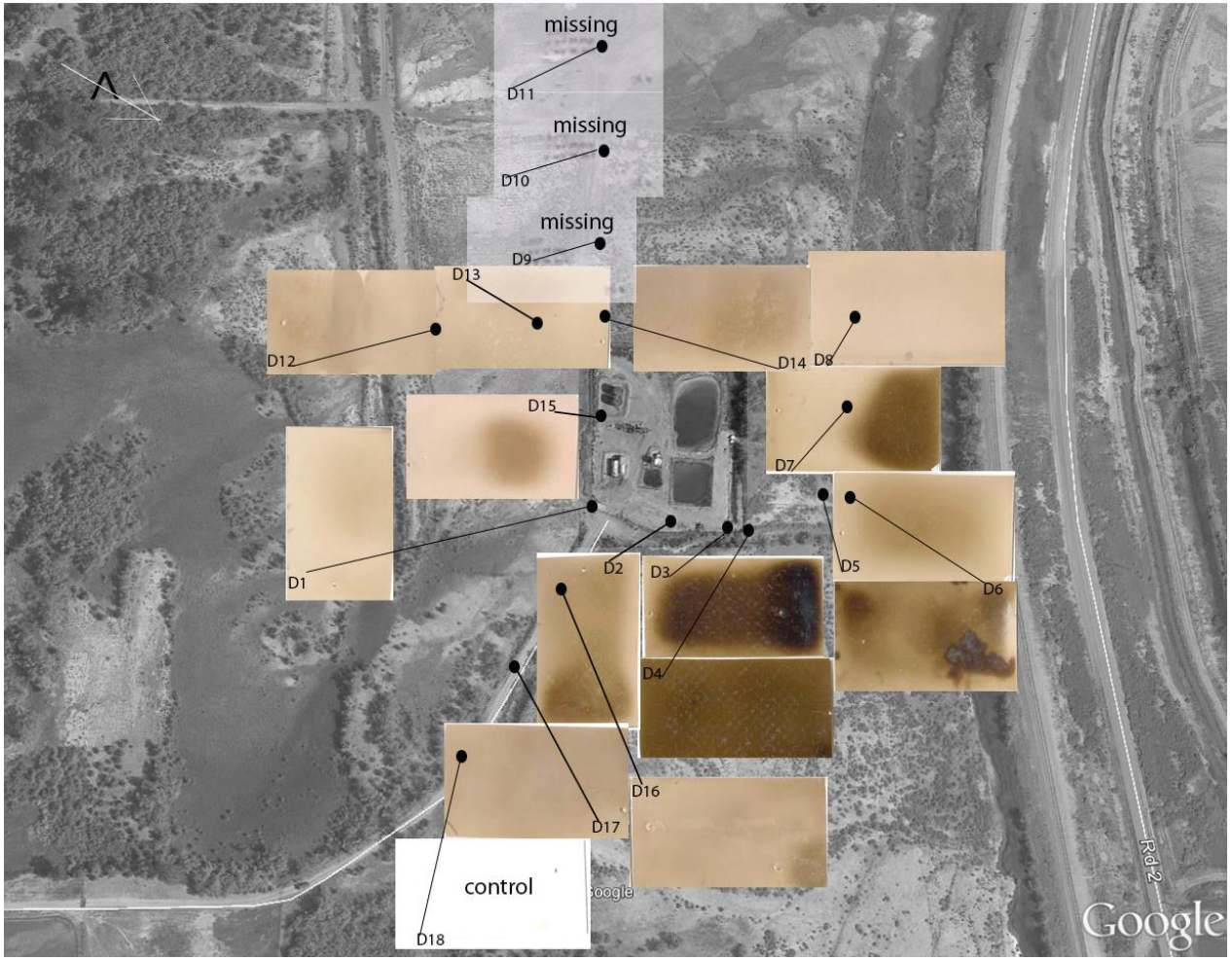
Deaver Round C Results

(Continued from previous slide)

- The Round C test strips were left out for three weeks.
- A few strips show unusual patterns of discoloration
- Three canisters were missing

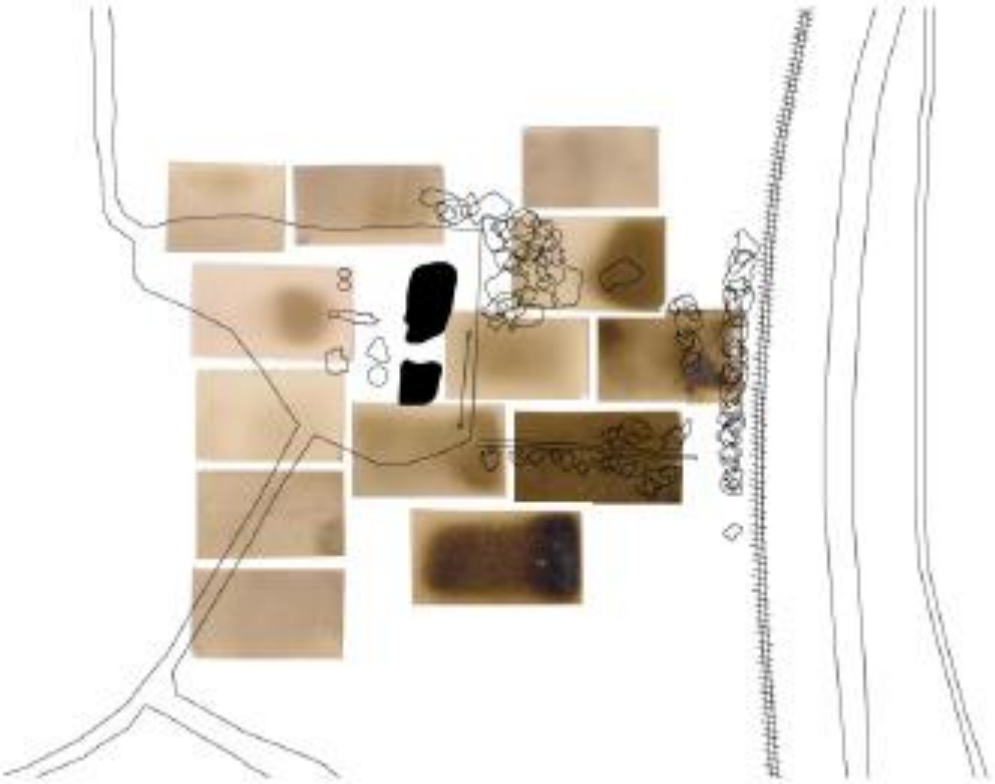
Lessons learned: Further investigation into unusual discoloration patterns is needed (e.g. experiments with light/water exposure)

Initial Maps: Round C



Our test map confirms what we saw in Round B – the heaviest H_2S concentration occurs at points D2, D3, D4, D6, D7, which are closest to the produced water impoundments.

Final Map: Round C



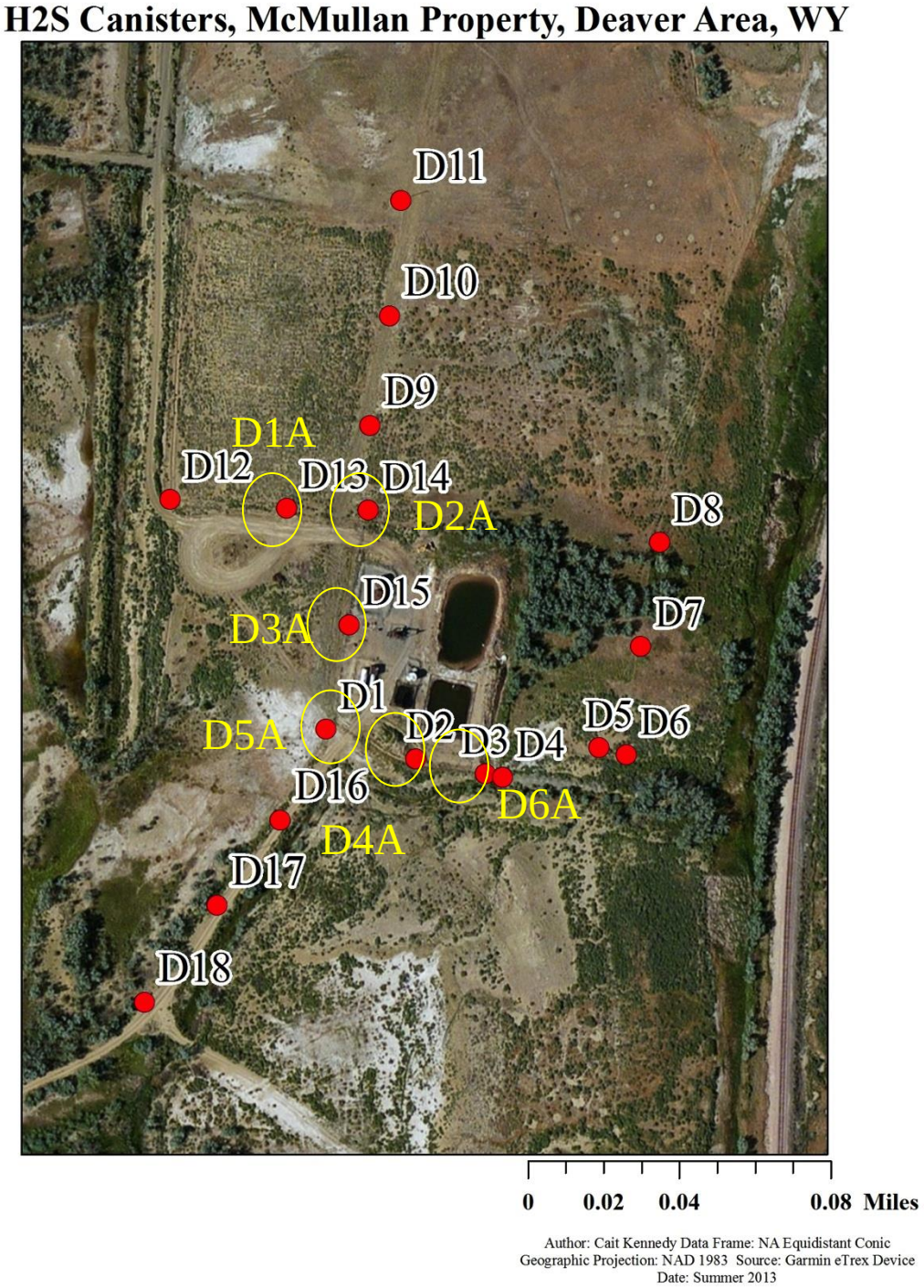
Round C
7/31/2013 - 8/22/2013
Aerial Photograph Google Earth 8/3/2013

The Round C map, which shows strips that had been left out for 2 weeks longer than Round B, indicates even heavier H_2S concentrations near produced water impoundments (D2, D3, D4, D6, D7) and discharge canals, showing how H2S exposure accumulates in these areas over time.

What's in a Name?

- One big takeaway from all three rounds concerns the importance of choosing a naming/canister labeling convention at the beginning and sticking to it.
- The way the data points were labeled changed slightly during each of the three rounds, which led to a considerable amount of confusion
- In Round A, only the lat/long were written on the canisters, and a label assigned afterwards
- The changing labels for each data point are shown in the table to the right

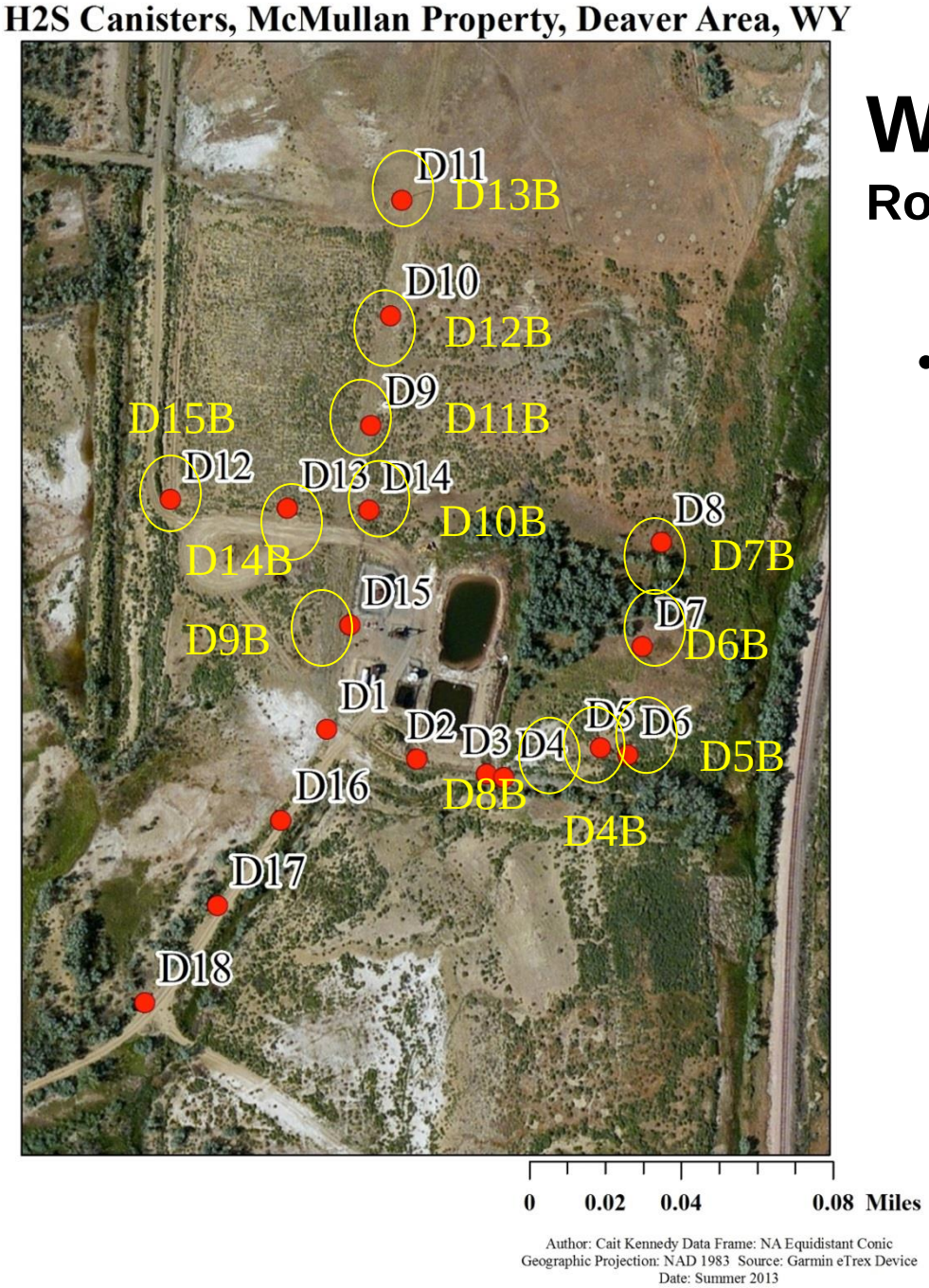
Label	Latitude & Longitude
D1c=D1B=D5A	44.923866, -108.652719
D2c=D2B=D4A	44.923946, -108.6532
D3c=D3B=D6A	44.923869, -108.652304
D4c=D8B	44.922813, -108.65405
D5c=D4B	44.923213, -108.653701
D6c=D5B	44.923572, -108.653415
D7c=D6B	44.923851, -108.652174
D8c=D7B	44.924016, -108.651505
D9c=D11B	44.924007, -108.651665
D10c=D12B	44.924329, -108.653186
D11c=D13B	44.924419, -108.651517
D12c=D15B	44.924788, -108.653174
D13c=D14B=D1A	44.924719, -108.654296
D14c=D10B=D2A	44.924764, -108.65362
D15c=D9B=D3A	44.924821, -108.651475
D16c=D16B	44.925127,-108.653227
D17c=D17B	44.925546, -108.653188
D18c=D18B	44.925996, -108.653219



Why the Change?

Round A

- Originally, the points were labeled in the order that they were placed as Deb and Cait walked around the property.
- Later, as more points were added, we attempted to re-name them so that they could be read in order on a map when seen from above.
- This is illustrated by the map to the left, which shows the Round C labels in black with the Round A labels in yellow.



Why the Change?

Round B

- The map to the left shows how the labels changed from Rounds B to C, with Round C labels in black and Round B labels in yellow.

Conclusions

- The photopaper sensing method is an **effective and relatively easy** way to detect and map H_2S.
- **Good field notes are essential**. For each round, canisters must be identified by GPS location, naming convention (e.g. D1a), and set date and pick up date.
- **Choose a naming convention and stick with it**. If new points are added, list the GPS location of all new points and assign a label. Write that label on the canister. At the *end of all rounds*, re-number if necessary.

Next Steps

- Develop a field guide
- Quantify and/or standardize the photopaper strips
- Develop open source tools for analyzing the photopaper strips and creating maps
- Design and make testing kits available through Public Lab