Mining Oil and Gas Well Integrity Data in Colorado and New Mexico

Greg Lackey

Gregory.Lackey@Colorado.edu

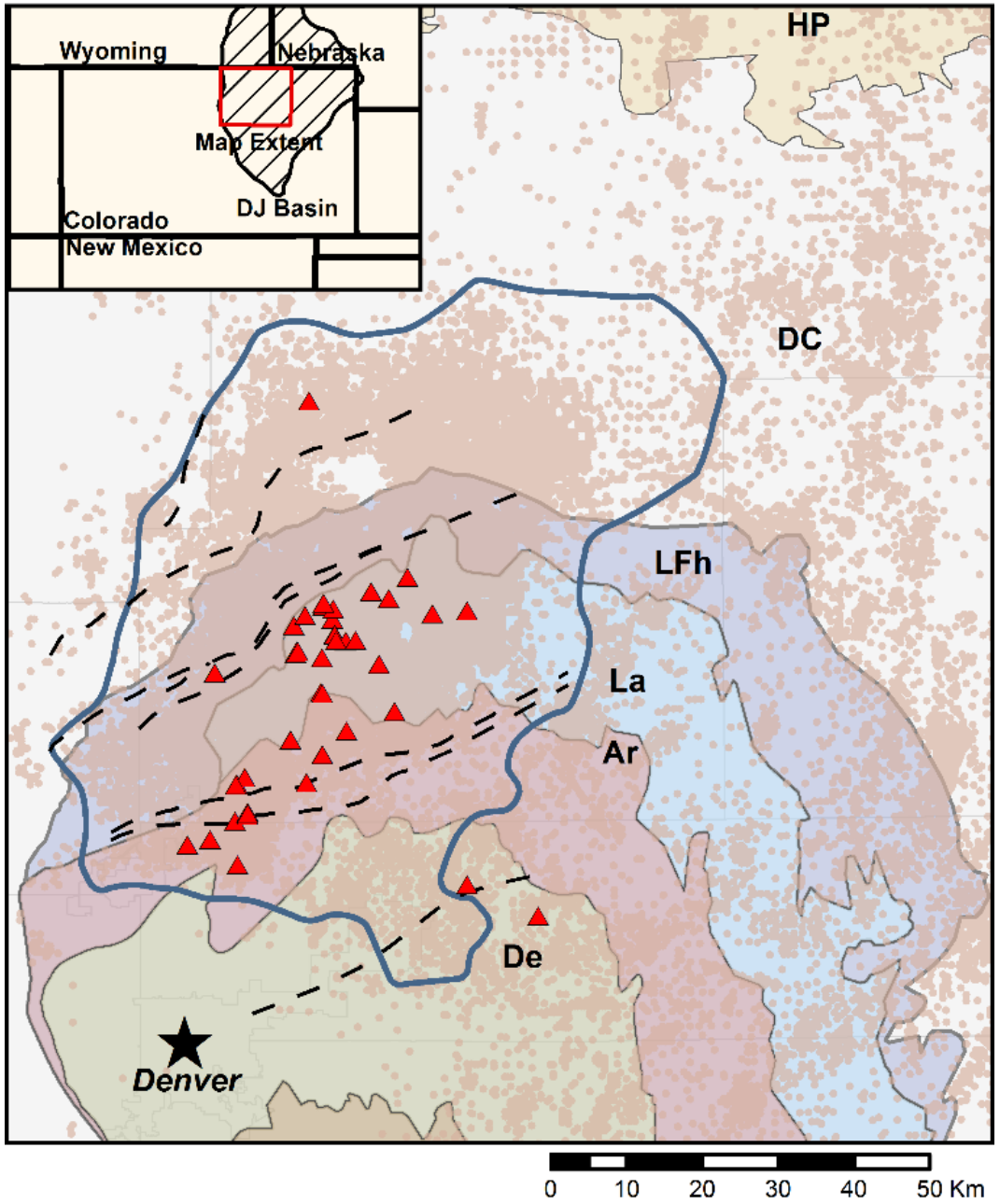
5/18/2018

University of Colorado **Boulder**

AirWaterGas

Sustainability Research Network

Wattenberg Field



4^{th} largest oil field
9^{th} largest gas field

Stray gas contamination:
Thermogenic CH_4
42 water wells
32 cases
11 "culprit" oil and gas wells

PNAS

CrossMark

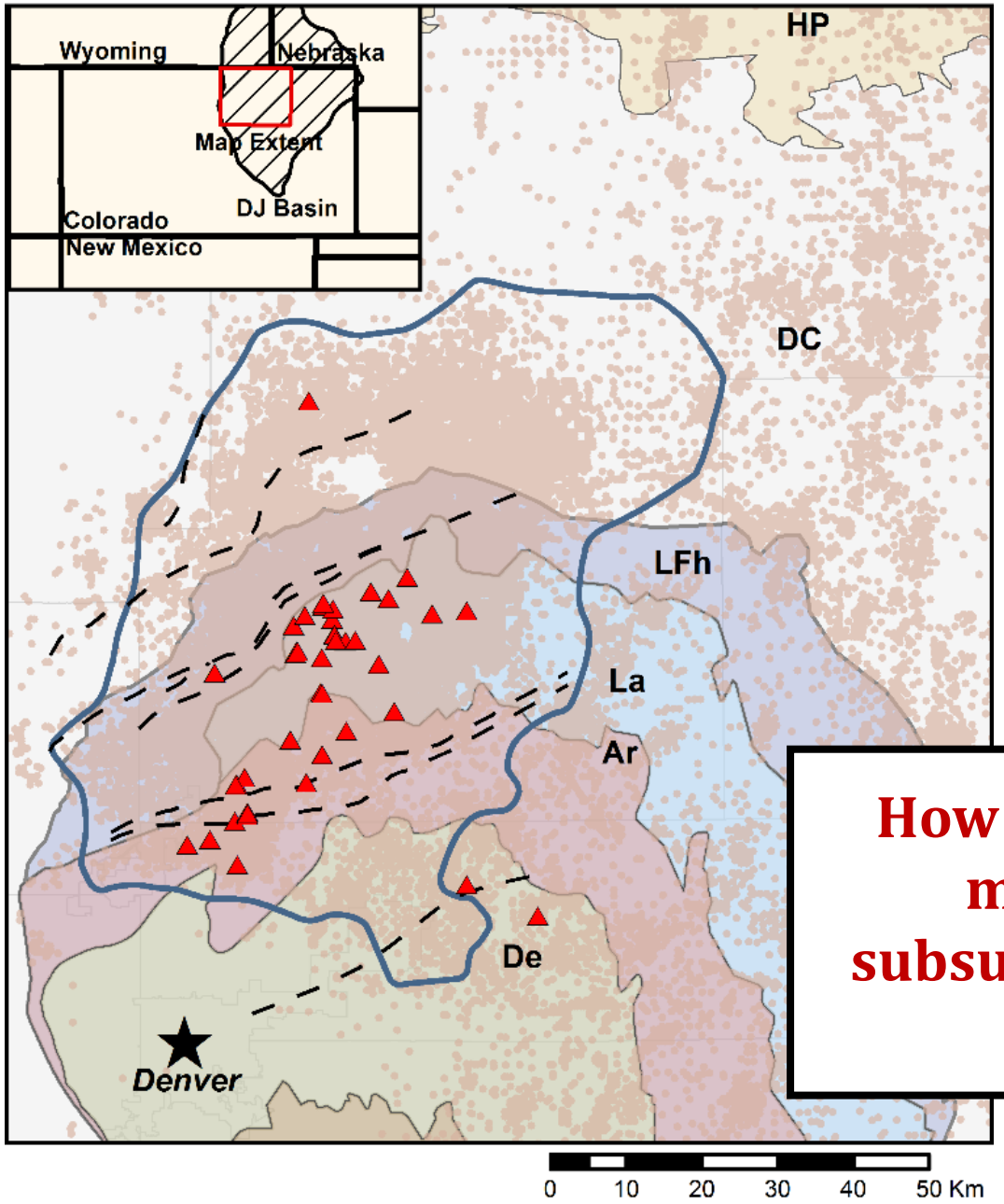
Groundwater methane in relation to oil and gas development and shallow coal seams in the Denver-Julesburg Basin of Colorado

Owen A. Sherwood[a,1], Jessica D. Rogers[b], Greg Lackey[b], Troy L. Burke[b], Stephen G. Osborn[c], and Joseph N. Ryan[b]

[a]Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309; [b]Department of Civil, Environmental and Architectural Engineering, University of Colorado, Boulder, CO 80309; and [c]Department of Geological Sciences, California State Polytechnical University, Pomona, CA 91768

Edited by Peter H. Gleick, Pacific Institute for Studies in Development, Environment, and Security, Oakland, CA, and approved June 7, 2016 (received for review November 24, 2015)

Wattenberg Field



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Stray gas contamination:
Thermogenic CH_4
42 water wells
32 cases
11 "culprit" oil and gas wells

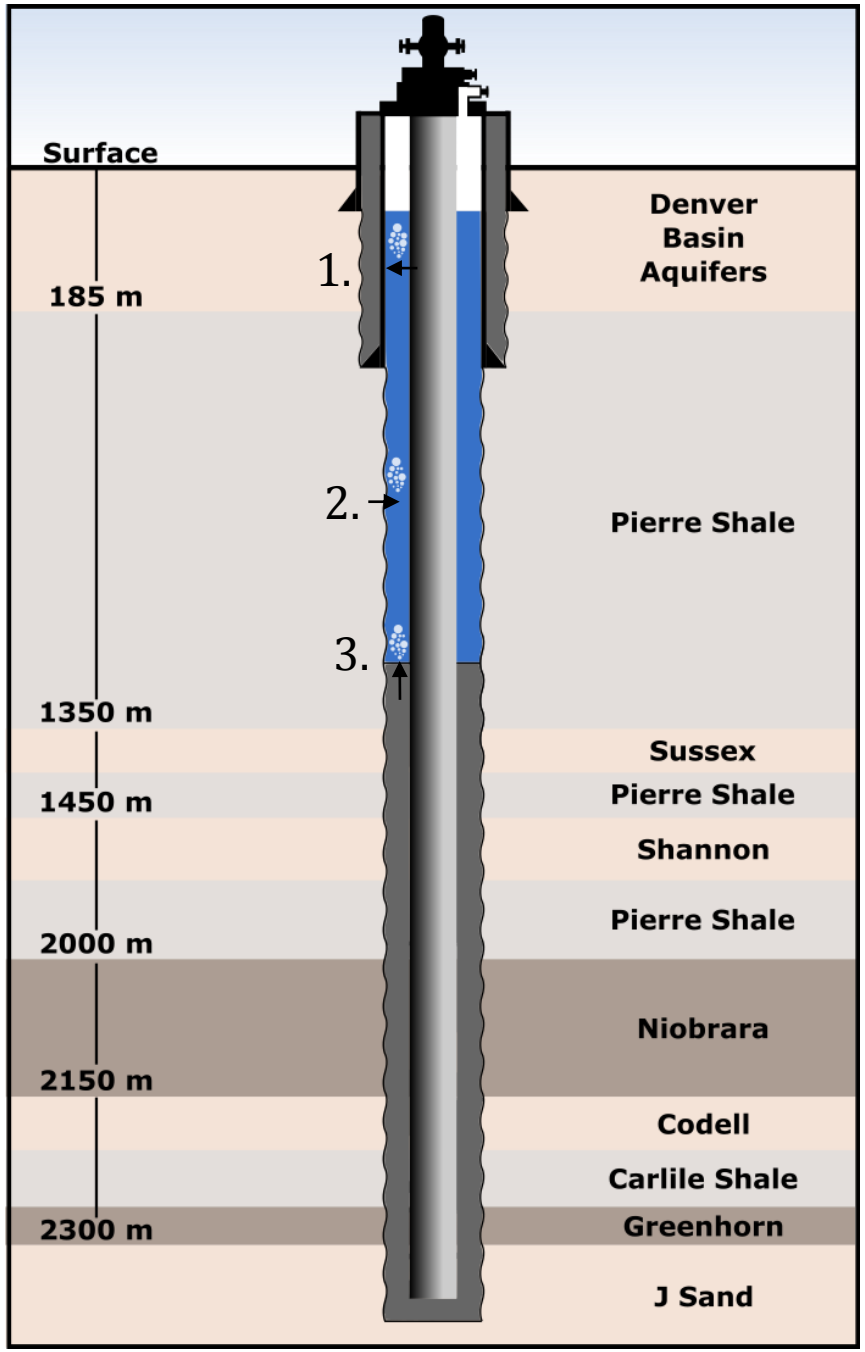
How did thermogenic stray gas migrate into the shallow subsurface through these culprit wells?

Well Leakage

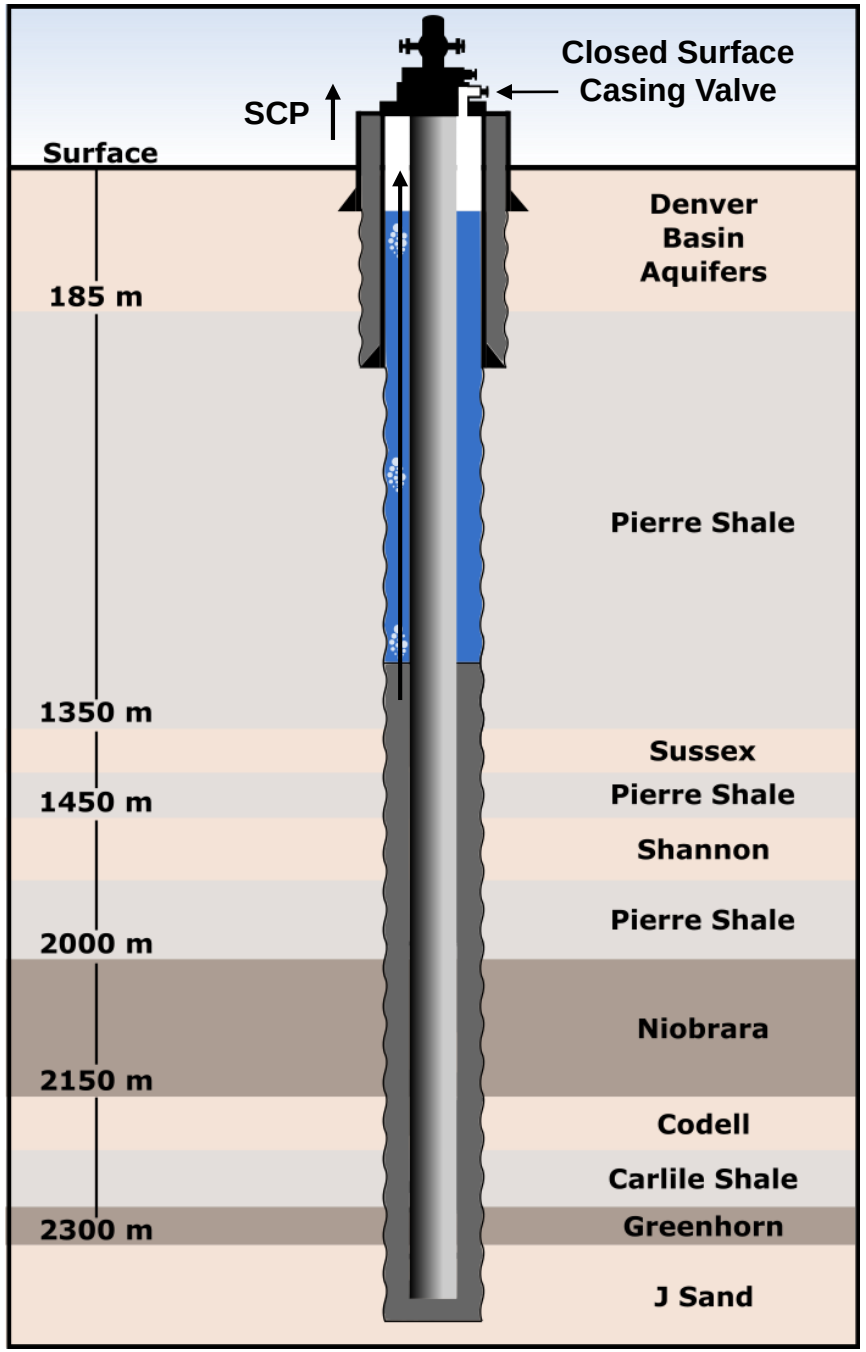
1. Casing leak

2. Unknown intermediate

3. Faulty cement seal or improper cement coverage

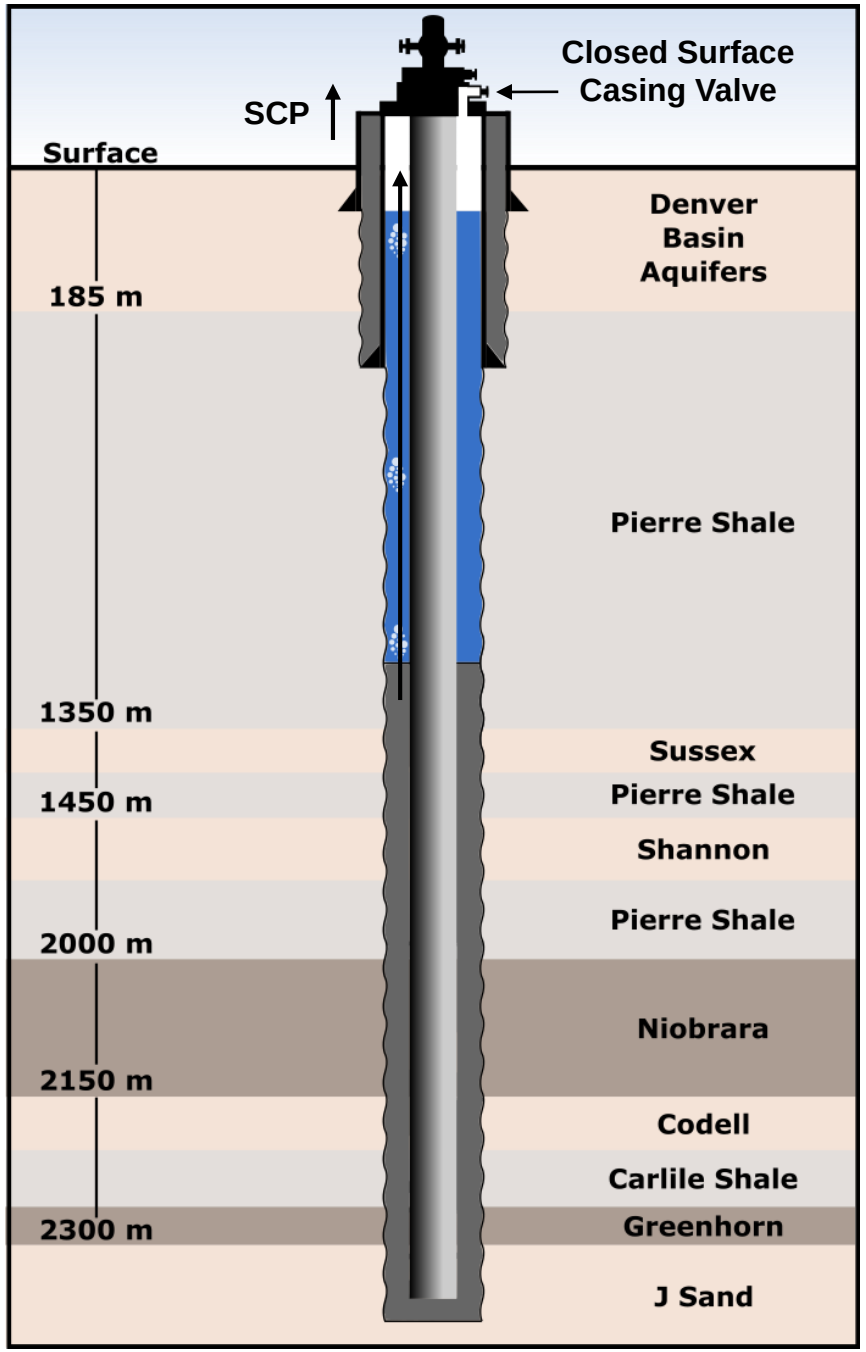


Sustained Casing Pressure (SCP)



Sustained Casing Pressure (SCP)

Sustained annular pressure (SAP), bradenhead pressure, surface casing vent flow (SCVF)



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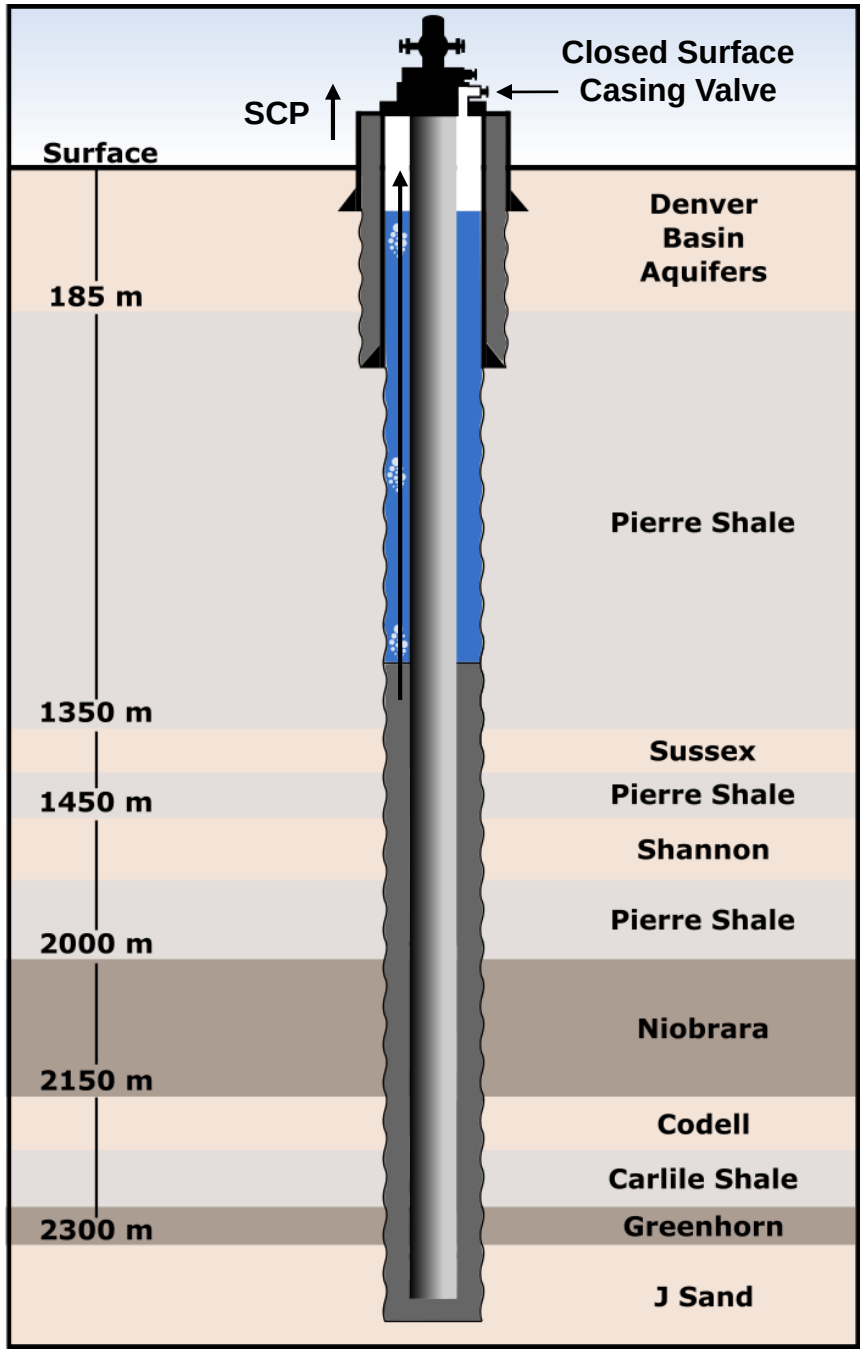
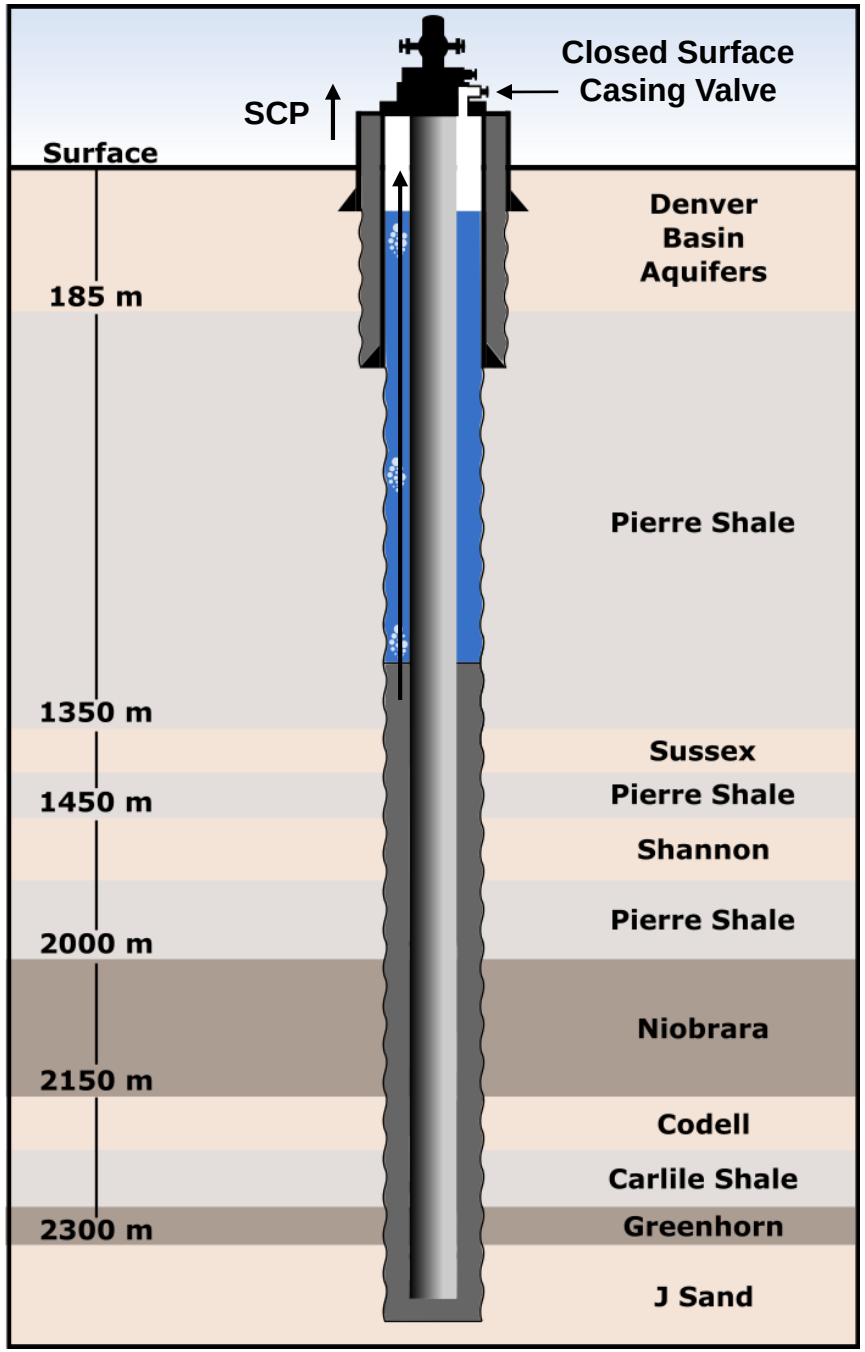


Sustained Casing Pressure (SCP)

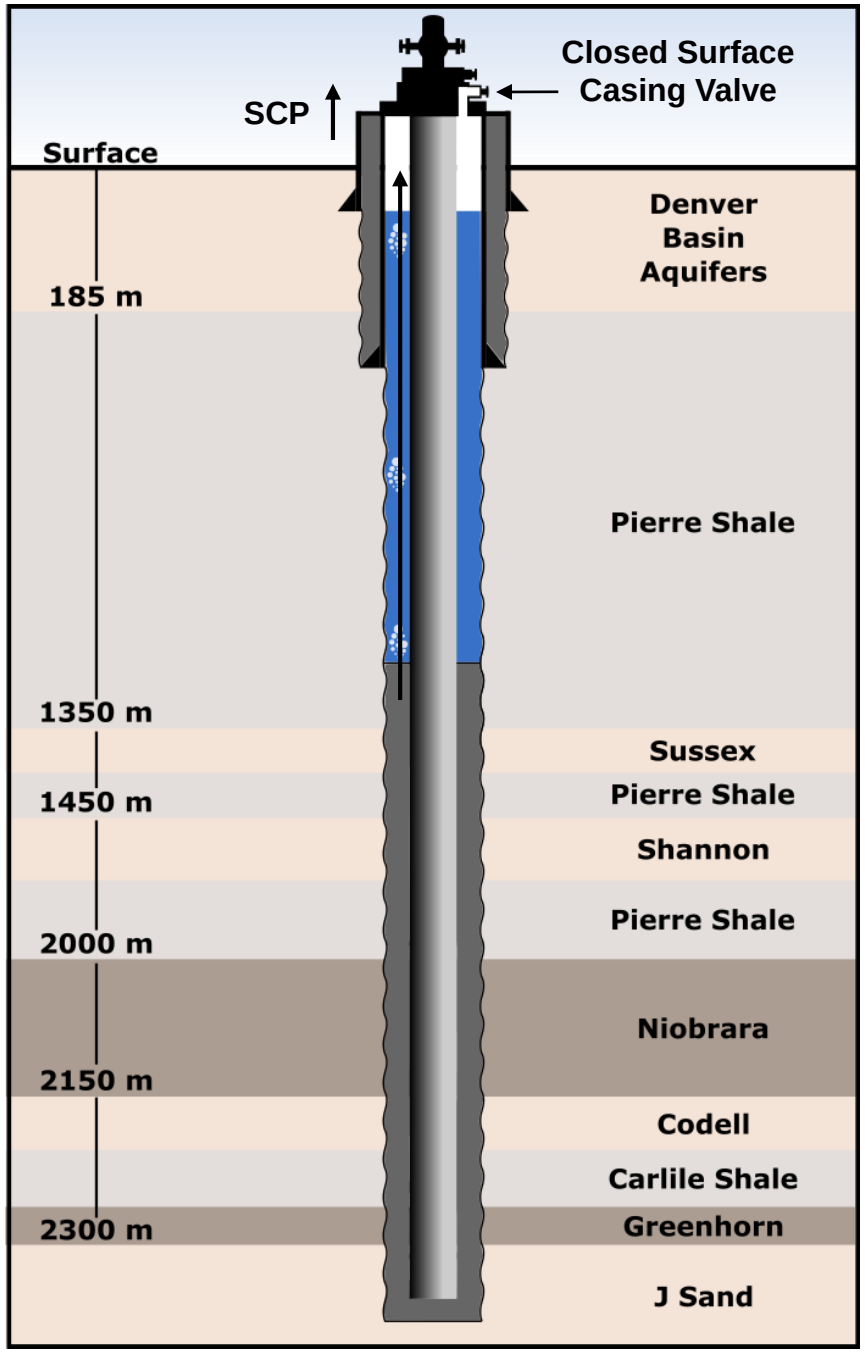
Sustained annular pressure (SAP), bradenhead pressure, surface casing vent flow (SCVF)

Should be no SCP in a properly functioning well

Sustained casing pressure is an easily measured gauge of well integrity, but is poorly documented



Not all wells that develop SCP induce stray gas migration



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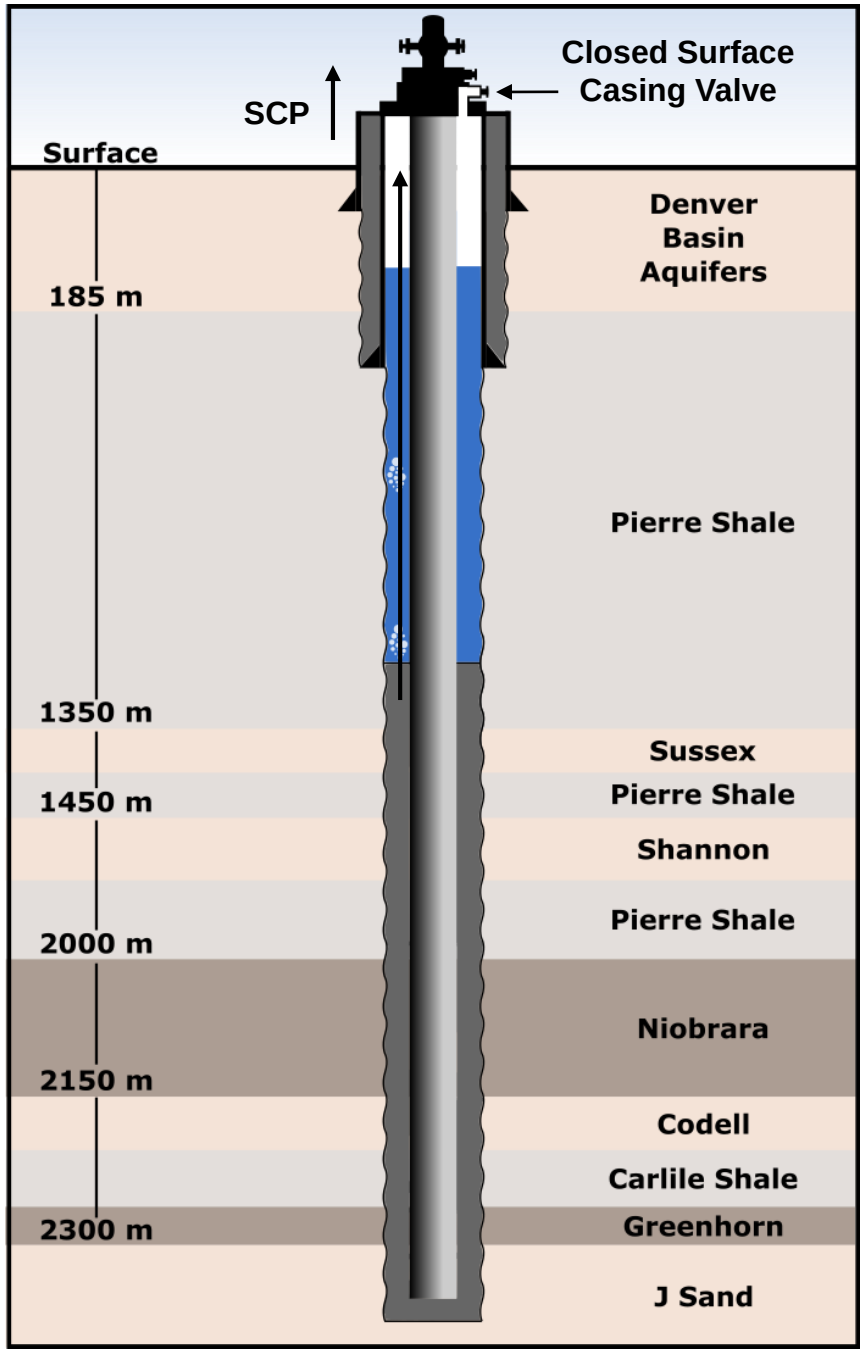
As pressure builds annular liquid is displaced



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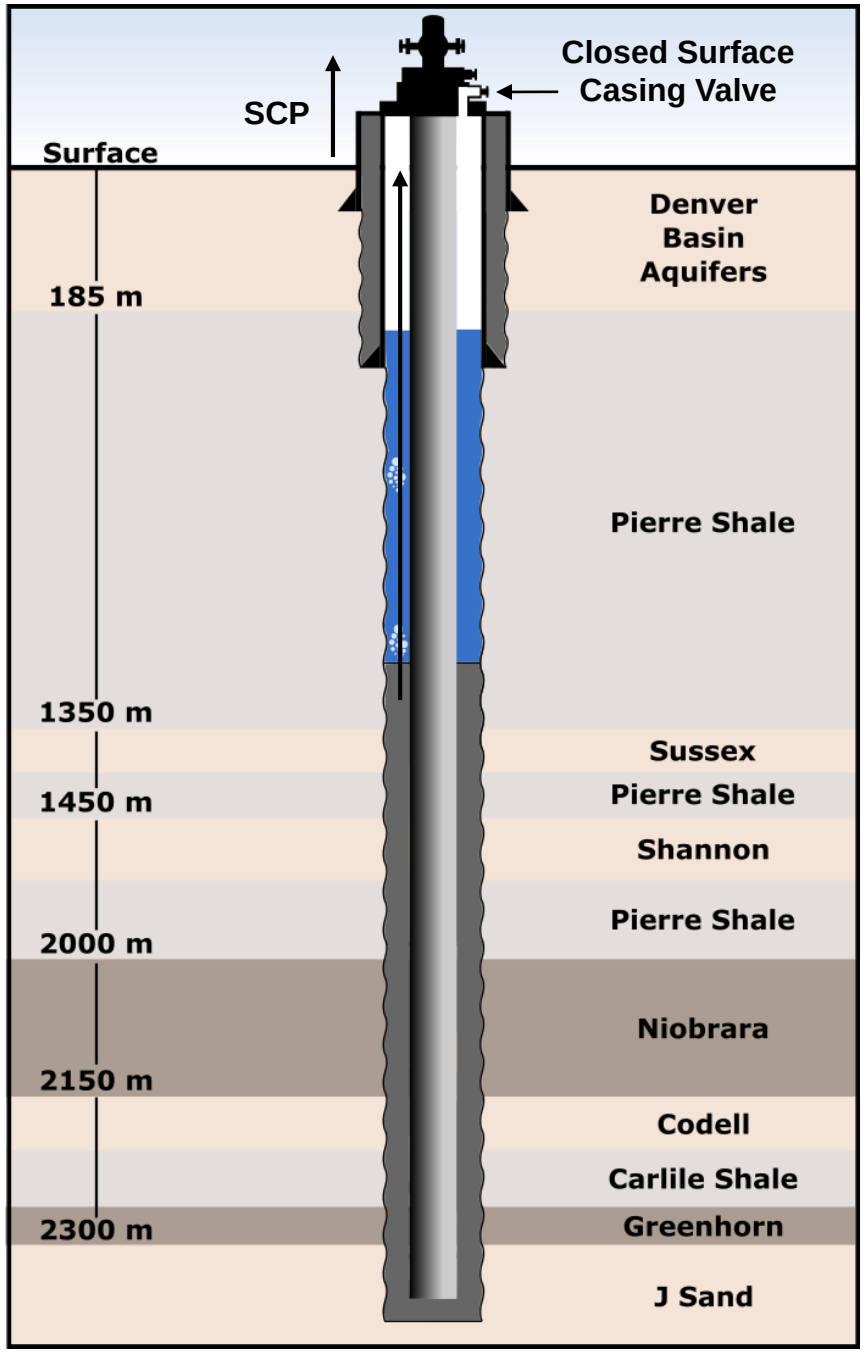

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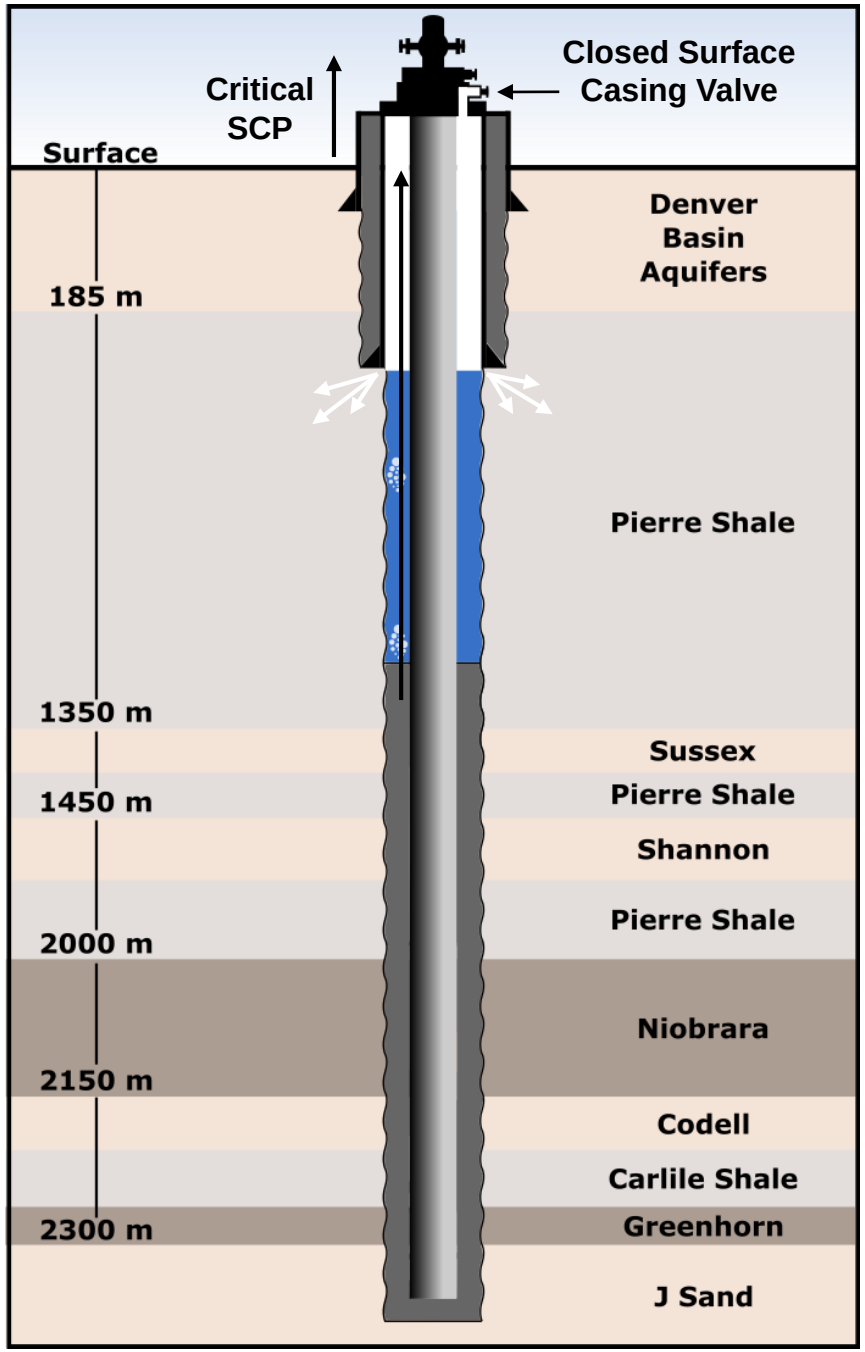
When SCP = formation fluid pressure at bottom of surface casing stray gas migration can be induced

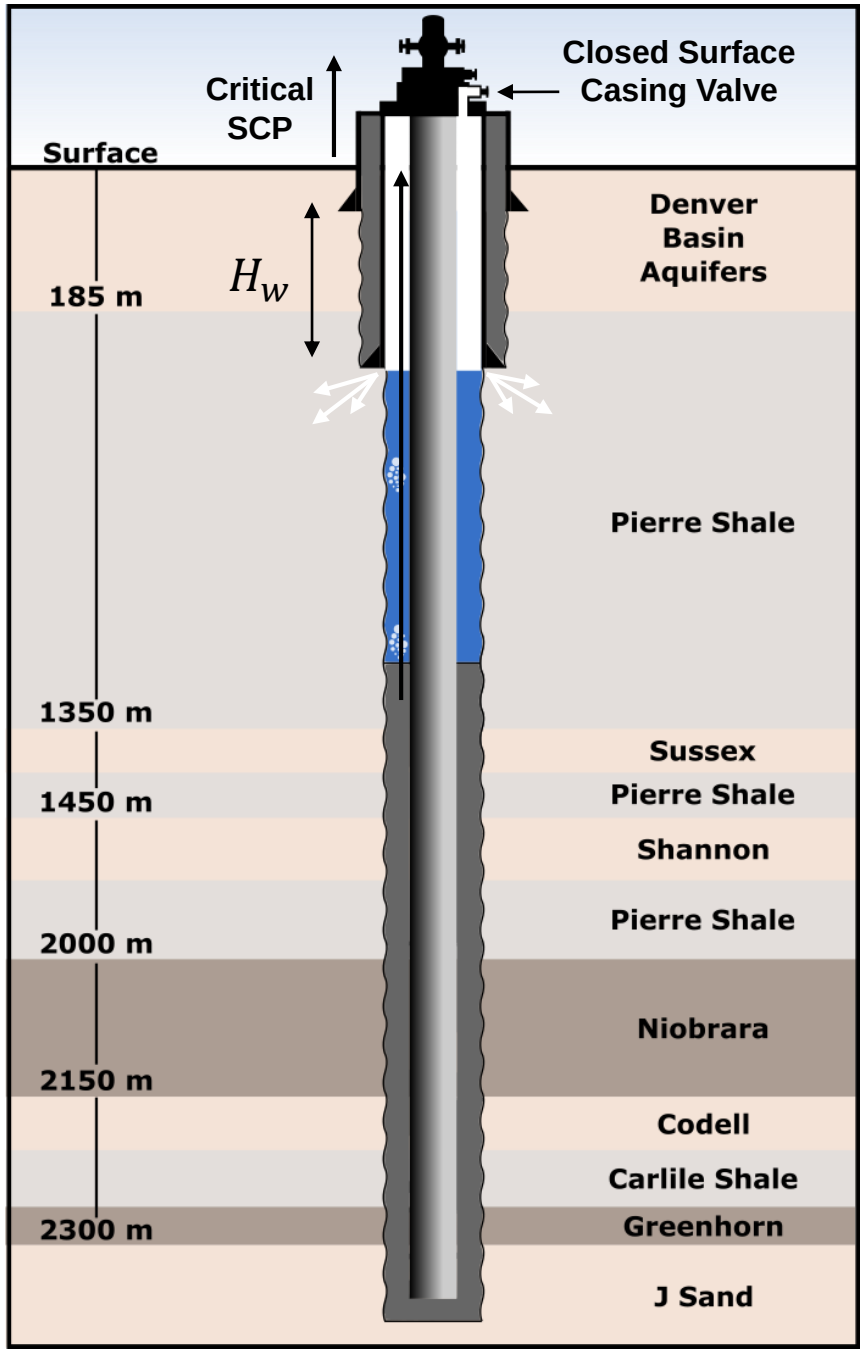


Not all wells that develop SCP induce stray gas migration

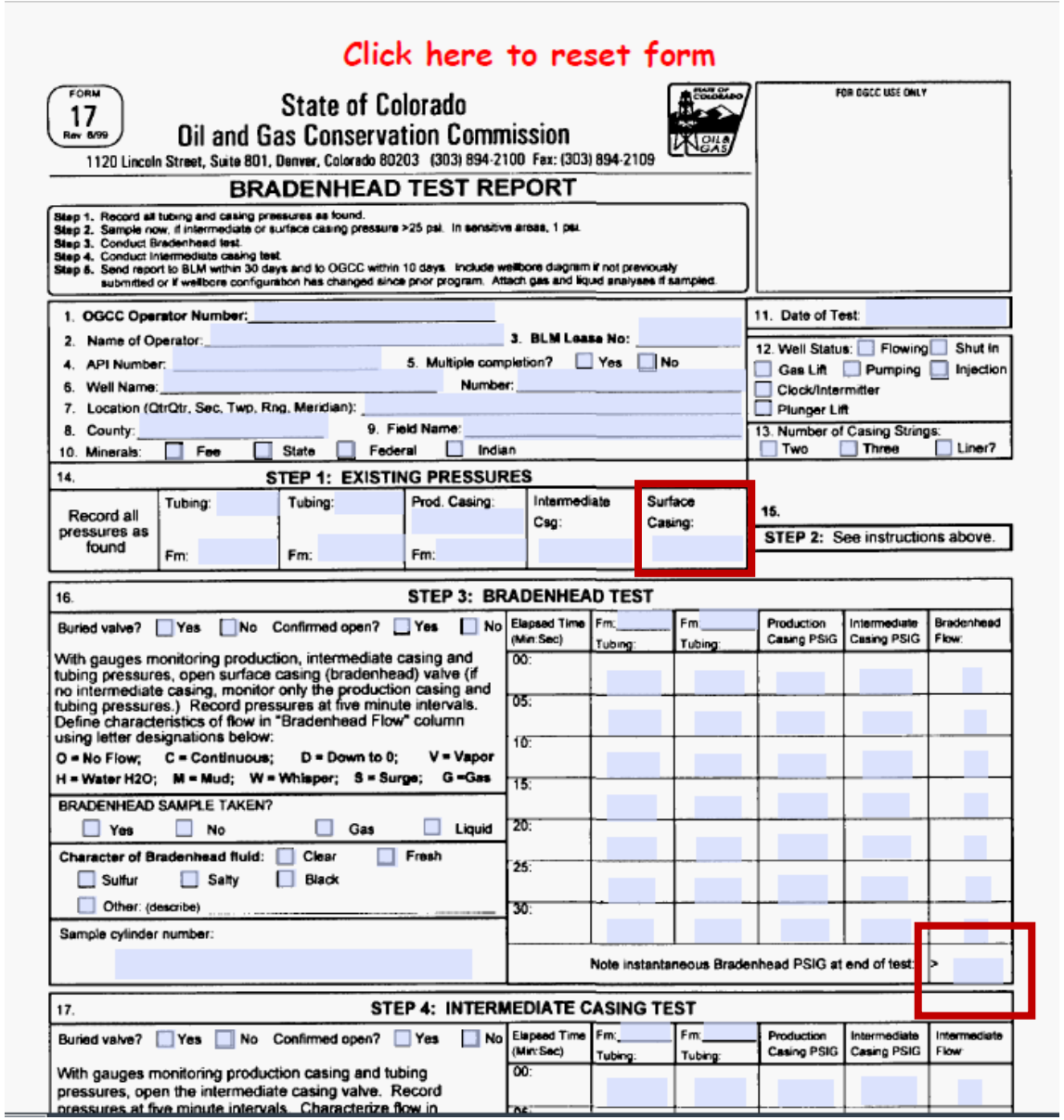
As pressure builds annular liquid is displaced

When SCP = formation fluid pressure at bottom of surface casing stray gas migration can be induced

Critical sustained casing pressure is a well-specific physically meaningful indicator of stray gas migration



Bradenhead Testing



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FORM 17 Rev 8/99

State of Colorado
Oil and Gas Conservation Commission

1120 Lincoln Street, Suite 801, Denver, Colorado 80203 (303) 894-2100 Fax: (303) 894-2109

FOR OGCC USE ONLY

BRADENHEAD TEST REPORT

Step 1. Record all tubing and casing pressures as found.
Step 2. Sample now, if intermediate or surface casing pressure >25 psi. In sensitive areas, 1 psi.
Step 3. Conduct Bradenhead test.
Step 4. Conduct Intermediate casing test.
Step 5. Send report to BLM within 30 days and to OGCC within 10 days. Include wellbore diagram if not previously submitted or if wellbore configuration has changed since prior program. Attach gas and liquid analyses if sampled.

1. OGCC Operator Number:
2. Name of Operator: 3. BLM Lease No:
4. API Number: 5. Multiple completion? Yes No
6. Well Name: Number:
7. Location (QtrQtr, Sec, Twp, Rng, Meridian):
8. County: 9. Field Name:
10. Minerals: Fee State Federal Indian

11. Date of Test:

12. Well Status: Flowing Shut In
Gas Lift Pumping Injection
Clock/Intermitter
Plunger Lift

13. Number of Casing Strings:
Two Three Liner?

14. STEP 1: EXISTING PRESSURES

Record all pressures as found	Tubing: Fm:	Tubing: Fm:	Prod. Casing: Fm:	Intermediate Csg:	Surface Casing:

15. STEP 2: See instructions above.

16. STEP 3: BRADENHEAD TEST

Buried valve? Yes No Confirmed open? Yes No

With gauges monitoring production, intermediate casing and tubing pressures, open surface casing (bradenhead) valve (if no intermediate casing, monitor only the production casing and tubing pressures.) Record pressures at five minute intervals. Define characteristics of flow in "Bradenhead Flow" column using letter designations below:

O = No Flow; C = Continuous; D = Down to 0; V = Vapor
H = Water H2O; M = Mud; W = Whisper; S = Surge; G =Gas

BRADENHEAD SAMPLE TAKEN?
Yes No Gas Liquid

Character of Bradenhead fluid: Clear Fresh
Sulfur Salty Black
Other: (describe)

Sample cylinder number:

Elapsed Time (Min:Sec)	Fm: Tubing:	Fm: Tubing:	Production Casing PSIG	Intermediate Casing PSIG	Bradenhead Flow:
00:					
05:					
10:					
15:					
20:					
25:					
30:					

Note instantaneous Bradenhead PSIG at end of test: >

17. STEP 4: INTERMEDIATE CASING TEST

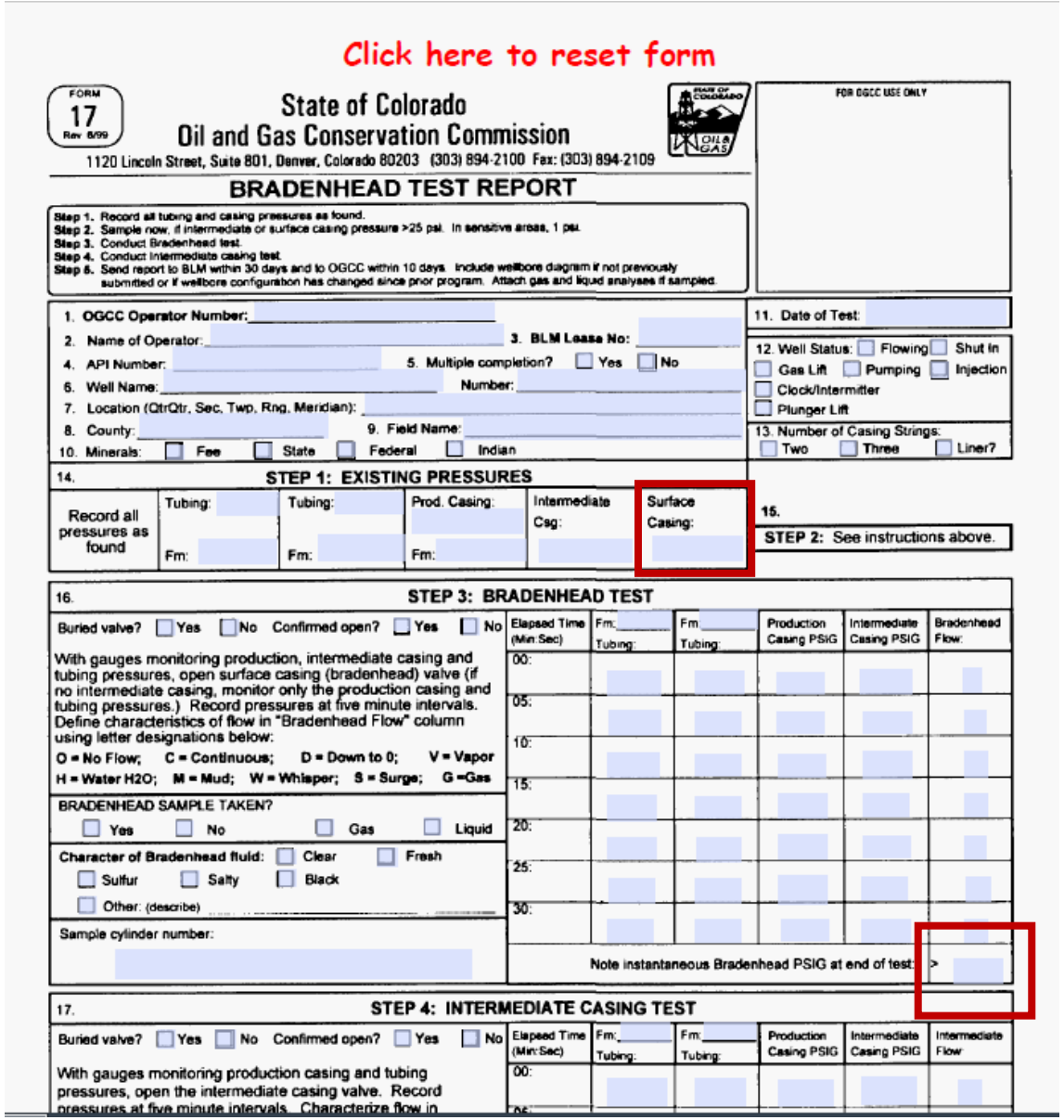
Buried valve? Yes No Confirmed open? Yes No

With gauges monitoring production casing and tubing pressures, open the intermediate casing valve. Record pressures at five minute intervals. Characterize flow in

Elapsed Time (Min:Sec)	Fm: Tubing:	Fm: Tubing:	Production Casing PSIG	Intermediate Casing PSIG	Intermediate Flow
00:					
05:					

Bradenhead Testing

- Pressure measured as found on surface casing



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8. County: 9. Field Name:
10. Minerals: Fee State Federal Indian

11. Date of Test:
12. Well Status: Flowing Shut In Gas Lift Pumping Injection Clock/Intermitter Plunger Lift
13. Number of Casing Strings: Two Three Liner?

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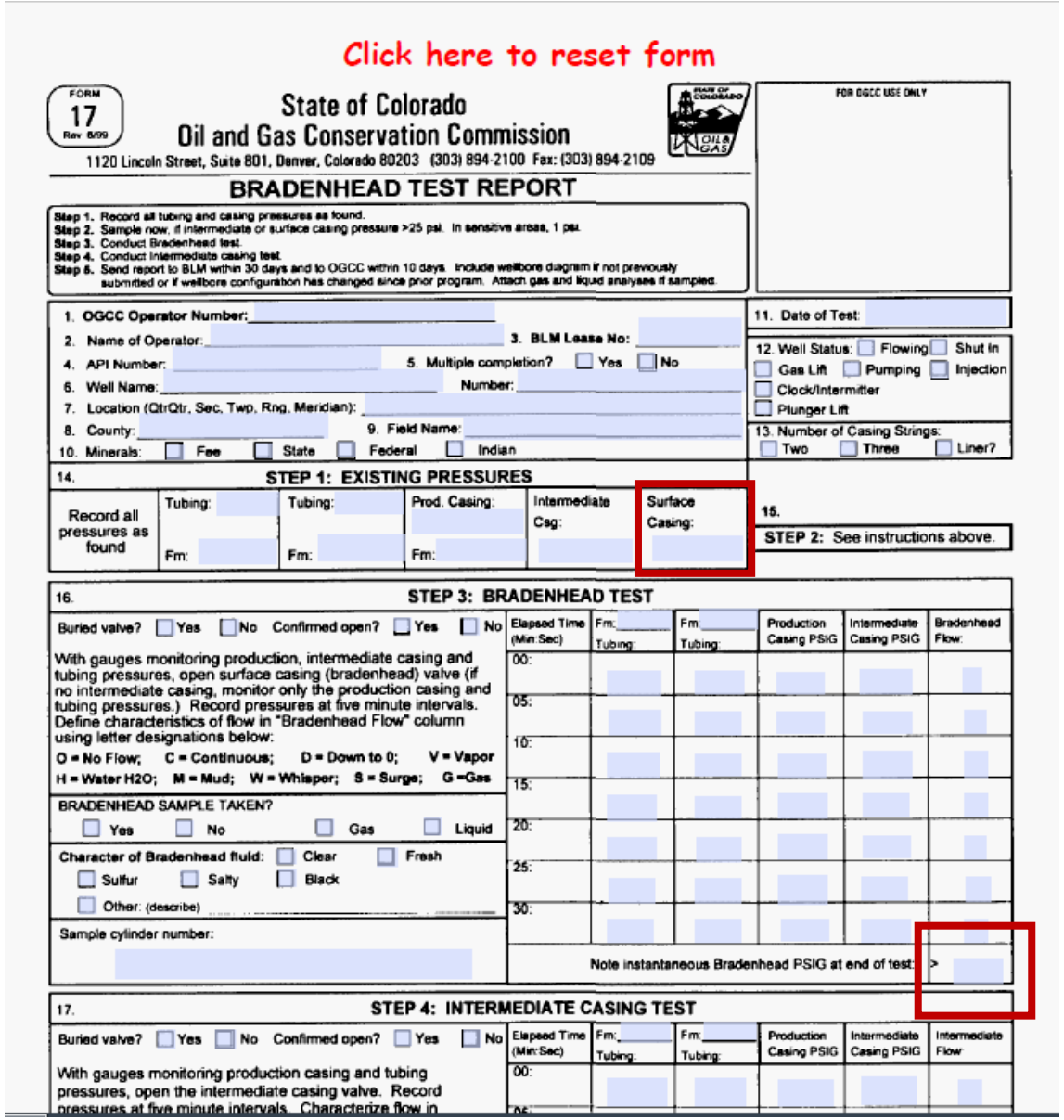
Bradenhead Testing

- Pressure measured as found on surface casing
- Instantaneous pressure measured at the end of the test



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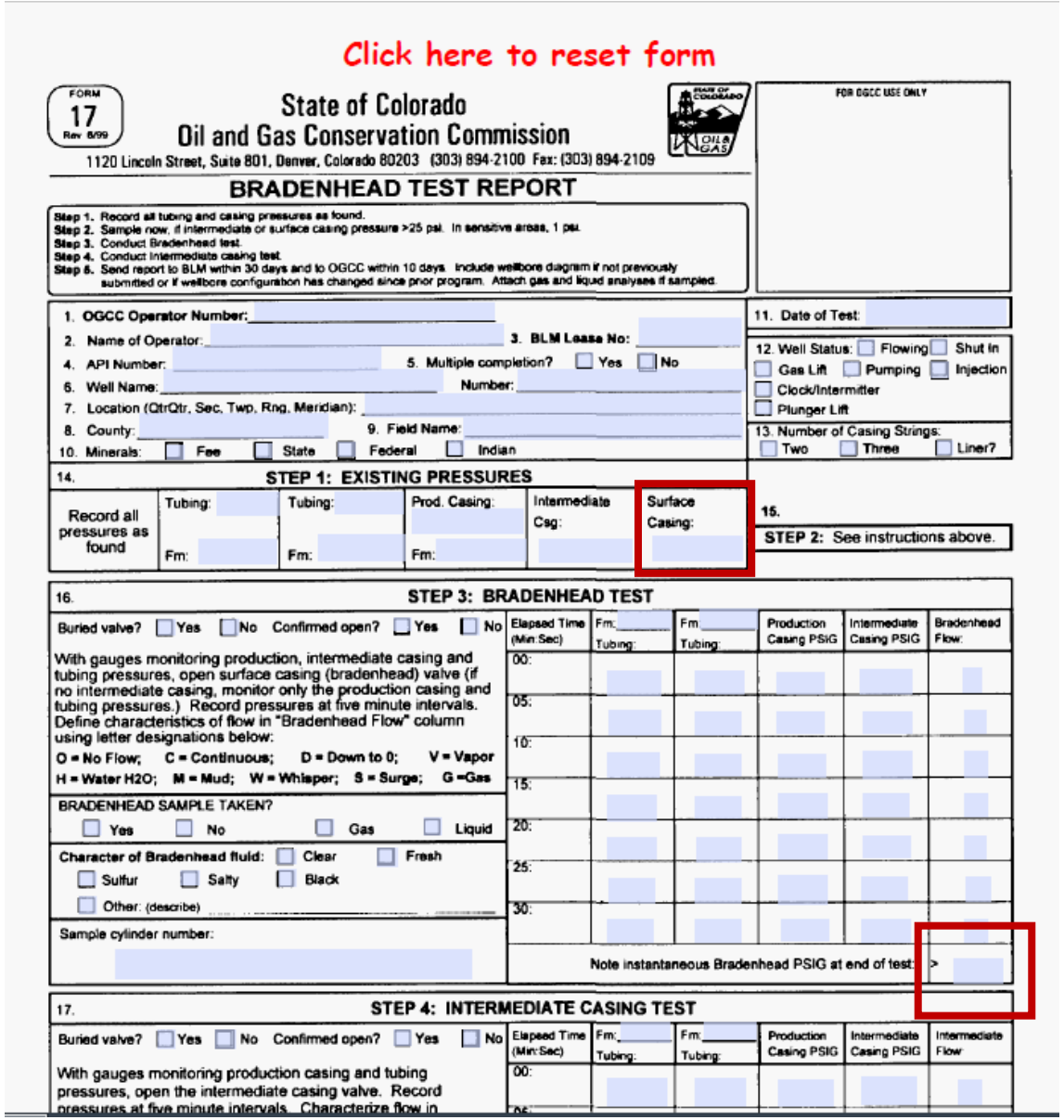
00:					

Bradenhead Testing

- Pressure measured as found on surface casing
- Instantaneous pressure measured at the end of the test
- Filed as text-based PDFs that can be mined using Python



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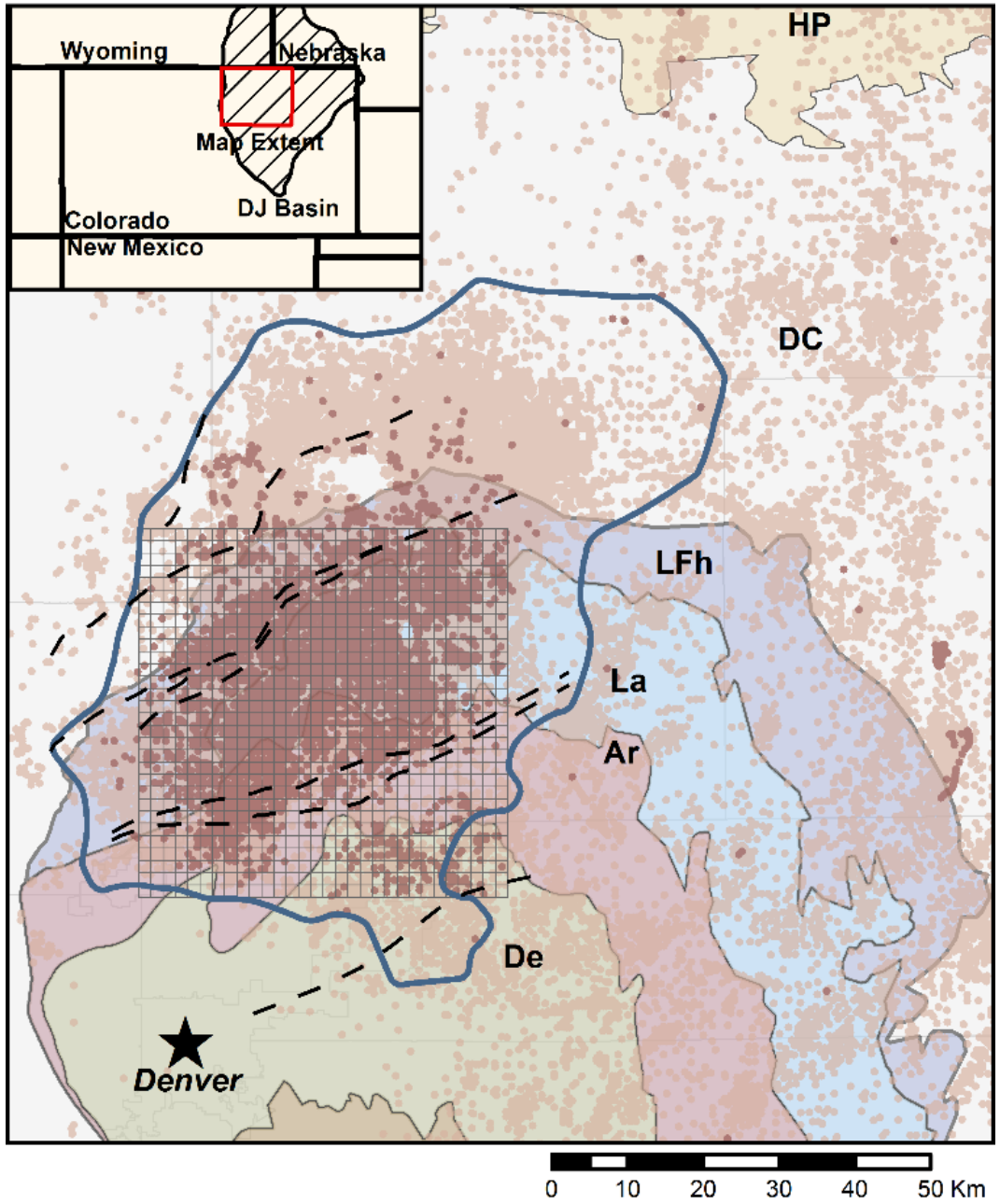
00:					

First Well Integrity Study



2010 bradenhead testing policy establishes Wattenberg Test Zone (WTZ)

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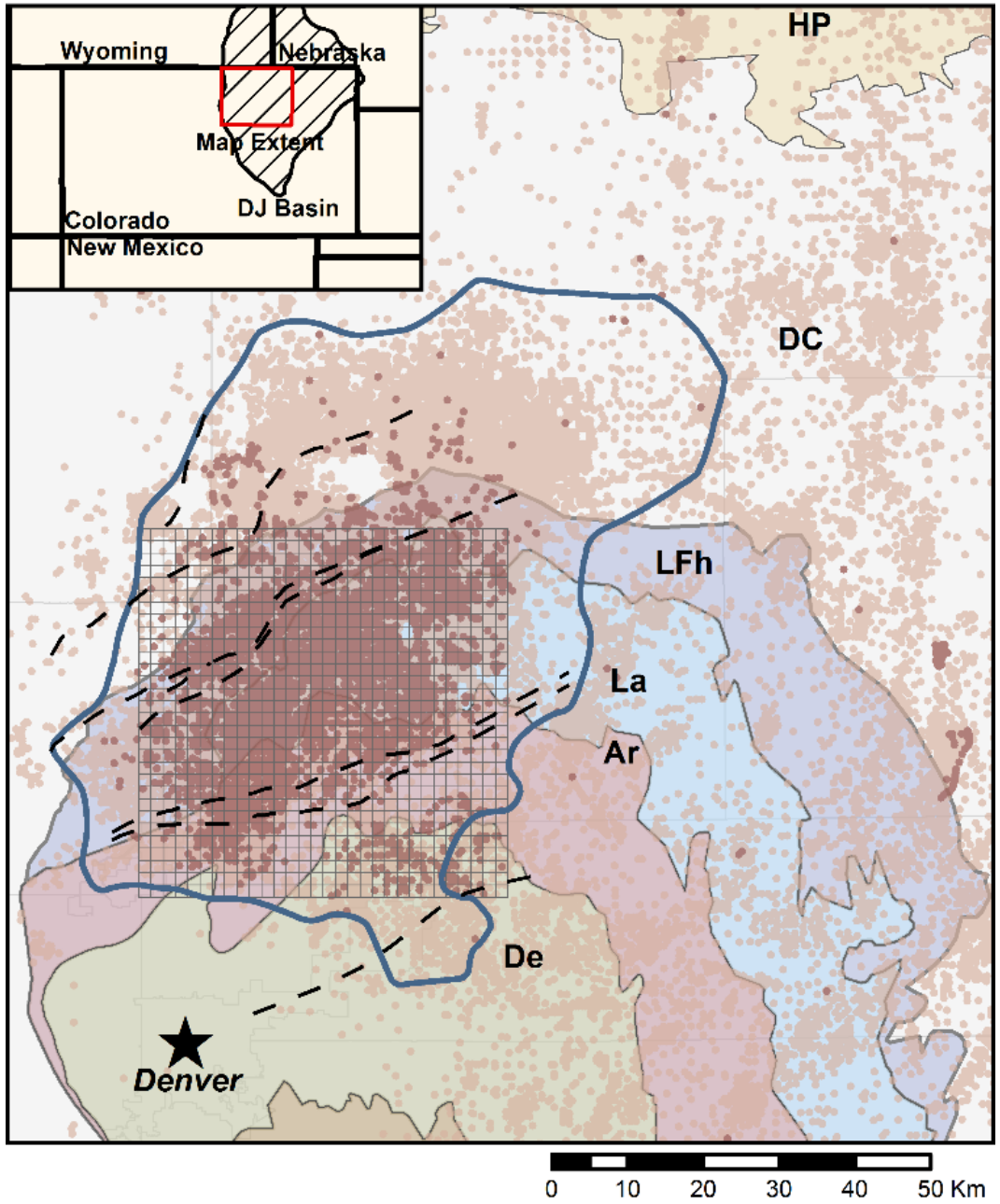

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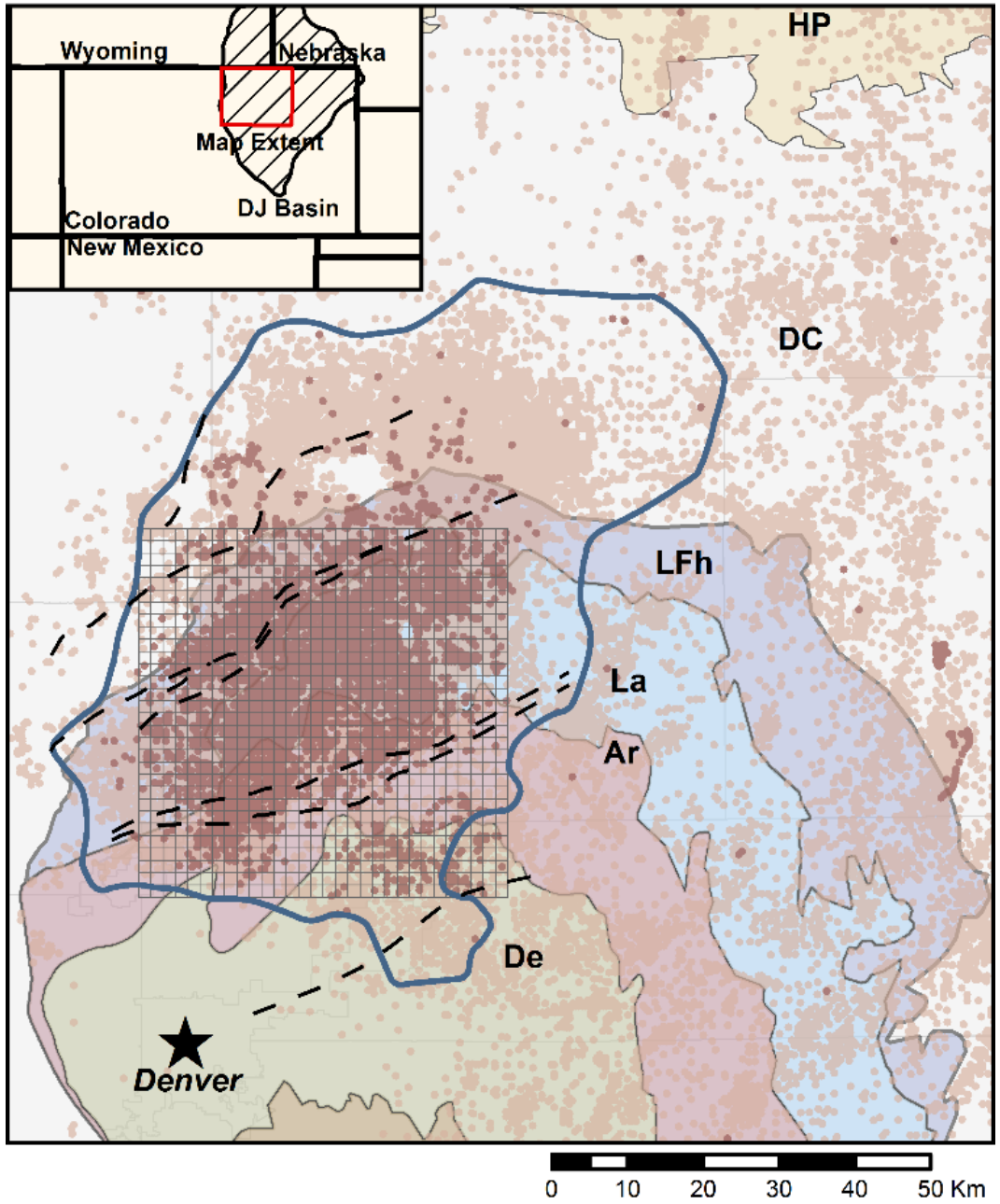
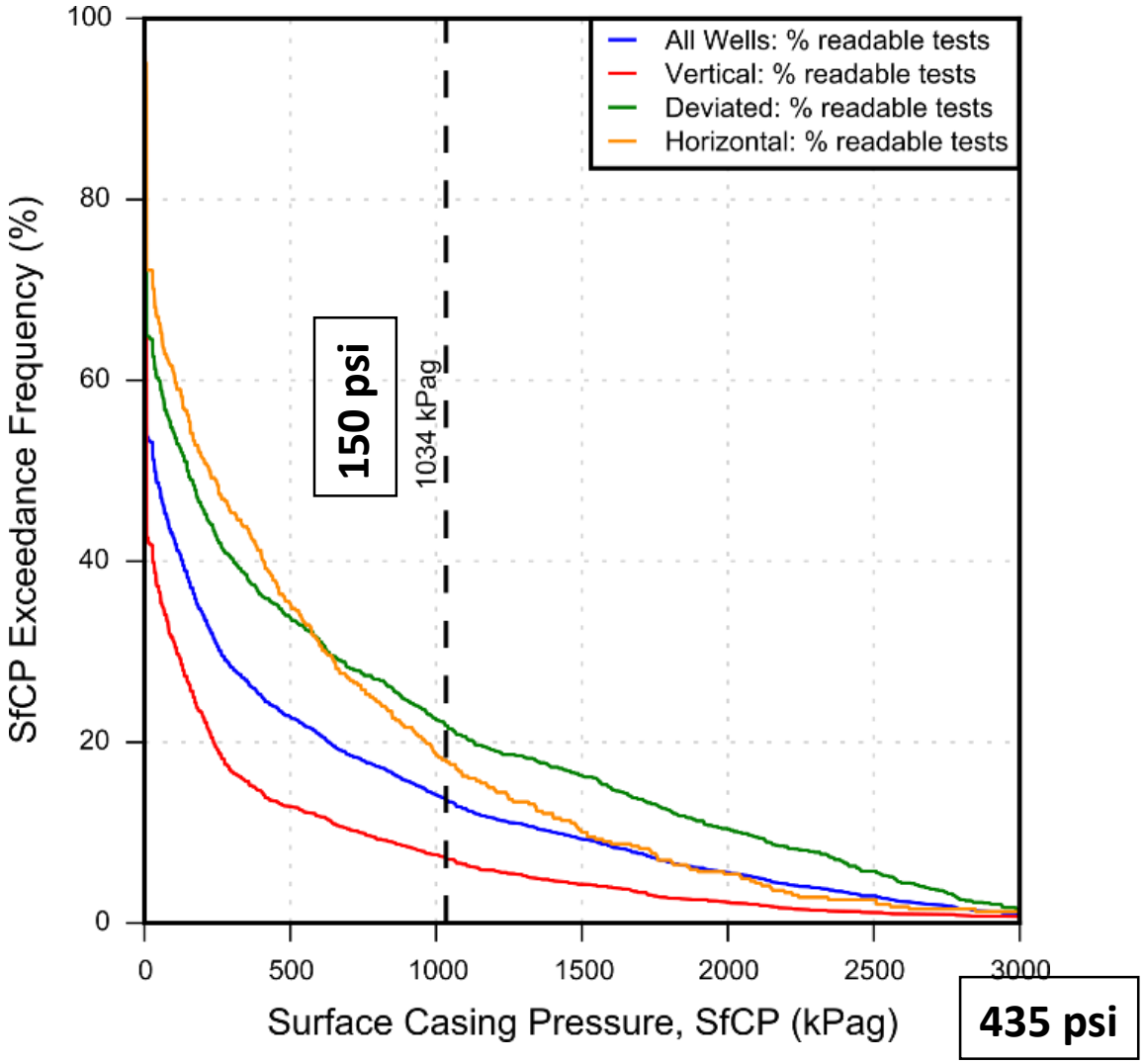


2010 bradenhead testing policy establishes Wattenberg Test Zone (WTZ)

3,923 readable bradenhead tests (after QA/QC)

Paired with QA/QC well construction data

How Many Wells Have SCP?



All Wells (13.8%), Vertical Wells (7.4%), Deviated Wells (21.9%), and Horizontal Wells (18%)

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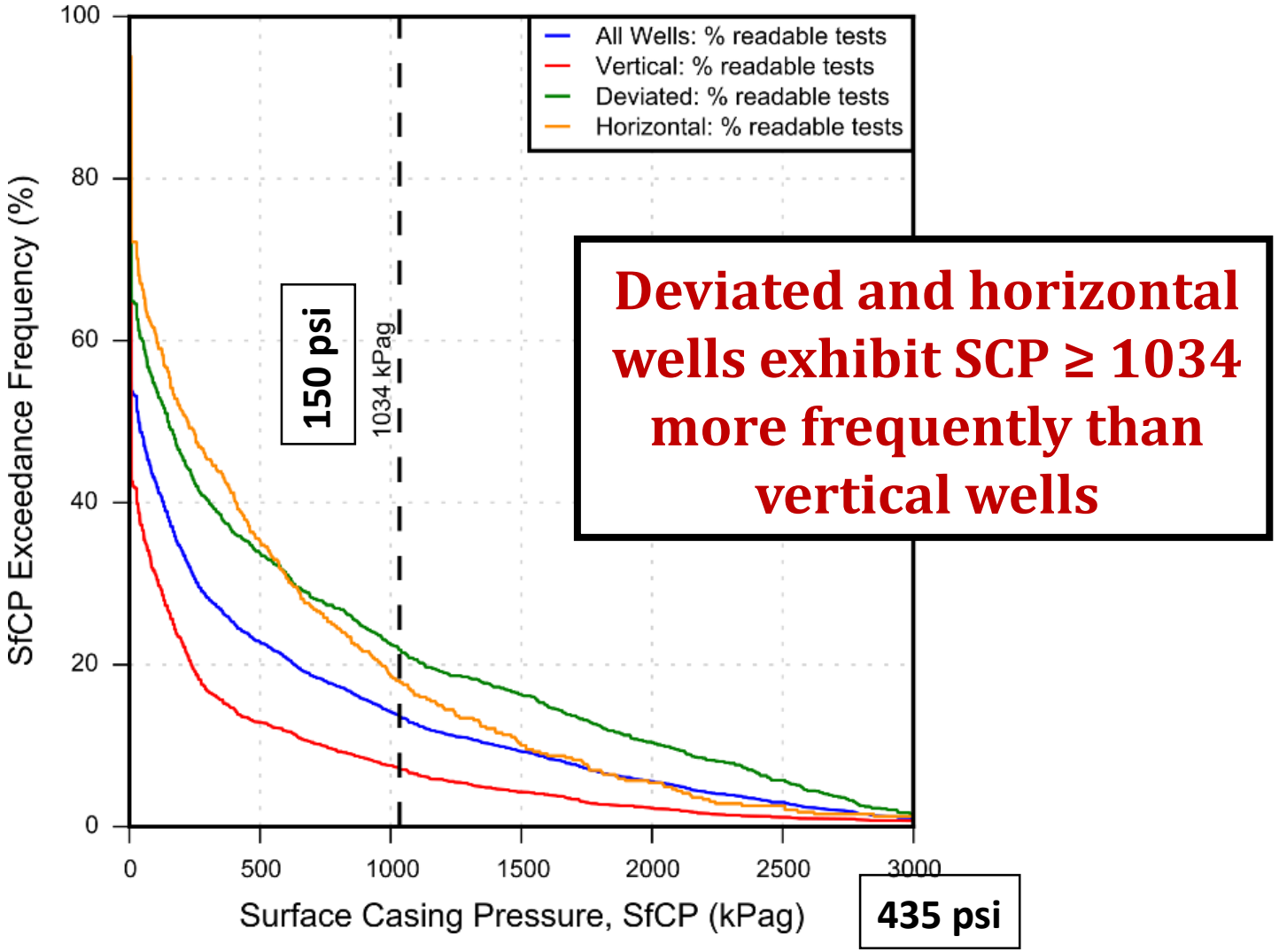

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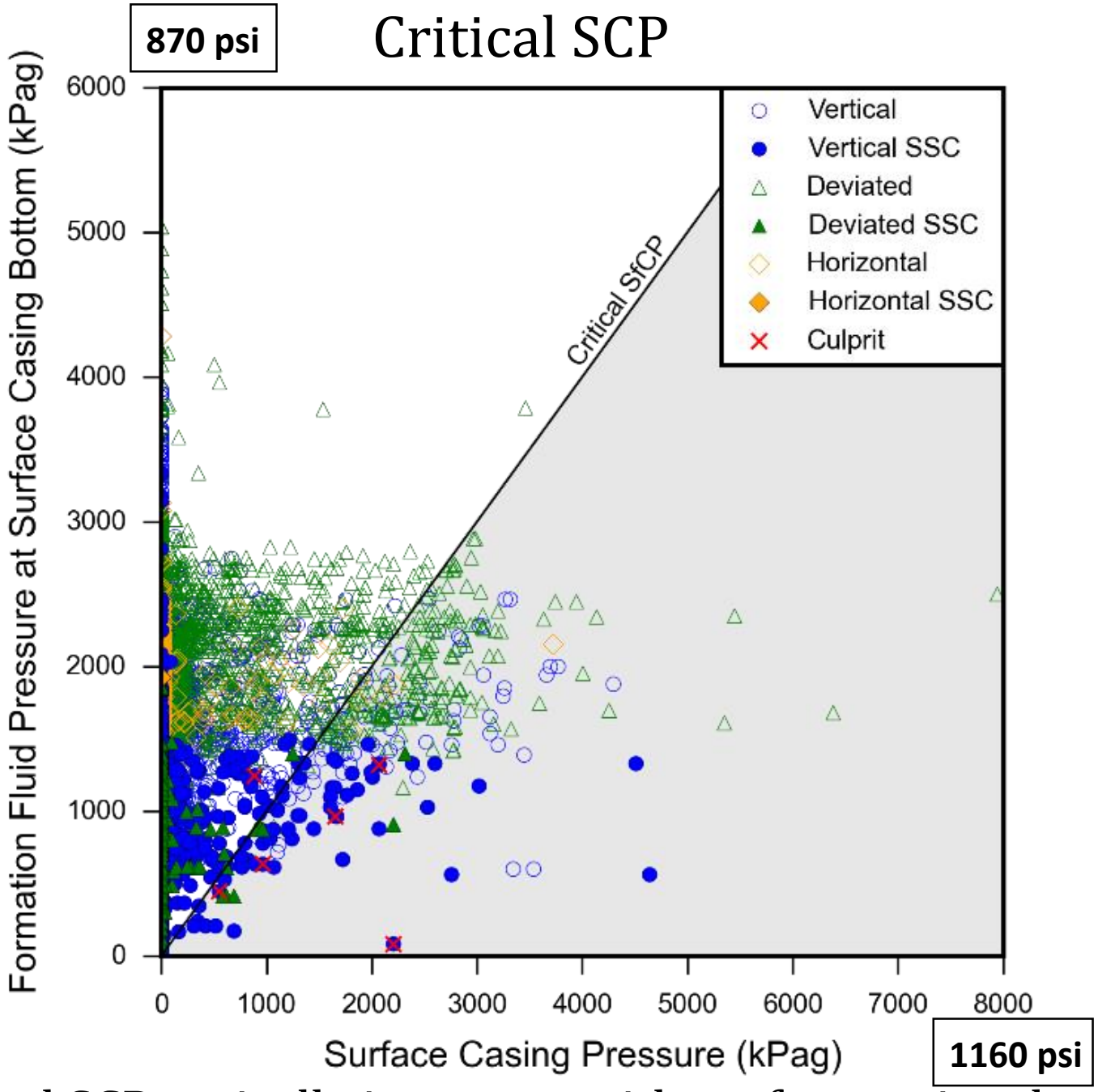
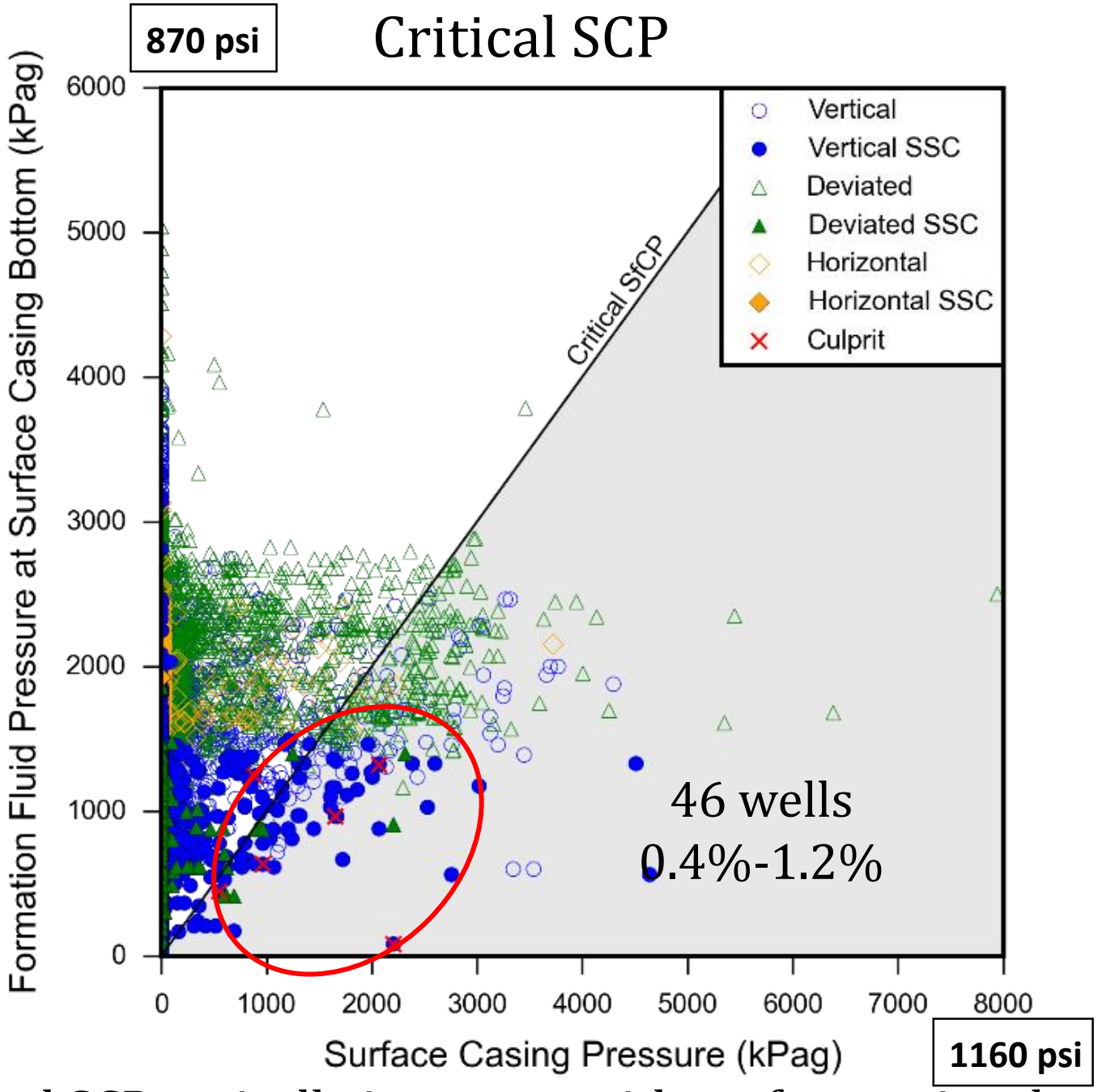
Critical SCP



Critical SCP typically increases with surface casing depth

Critical SCP

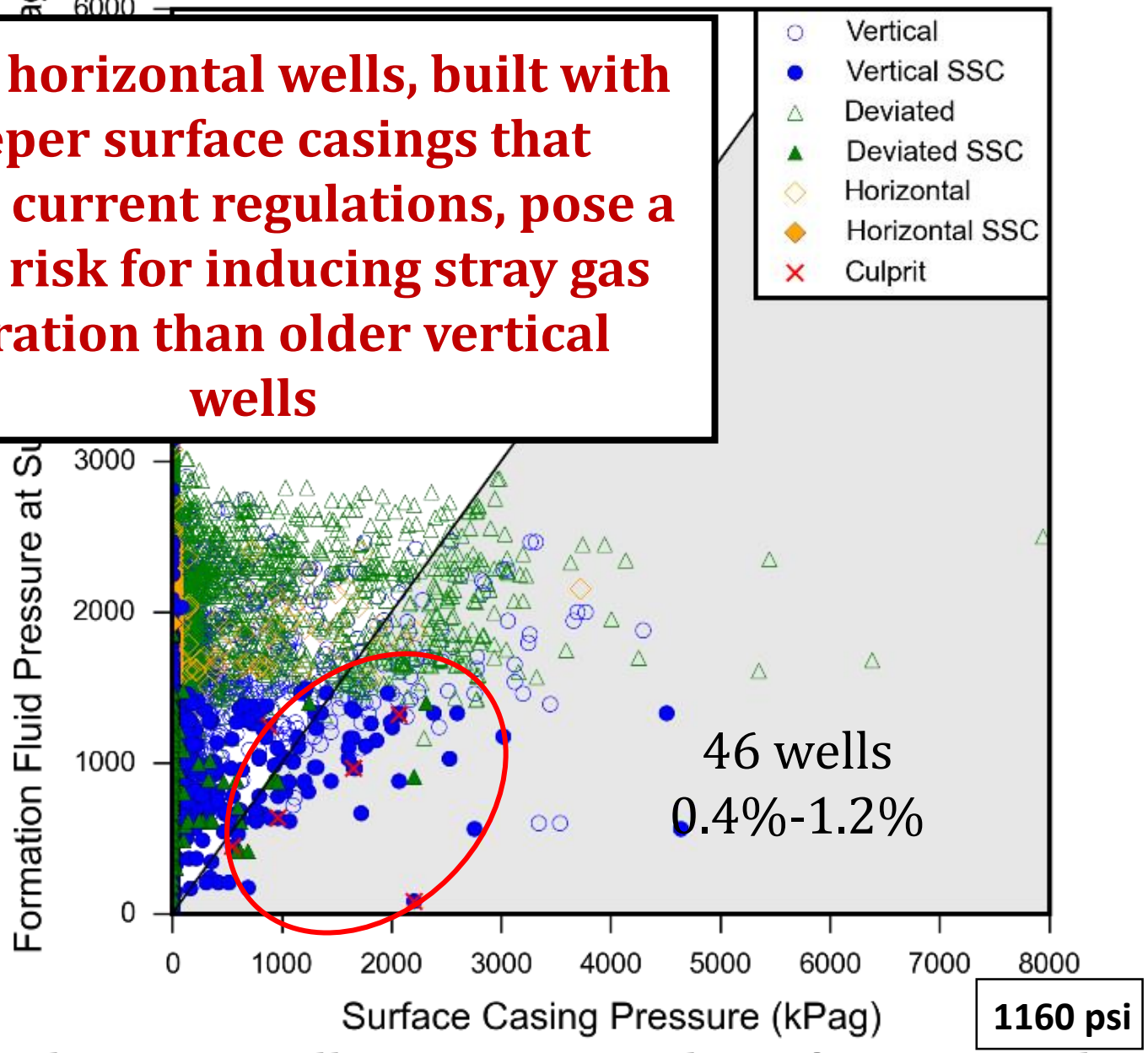


Critical SCP typically increases with surface casing depth

Critical SCP

870 psi

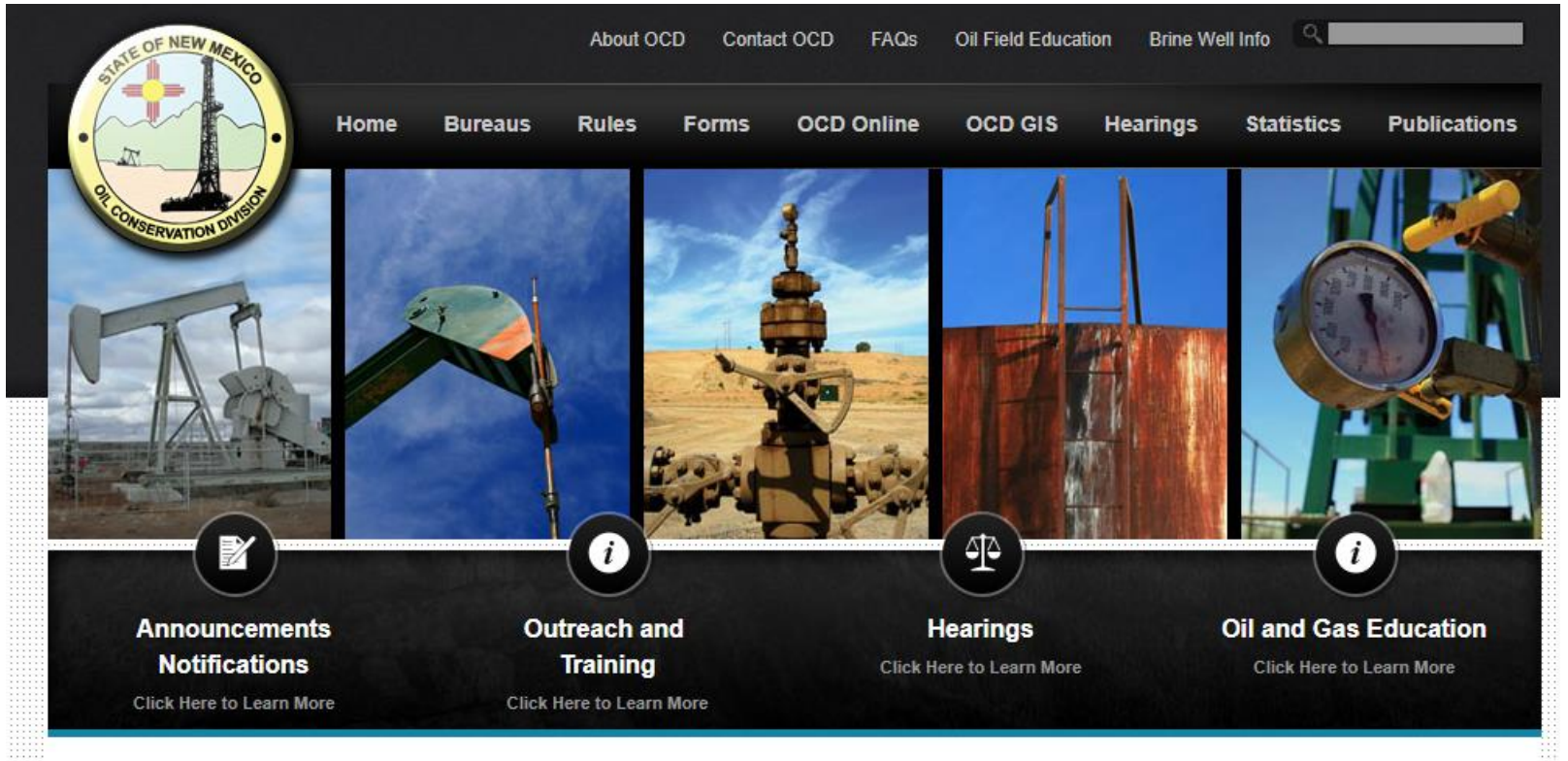
Newer horizontal wells, built with deeper surface casings that exceed current regulations, pose a lower risk for inducing stray gas migration than older vertical wells



1160 psi

Critical SCP typically increases with surface casing depth

New Mexico



http://www.emnrd.state.nm.us/ocd/)

New Mexico

NEW MEXICO ENERGY, MINERALS
& NATURAL RESOURCES DEPARTMENT

OIL CONSERVATION DIVISION

BRADENHEAD TEST REPORT

(submit 1 copy to above address)

Date of Test 6-22-11 Operator ConocoPhillips API #30-0 45-23745

Property Name San Juan 32 Well No. 348 Location: Unit ___ Section 36 Township 32 Range 12

Well Status (Shut-In or Producing) Initial PSI: Tubing 145 Intermediate N/A Casing 148 Bradenhead 135

OPEN BRADENHEAD AND INTERMEDIATE TO ATMOSPHERE INDIVIDUALLY FOR 15 MINUTES EACH

Testing TIME	PRESSURE Bradenhead BH	Int	Csg	INTERM Int	Csg
5 min	0		143		
10 min	0		143		
15 min	0		143		
20 min					
25 min					
30 min					

FLOW CHARACTERISTICS	BRADENHEAD	INTERMEDIATE
Steady Flow		
Surges		
Down to Nothing	✓	
Nothing		
Gas		
Gas & Water		
Water		

If bradenhead flowed water, check all of the descriptions that apply below:

CLEAR ___ FRESH ___ SALTY ___ SULFUR ___ BLACK

5 MINUTE SHUT-IN PRESSURE BRADENHEAD 0 INTERMEDIATE N/A

REMARKS: BH to vapors in 60 seconds - to nothing in 15

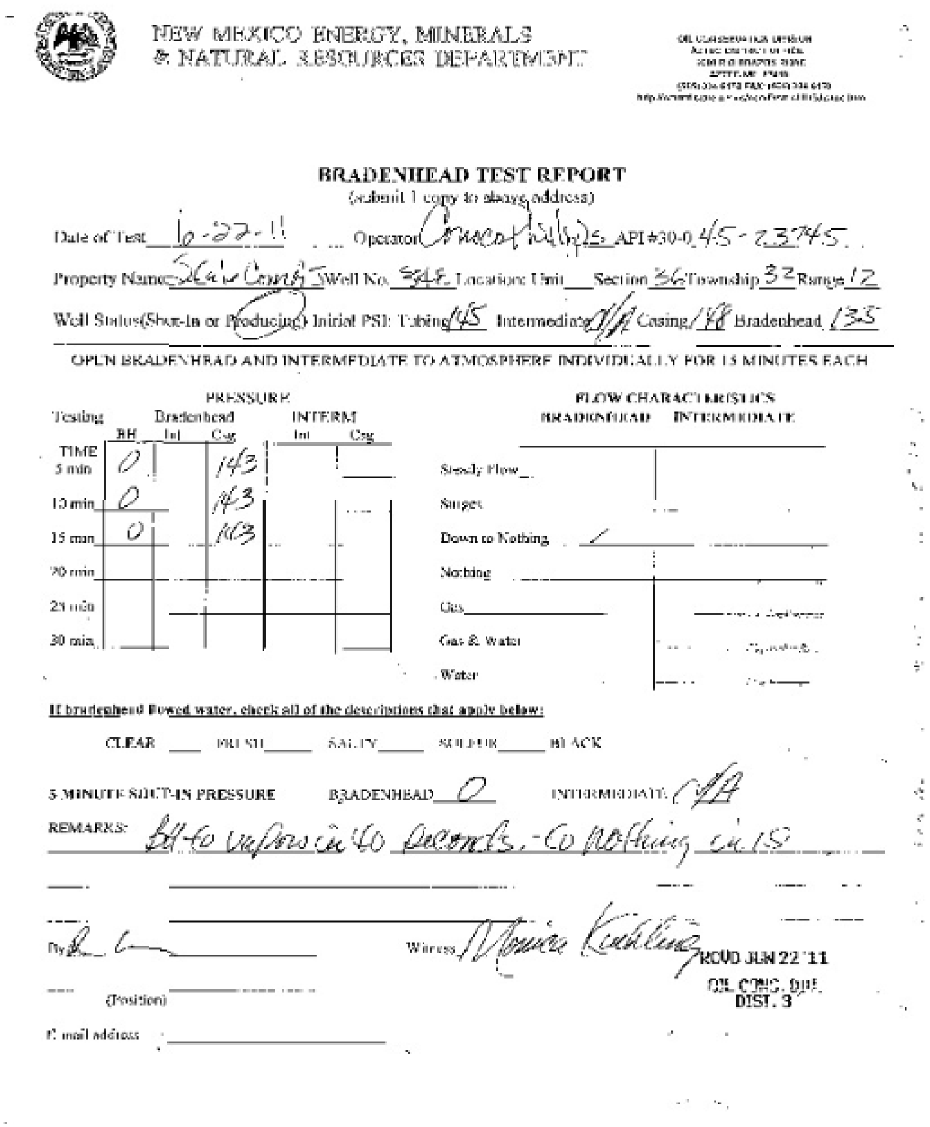
By [signature] Witness [signature]

(Position)

E-mail address

RCVD JUN 22 '11
OIL CONS. DIV.
DIST. 3

New Mexico Challenges



NEW MEXICO ENERGY, MINERALS & NATURAL RESOURCES DEPARTMENT

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(submit 1 copy to above address)

Date of Test 10-22-11 Operator ConocoPhillips API #30-0 45-23745
Property Name State Com S Well No. 34E Location: Unit ___ Section 36 Township 32 Range 12
Well Status(Shut-In or Producing) Initial PSI: Tubing 45 Intermediate N/A Casing 148 Bradenhead 135

OPEN BRADENHEAD AND INTERMEDIATE TO ATMOSPHERE INDIVIDUALLY FOR 15 MINUTES EACH

Testing TIME	PRESSURE Bradenhead BH	Int	Csg	INTERM Int	Csg
5 min	0		143		
10 min	0		143		
15 min	0		143		
20 min					
25 min					
30 min					

FLOW CHARACTERISTICS	BRADENHEAD	INTERMEDIATE
Steady Flow		
Surges		
Down to Nothing	✓	
Nothing		
Gas		
Gas & Water		
Water		

If bradenhead flowed water, check all of the descriptions that apply below:

CLEAR ___ FRESH ___ SALTY ___ SULFUR ___ BLACK

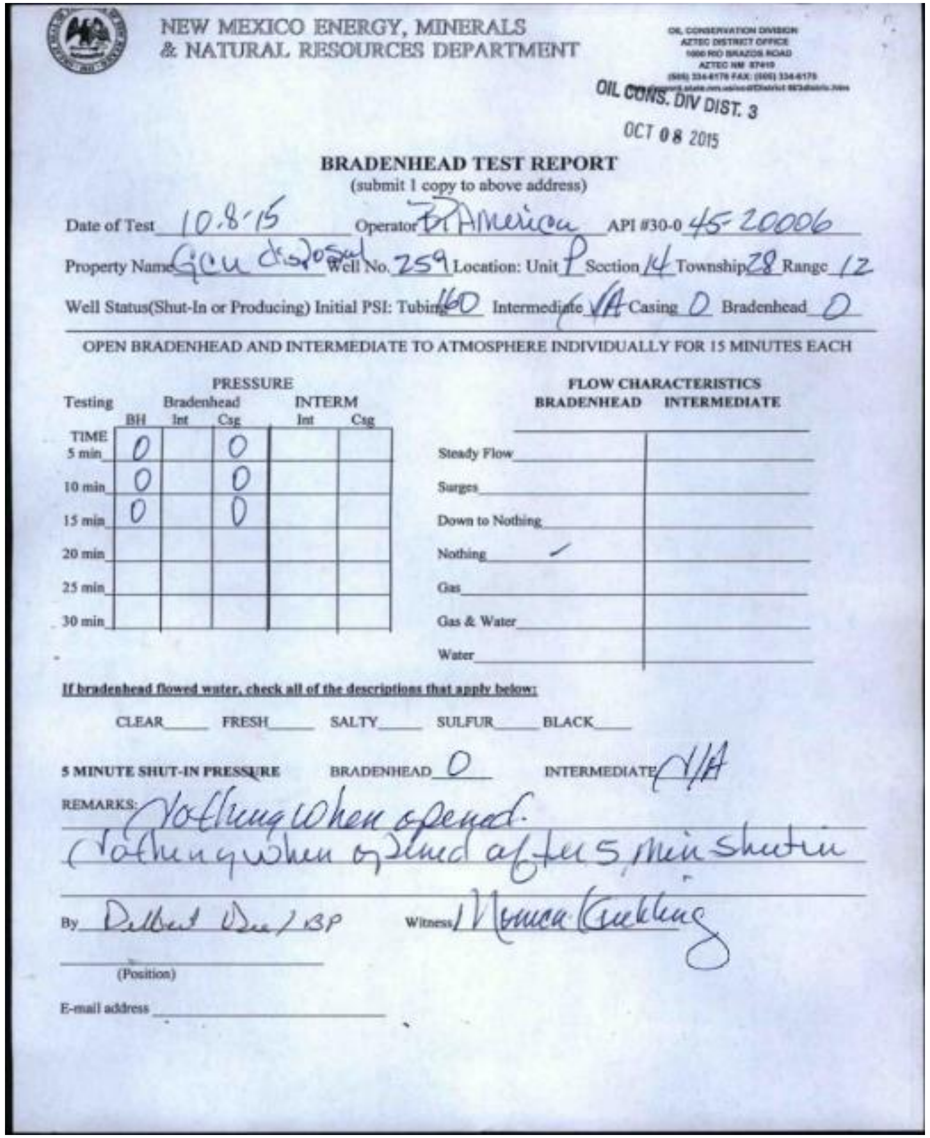
5 MINUTE SHUT-IN PRESSURE BRADENHEAD 0 INTERMEDIATE N/A

REMARKS: BH-to nothing in 40 seconds. -Co nothing in 15

By ___ (Position) Witness Monica Kuehling

E-mail address

RCVD JUN 22 '11 OIL CONS. DIV. DIST. 3



NEW MEXICO ENERGY, MINERALS & NATURAL RESOURCES DEPARTMENT

OIL CONSERVATION DIVISION AZTEC DISTRICT OFFICE 1000 RIO BRAZOS ROAD AZTEC NM 87410

OIL CONS. DIV DIST. 3 OCT 08 2015

BRADENHEAD TEST REPORT
(submit 1 copy to above address)

Date of Test 10.8.15 Operator BP America API #30-0 45-20006
Property Name GCU disposal Well No. 259 Location: Unit P Section 14 Township 28 Range 12
Well Status(Shut-In or Producing) Initial PSI: Tubing 160 Intermediate N/A Casing 0 Bradenhead 0

OPEN BRADENHEAD AND INTERMEDIATE TO ATMOSPHERE INDIVIDUALLY FOR 15 MINUTES EACH

Testing TIME	PRESSURE Bradenhead BH	Int	Csg	INTERM Int	Csg
5 min	0		0		
10 min	0		0		
15 min	0		0		
20 min					
25 min					
30 min					

FLOW CHARACTERISTICS	BRADENHEAD	INTERMEDIATE
Steady Flow		
Surges		
Down to Nothing		
Nothing	✓	
Gas		
Gas & Water		
Water		

If bradenhead flowed water, check all of the descriptions that apply below:

CLEAR ___ FRESH ___ SALTY ___ SULFUR ___ BLACK ___

5 MINUTE SHUT-IN PRESSURE BRADENHEAD 0 INTERMEDIATE N/A

REMARKS: Nothing when opened. Nothing when opened after 5 min shutin

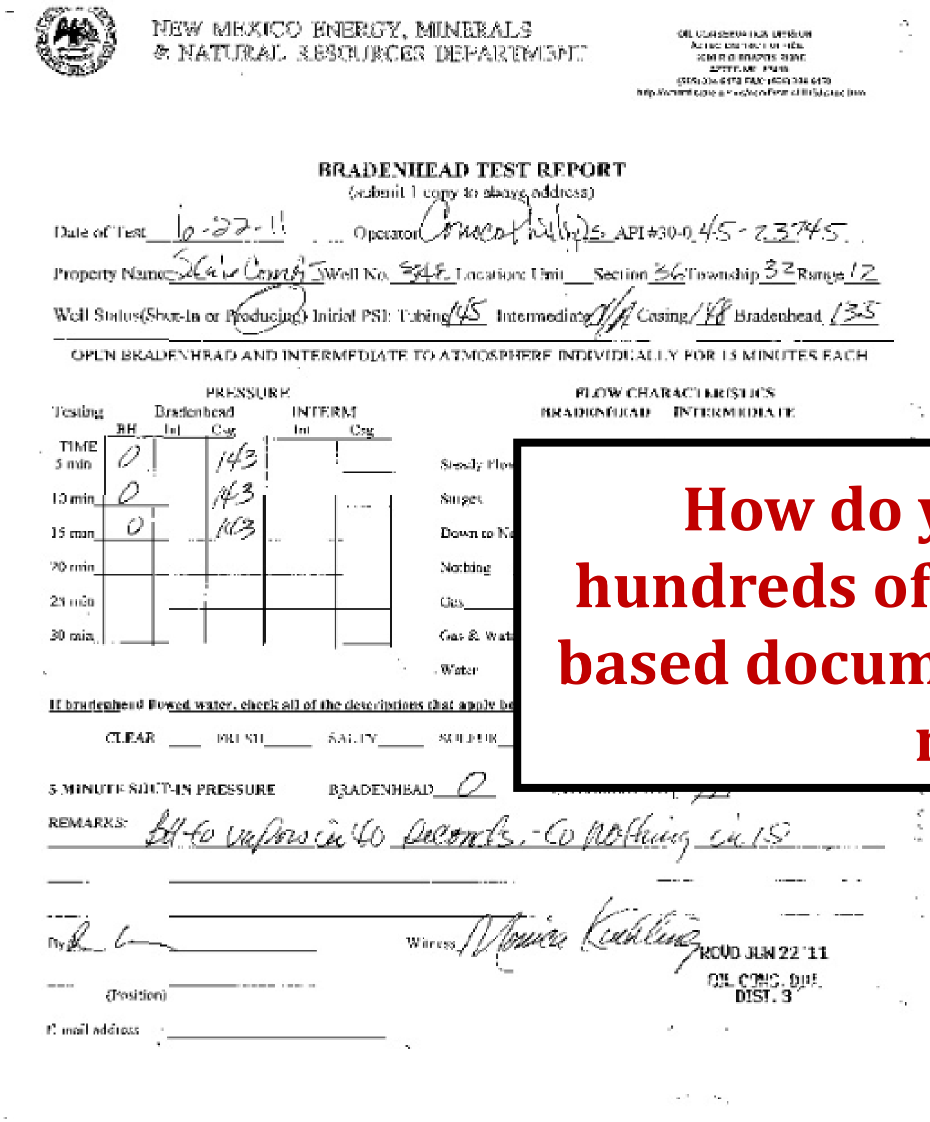
By Delbert Dee / BP Witness Monica Kuehling

(Position)

E-mail address

2.25 million documents labeled only by API# and all are scanned images (~600,000 of interest)

New Mexico Challenges



NEW MEXICO ENERGY, MINERALS
& NATURAL RESOURCES DEPARTMENT

BRADENHEAD TEST REPORT
(submit 1 copy to above address)

Date of Test 10-22-11 Operator ConocoPhillips API #30-0 45-23745

Property Name [illegible] Well No. 34E Location: Unit ___ Section 36 Township 32 Range 12

Well Status(Shut-In or [✓ Producing]) Initial PSI: Tubing 145 Intermediate N/A Casing 148 Bradenhead 135

OPEN BRADENHEAD AND INTERMEDIATE TO ATMOSPHERE INDIVIDUALLY FOR 15 MINUTES EACH

PRESSURE

Testing TIME	Bradenhead BH	Bradenhead Int	Bradenhead Csg	INTERM Int	INTERM Csg
5 min	0		143		
10 min	0		143		
15 min	0		143		
20 min					
25 min					
30 min					

FLOW CHARACTERISTICS
BRADENHEAD INTERMEDIATE

Steady Flow
Surges
Down to N
Nothing
Gas
Gas & Wat
Water

If bradenhead flowed water, check all of the descriptions that apply be

CLEAR ___ FRESH ___ SALTY ___ SULFUR ___

5 MINUTE SHUT-IN PRESSURE BRADENHEAD 0

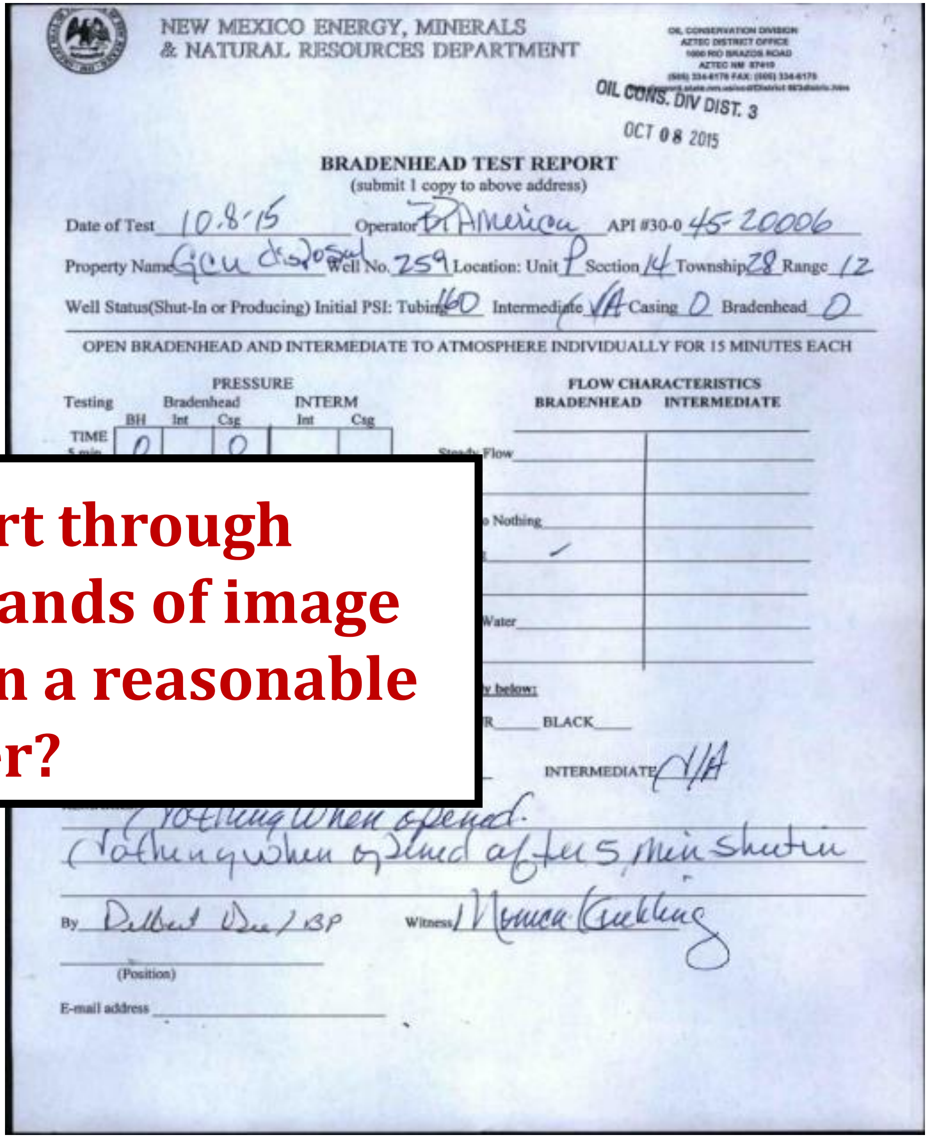
REMARKS: [illegible]

By [illegible] Witness [illegible]

(Position)

E-mail address

RCVD JUN 22 '11
OIL CONS. DIV.
DIST. 3



NEW MEXICO ENERGY, MINERALS
& NATURAL RESOURCES DEPARTMENT

OIL CONSERVATION DIVISION
AZTEC DISTRICT OFFICE
1000 RIO BRAZOS ROAD
AZTEC NM 87410

OIL CONS. DIV DIST. 3
OCT 08 2015

BRADENHEAD TEST REPORT
(submit 1 copy to above address)

Date of Test 10.8.15 Operator BP America API #30-0 45-20006

Property Name GCU disposal Well No. 259 Location: Unit P Section 14 Township 28 Range 12

Well Status(Shut-In or Producing) Initial PSI: Tubing 160 Intermediate N/A Casing 0 Bradenhead 0

OPEN BRADENHEAD AND INTERMEDIATE TO ATMOSPHERE INDIVIDUALLY FOR 15 MINUTES EACH

PRESSURE

Testing TIME	Bradenhead BH	Bradenhead Int	Bradenhead Csg	INTERM Int	INTERM Csg
5 min	0		0		

FLOW CHARACTERISTICS
BRADENHEAD INTERMEDIATE

Steady Flow
Nothing ✓
Water

y below:

R ___ BLACK ___

INTERMEDIATE N/A

Nothing when opened.
Nothing when opened after 5 min shut in

By Delbert Dee / BP Witness [illegible]

(Position)

E-mail address

How do you sort through hundreds of thousands of image based documents in a reasonable manner?

2.25 million documents labeled only by API# and all are scanned images (~600,000 of interest)

TensorFlow

Open source machine learning framework developed by Google

TensorFlow

Open source machine learning framework developed by Google

Can be used for broad range of machine learning tasks but was developed for deep neural network modeling

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Open source machine learning framework developed by Google

Can be used for broad range of machine learning tasks but was developed for deep neural network modeling

Commonly used for categorization tasks

Roughly How it Works

"MobileNet" convolutional neural network

https://arxiv.org/pdf/1704.04861.pdf

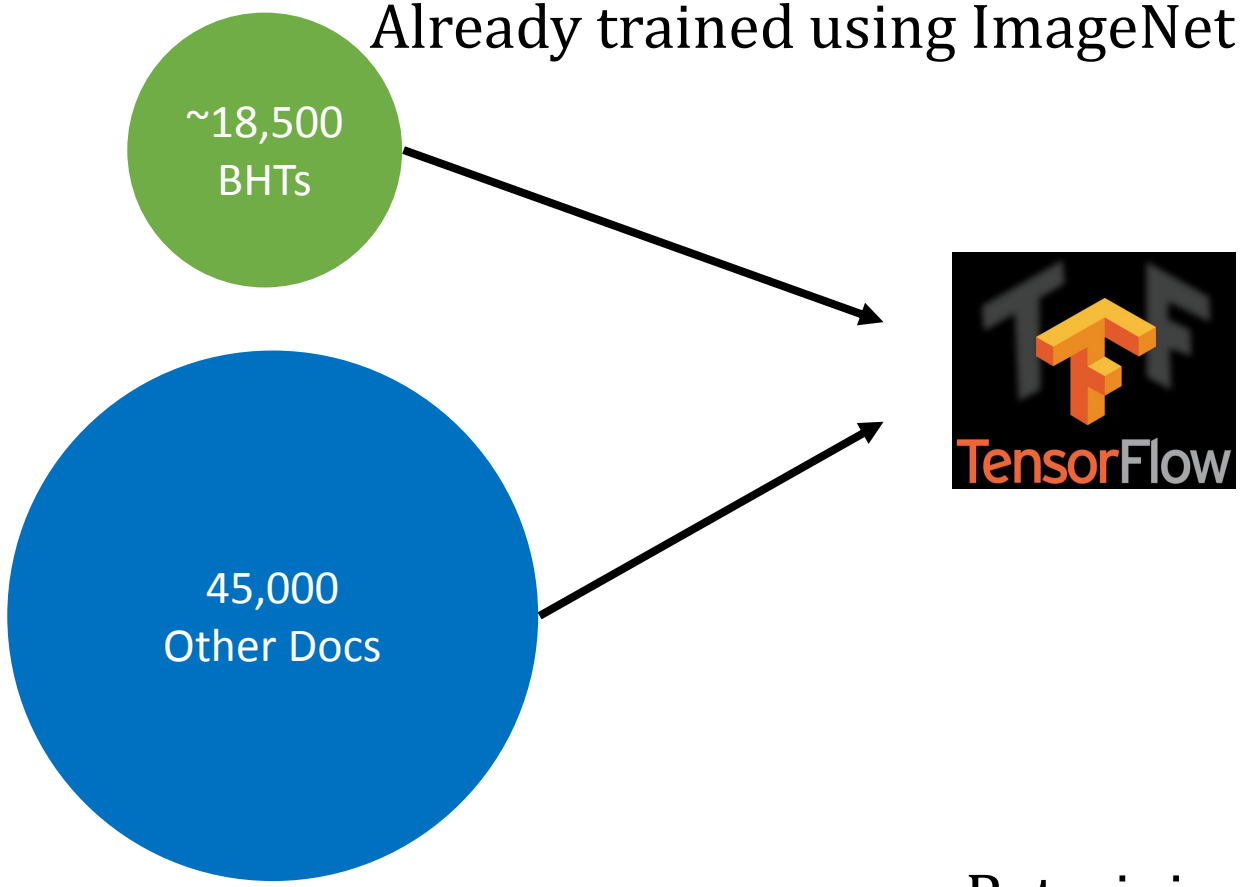
Already trained using ImageNet (>14 million images)

Roughly How it Works

"MobileNet" convolutional neural network

https://arxiv.org/pdf/1704.04861.pdf

Already trained using ImageNet (>14 million images)



Retraining

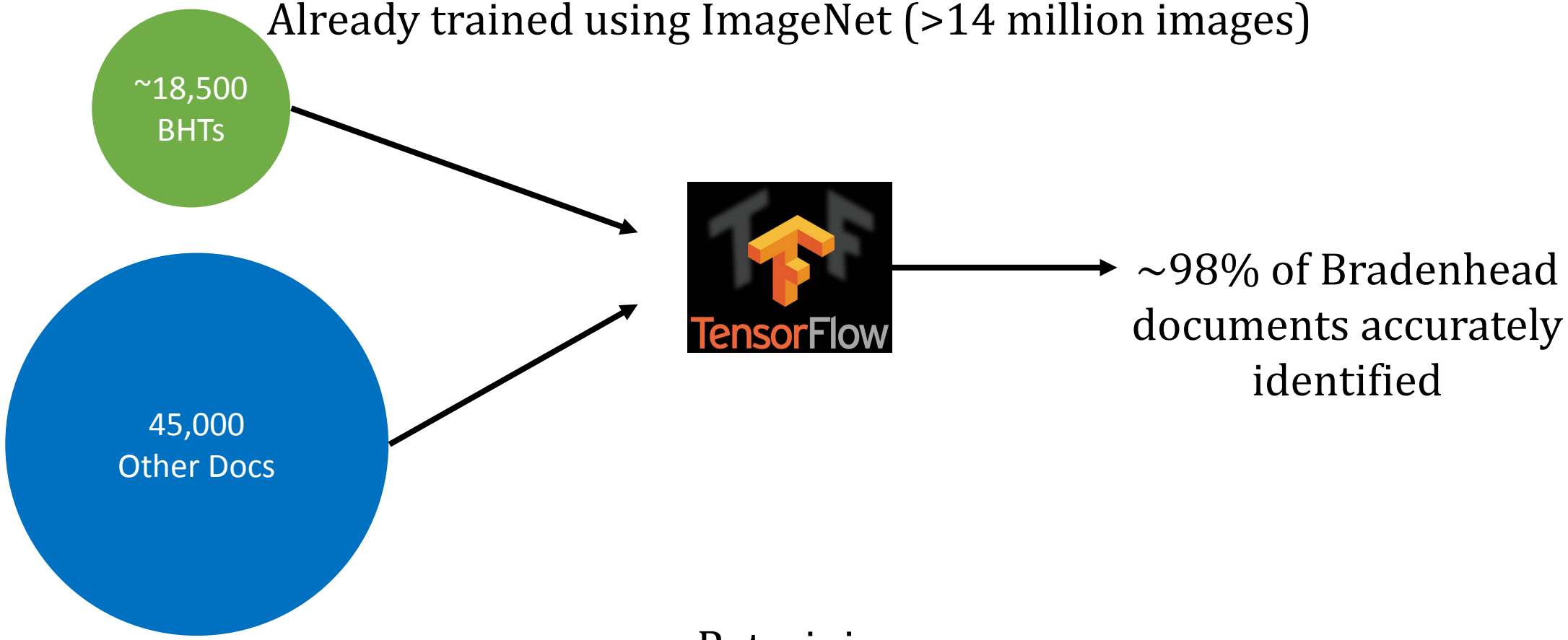
(https://codelabs.developers.google.com/codelabs/tensorflow-for-poets/#)

Roughly How it Works

"MobileNet" convolutional neural network

https://arxiv.org/pdf/1704.04861.pdf

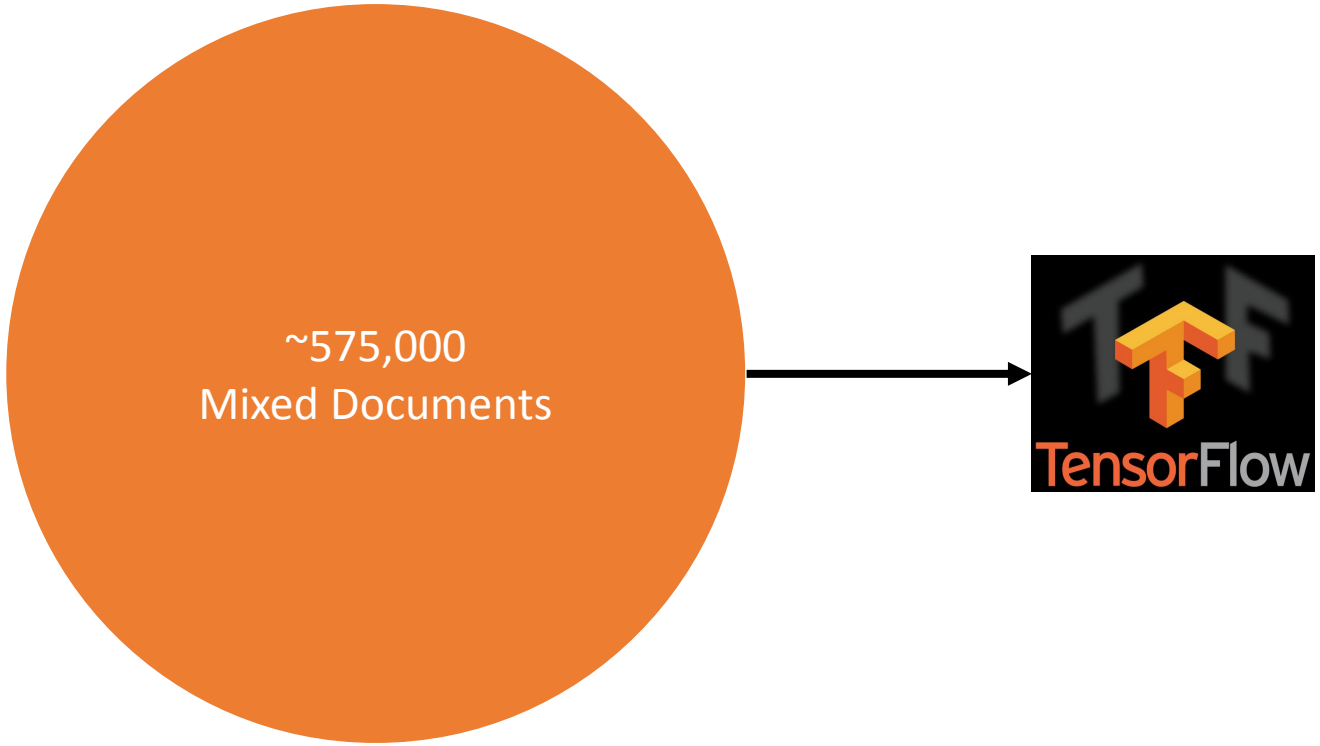
Already trained using ImageNet (>14 million images)



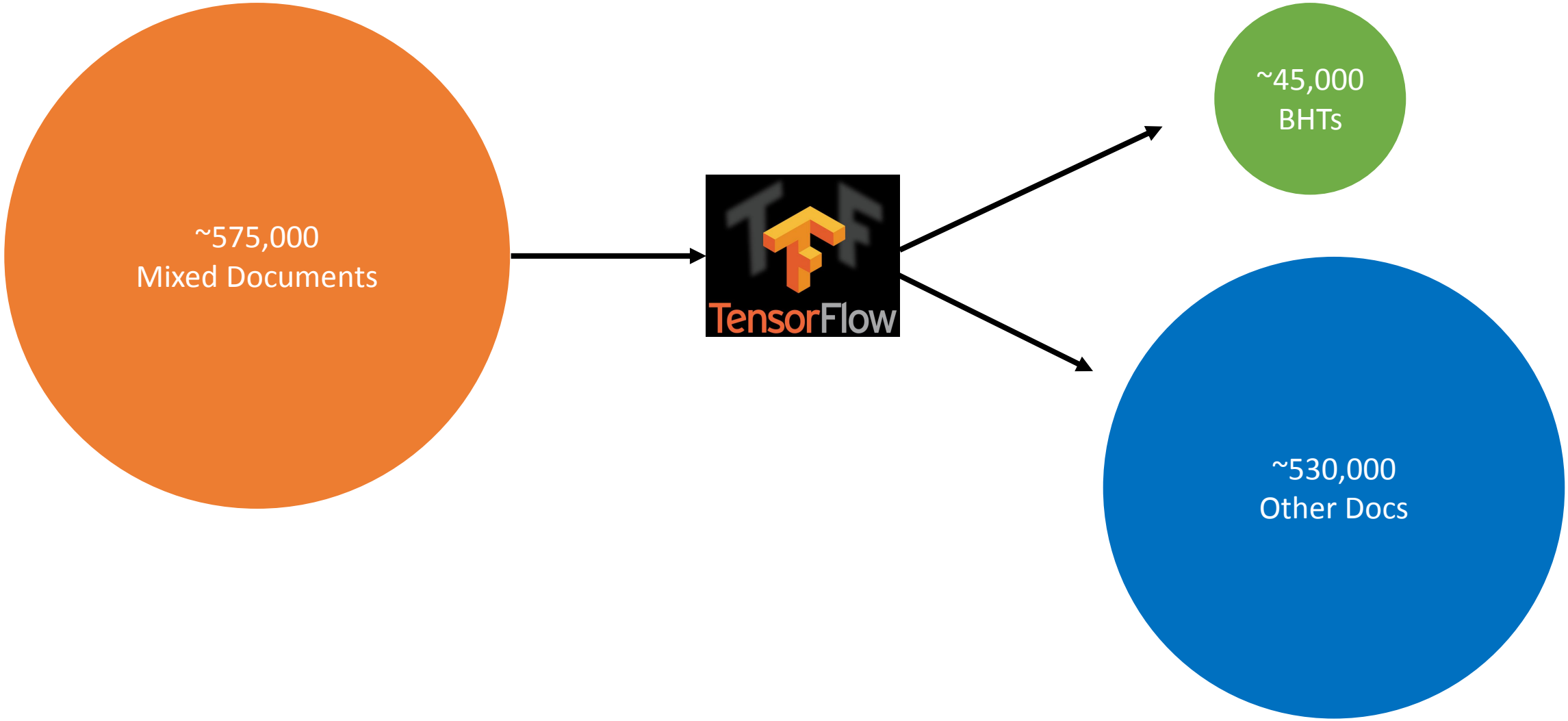
Retraining

(https://codelabs.developers.google.com/codelabs/tensorflow-for-poets/#)

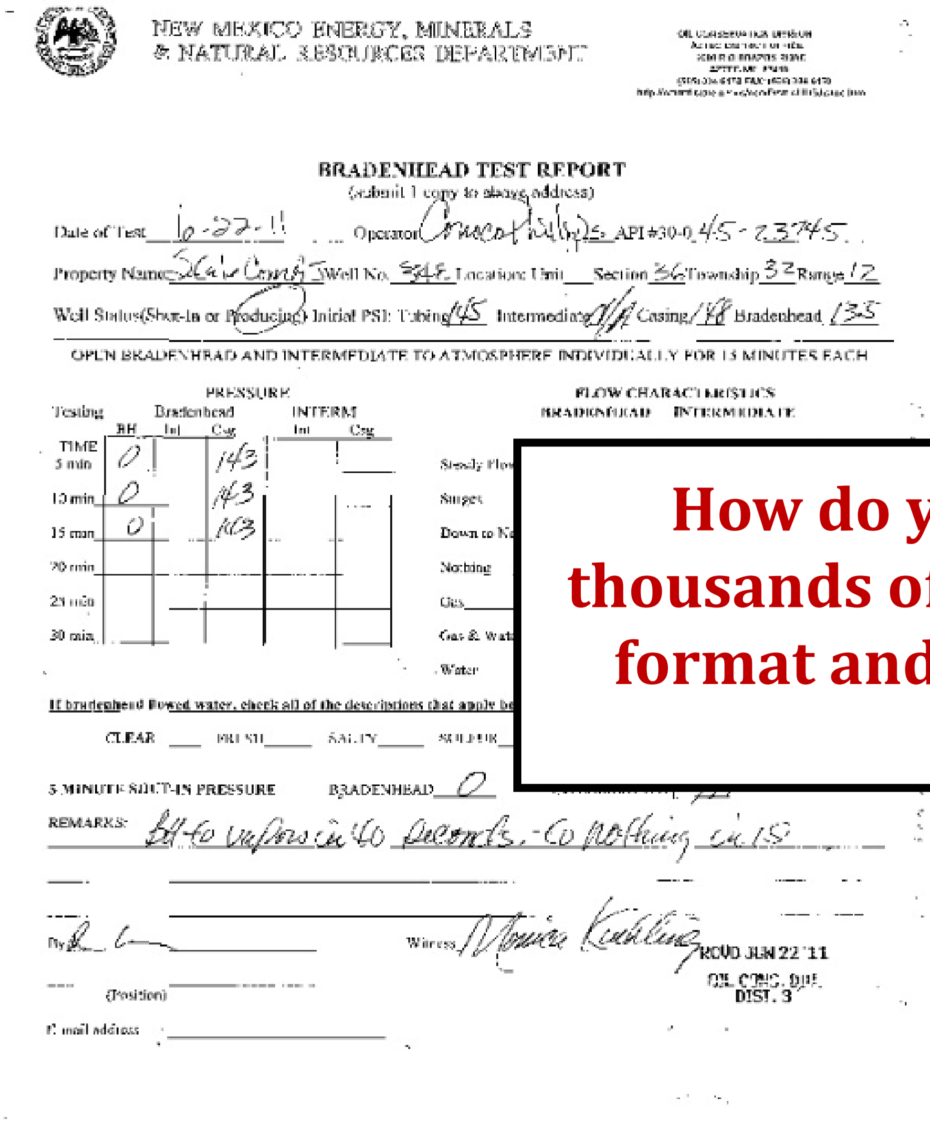
Document Sorting



Document Sorting



New Mexico Challenges



NEW MEXICO ENERGY, MINERALS & NATURAL RESOURCES DEPARTMENT

BRADENHEAD TEST REPORT

(submit 1 copy to above address)

Date of Test 10-22-11 Operator ConocoPhillips API #30-0 45-23745

Property Name [illegible] Well No. 34E Location: Unit ___ Section 36 Township 32 Range 12

Well Status(Shut-In or [✓ Producing]) Initial PSI: Tubing 145 Intermediate N/A Casing 148 Bradenhead 135

OPEN BRADENHEAD AND INTERMEDIATE TO ATMOSPHERE INDIVIDUALLY FOR 15 MINUTES EACH

Testing TIME	Bradenhead BH	Bradenhead Int	Bradenhead Csg	INTERM Int	INTERM Csg
5 min	0		143		
10 min	0		143		
15 min	0		143		
20 min					
25 min					
30 min					

5 MINUTE SHUT-IN PRESSURE BRADENHEAD 0

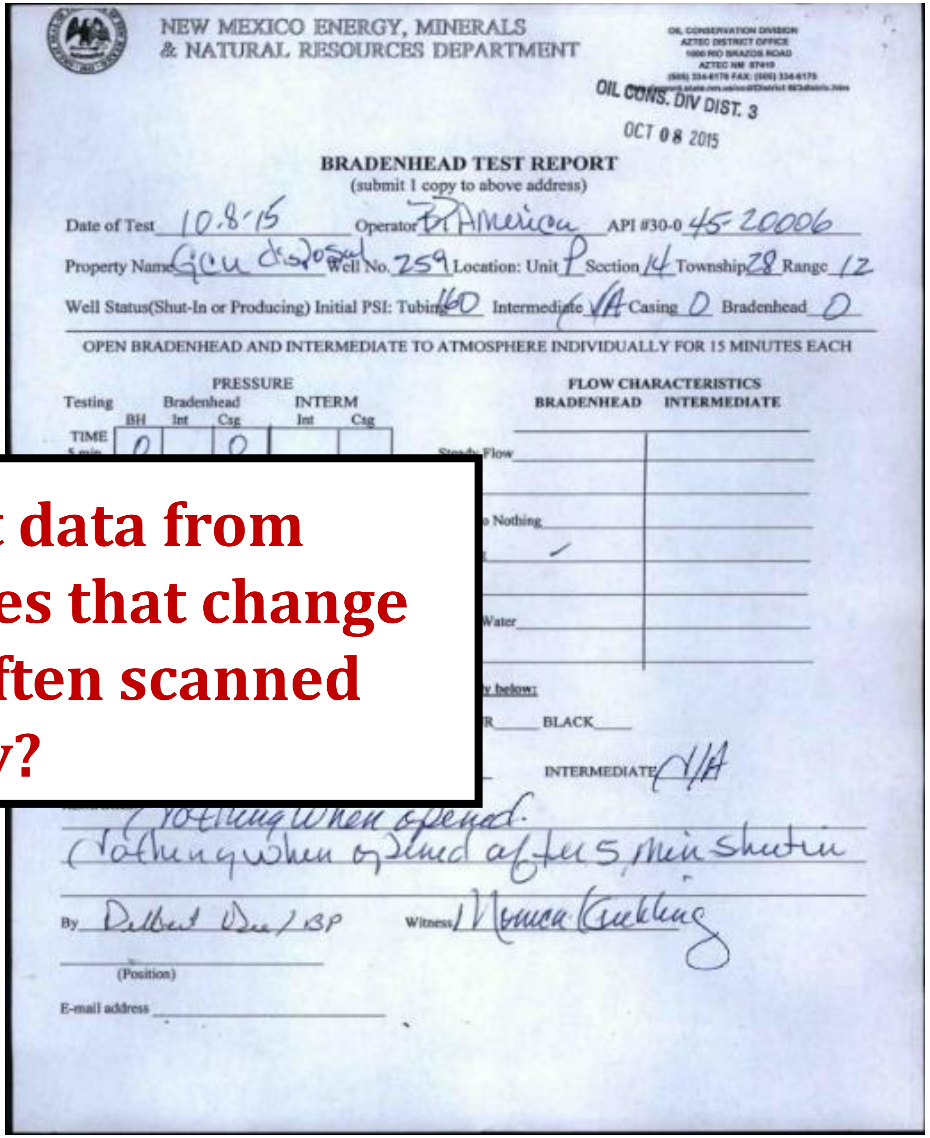
REMARKS: [illegible]

Witness [illegible]

RCVD JUN 22 '11
OIL CONS. DIV.
DIST. 3

(Position)

E-mail address



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OIL CONSERVATION DIVISION
AZTEC DISTRICT OFFICE
1000 RIO BRAZOS ROAD
AZTEC NM 87410

OIL CONS. DIV DIST. 3
OCT 08 2015

BRADENHEAD TEST REPORT

(submit 1 copy to above address)

Date of Test 10.8.15 Operator BP America API #30-0 45-20006

Property Name GCU disposal Well No. 259 Location: Unit P Section 14 Township 28 Range 12

Well Status(Shut-In or Producing) Initial PSI: Tubing 160 Intermediate NA Casing 0 Bradenhead 0

OPEN BRADENHEAD AND INTERMEDIATE TO ATMOSPHERE INDIVIDUALLY FOR 15 MINUTES EACH

Testing TIME	Bradenhead BH	Bradenhead Int	Bradenhead Csg	INTERM Int	INTERM Csg
5 min	0		0		

BLACK ___

INTERMEDIATE N/A

Nothing when opened.
Nothing when opened after 5 min shutin

By Delbert Dee / BP Witness [illegible]

(Position)

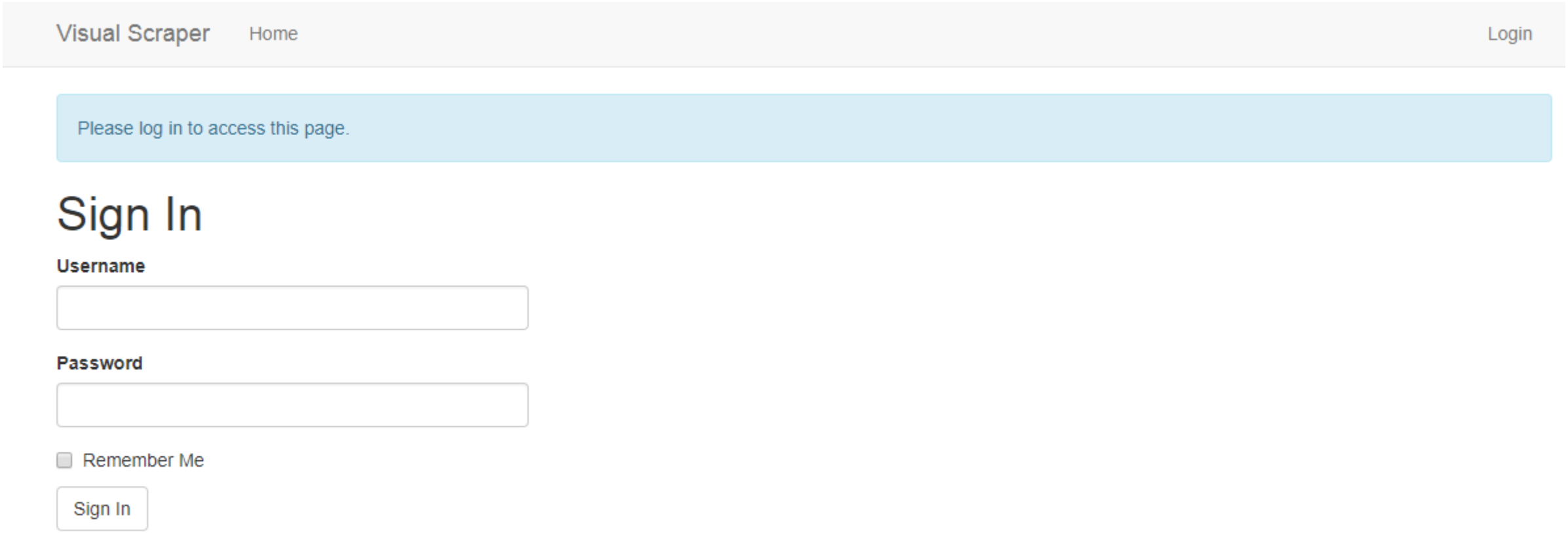
E-mail address

How do you get data from thousands of images that change format and are often scanned poorly?

2.25 million documents labeled only by API# and all are scanned images (~600,000 of interest)

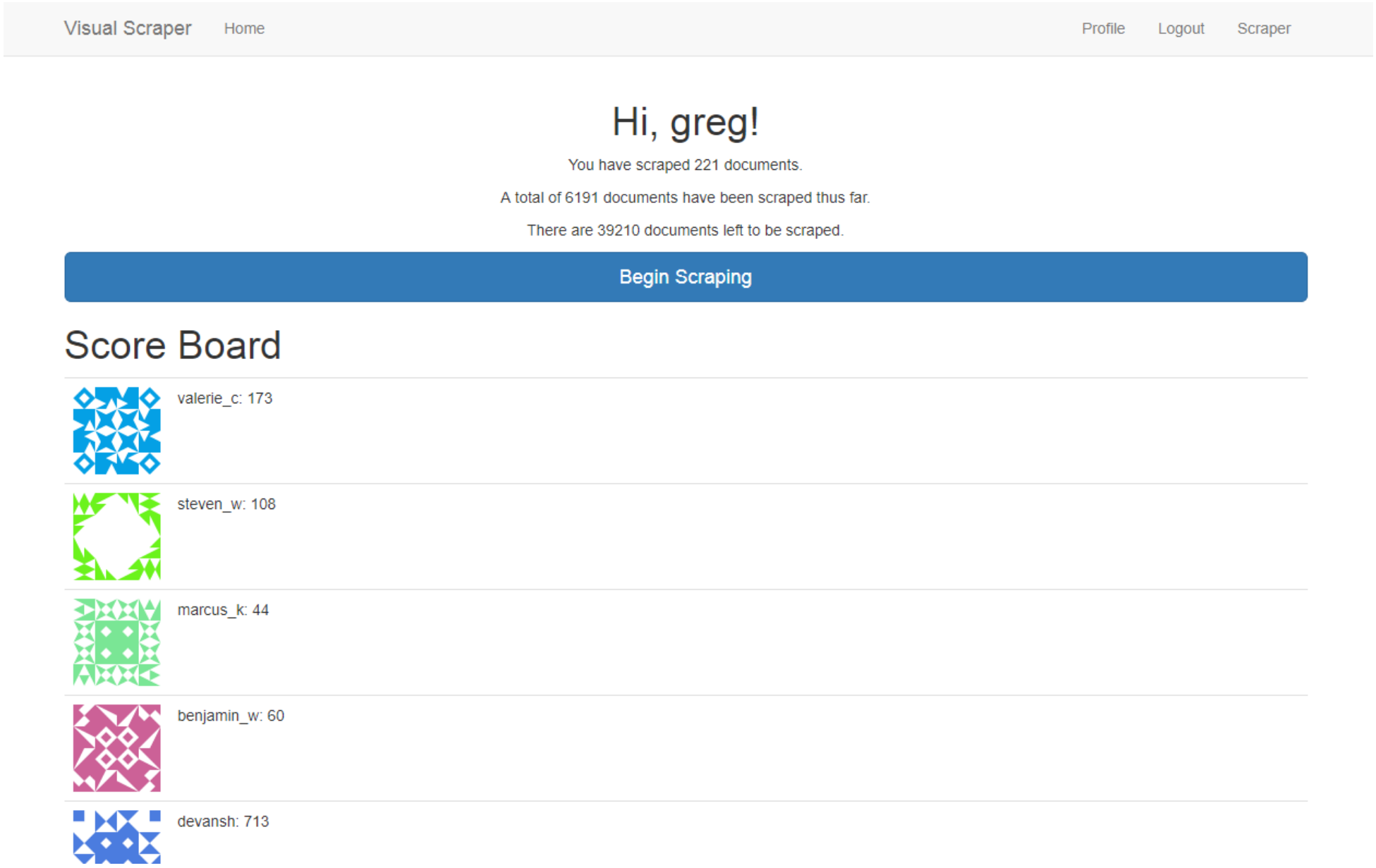
Web Application

Web Application



scraper.airwatergas.org

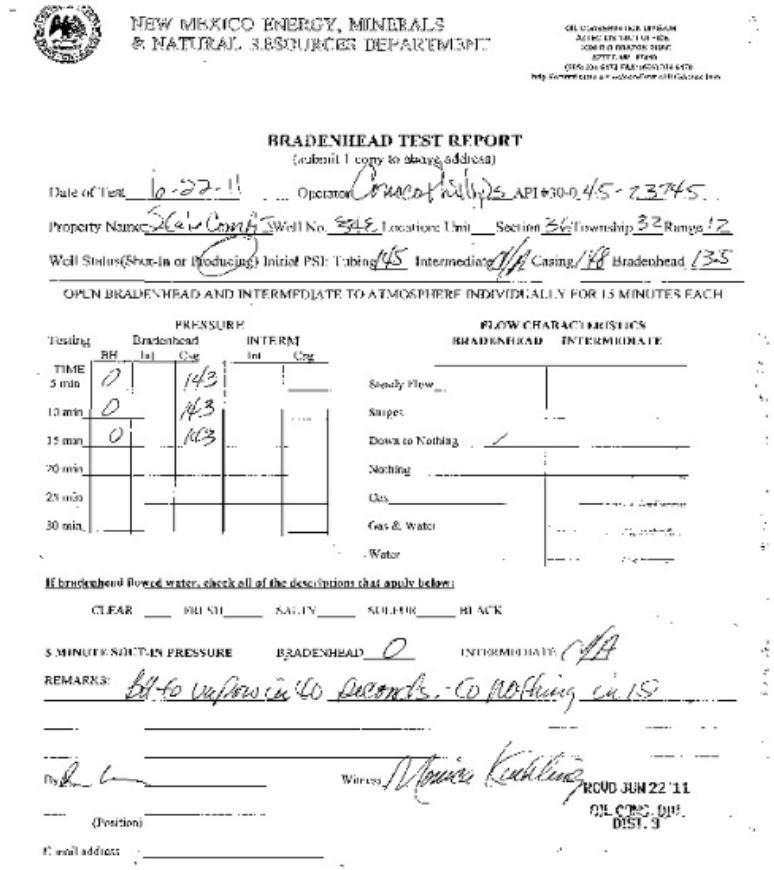
Web Application



Web Application

Visual Scraper | Home | Profile | Logout | Scraper

3004534135_9_wf.jpg Successfully Submitted!



NEW MEXICO ENERGY, MINERALS & NATURAL RESOURCES DEPARTMENT

BRADENHEAD TEST REPORT
(submit 1 copy to above address)

Date of Test 10-22-11 Operator ConocoPhillips API #30-045-23745

Property Name Slaw Com S Well No. 34E Location: Unit ___ Section 36 Township 32 Range 12

Well Status (Shut-In or Producing) Initial PSI: Tubing 145 Intermediate N/A Casing 148 Bradenhead 135

OPEN BRADENHEAD AND INTERMEDIATE TO ATMOSPHERE INDIVIDUALLY FOR 15 MINUTES EACH

PRESSURE

Testing Time	Bradenhead BH	Bradenhead Int	Bradenhead Csg	INTERM Int	INTERM Csg
5 min	0		143		
10 min	0		143		
15 min	0		143		
20 min					
25 min					
30 min					

FLOW CHARACTERISTICS

	BRADENHEAD	INTERMEDIATE
Steady Flow		
Surges		
Down to Nothing	/	
Nothing		
Gas		
Gas & Water		
Water		

If bradenhead flowed water, check all of the descriptions that apply below:

CLEAR ___ FRESH ___ SALTY ___ SULFUR ___ BLACK

5 MINUTE SHUT-IN PRESSURE BRADENHEAD 0 INTERMEDIATE N/A

REMARKS: BH to vaflow in 60 seconds - Co Nothing in 15

By ___ Witness Maurice Kuehling

(Position)

E-mail address

RCVD JUN 22 '11
OIL CONS. DIV.
DIST. 3

Document Name: 3004523745_44_wf.jpg

Entry Data

Go Back

Test Date (e.g. YYYY-MM-DD)

2011-06-28

Initial Bradenhead Pressure

Initial Intermediate 1 Pressure

Initial Intermediate 2 Pressure

Initial Casing Pressure

Initial Tubing Pressure

Final Bradenhead Pressure

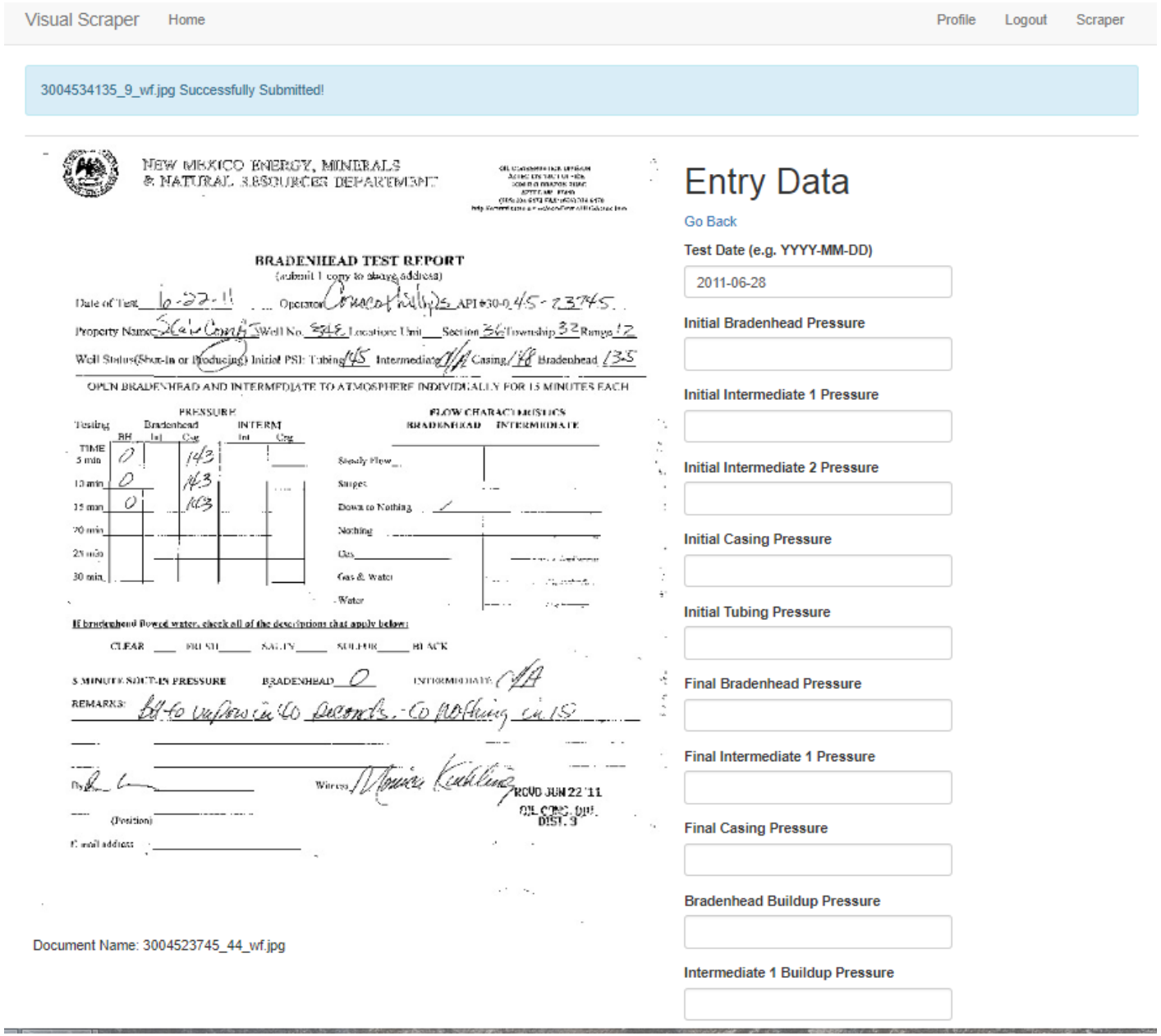
Final Intermediate 1 Pressure

Final Casing Pressure

Bradenhead Buildup Pressure

Intermediate 1 Buildup Pressure

Web Application



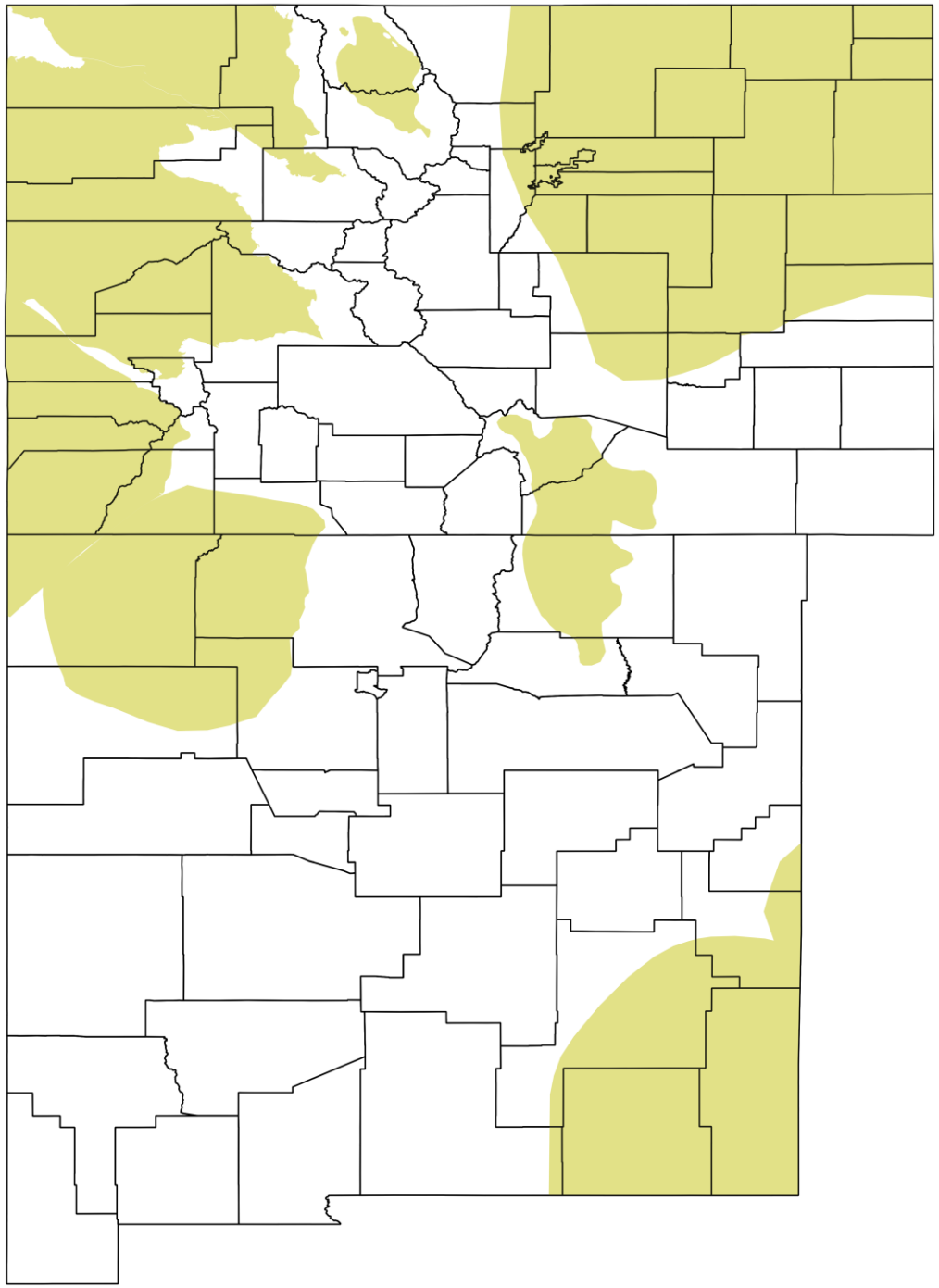
Website accessible from anywhere

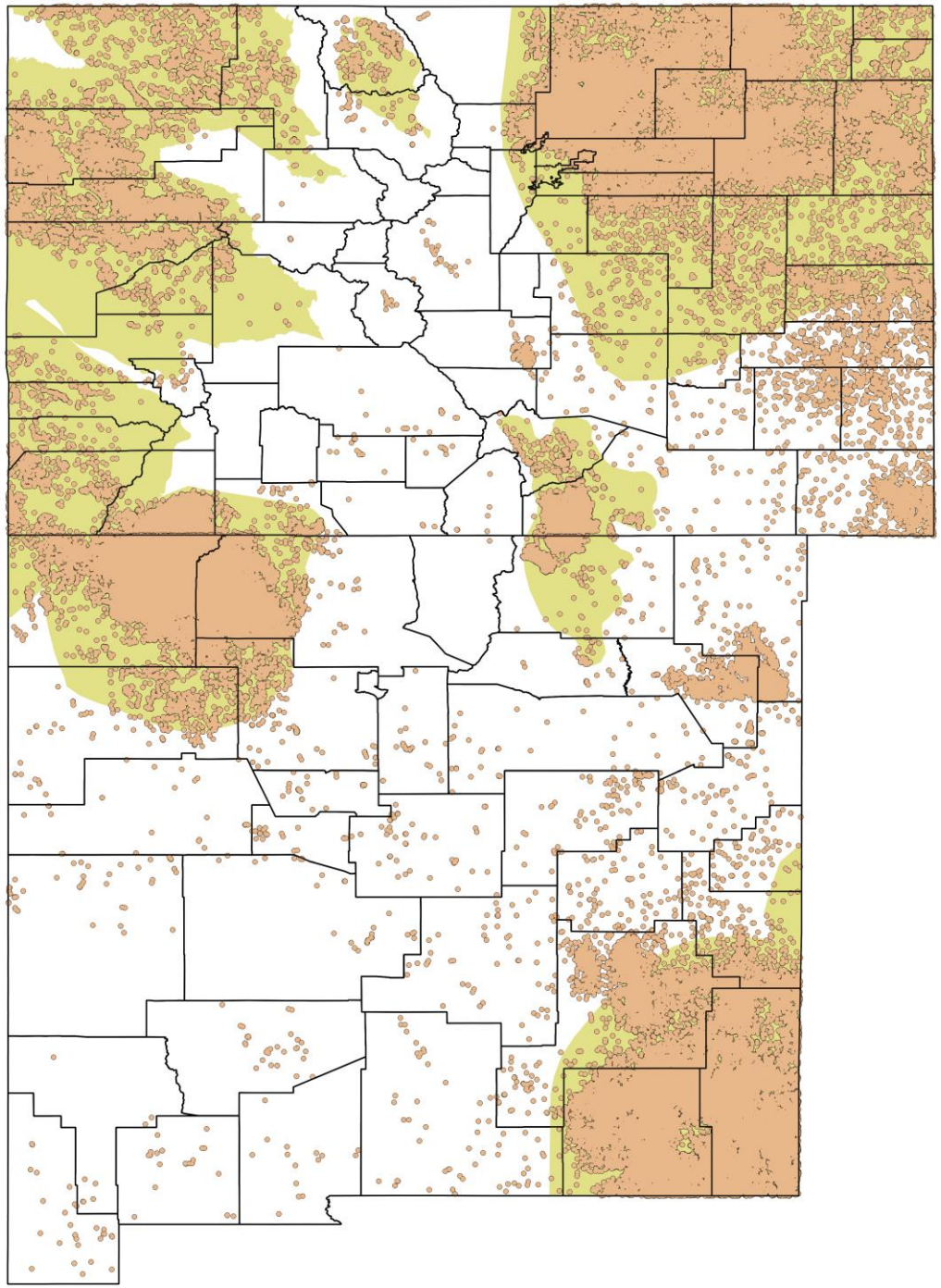
Multiple scrapers can work at the same time

~15 seconds a document

190 hours of work

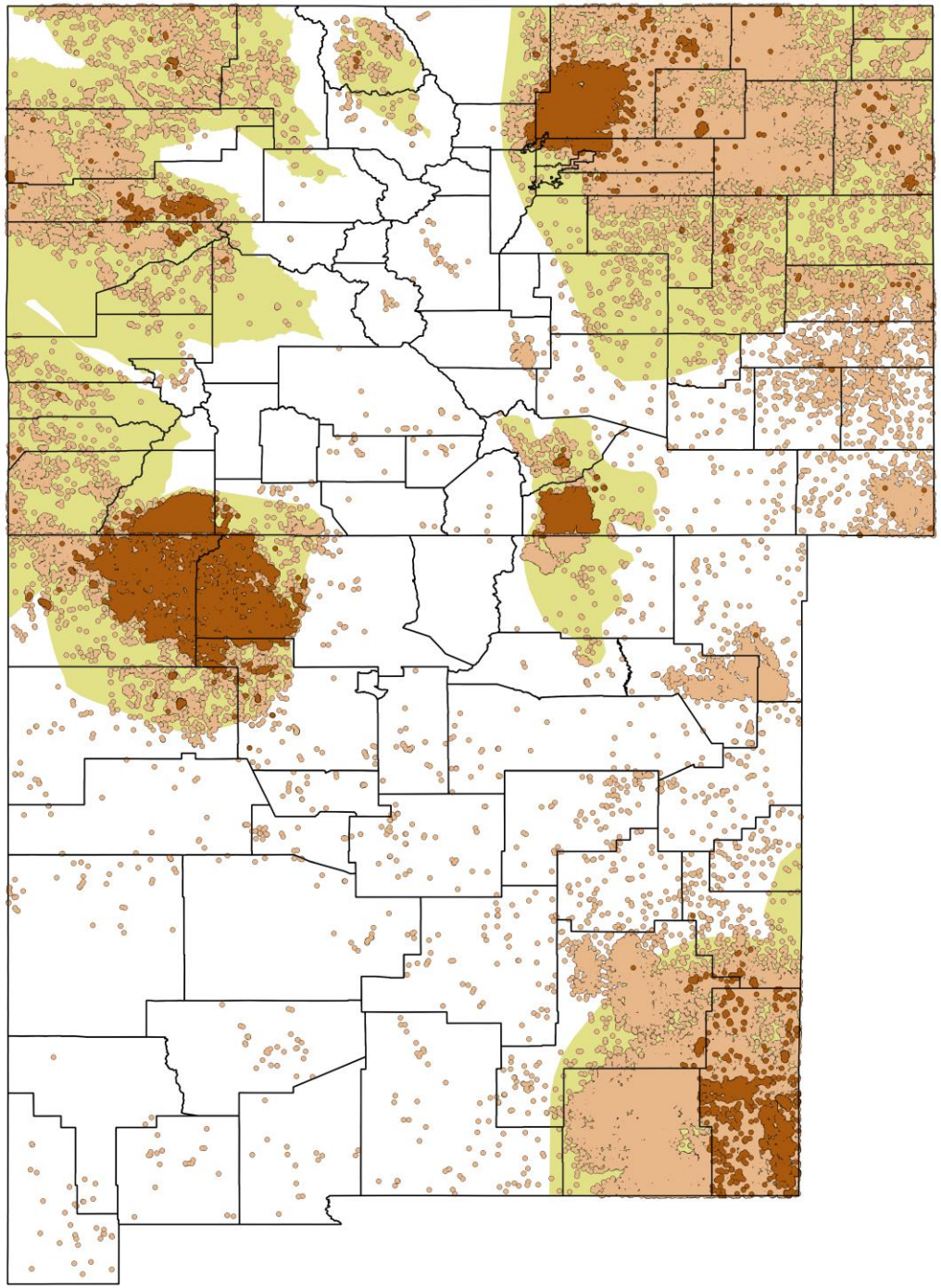
Preliminary Data





Preliminary Data

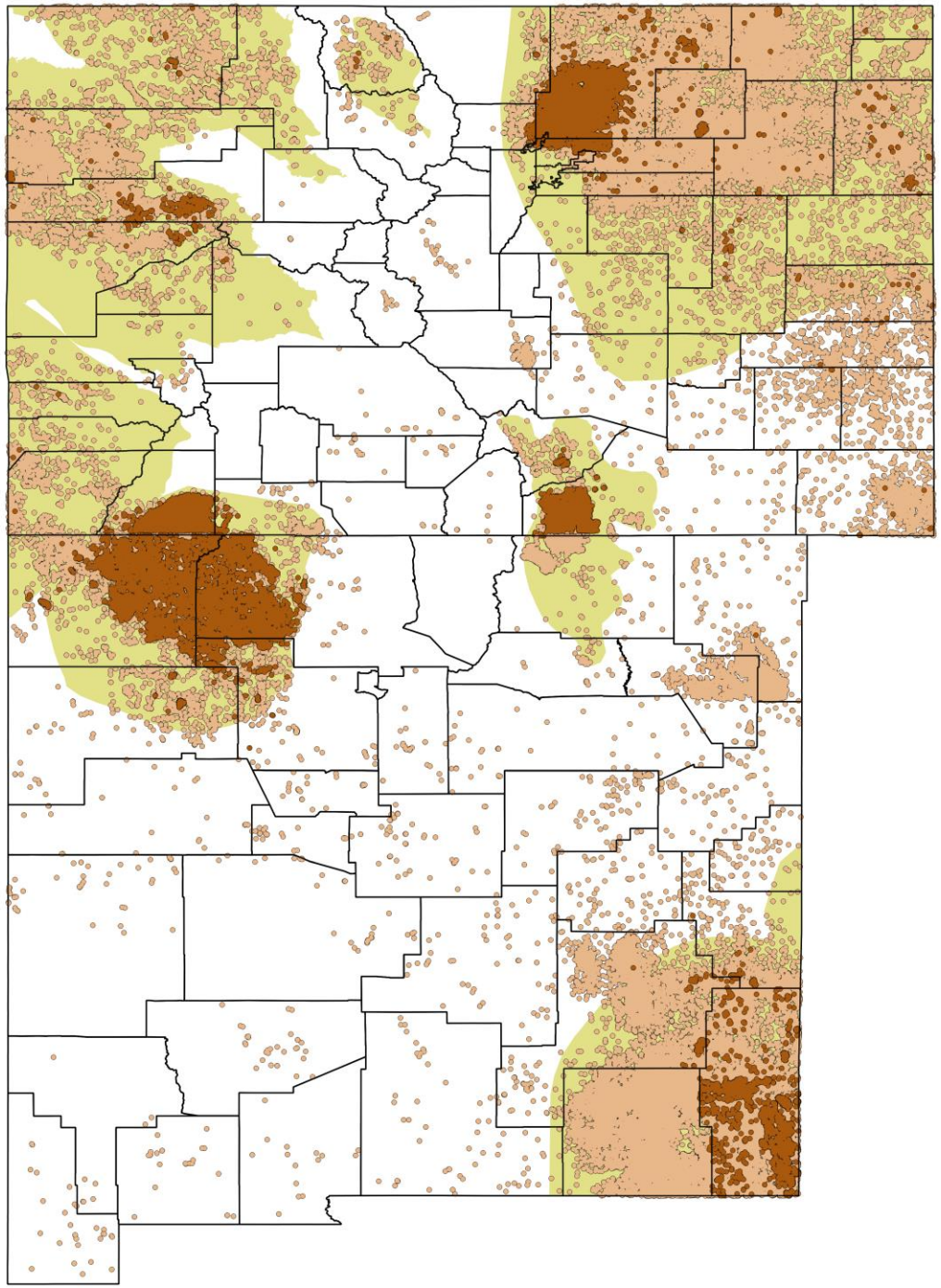
Well construction records for 232,645 wells in Colorado (114,843) and New Mexico (117,802).



Preliminary Data

Well construction records for 232,645 wells in Colorado (114,843) and New Mexico (117,802).

Well integrity test records for 34,727 wells. 19,540 in Colorado and 15,187 in New Mexico.



Preliminary Data

Well construction records for 232,645 wells in Colorado (114,843) and New Mexico (117,802).

Well integrity test records for 34,727 wells. 19,540 in Colorado and 15,187 in New Mexico.

After release of PA DEP well integrity data this will be the second largest dataset of well integrity information in the United States.

Conclusions

- Sustained casing pressure is an easily measure, but poorly documented, gauge of oil and gas well integrity.

- Bradenhead testing in Colorado and New Mexico provides insight into the development of SCP in oil and gas wells and can be used to identify wells that pose a high risk of inducing stray gas migration.

- Image based documents of interest can be identified and sorted from databases that contain seemingly unmanageable numbers of files using TensorFlow.

- Data from these documents can be easily obtained using a simple document scraping web application.

Acknowledgements

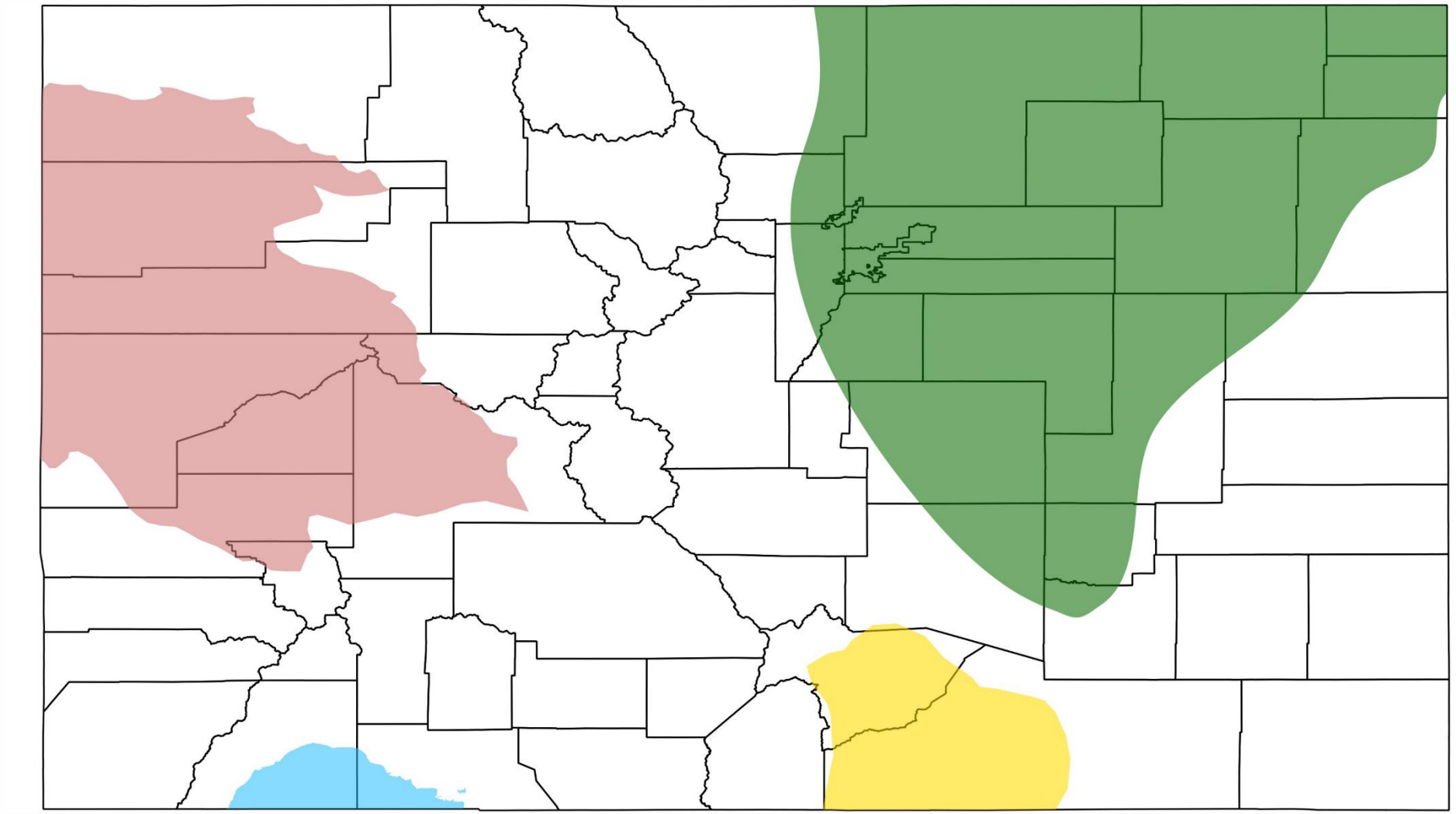
- National Science Foundation Sustainability Research Network Program (Grant CBET-1240584).

AirWaterGas Sustainability Research Network

- Harihar Rajaram, Owen Sherwood, Joe Ryan, Troy Burke, Devansh Chauhan
- Summer scrapers: Natalie Guinan, Steven Wilder, Lewis Schiebel, Marcus Knipp, Valerie Constien, Benjamin Willows, Ludvig Zwilgmeyer

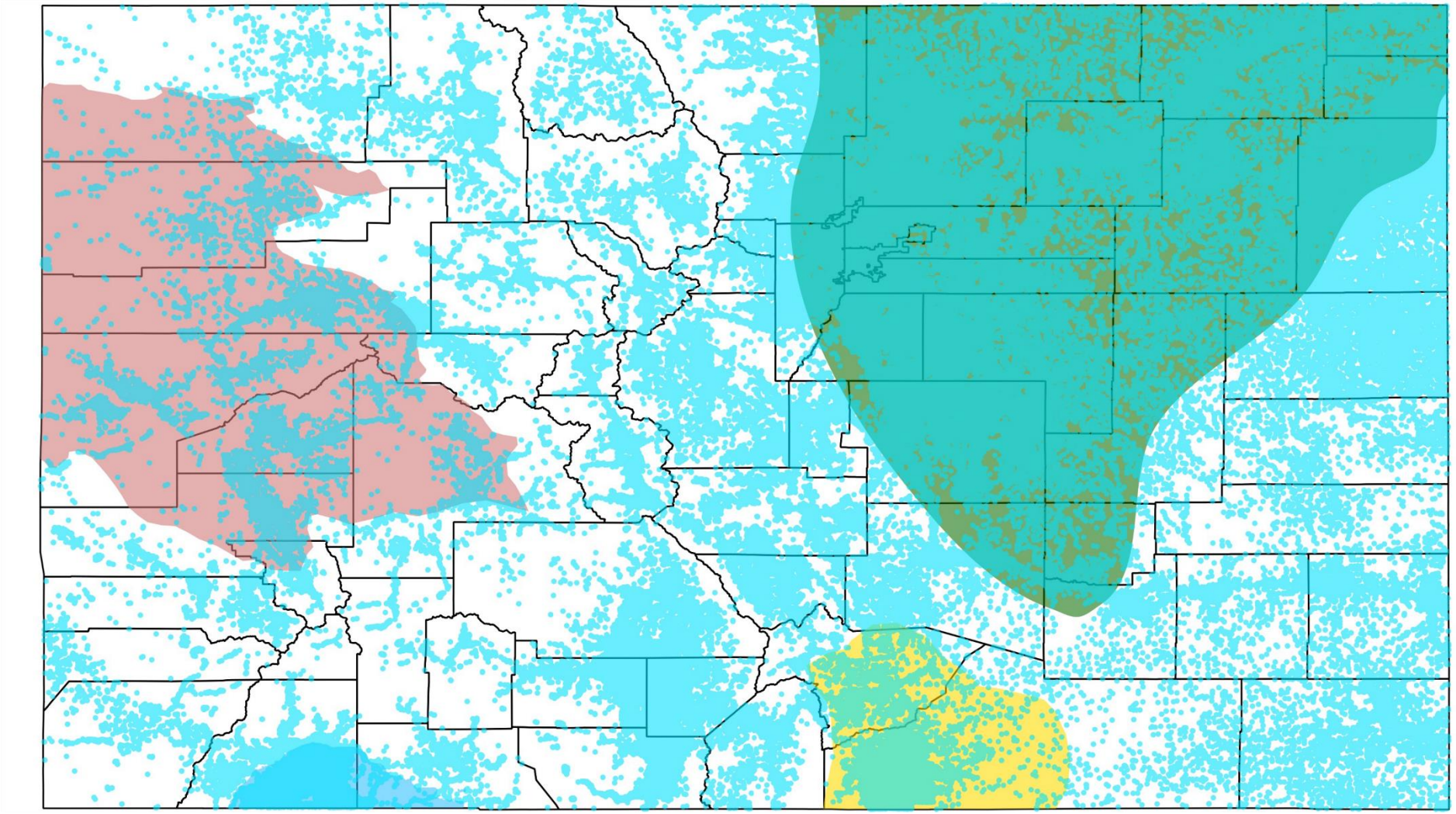
Extra Slides

Drilling in Colorado



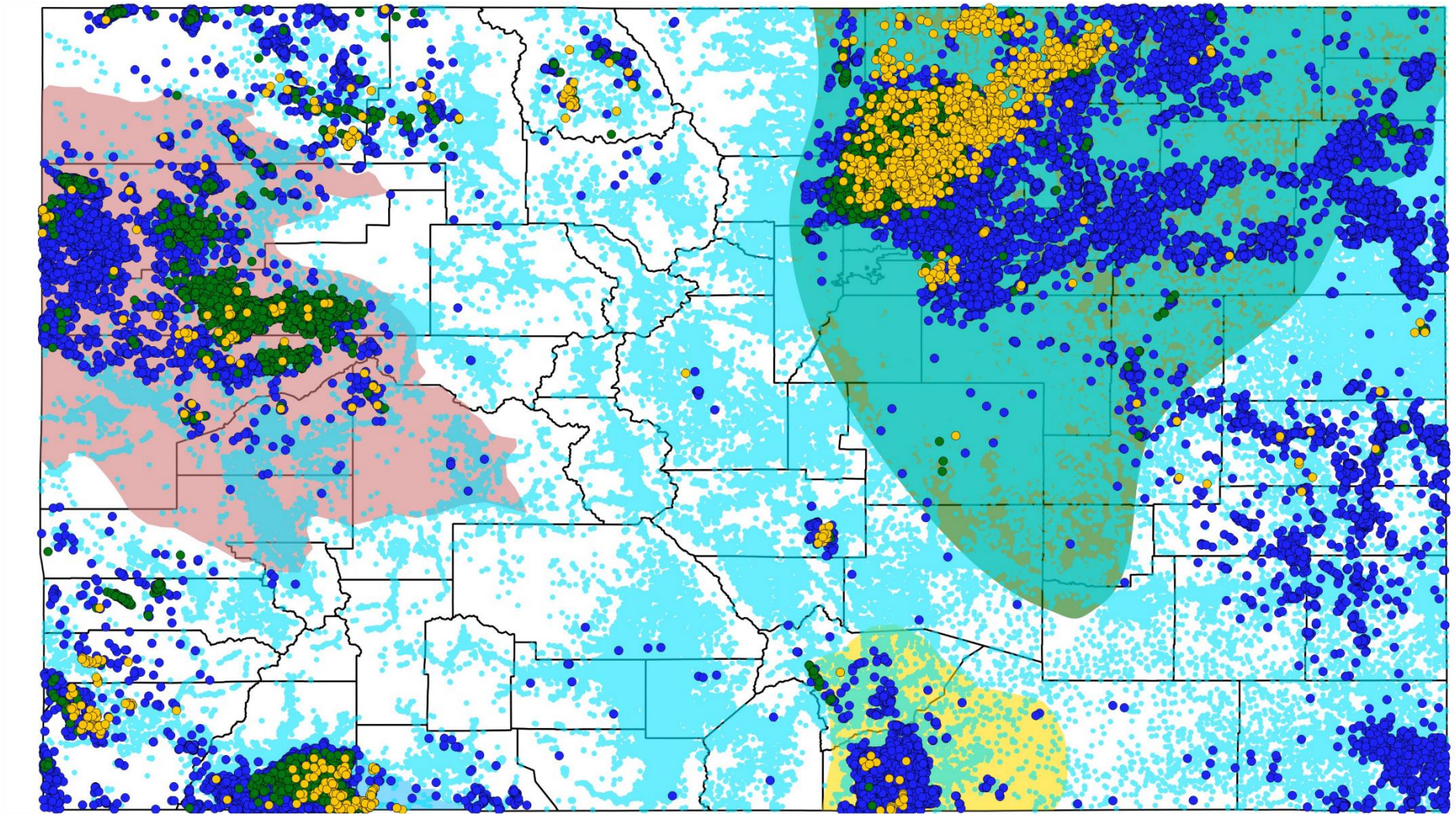
Four major oil and gas basins: DJ, Piceance, San Juan, and Raton

Drilling in Colorado



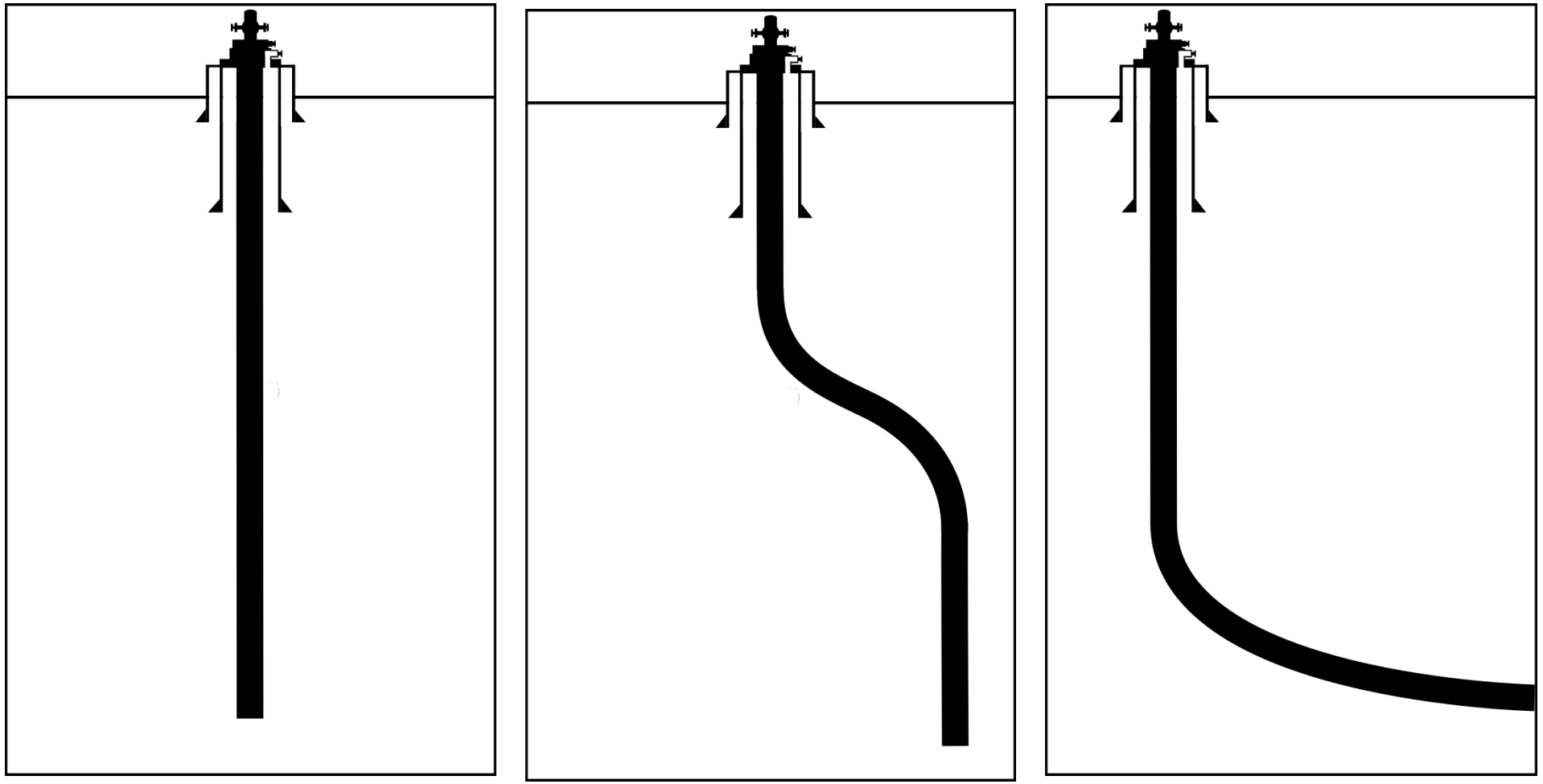
> 300,000 Water wells

Drilling in Colorado



Total: 64,289; Vert: 42,279; Dev: 18,761; Horiz: 3,249

Well Configurations

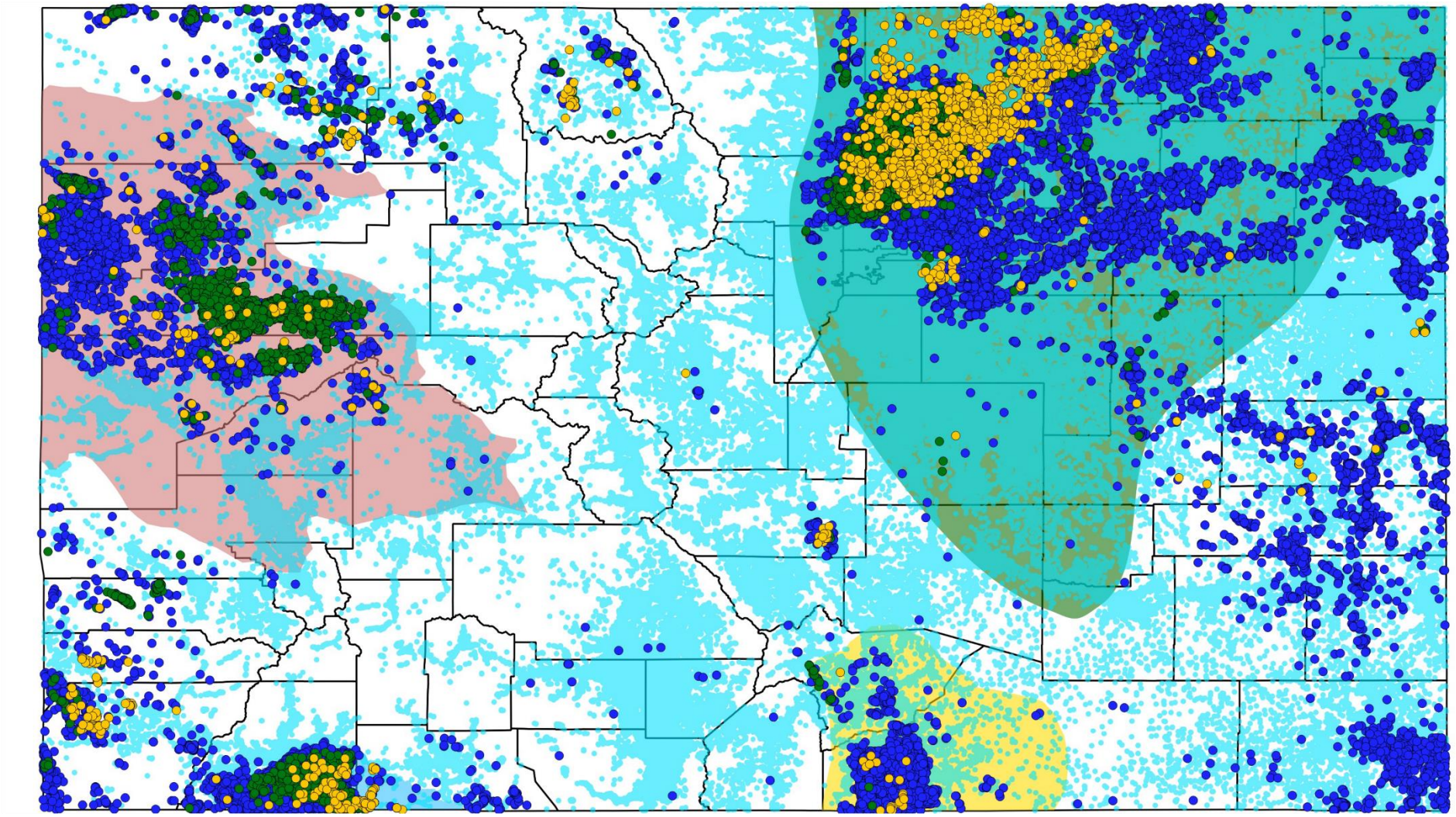


Vertical

Deviated/Directional

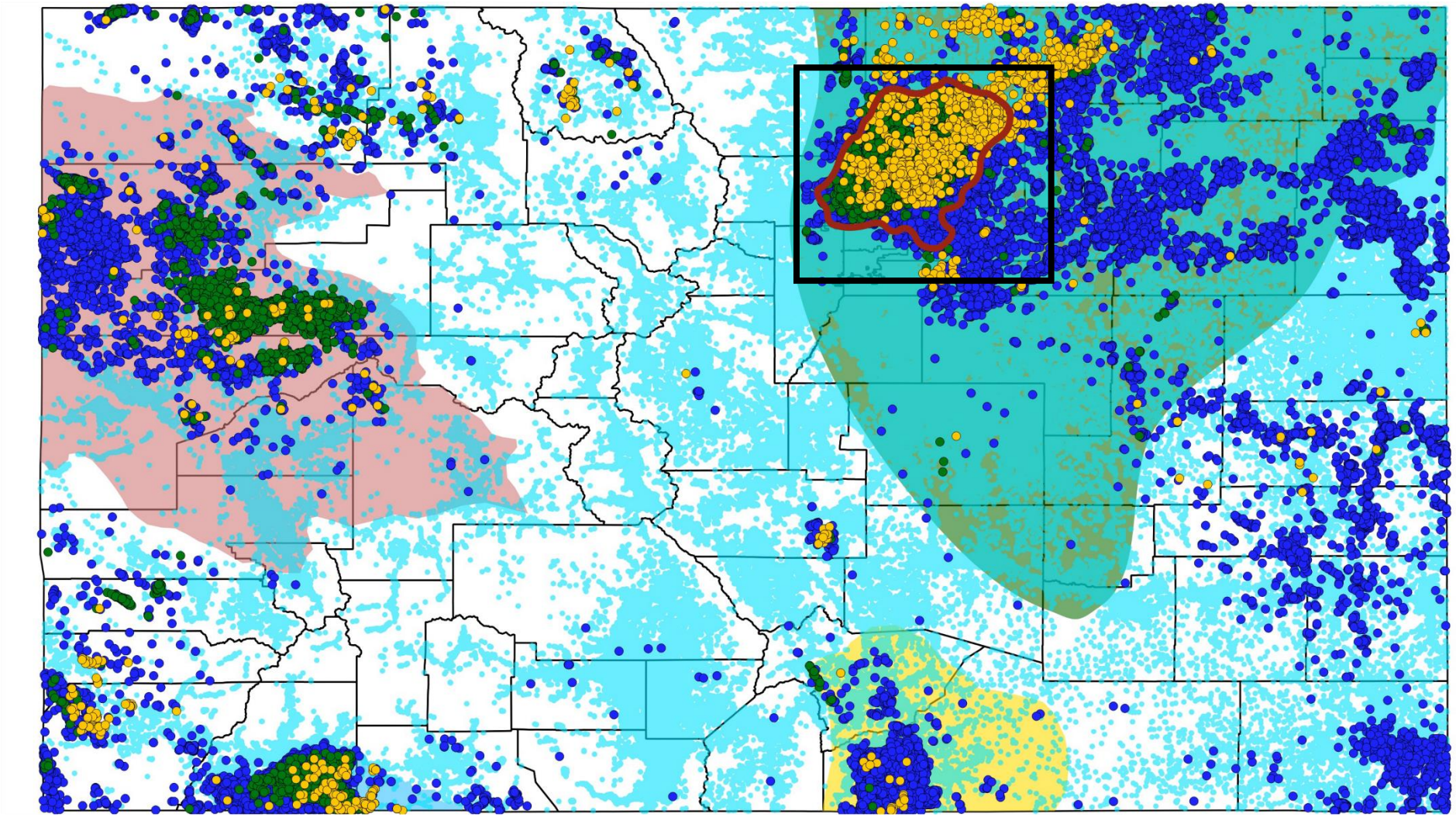
Horizontal

Drilling in Colorado



Total: 64,289; Vert: 42,279; Dev: 18,761; Horiz: 3,249

Drilling in Colorado

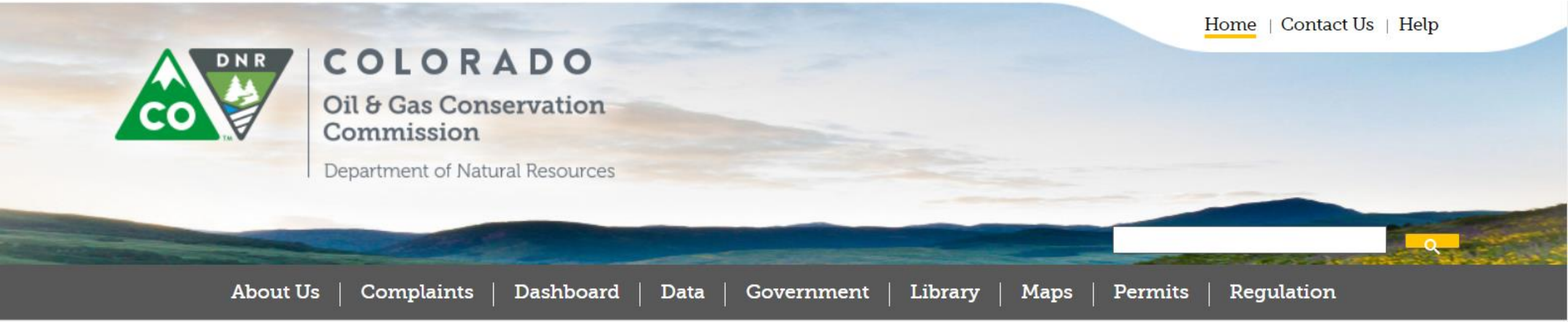


Total: 64,289; Vert: 42,279; Dev: 18,761; Horiz: 3,249

COGCC Data

cogcc.state.co.us

COGCC Data



cogcc.state.co.us

Scrapy

Python web scraping application