EnergyMakers Advisory Group

Texas Delaware Basin DMG SWD Permit and Performance Parameters

Backdrop to 3P Report (Permit & Performance Parameters)

EnergyMakers is Industry Consultant – Water Management, Water Treatment, Permitting, Subsurface Specialists, 30+ years in O&G

Have executed BHP pressure surveys across Texas – every basin, every formation - since 2014 (going back to the 1960's!)

Subsurface research specialists; subsurface issues & communications for landowners and mineral owners, forensic due diligence on cause and effect

Extensive research on Seismicity relationship to Pressure & Operational Regimes

Apply findings to permit strategies for our clients – finding safe, well-performing SWD locations

Opinions in this presentation are our own, and do not reflect, in any way, opinions of the Texas RRC.

Status of Texas RRC Permian SWD Review Policies

TX RRC Presented Proposed Concepts to Industry Dec 3, 2024, Industry Feedback solicited

Official feedback rounds January and March, '25

Final policies / notice to operators published May 15, '25

Review Policies implemented June 1, 2023

Proposal applies to:

- Permian Wells
- Newly Permitted Wells **only**

125 Parameters include Texas RRC Algorithms, ea. Block

For an AOR Well: (0.25 MILE "RULE")	Affirm	Not Affirmed
- Cement thru injection zone	PASS	FAIL
- Casing thru injection zone	PASS	FAIL
- Plugs isolating injection zone	PASS	FAIL
		MBHIP
FROM CONFINEMENT CALCULATIONS: GREEN = CONFINED RED = NOT CONFINED		0.67
ARE THERE WELLS IN AOR WITH NO WELL DATA?	NO	
ARE THERE WELLS IN AOR THAT MEET ANY OF THE FOLLOWING CRITERIA?	NO	
PLUGGED WELLS		
UNPLUGGED, AND AT LEAST 1 OF THE FOLLOWING		
INACTIVE WELL PROVISIONS (RULES 14 AND 15) - WB_14B2_FLAG		
NO ACTIVE OPERATOR - WL_14B2_OPER_DELQ		
ORPHAN WELL LIST		
ALL WELL SEARCH IN AOR: LARGEST OVERALL ASSESSMENT VALUE =	148	
(1/DISTANCE FROM INJECTION WELL) * AGE OF WELL * (1/DATA QUALITY IMPAIRMENT)		
MBHIP reduction due to AOR review		0.00
VOLUME (MMBBL): PROJECTED INTO AOR USING APPLICANT REQUESTED	36.50	
MDIV ALLOWABLE FOR 5 YEARS TO NOT EXCEED MBHIP (BWPD)	1,266	

$$q = \frac{A * h * \varnothing * c_t}{5.615 * t} * \Delta p$$

SPECIAL CONDITIONS FROM PRESSU...

- Date/Time Stamp FOR AOR for all values
- Last Injection rate (M.S.I.P.)
- Last Injection pressure
- Instantaneous Shut-In Pressure (ISIP)
- Depth reference for BHP estimate
- Estimated BHP based on ISIP
- Cumulative Volume for this well
- Update to well list w/ classified on schedule or r...
- TOC on AOR well list
- Cumulative RATE for this AOR
- Cumulative Volume for this AOR

- No more permits in the Bell Canyon OR Depth...
- Volume based on single injector (applicant's...

	PROGRAM INPUTS ARE IN LIGHT BLUE
1.00	MILE AOR
0.10	MAX MBHIP REDUCTION
100%	PERCENTAGE OF FRACTURE GRADIENT ALLOWABLE
5	YEARS TO CALCULATE CUMULATIVE VOLUME INJECTED IN AOR
	VALUES IN BLUE CELLS ARE DIRECTLY FROM RAD RESPONSES
2,510	(FT) ZONE THICKNESS FROM RAD RESPONSE
3,248	(FT) TOP OF PERMITTED INJECTION INTERVAL FROM RAD RESPONSE
#####	(BWPD) INJECTION RATE BWPD FROM RAD RESPONSE
0.67	(PSI/FT.) FRACTURE GRADIENT FROM RAD RESPONSE
0.63	(PSI/FT.) PORE PRESSURE GRADIENT FROM RAD RESPONSE
15%	POROSITY FOR VOLUME CALCULATIONS
	CALCULATED VALUES ARE IN LIGHT GREEN
#####	QUALITY IMPAIRMENT USED IN THIS EVAL
148	OVERALL AOR ASSESSMENT VALUE
131	(PSI) INCREASE FOR 5 -YEARS OF INJECTION
0.040	(PSI/FT) INCREASE FROM 5 -YEARS OF INJECTION
0.670	(PSI/FT) FINAL PORE PRESSURE GRADIENT
0.26	(PSI/FT) ESTIMATED MSIP USING ESTIMATED FRICTION PRESSURE
	INPUTS OBTAINED FROM AOR+ REVIEW
	...WELL 1
	...WELL Y
	...ELLS WI
	...ELLS WI
	...ELLS CLI

			B3	B4
WB_14B2_FLAG	YES			
WL_14B2_FLAG	NO		YES	YES
WL_14B2_CODE			NO	NO
WL_14B2_DIST_SFP				
WL_14B2_DIST_SF_CLNUP				
WL_14B2_DIST_ST_PLG				
WL_14B2_EXT_STATUS				
WL_14B2_FLDOPS_HOLD				
WL_14B2_GOOD_FAITH				
WL_14B2_H15_DELQ				
WL_14B2_H15_PROB				
WL_14B2_MECH_INTEG				
WL_14B2_OPER_DELQ				
WL_14B2_PLG_ORD_SF				
WL_14B2_POLLUTION				
WL_14B2_WELL_OTHER				

$$\Delta p = \frac{5.615 * V}{A * h * \varnothing * c_t}$$

$$q = \frac{A * h * \varnothing * c_t}{5.615 * t} * \Delta p$$

All contrived/measured frac barriers are greater

A max BHIP is self regulating on injection rate

0.6 psi/ft is too low 0.8 psi/ft is too high

Measured and reported 2X / year

2 mile AOR as a constant

The permitted intervals render calculated radius as moo...

RRC will gain relevant emphasis on potentially impacted wellbores.

...ss l wells do a 2.5 mile AOR review every 5 years

Annual reporting into a UIC database (similar to CID)

...ude all wells injecting > 5,000 bwpd

...t report due within 30 days of new well completion

...te/Time Stamp FOR AOR for all values

...t Injection rate (M.S.I.P.)

...t Injection pressure

...antaneous Shut-In Pressure (ISIP)

...th reference for BHP estimate

...mated BHP based on ISIP

...nulative Volume for this well

...date to well list w/ classified on schedule or no...

...on AOR well list

...more permits in the Bell Canyon OR Depth Lim...

...t often overpressured now w/large number of existing in...

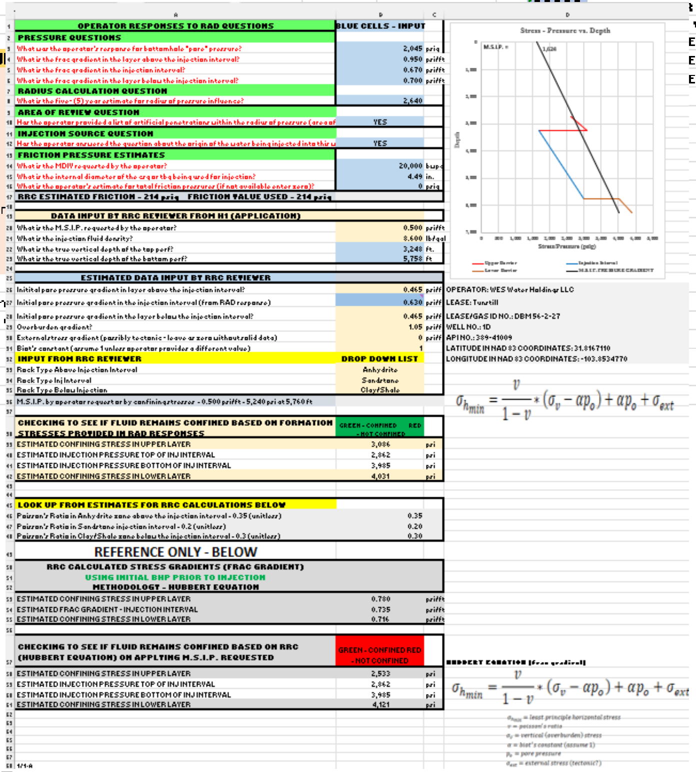
...the most older penetrations from vertical wells

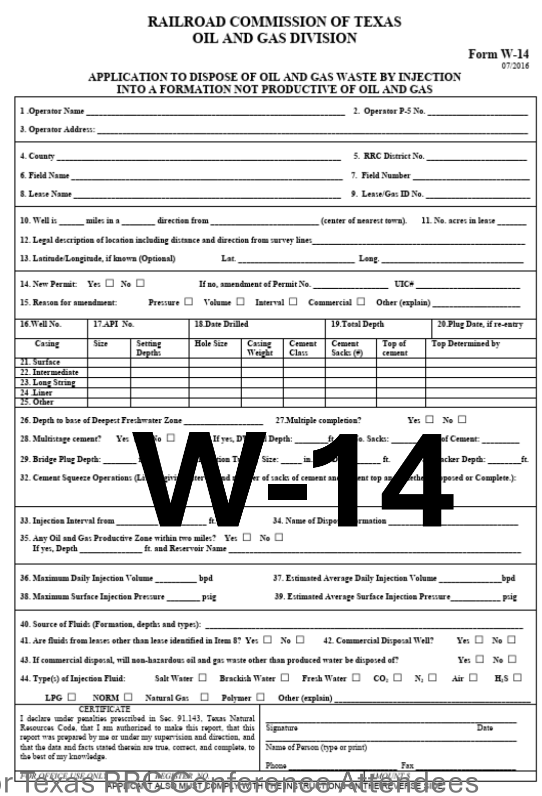
...ng deeper into Cherry/Brushy/Bone Springs avoids BUC...

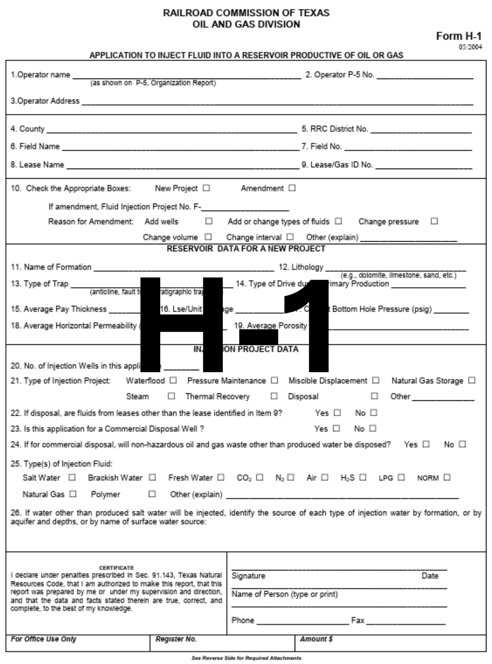
...erpressured Bell Canyon can improve isolation of zones...

...omplete AOR well data - must be located / mo...

CALCULATIONS FOR VOLUMETRIC AND INJECTION RATE		
MBHIP	2,176	psi
AVERAGE PORE PRESSURE FROM RAD	2,045	psi
INJECTION RATE BWPD FROM RAD RESPONSE	20,000	BWPD
INJECTION TIME	5	YEARS
CUMULATIVE VOLUME REQUESTED OVER 5 YEARS	36,500,000	BBLS
ZONE THICKNESS FROM RAD RESPONSE	2,510	feet
RADIUS FOR AOR CALCULATIONS	1.00	MILES
RADIUS FOR AOR CALCULATIONS	5,280	FEET
AREA OF AOR	87,582,577	FT^2
VOLUME OF AOR	2.19832E+11	FT^3
POROSITY FROM RAD RESPONSE	15%	
COMPRESSIBILITY	3.00E-06	1/psi
PORE VOLUME FROM AOR CALCULATIONS	###########	FT^3
PORE VOLUME IN BBLS FOR 1 MILE AOR	5,872,634,034	BBLS
PRESSURE INCREASE ALLOWED (MBHIP - AVE PORE PRESSURE)	131	psi
MDIV ALLOWABLE FOR 5 YEARS TO NOT EXCEED MBHIP	1,266	BWPD
PORE VOLUME IN BBLS FOR 1 MILE AOR	5,872,634,034	BBLS
BBLS REQUIRED TO ACHIEVE MBHIP (MAX)	2,310,764	BBLS
TOTAL VOLUME IN RESERVOIR AT MBHIP (MAX)	5,874,944,798	BBLS
% OF PORE VOLUME OCCUPIED PRIOR TO INJECTION IN 1 MILE AC...	99.96%	
PERCENTAGE OF PORE VOLUME LEFT TO INJECT BELOW MBHIP	0.04%	







3P Report: a Rapid Screening Toolkit organized by Topic

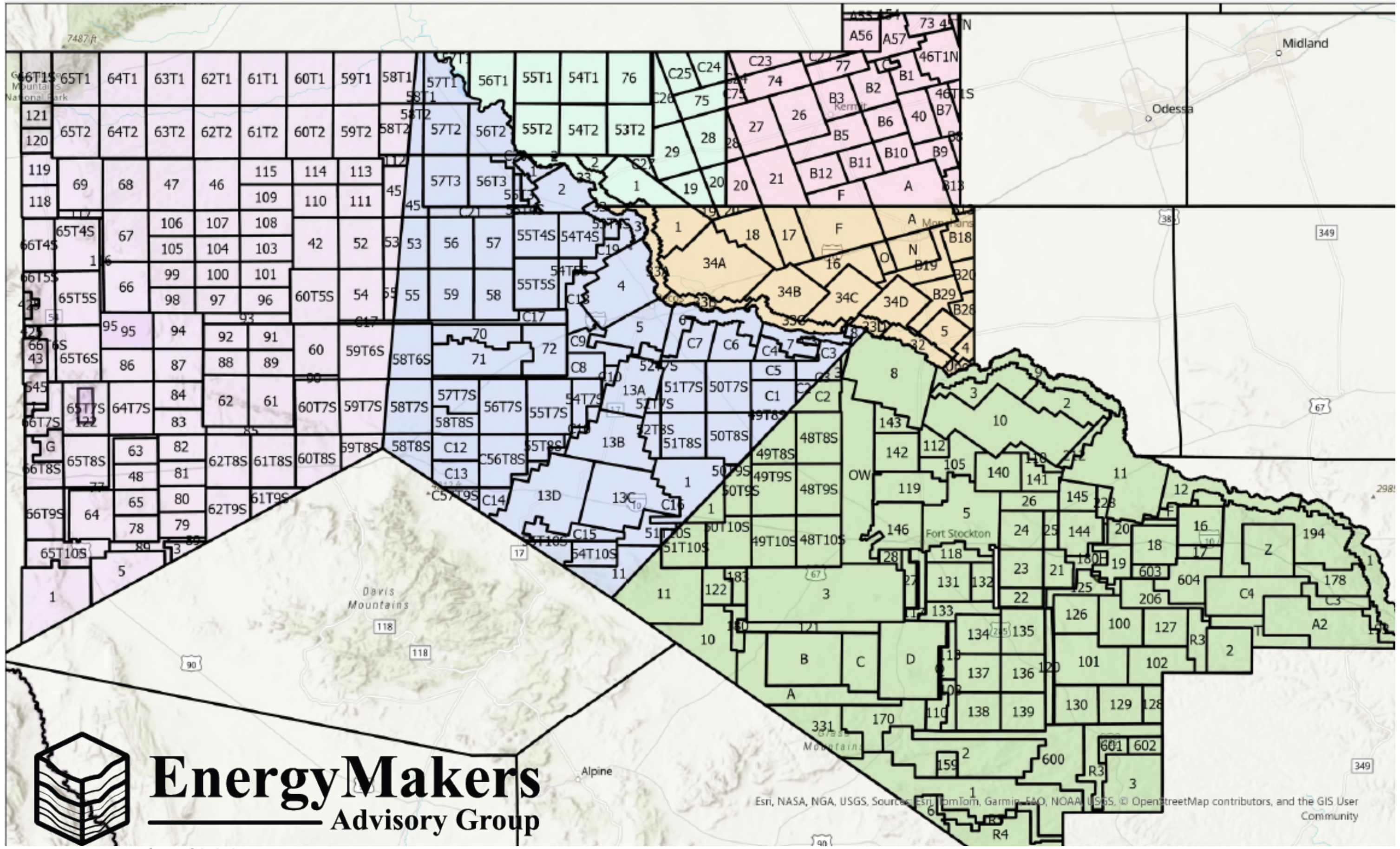
- **SWD Permit and Performance Feasibility**
- **125 Parameters / Calculations per Block**

Permit and Performance Parameters

Chapter Headings	Number of Parameters	Number of Maps
A Metadata	14	1
B Fracture Gradient	7	7
C Bottomhole Pressure Gradient	17	17
D Surface Pressure Gradient	9	1
E Penetration Data Completeness	21	15
F 1/2 Mile Radius of Review (Block Statistical, RRC Reqs)	4	4
G 2 Mile Radius of Review (Block Statistical, RRC Reqs)	9	8
H Protection of Injection Interval (Custom)	Custom	Custom
I Protection of Freshwater	12	7
J Environmental Risks & Considerations	19	17
K SWD Performance Indicators	33	10
L Performance MDIV Calculations	4	4
M Performance MSIP Calculations	11	4
N FIX Voluntary Well Remediation Indicators	6	6
O Confinement Intervals / (Custom Option)	4	Custom

Permit & Performance Feasibility Parameters

- ☑ Statistics (planning)
- ☑ Location ID /Screening/Risking (focus)
- ☑ Permitting & Compliance Data Packages/ (permitting)



	Total Block Count	Blocks with SWD
Culberson	117	14
Loving	22	20
Reeves	82	58
Ward	28	13
Winkler	35	7
Pecos	103	14
	387	126

Average Block size is 2.5 X larger than a 2 Mile radius AOR

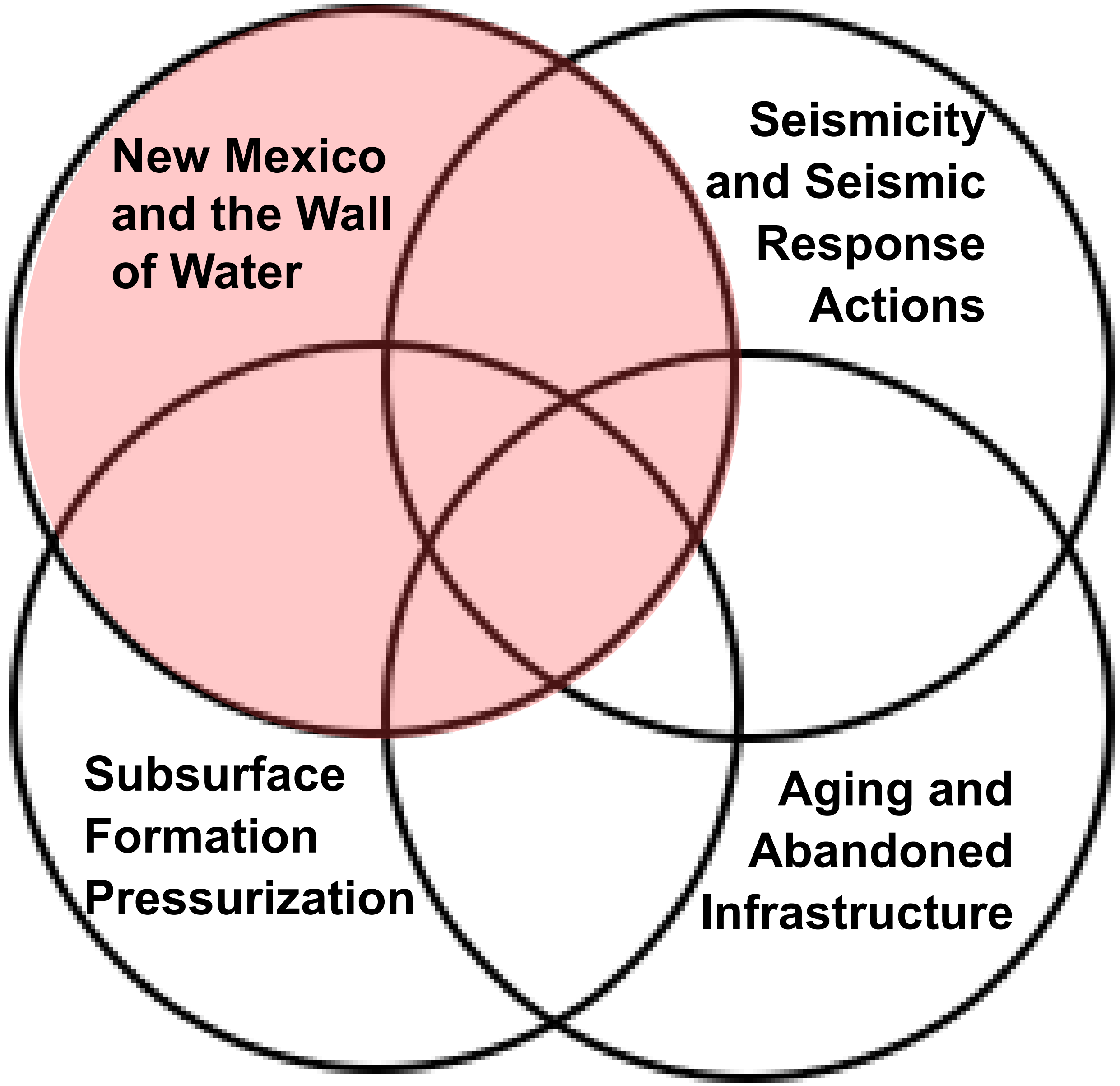
But First…a little background

How did we get where we are today?

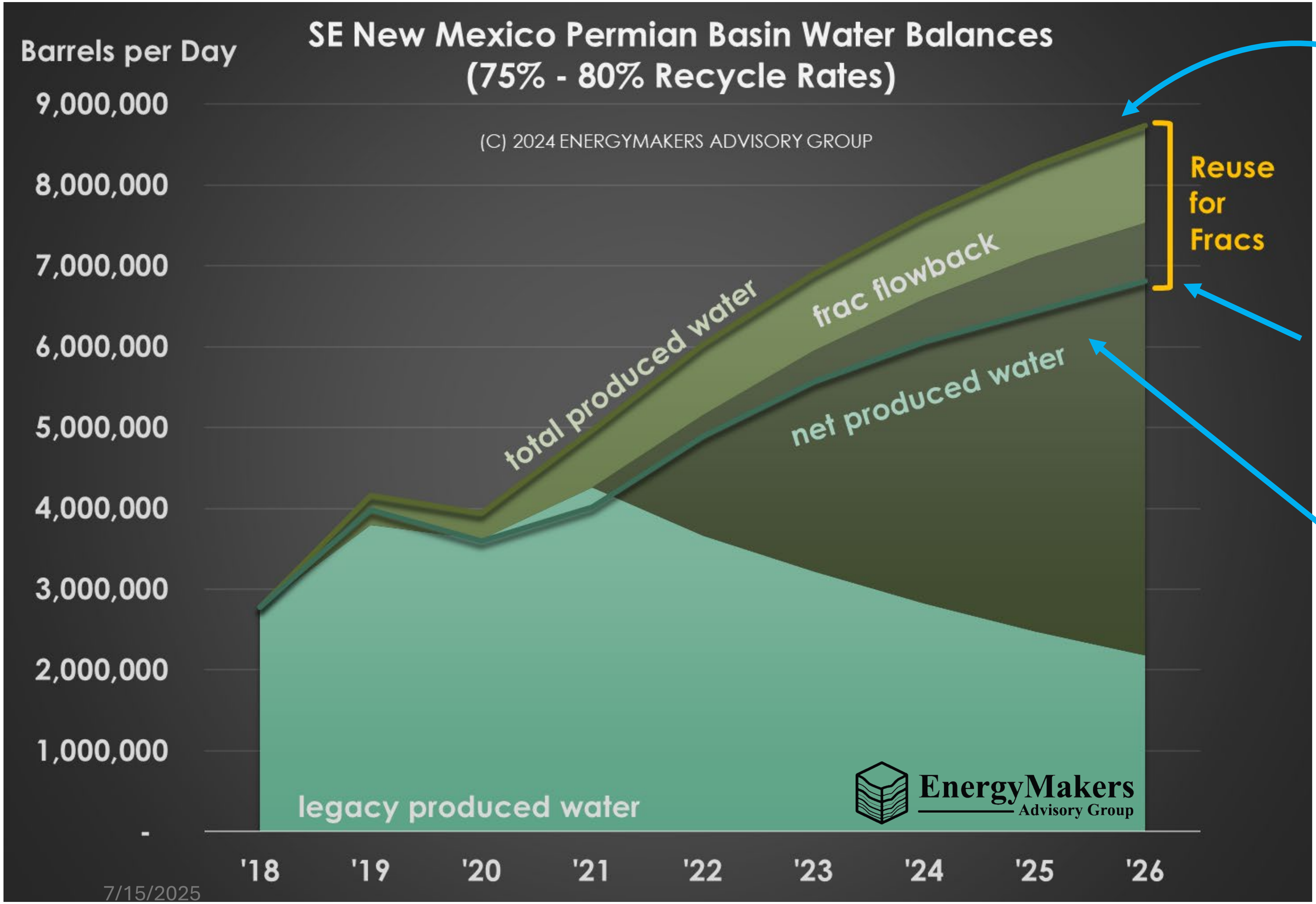
What were the drivers?

How do these “risks” relate to each other?

Subsurface Environmental Risk Factors in the Permian



The Wall of Water Coming from New Mexico to Texas



"Wall of Produced Water" co-produced with Oil and Gas (O&G) in SE New Mexico

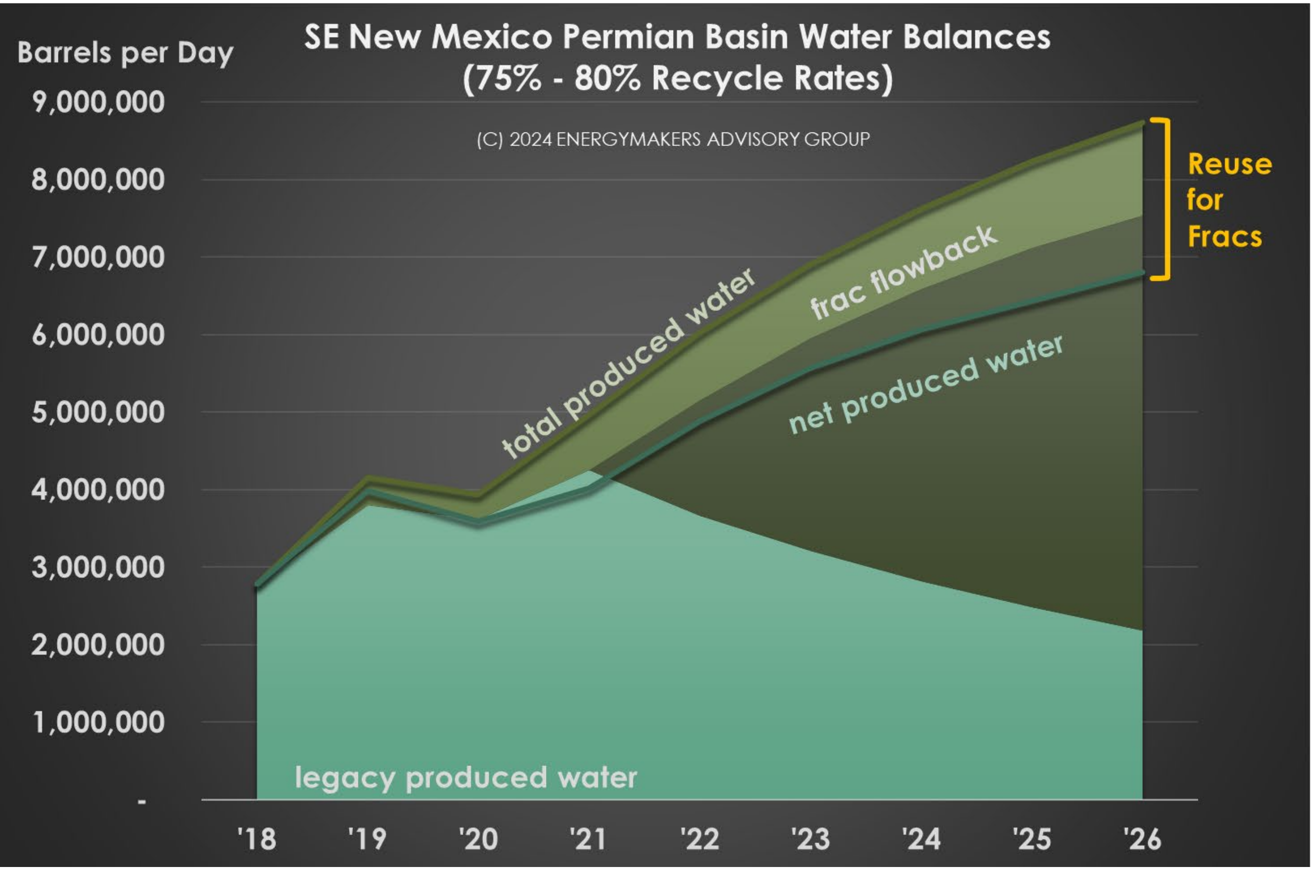
Recycling Reuse in O&G will consume ~ 20% of PW

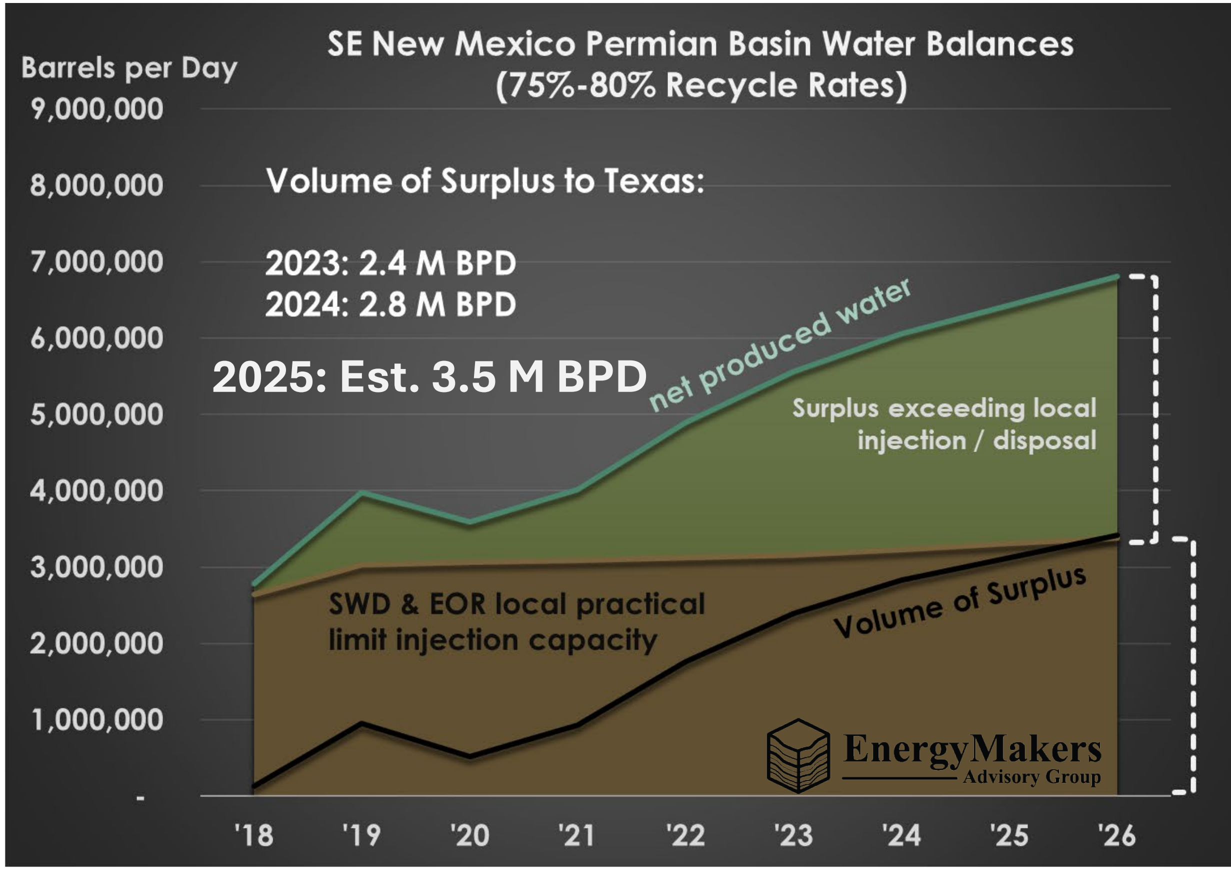
"Net Produced Water", after recycling, is surplus PW that must be:

- Injected Underground
- Piped out of Area
- Find an Alternate Beneficial Use

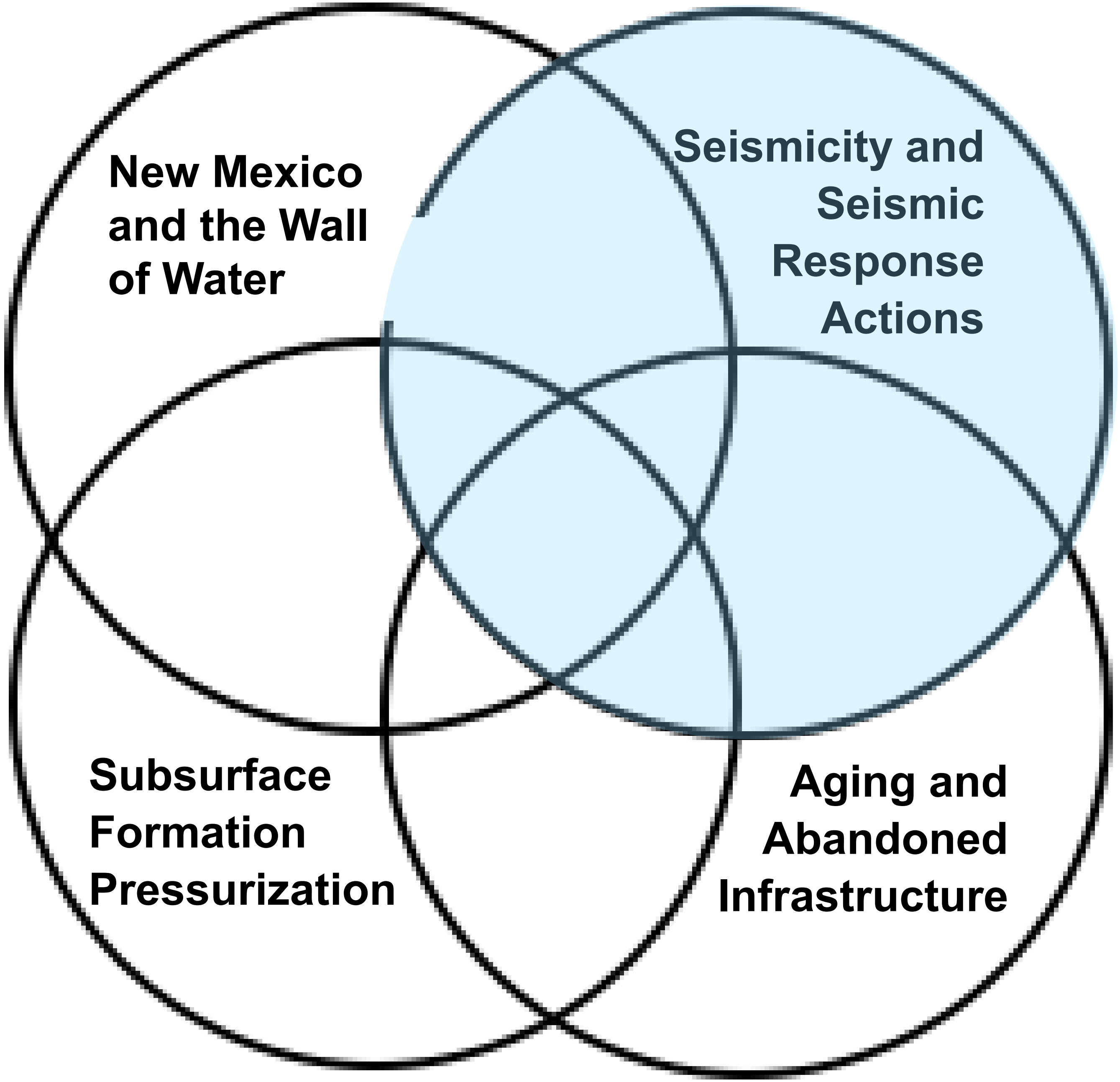
After we have recycled all we can use in Oil and Gas....

...the left over Net Produced Water (PW) needs an outlet. Currently, SWD & EOR injection are the primary outlet. SWD and EOR growth is increasingly limited, leaving a growing surplus (black line).

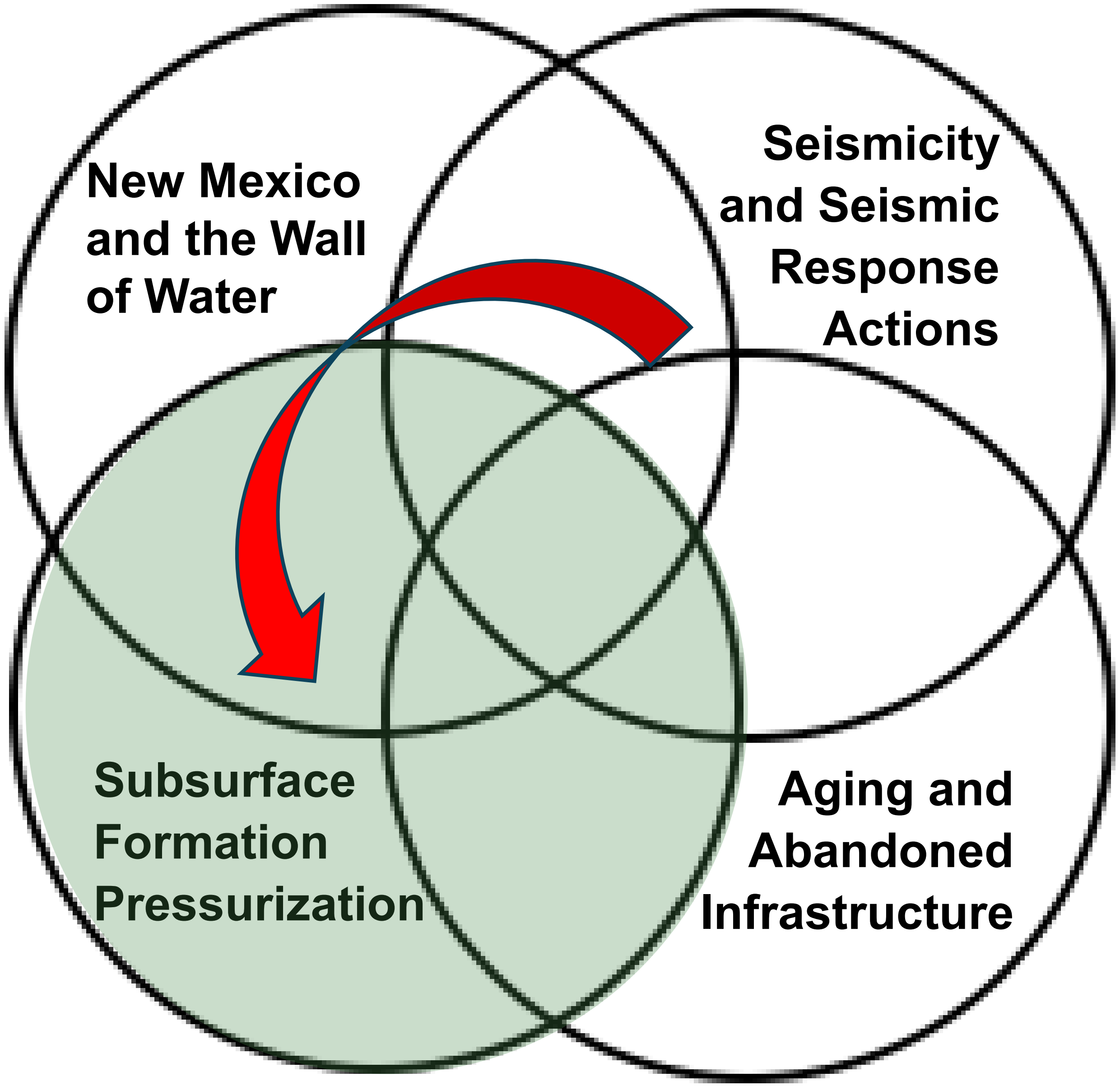




Subsurface Environmental Risk Factors in the Permian



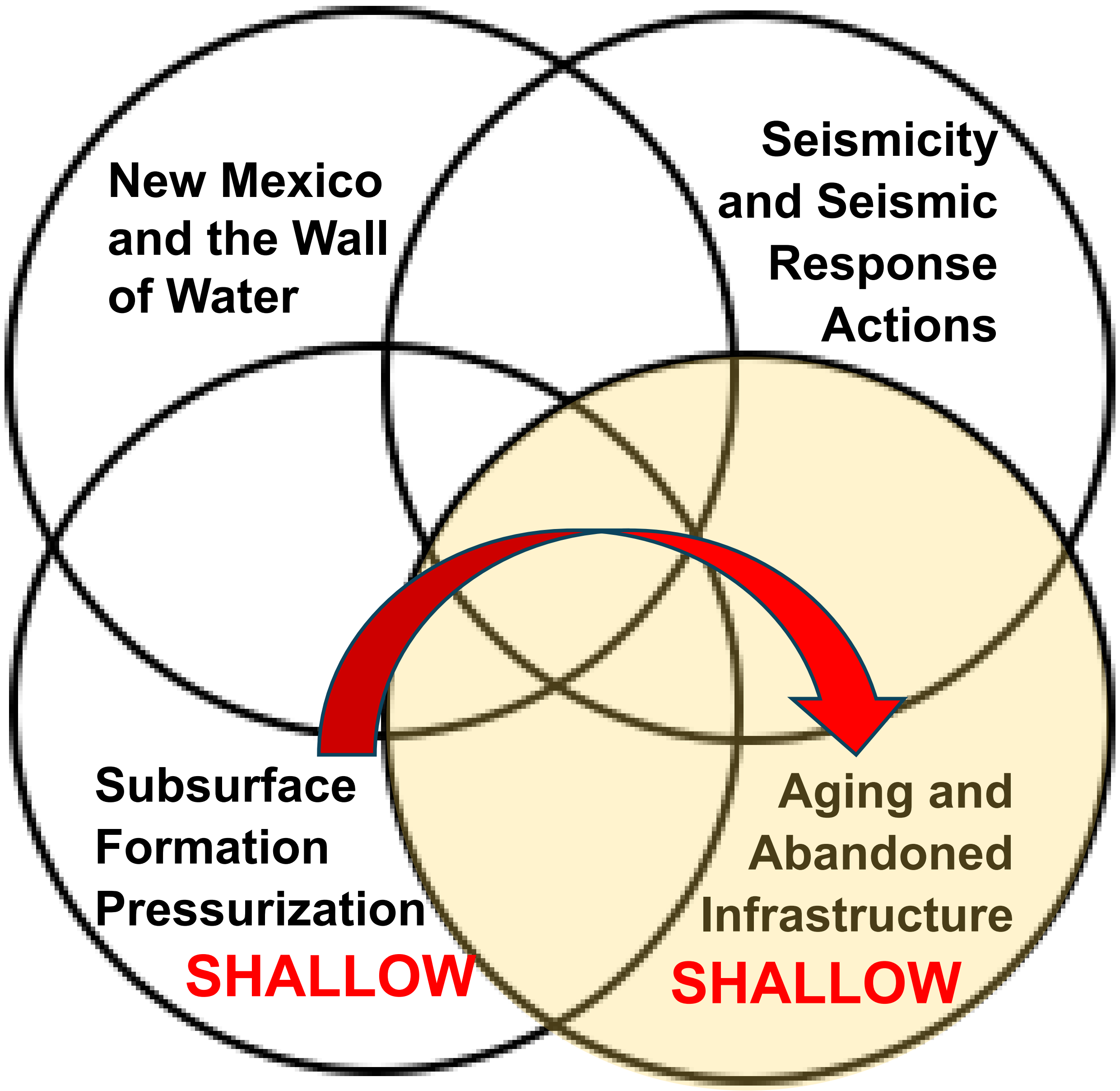
DEEP SRA BANS RESULTS IN PW REDIRECTION TO SHALLOW SWD

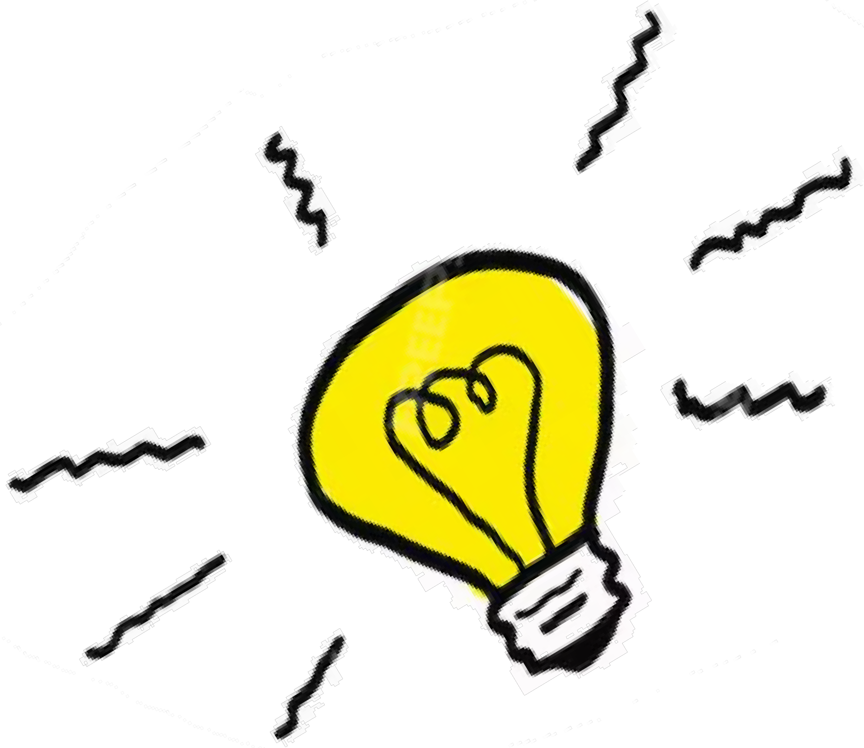


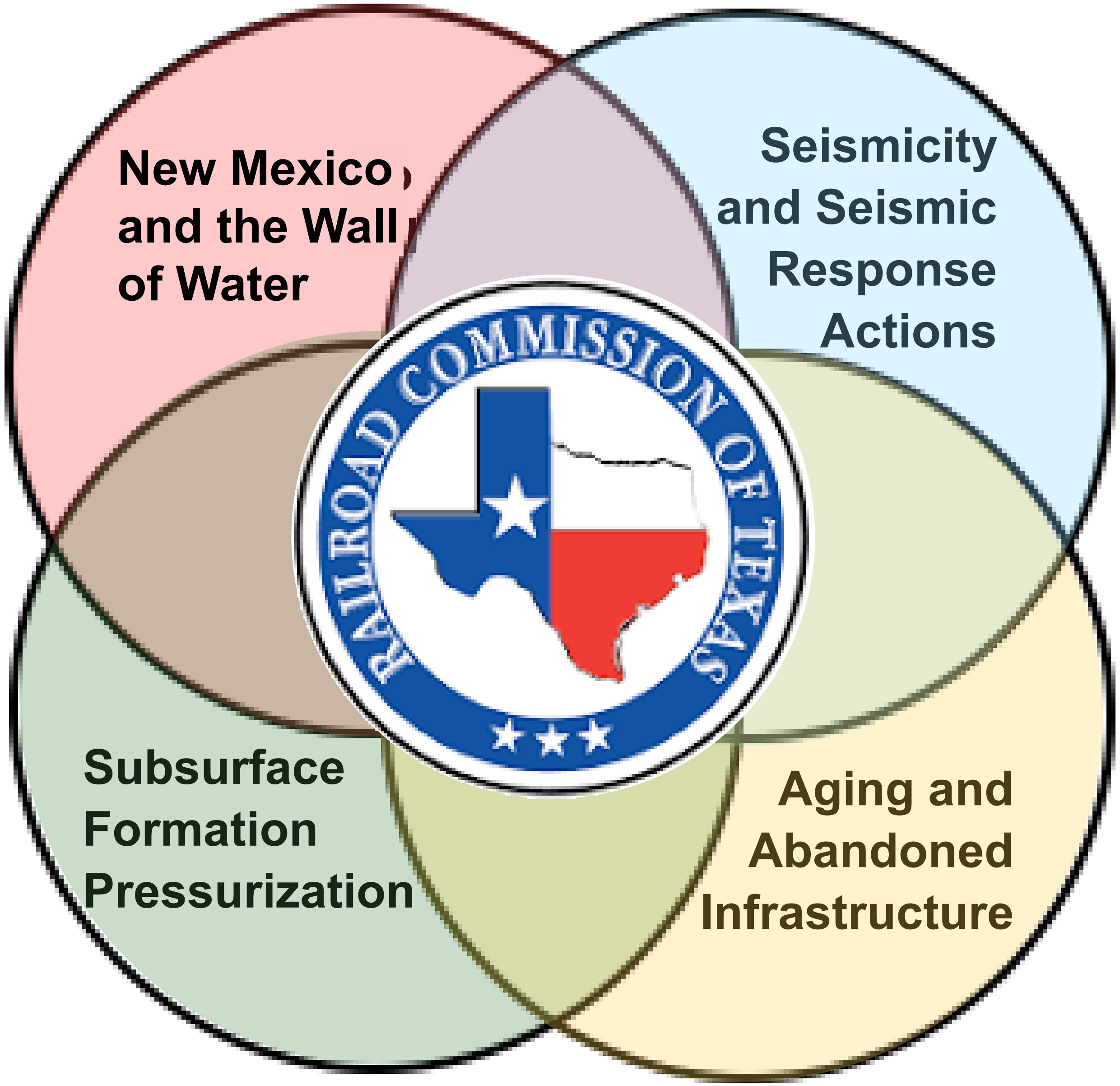
SHALLOW FORMATIONS ARE OVERPRESSURED & INCREASING IN PRESSURE

Orphan Wells and Aging Infrastructure

- Orphan wells can be shallow, leaky subsurface pollution conduits.
- Aging infrastructure and compromised integrity means they were not built for today's pressures.
- The vast majority of Orphan wells are in old shallow EOR fields.
- **Orphan wells can be close to groundwater and freshwater formations**






New Mexico and the Wall of Water
Seismicity and Seismic Response Actions
RAILROAD COMMISSION OF TEXAS
Subsurface Formation Pressurization
Aging and Abandoned Infrastructure

Texas RRC "Raising the Bar" for new Permian SWD Permits

(EnergyMaker's synopsis of proposed new permitting concepts under discussion)

Ch Ch Ch Ch Changes……

Expanding the AOR : ¼ mile to 2 miles

Limited by local Frac Data

Limited by local & projected Operating BHPs

Daily/Monthly Reporting and Submission

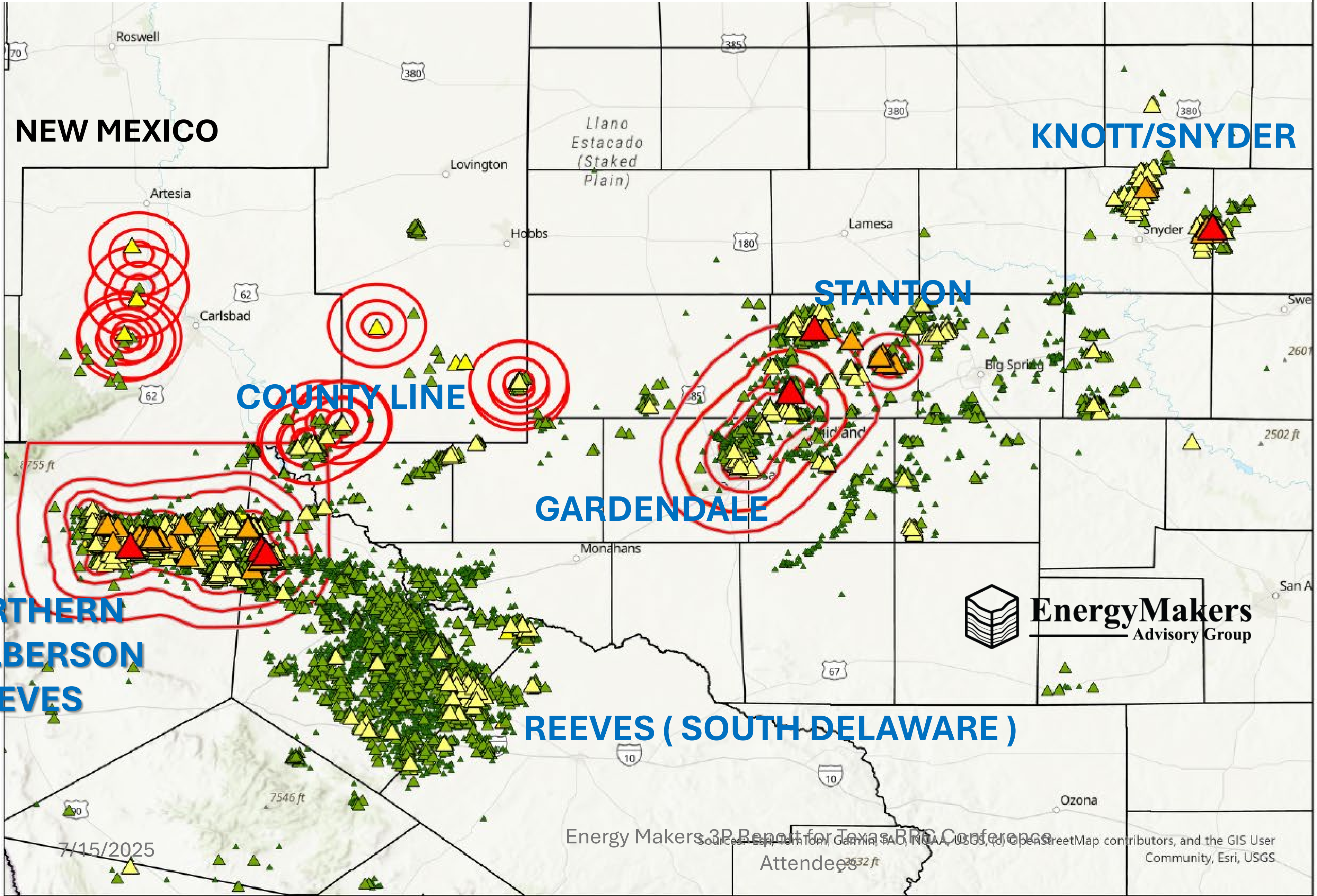
Reduce exposure to:

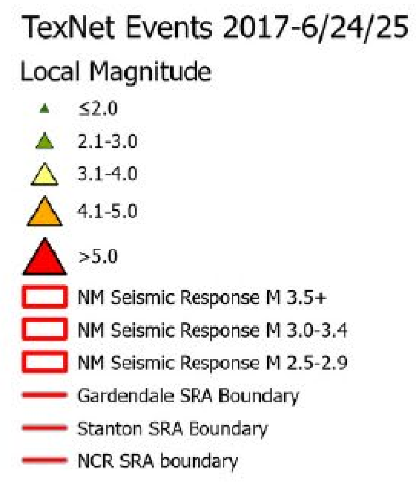
- Freshwater contamination
- Leaky /compromised nearby wells
- Unconfined intervals
- Old Wells / compromised infrastructure
- "unknown unknowns" (missing data)

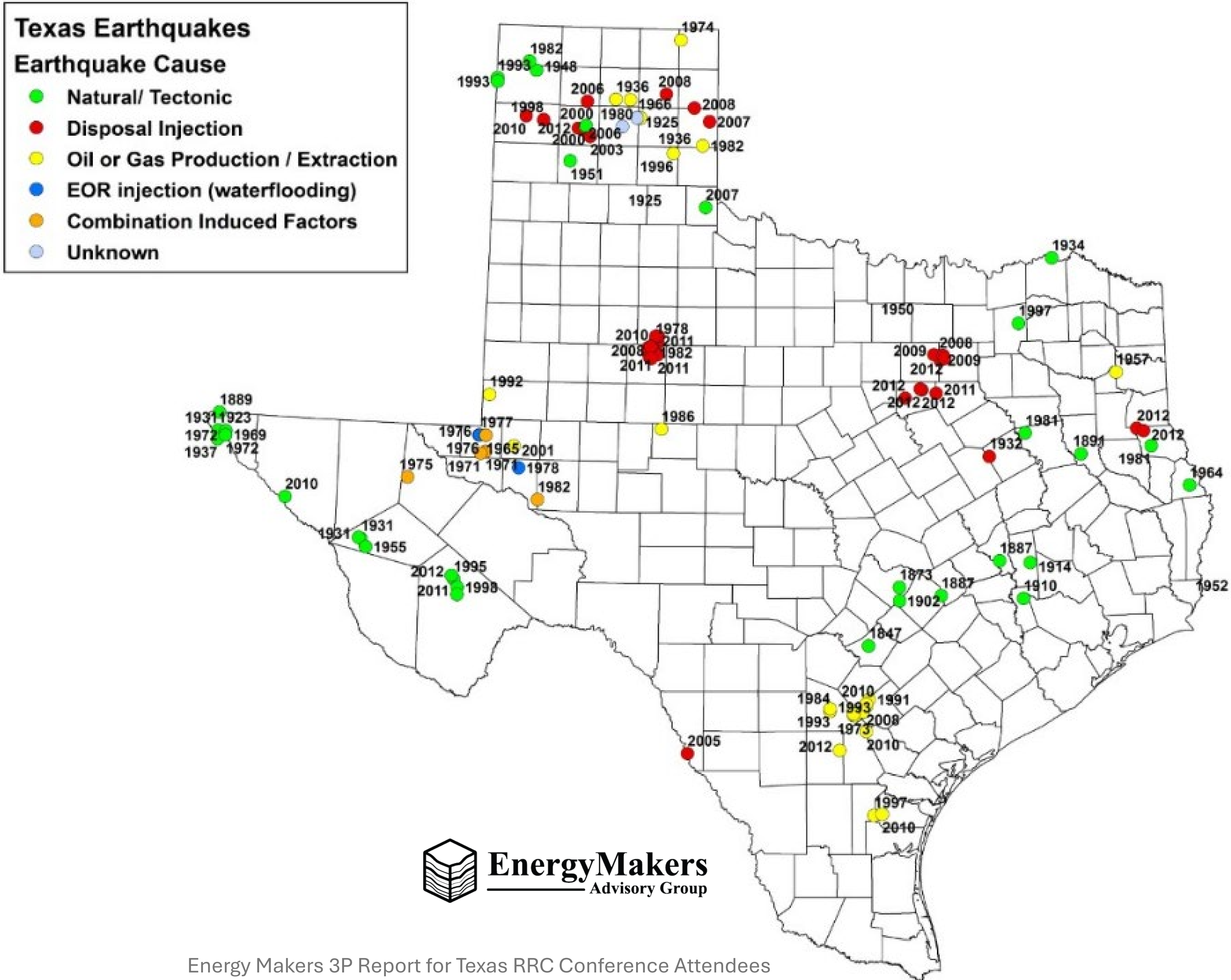
- ➢ Will regulate shallow SWD mainly on pressure (BHPs)
- ➢ Will regulate deeper SWD wells based on seismic risk

Background: Understanding Induced Seismicity is….. "Complicated"

Seismically Active Areas in The Permian







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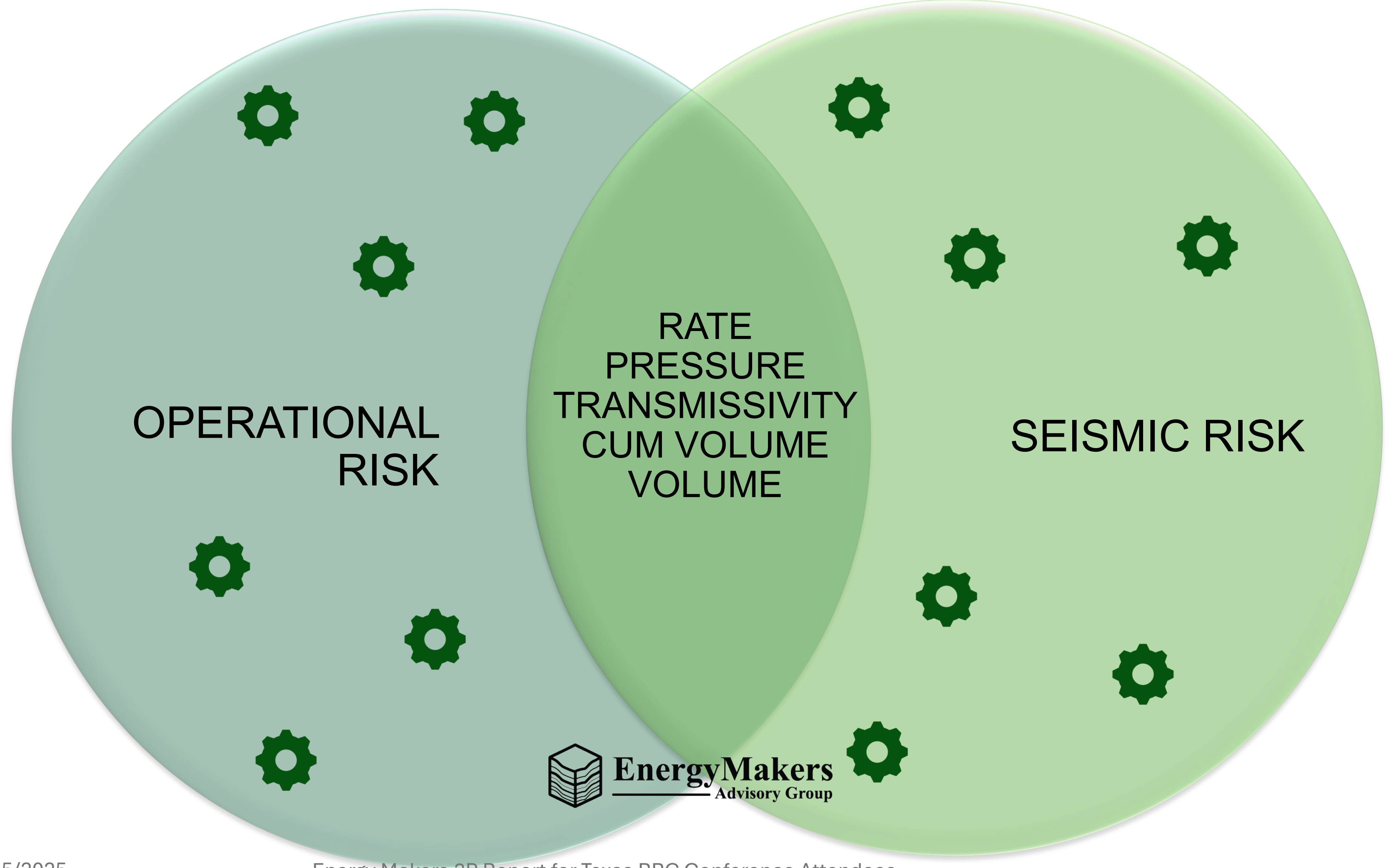
Pressure Problems are different than Seismic Problems



Contributors to Induced Seismicity are multifaceted and complex

Reservoir Conditions Ex:

- Presence and proximity to faults and fault networks
- Fault orientation relative to local stress fields
- Pore pressure and pathways
- Fault friction and structure, etc.
- Rock Strength / Brittleness
- Temperature
- Pathways to deep basement faults
- Fluid / pressure balance in reservoir

Formation Permeability Ex:

Can be complex:

- Higher permeability formations provide more pathways for fluid/pressure transmission and dispersion,
- Higher permeability faults can allow pore pressure diffusion to be channeled long distances, and
- Lower permeability faults can serve as a bottleneck allowing stress to accumulate

Injection Parameters Ex:

- Cumulative injected volume
- Injection rate
- Injection pressure
- Fluid temperature
- Injection depth
- etc.

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Prevailing Wisdom about Induced Seismicity….

Doesn't always prove to be true when you look at the data.

See Presentation Details at Conference:

Claim #1: ***"High Local SWD Volumes Induce Seismicity"***

Claim #2: ***"Deep SWD Volumes Induce Seismicity"***

Claim #3: ***"High Pressures Induce Seismicity"***

Midland Basin Bottomhole Pressures (psi/ft) by County and Depth Interval - 2021

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BottomHole Pressure Gradient PSI/FT	≤0.5	0.50-0.60	0.60-0.70	0.70-0.80	0.80-0.90	0.90 +
Texas RRC References for Environmental Concerns		Can Flow to Surface	Moderate risk to USDW	Elevated risk to USDW	Likely Fracture Initiation	Fracture containment issues

Midland Basin Counties Avg. Bottomhole Pressure Gradient / County (psi/ft)

Ft. Subsurface	County A	County B	County C	County D	County E	County F	County G	County H	County I	County J	County K	County L	County M	County N	County O	County P	County Q	County R	County S	County T	County U	County V	County W	County X	County Y	County Z	County ZZ
-							0.61									0.81		0.92	0.97	0.67	0.84						0.99
1,000	0.78	0.46	0.46	0.87	0.72		0.85		0.93						0.81	0.88	0.88	0.75	0.71	0.76		0.83		0.69			0.74
2,000		0.59					0.85		0.79		0.61			0.77	0.60	0.80	0.83	0.74	0.62	0.76	0.73	0.52		0.57	0.60		0.63
3,000	0.91	0.66	0.73	0.74		0.66	0.68	0.64	0.73	0.93	0.64	0.67	0.71	0.75	0.62	0.78	0.83	0.56	0.65	0.76	0.70	0.65	0.71	0.69	0.66	0.65	0.52
4,000	0.77	0.74	0.70	0.80	0.74	0.69	0.59	0.64	0.68	0.71	0.63	0.67	0.66	0.65	0.54		0.75	0.65	0.57	0.75	0.68	0.70	0.69	0.64	0.66	0.60	0.88
5,000	0.81	0.67	0.67	0.72	0.71	0.66	0.65		0.68	0.72	0.60	0.72	0.59	0.61	0.47		0.62	0.69	0.51		0.57	0.53	0.61	0.57	0.63	0.55	0.47
6,000		0.63	0.65	0.63	0.66	0.69			0.64	0.68	0.63	0.49	0.58	0.52	0.48	0.48	0.62		0.53	0.56	0.48		0.58	0.50	0.33	0.48	0.46
7,000		0.66	0.69	0.71			0.45		0.48	0.53	0.48	0.49	0.57	0.61	0.65	0.51	0.63	0.67		0.77		0.53	0.48	0.49	0.54	0.53	0.50
8,000		0.64	0.51	0.49		0.56	0.51			0.49	0.56	0.54	0.57	0.57	0.53	0.59		0.62		0.68		0.51	0.72	0.49	0.56	0.42	0.66
9,000		0.41		0.47						0.49	0.54		0.64	0.45	0.62					0.56	0.58			0.46		0.30	0.60
10,000		0.51		0.51						0.49	0.51	0.53			0.58						0.65	0.57	0.51		0.49	0.46	
11,000	0.47	0.35								0.47	0.45	0.57	0.45		0.45						0.60	0.60	0.48	0.58	0.46		
12,000		0.47	0.43							0.46	0.53	0.56									0.60		0.61	0.58			
13,000		0.44	0.47								0.49	0.54											0.59	0.56			

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Earthquake Correlations to Pressures: Central Oklahoma

Central Oklahoma Counties: A Bifurcated Landscape

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CENTRAL OKLAHOMA

Injection Depth Range (ft)	Beckham	Roger Mills	Dewey	Custer	Washita	Caddo	Blaine	Kingfisher	Canadian	Grady	Mcclain	Cleveland	Oklahoma	Logan	Payne	Lincoln	Pottawatomie	Seminole	Hughes	Okfuskee	Creek	Tulsa	Okmulgee	Wagoner	Muskogee	Mcintosh	Pittsburg	Latimer	Haskell	Leflore
0-999	0.40									1.51					0.45	0.44		0.59	0.66	0.54	0.46	0.44	0.49	0.54	0.73					
1,000+	0.54	1.00	0.57		1.27	0.79			0.85	0.68	0.84	0.82		0.81	0.61	0.59	0.48	0.53	0.59	0.51	0.59	0.55	0.51	0.56	0.58		0.64	0.92	0.54	0.89
2,000+	0.44	0.86				0.78		0.99	0.81	0.61	0.56	0.61	0.62	0.56	0.51	0.54	0.54	0.52	0.51	0.51	0.51	0.45	0.50		0.60	0.56	0.64	0.95		0.63
3000+	0.64		0.81		0.93	0.69	0.63	0.69	0.48	0.57	0.63		0.55	0.55	0.53	0.52	0.50	0.50	0.51	0.50	0.46	0.47	0.50		0.62	0.66	0.66			
4000+	0.68	0.65	0.64	0.66	0.79	0.58	0.64	0.63	0.70	0.65	0.59	0.56	0.58	0.55	0.54	0.52	0.52	0.51	0.52	0.53	0.50		0.47						0.46	
5000+	0.56	0.66	0.61	0.52	0.70	0.57	0.60	0.59		0.61	0.70	0.59	0.52	0.54	0.51	0.49	0.54	0.52	0.48	0.47										0.48
6000+	0.44		0.61			0.53	0.60	0.56	0.64	0.65	0.61	0.54	0.54	0.53	0.52	0.49	0.48	0.50	0.54	0.51						0.56				
7000+			0.59			0.46		0.59	0.56	0.62	0.53	0.54	0.59	0.52	0.50	0.48	0.48	0.49	0.63	0.47							0.63			
8000+	0.57			0.67		0.61	0.44	0.50	0.56	0.62	0.59	0.55	0.55	0.52	0.50	0.50	0.48	0.48	0.72								0.58			
9000+			0.54			0.53		0.58	0.56	0.55	0.54		0.50			0.47			0.70											
10000+			0.53			0.54				0.62			0.48												0.48			0.51		
11000+													0.50						0.54											
12000+						0.56																								
16000+										0.56																				
17000+																					0.46									

Earthquake Correlations to Pressures: State of Oklahoma

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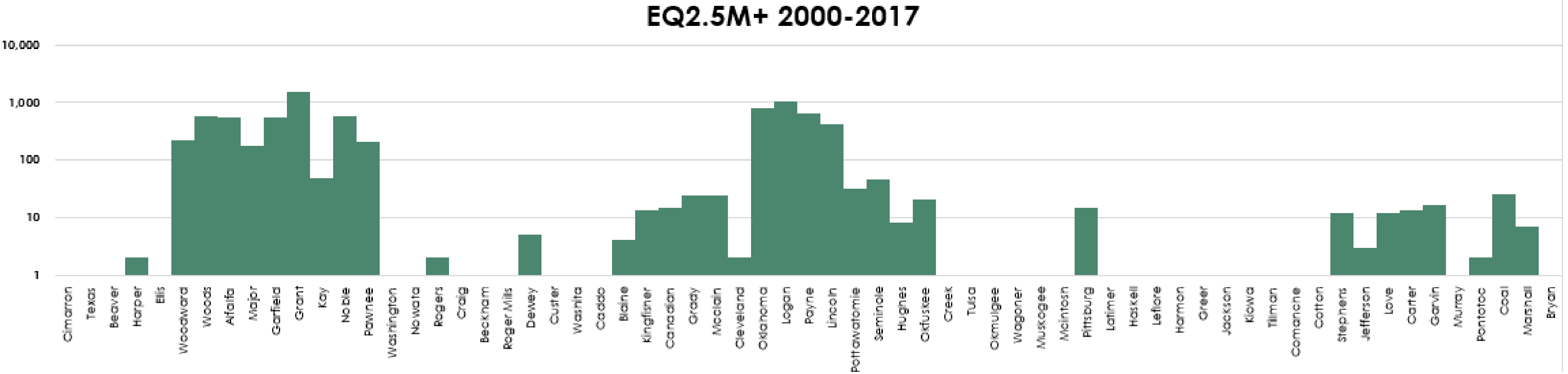
Injection Depth Range (ft)	Northern Oklahoma Counties: Substantially Underpressured (Occasional Shallow Exceptions)																	
0-999							0.43							0.43	0.46	0.71	0.67	
1,000+	0.57	0.44	0.74		1.06		0.82			0.67	0.66	0.54	0.59	0.55	0.53	0.49	0.62	0.53
2,000+	0.55	0.47	0.45		0.72		0.67	0.74		0.55	0.60	0.52	0.55	0.51	0.45	0.53		
3000+	0.50	0.47	0.49	0.55	0.53	0.64	0.62		0.68	0.55	0.56	0.52	0.52	0.50				
4000+	0.49	0.49	0.46	0.68	0.58	0.51	0.47	0.53	0.56	0.52	0.54	0.50	0.54	0.50				
5000+	0.66	0.56	0.46	0.52	0.52	0.48	0.47	0.50	0.63	0.55	0.53	0.50	0.50	0.52			0.48	
6000+		0.53	0.48	0.65	0.46	0.44	0.50	0.53	0.57	0.57	0.52	0.50	0.53					
7000+		0.52	0.62	0.66		0.56	0.48	0.49	0.54	0.52	0.55	0.50	0.52					
8000+			0.46	0.49	0.62		0.47	0.48	0.54	0.50		0.47						
9000+						0.66	0.44	0.50	0.52	0.50	0.52							
10000+						0.48	0.45		0.57									
11000+							0.46											
12000+																		
16000+																		
17000+																		

Injection Depth Range (ft)	Central Oklahoma Counties: A Bifurcated Landscape																													
0-999	0.40									1.51					0.45	0.44		0.59	0.66	0.54	0.46	0.44	0.49	0.54	0.73					
1,000+	0.54	1.00	0.57		1.27	0.79			0.85	0.68	0.84	0.82		0.81	0.61	0.59	0.48	0.53	0.59	0.51	0.59	0.55	0.51	0.56	0.58		0.64	0.92	0.54	0.89
2,000+	0.44	0.86				0.78		0.99	0.81	0.61	0.56	0.61	0.62	0.56	0.51	0.54	0.54	0.52	0.51	0.51	0.51	0.45	0.50		0.60	0.56	0.64	0.95		0.63
3000+	0.64		0.81		0.93	0.69	0.63	0.69	0.48	0.57	0.63		0.55	0.55	0.53	0.52	0.50	0.50	0.51	0.50	0.46	0.47	0.50		0.62	0.66	0.66			
4000+	0.68	0.65	0.64	0.66	0.79	0.58	0.64	0.63	0.70	0.65	0.59	0.56	0.58	0.55	0.54	0.52	0.52	0.51	0.52	0.53	0.50		0.47						0.46	
5000+	0.56	0.66	0.61	0.52	0.70	0.57	0.60	0.59		0.61	0.70	0.59	0.52	0.54	0.51	0.49	0.54	0.52	0.48	0.47										0.48
6000+	0.44		0.61			0.53	0.60	0.56	0.64	0.65	0.61	0.54	0.54	0.53	0.52	0.49	0.48	0.50	0.54	0.51						0.56				
7000+			0.59			0.46		0.59	0.56	0.62	0.53	0.54	0.59	0.52	0.50	0.48	0.48	0.49	0.63	0.47							0.63			
8000+	0.57			0.67		0.61	0.44	0.50	0.56	0.62	0.59	0.55	0.55	0.52	0.50	0.50	0.48	0.48	0.72								0.58			
9000+			0.54			0.53		0.58	0.56	0.55	0.54		0.50			0.47			0.70											
10000+			0.53			0.54				0.62			0.48												0.48			0.51		
11000+													0.50						0.54											
12000+						0.56																								
16000+										0.56																				
17000+																					0.46									

Injection Depth Range (ft)	Southern Oklahoma Counties: EOR may Contribute to Pressure Schemes																
0-999		0.44		0.48		0.60		0.72	0.46		0.81	0.65		0.70			0.64
1,000+			0.71	0.49	0.62	0.58	0.60	0.58	0.69	0.60	0.72	0.71	0.67	0.67	0.88	0.69	
2,000+			0.64		0.58	0.67	0.58	0.58	0.54	0.55	0.63	0.66	0.62	0.62	0.55	0.53	
3000+			0.47		0.55			0.60	0.62	0.53	0.66	0.63	0.66	0.71	0.77		
4000+	0.64		0.59		0.53			0.61			0.66	0.64	0.65	0.70		0.54	
5000+					0.61			0.60		0.54	0.65	0.62		0.50	0.69	0.58	0.56
6000+						0.52		0.58		0.70	0.68	0.59	0.50		0.73		0.50
7000+								0.65		0.60	0.55	0.53			0.51		
8000+								0.57		0.70	0.47	0.55			0.53		
9000+			0.48							0.72	0.47	0.53			0.55		
10000+										0.64	0.46	0.60					
11000+												0.49					
12000+																	
16000+																	
17000+																	

Earthquakes: State of Oklahoma, by County



Earthquake Correlations to Pressures: State of Oklahoma

Low Pressure psi/ft | High Pressure psi/ft

Subsurface Depth 1,000' increments

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Northern Oklahoma Counties: Substantially Underpressured (Occasional Shallow Exceptions)

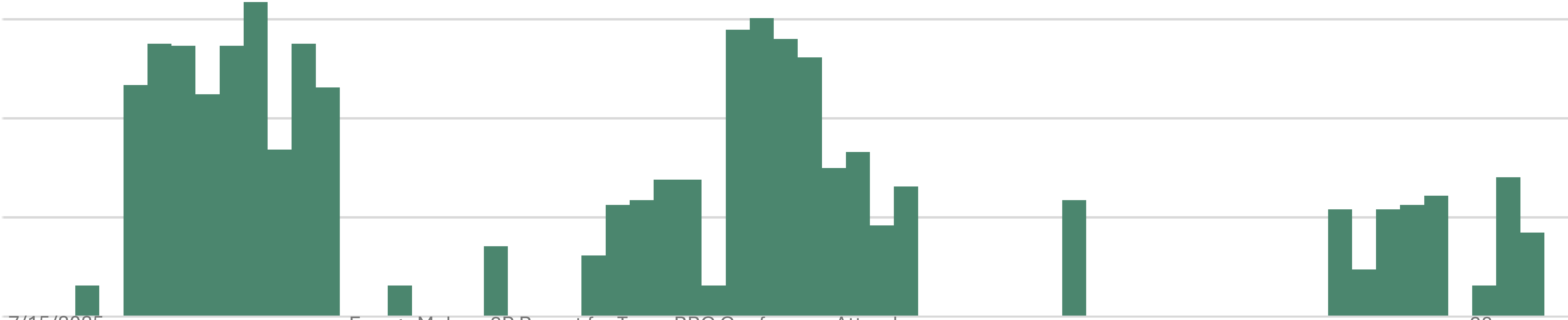
						0.43							0.43	0.46	0.71	0.67	
0.57	0.44	0.74		1.06		0.82			0.67	0.66	0.54	0.59	0.55	0.53	0.49	0.62	0.53
0.55	0.47	0.45		0.72		0.67	0.74		0.55	0.60	0.52	0.55	0.51	0.45	0.53		
0.50	0.47	0.49	0.55	0.53	0.64	0.62		0.68	0.55	0.56	0.52	0.52	0.50				
0.49	0.49	0.46	0.68	0.58	0.51	0.47	0.53	0.56	0.52	0.54	0.50	0.54	0.50				
0.66	0.56	0.46	0.52	0.52	0.48	0.47	0.50	0.63	0.55	0.53	0.50	0.50	0.52			0.48	
	0.53	0.48	0.65	0.46	0.44	0.50	0.53	0.57	0.57	0.52	0.50	0.53					
	0.52	0.62	0.66		0.56	0.48	0.49	0.54	0.52	0.55	0.50	0.52					
		0.46	0.49	0.62		0.47	0.48	0.54	0.50		0.47						
					0.66	0.44	0.50	0.52	0.50	0.52							
					0.48	0.45		0.57									
						0.46											

Central Oklahoma Counties: A Bifurcated Landscape

0.40									1.51					0.45	0.44		0.59	0.66	0.54	0.46	0.44	0.49	0.54	0.73					
0.54	1.00	0.57		1.27	0.79			0.85	0.68	0.84	0.82		0.81	0.61	0.59	0.48	0.53	0.59	0.51	0.59	0.55	0.51	0.56	0.58		0.64	0.92	0.54	0.89
0.44	0.86				0.78		0.99	0.81	0.61	0.56	0.61	0.62	0.56	0.51	0.54	0.54	0.52	0.51	0.51	0.51	0.45	0.50		0.60	0.56	0.64	0.95		0.63
0.64		0.81		0.93	0.69	0.63	0.69	0.48	0.57	0.63		0.55	0.55	0.53	0.52	0.50	0.50	0.51	0.50	0.46	0.47	0.50		0.62	0.66	0.66			
0.68	0.65	0.64	0.66	0.79	0.58	0.64	0.63	0.70	0.65	0.59	0.56	0.58	0.55	0.54	0.52	0.52	0.51	0.52	0.53	0.50		0.47						0.46	
0.56	0.66	0.61	0.52	0.70	0.57	0.60	0.59		0.61	0.70	0.59	0.52	0.54	0.51	0.49	0.54	0.52	0.48	0.47										0.48
0.44		0.61			0.53	0.60	0.56	0.64	0.65	0.61	0.54	0.54	0.53	0.52	0.49	0.48	0.50	0.54	0.51						0.56				
		0.59			0.46		0.59	0.56	0.62	0.53	0.54	0.59	0.52	0.50	0.48	0.48	0.49	0.63	0.47							0.63			
0.57			0.67		0.61	0.44	0.50	0.56	0.62	0.59	0.55	0.55	0.52	0.50	0.50	0.48	0.48	0.72								0.58			
		0.54			0.53		0.58	0.56	0.55	0.54		0.50			0.47			0.70											
		0.53			0.54				0.62			0.48												0.48			0.51		
												0.50						0.54											
					0.56																								
									0.56																				
																				0.46									

Southern Oklahoma Counties: EOR may Contribute to Pressure Schemes

	0.44		0.48		0.60		0.72	0.46		0.81	0.65		0.70			0.64
		0.71	0.49	0.62	0.58	0.60	0.58	0.69	0.60	0.72	0.71	0.67	0.67	0.88	0.69	
		0.64		0.58	0.67	0.58	0.58	0.54	0.55	0.63	0.66	0.62	0.62	0.55	0.53	
		0.47		0.55			0.60	0.62	0.53	0.66	0.63	0.66	0.71	0.77		
0.64		0.59		0.53			0.61			0.66	0.64	0.65	0.70		0.54	
				0.61			0.60		0.54	0.65	0.62		0.50	0.69	0.58	0.56
					0.52		0.58		0.70	0.68	0.59	0.50		0.73		0.50
							0.65		0.60	0.55	0.53			0.51		
							0.57		0.70	0.47	0.55			0.53		
		0.48							0.72	0.47	0.53			0.55		
									0.64	0.46	0.60					
											0.49					



Claim # 1: ***Local Injection Volumes Drive Seismicity***

Development of complex patterns of anthropogenic uplift and subsidence in the Delaware Basin of West Texas and southeast New Mexico, USA

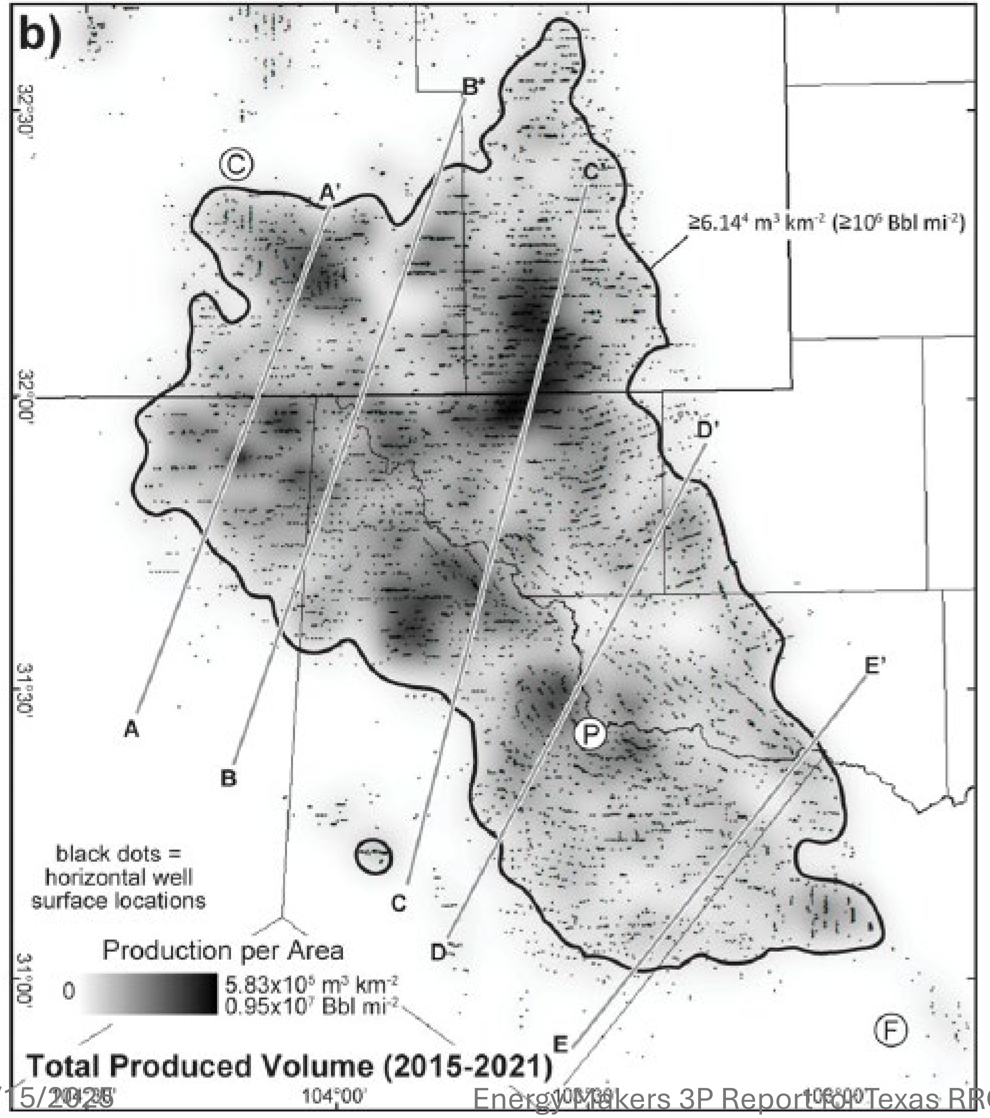
Peter Hennings [a,*], Scott Staniewicz [b], Katie Smye [a], Jingyi Chen [b], Elizabeth Horne [a], Jean-Philippe Nicot [a], Jun Ge [a], Robert Reedy [a], Bridget Scanlon [a]

[a] *Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin, P.O. Box X, Austin, TX 78713-8924, United States of America*
[b] *Department of Aerospace Engineering and Engineering Mechanics, The University of Texas at Austin, Austin, TX 78713-8924, United States of America*

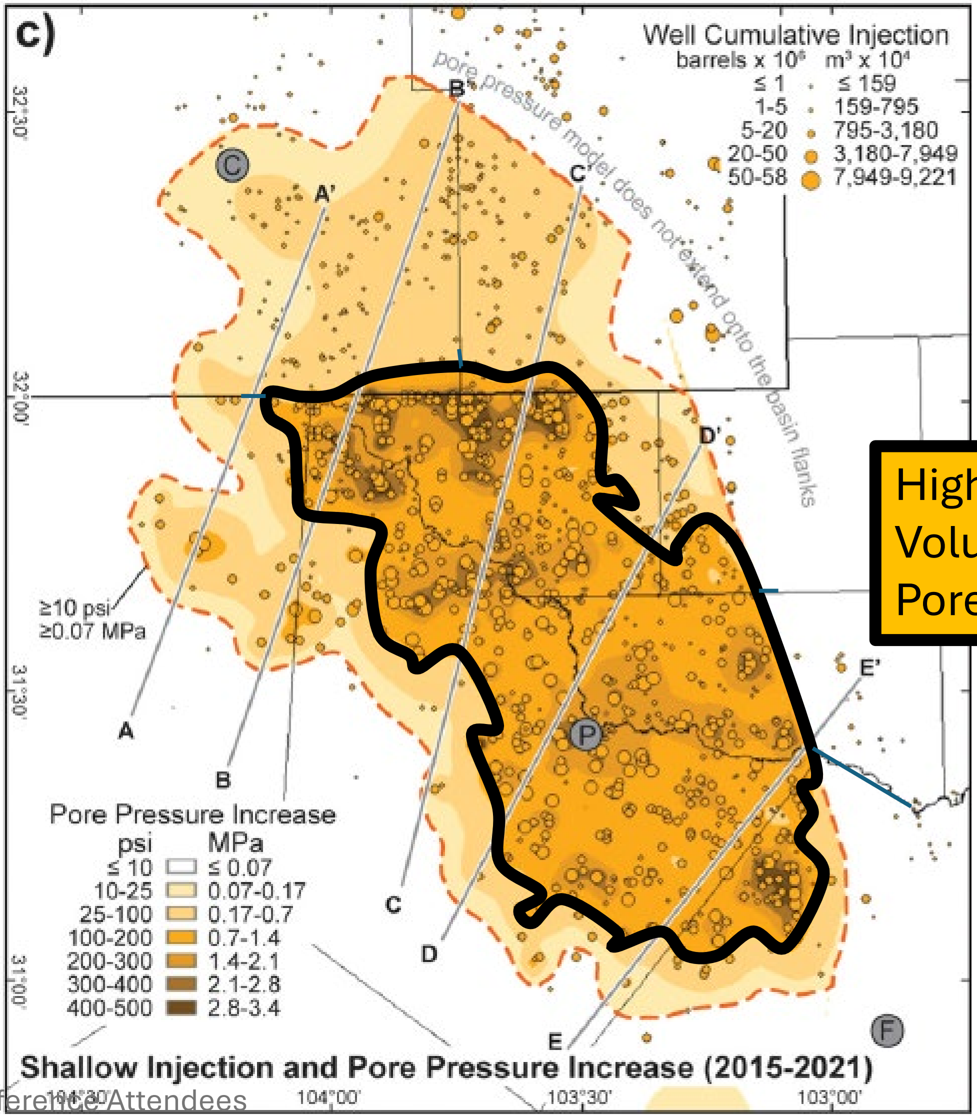
Annotations and commentary to follow by Energy Makers Advisory Group

Local versus "Far Field" Effects

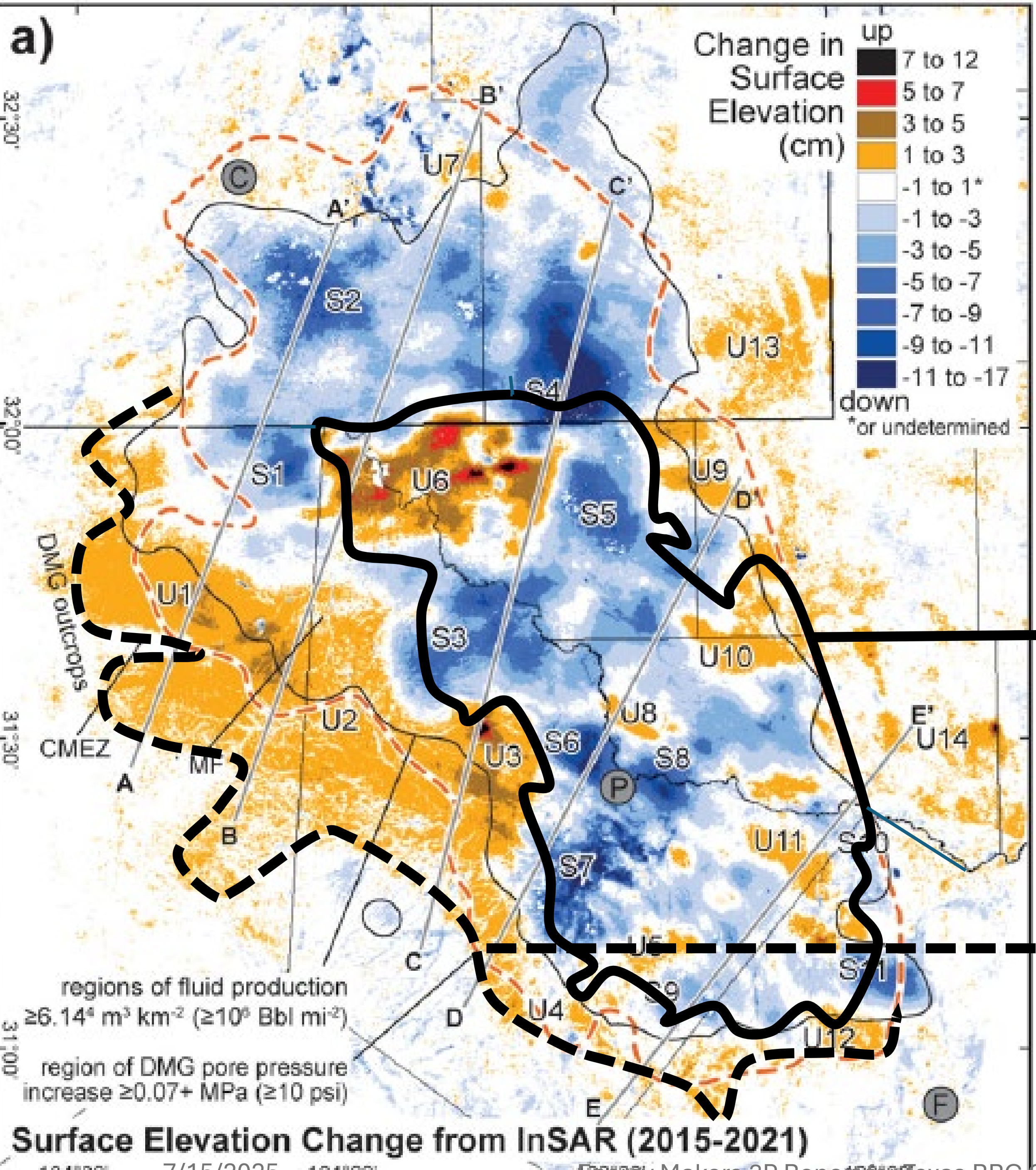
Produced Volumes > Surface Elevation Decrease



Injected Volumes > Surface Elevation Increase



High Injection Volumes, High Pore Pressure



Development of complex patterns of anthropogenic uplift and subsidence in the Delaware Basin of West Texas and southeast New Mexico, USA

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[b] Department of Aerospace Engineering and Engineering Mechanics, The University of Texas at Austin, Austin, TX 78713-8924, United States of America

High Injection Volumes, High Pore Pressure

InSAR Surface Elevation Change

Development of complex patterns of anthropogenic uplift and subsidence in the Delaware Basin of West Texas and southeast New Mexico, USA

Peter Hennings [a,*], Scott Staniewicz [b], Katie Smye [a], Jingyi Chen [b], Elizabeth Horne [a], Jean-Philippe Nicot [a], Jun Ge [a], Robert Reedy [a], Bridget Scanlon [a]

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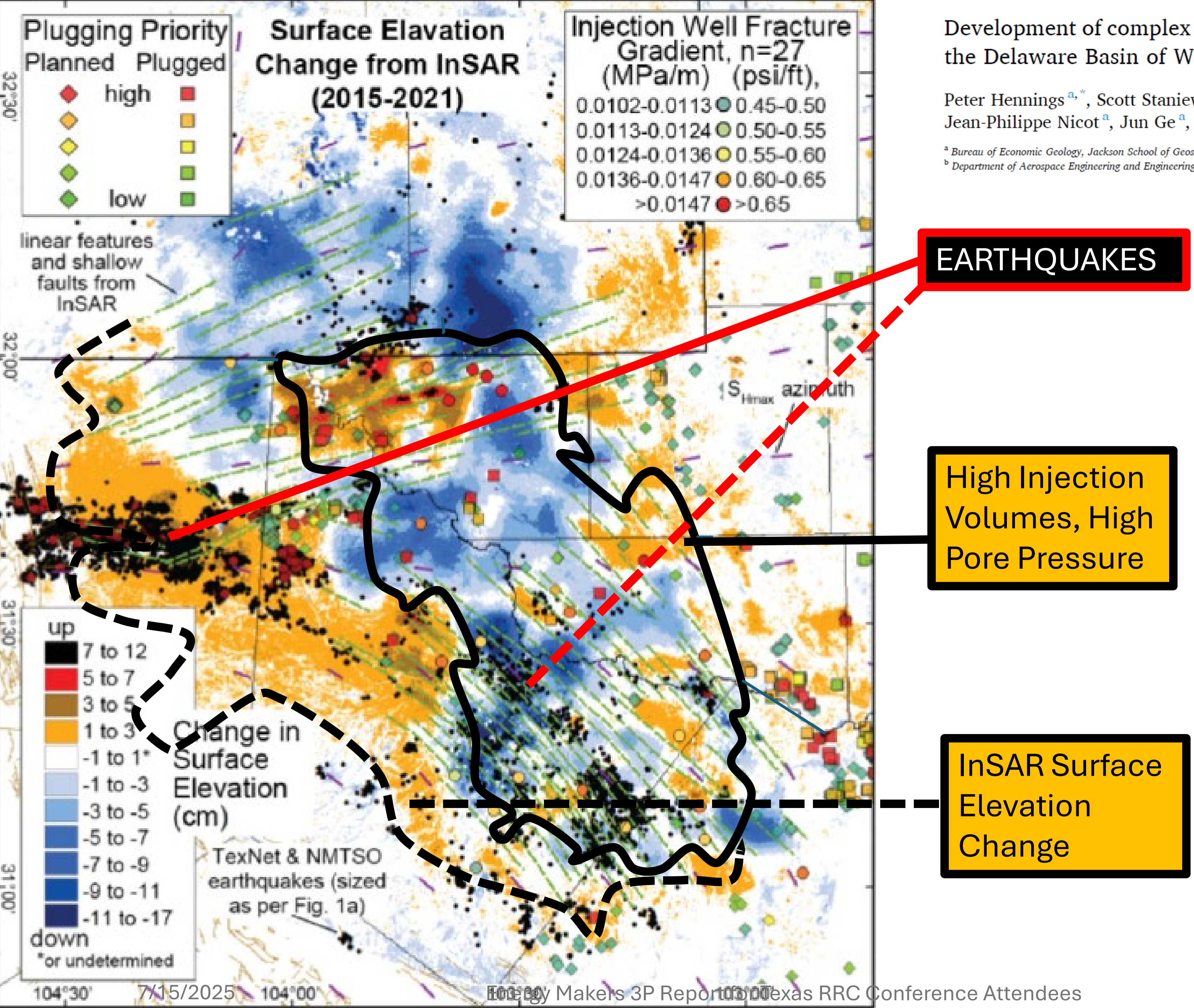

"Far Field" injection <u>and production</u> effects play a dominant role in Induced Seismicity – slow, long term, subsurface pressure communication pathways

Repeat: Contributors to Induced Seismicity are multifaceted and complex

Reservoir Conditions Ex:

- Presence and proximity to faults and fault networks
- Fault orientation relative to local stress fields
- Pore pressure and pathways
- Fault friction and structure, etc.
- Rock Strength / Brittleness
- Temperature
- Pathways to deep basement faults
- Fluid / pressure balance in reservoir

Formation Permeability Ex:

Can be complex:

- Higher permeability formations provide more pathways for fluid/pressure transmission and dispersion,
- Higher permeability faults can allow pore pressure diffusion to be channeled long distances, and
- Lower permeability faults can serve as a bottleneck allowing stress to accumulate

Injection Parameters Ex:

- Cumulative injected volume
- Injection rate
- Injection pressure
- Fluid temperature
- Injection depth
- etc.

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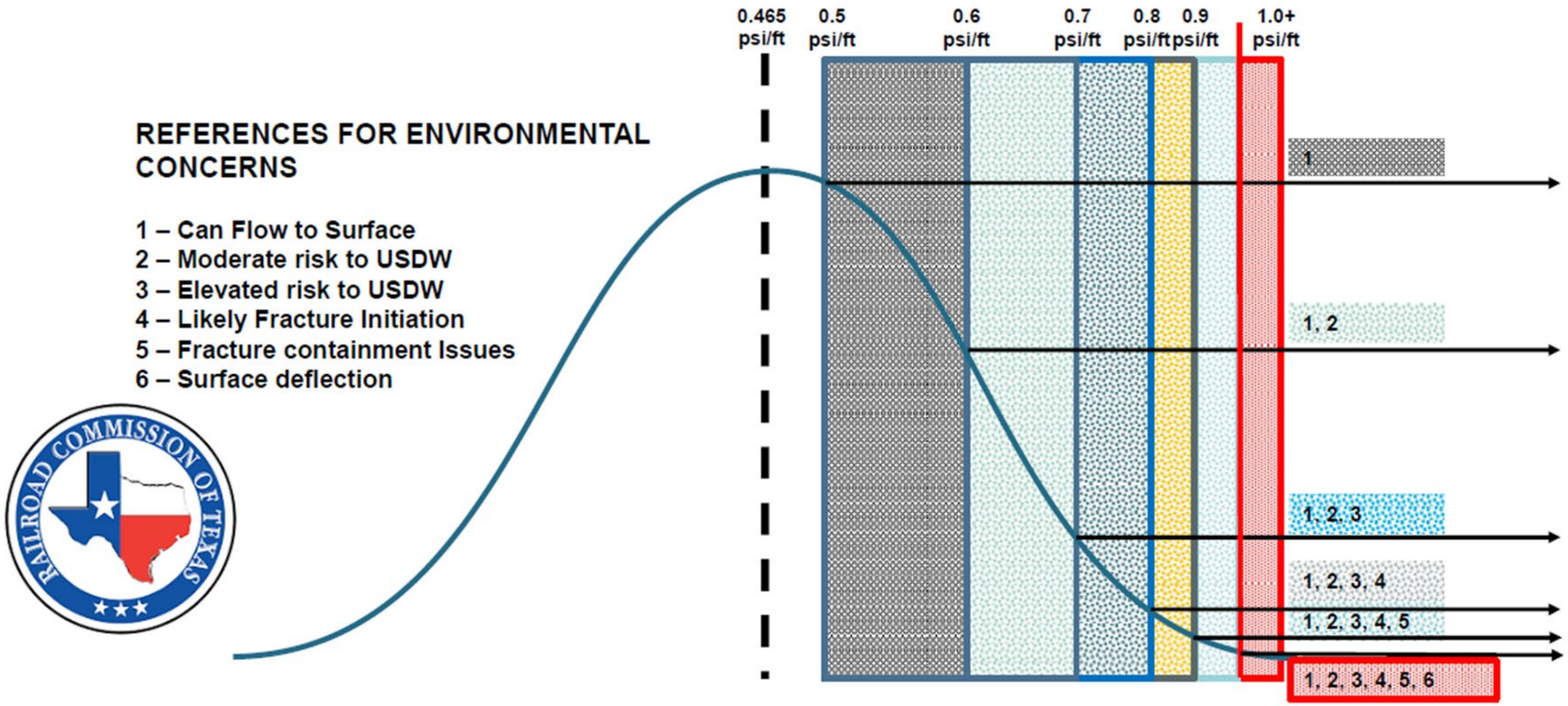
Chapter B
Fracture Gradient

Increased Reservoir Pressure

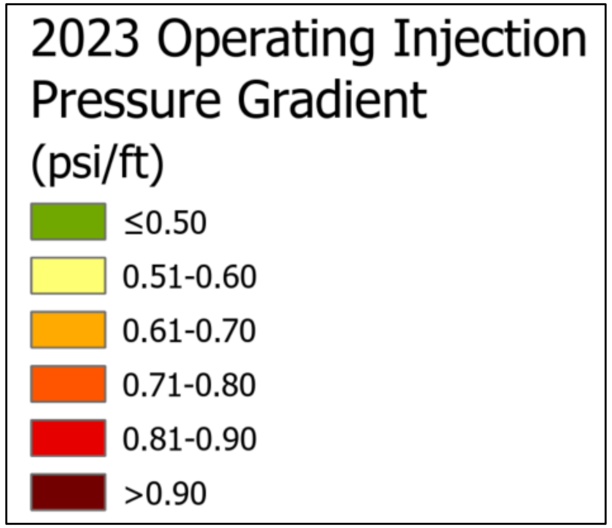
SIMPLE DISTRIBUTION OF ELEVATED PORE PRESSURE
DUE TO PRODUCED WATER INJECTION



BottomHole Pressure Gradient PSI/FT	≤0.5	0.50-0.60	0.60-0.70	0.70-0.80	0.80-0.90	0.90 +
Texas RRC References for Environmental Concerns		Can Flow to Surface	Moderate risk to USDW	Elevated risk to USDW	Likely Fracture Initiation	Fracture containment issues

3P Report: Bottom Hole Pressure Gradients, DMG

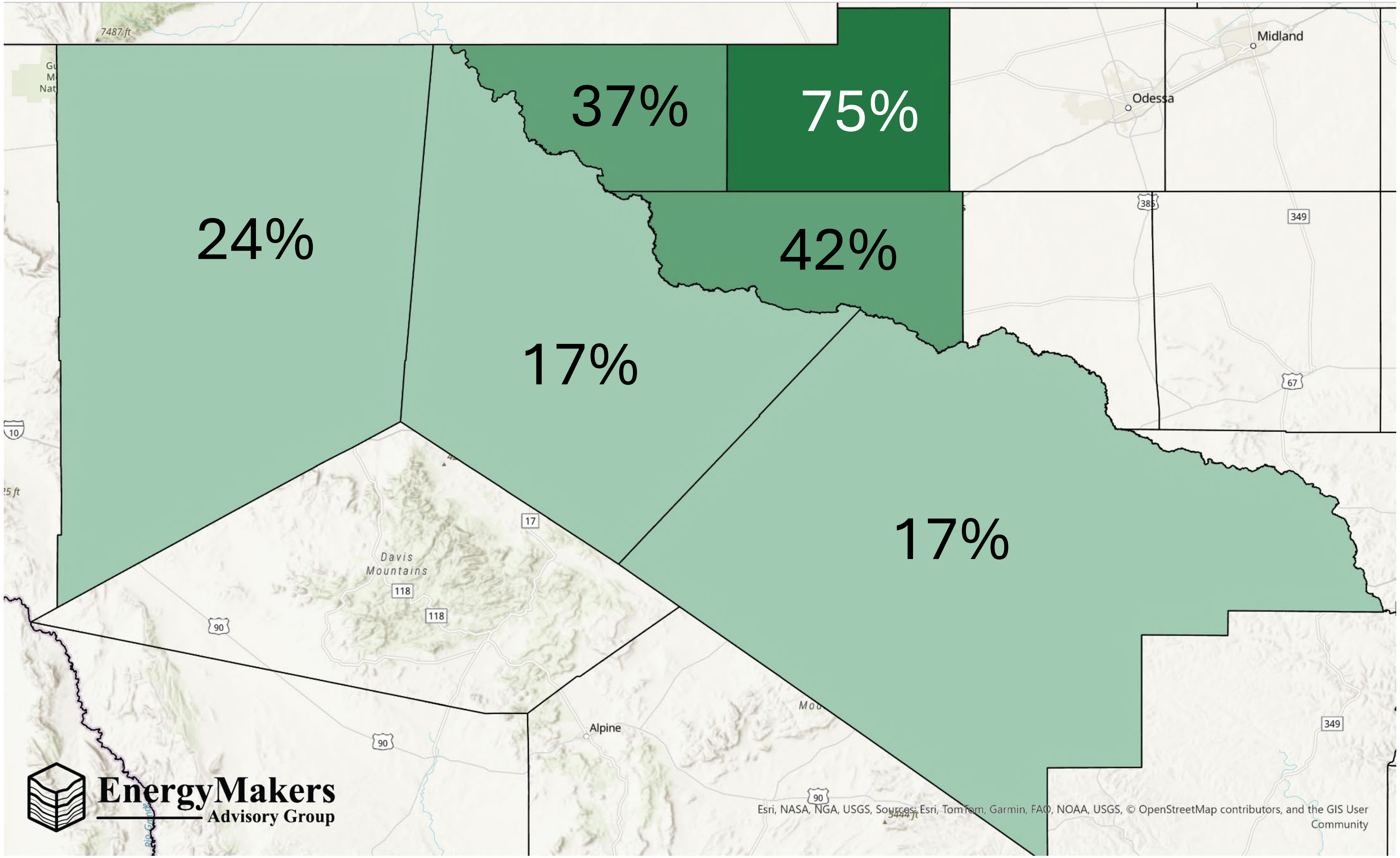
See Map Details at Conference!



Likelihood of injecting <u>below</u> DMG **Frac Pressure**?: (Yes, I am)

By County

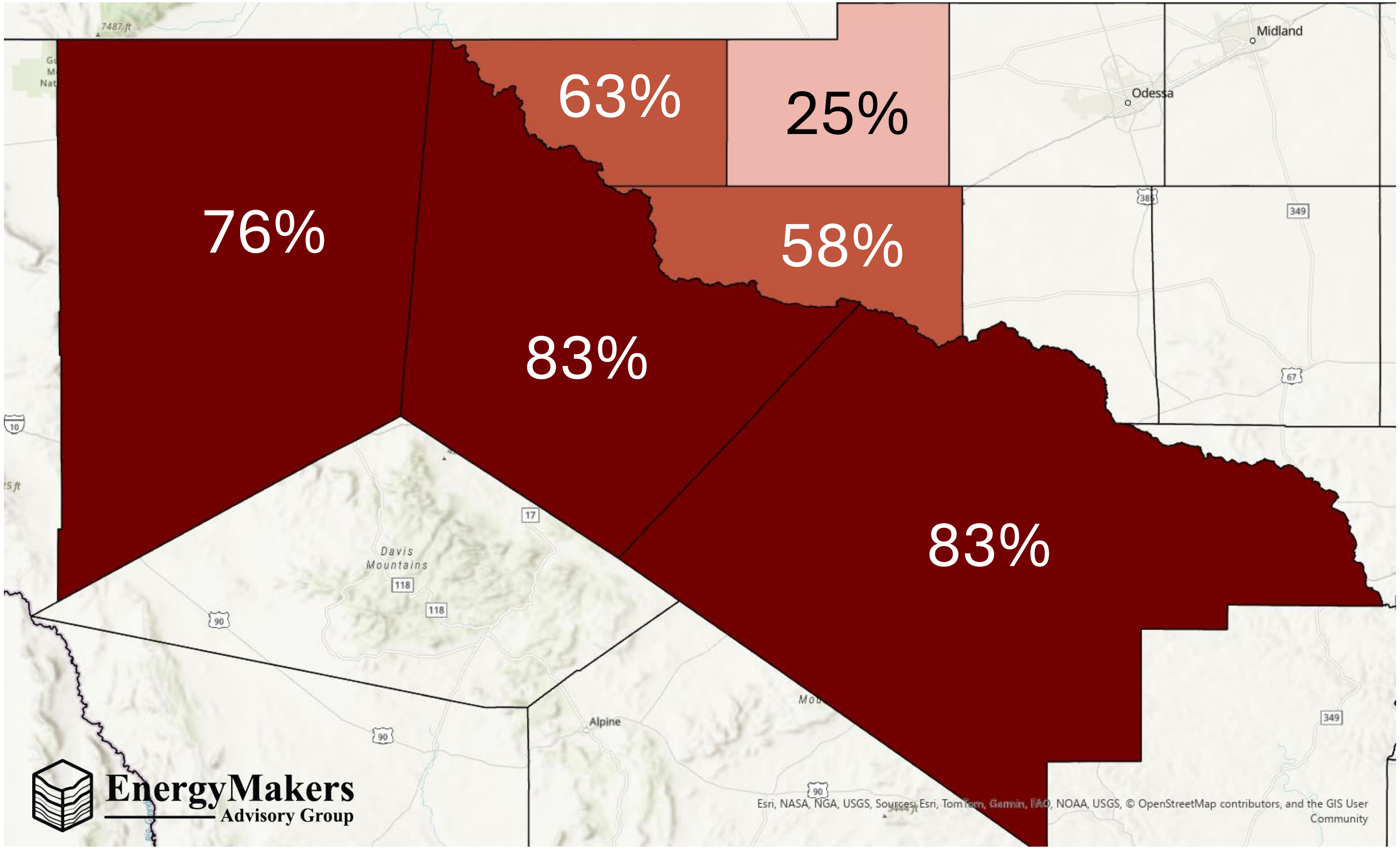
Percent of Wells w/ 2023 BHP =< Local Estimated DMG Frac Gradient



Likelihood of injecting above DMG **Frac Pressure**?:

By County

Percent of Wells w/ 2023 BHP >= Local Estimated DMG Frac Gradient



Under new guidance, the following % wells, injecting above estimated frac pressures for the Injection Interval, will require proof of upper and lower confinement with frac pressures above injection interval BHPs

Consequence?

SWD Permit Applicants will be required to profile Upper and Lower Confinement Intervals:

- Are 25’ thick or greater (relatively easy!)
- Have fracture pressures greater than anticipated injection Zone operating pressures
- Provide reliable confinement: prohibit fluid flow, (contemplate fractures, karsts, permeability, etc.)
- In the DMG, candidates may include the Castille or San Andres (upper confinement), or Cutoff Shale/Avalon/ Bonespring (lower confinement)
- Exercise requires geologic scrutiny – not a “layup”.

Chapter B
Bottomhole Pressure Gradients (and impact on Maximum Daily Allowable Injection Volumes)

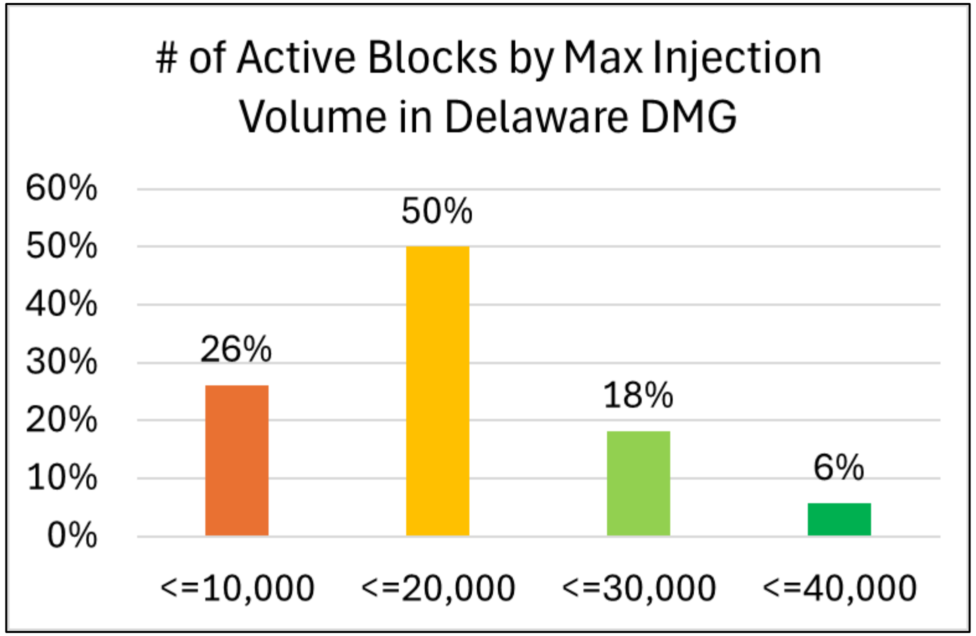
Translating TRRC Guidance to Maximum Daily Injection Volumes

BottomHole Pressure Gradient PSI/FT	≤0.5	0.50-0.60	0.60-0.70	0.70-0.80	0.80-0.90	0.90 +
Texas RRC References for Environmental Concerns		Can Flow to Surface	Moderate risk to USDW	Elevated risk to USDW	Likely Fracture Initiation	Fracture containment issues
Maximum Daily Injection Volumes	40,000 BPD	30,000 BPD	20,000 BPD	10,000 BPD	10,000 BOD	10,000 BPD

Detailed Maps Available at Conference Proceedings

MDIV is calculated for Average BHPS in the 2 Mile AOR.

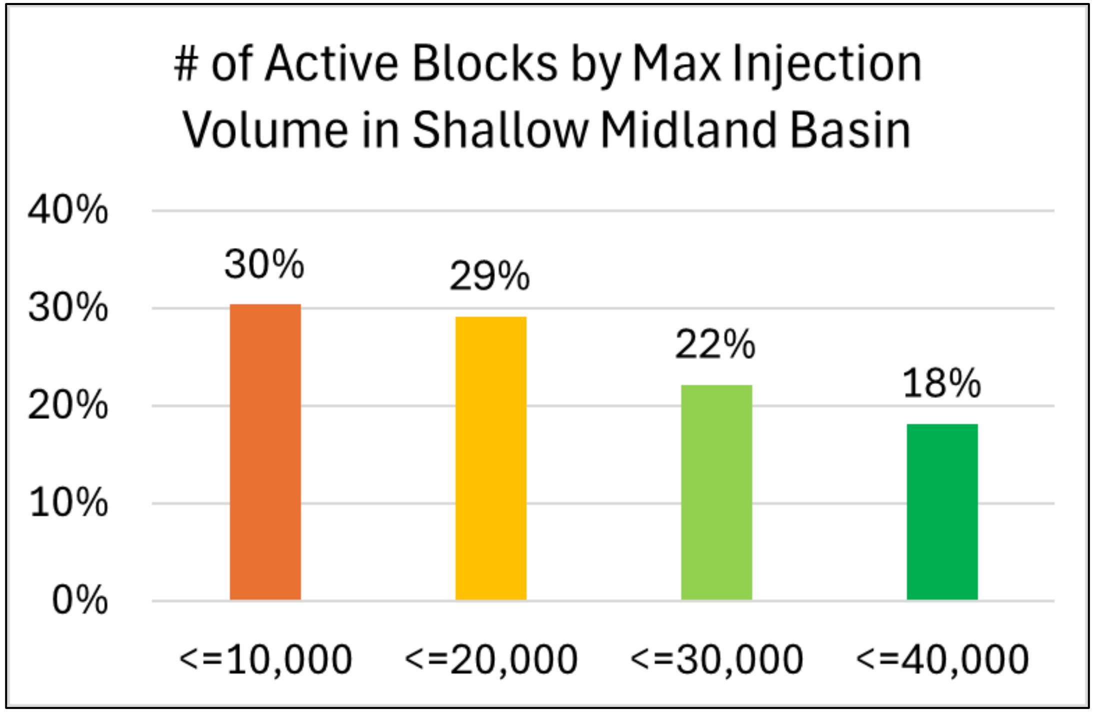
In the Delaware Basin on average 76% of DMG blocks will be restricted to 10,000 – 20,000 BPD.



Maximum Daily Injection Volumes	40,000 BPD	30,000 BPD	20,000 BPD	10,000 BPD	10,000 BOD	10,000 BPD

Similarly, 59 % of blocks in the Shallow Midland Basin would on average be restricted to 10,000-20,000 BPD, (41% at 30,000+ BPD)

Detailed Maps Available at Conference Proceedings



Maximum Daily Injection Volumes	40,000 BPD	30,000 BPD	20,000 BPD	10,000 BPD	10,000 BOD	10,000 BPD

Finding Relief From High BHPs is possible

Percent of Blocks with BHP IPG ≤0.6 psi/ft

Across the Delaware, **18%** of active DMG Blocks have BHPs =<.6psi/ft, and might allow MDIV as high as 30,000 BPD

Detailed Maps Available at Conference Proceedings

Tip #1: In the Midland Basin, Lower relative Pressures are obtained with Depth in many areas

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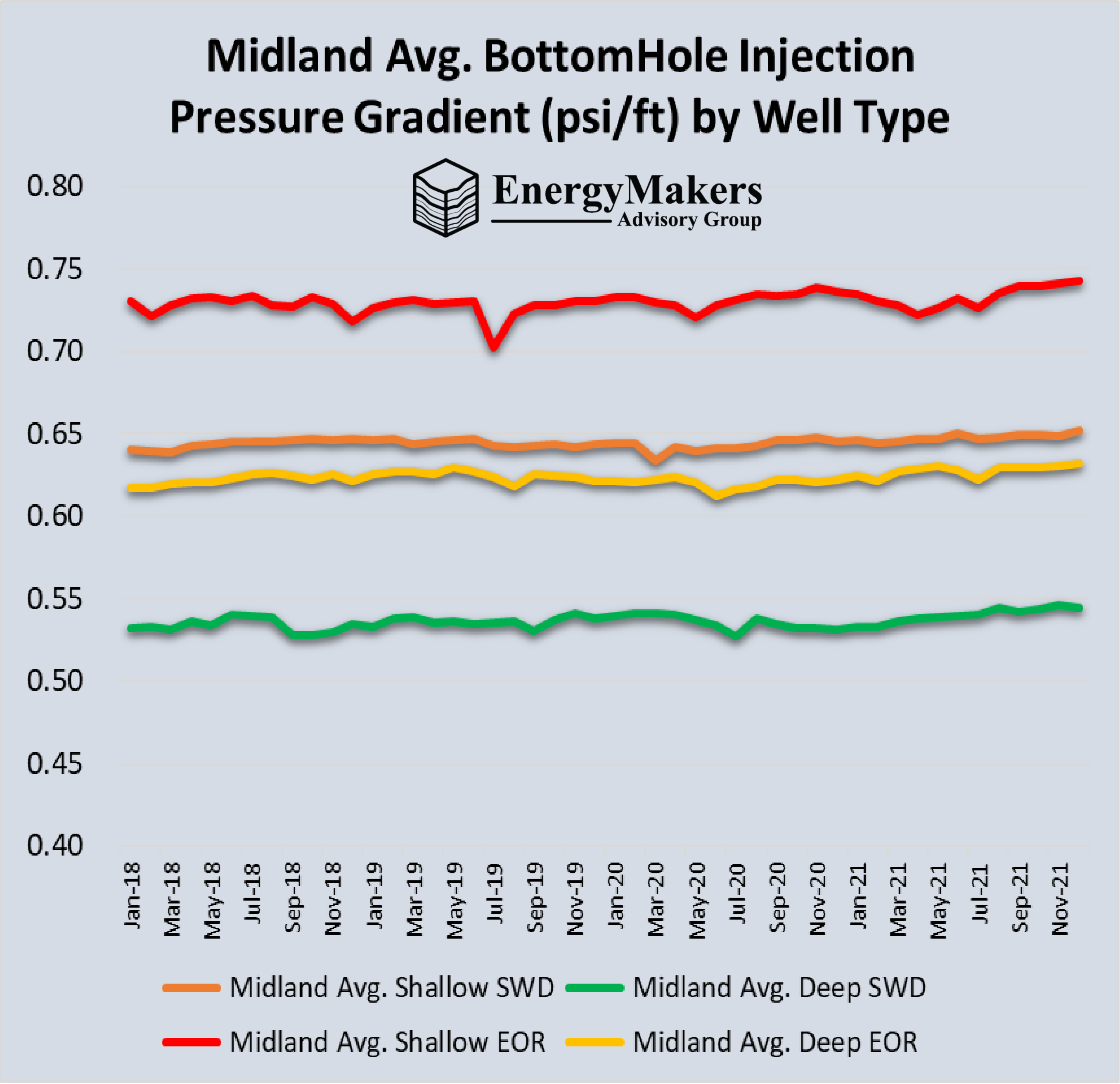
EOR INJECTORS	Active Count	≤0.5	0.50-0.60	0.60-0.70	0.70-0.80	0.80-0.90	0.90 +	Min Injection Depth	Max Injection Depth
Grayburg	406	30	204	76	89	7	0	4,059	4,902
San Andres	703	29	154	164	186	87	83	3,900	6,960
Clear Fork	418	11	75	253	78	1	0	3,700	7,360
Wolfcamp	52	10	5	20	17	0	0	7,000	9,018

Data Source: EnergyMakers Advisory Group 2024 Permian BHP Survey

SWD INJECTORS	Active Count	≤0.5	0.50-0.60	0.60-0.70	0.70-0.80	0.80-0.90	0.90 +	Min Injection Depth	Max Injection Depth
Grayburg	12	0	4	8	0	0	0	4,220	5,080
San Andres	71	7	23	21	12	8	4	3,877	6,452
Clear Fork	13	0	3	7	3	0	0	3,900	6,820
Devonian	27	9	11	5	2	0	0	5,000	12,800
Ellenburger	30	19	9	2	0	0	0	6,215	13,386

Data Source: EnergyMakers Advisory Group 2024 Permian BHP Survey



Tip # 2: Stay away from shallow EOR plays…and possible pressure communication

SHALLOW EOR

SHALLOW SWD

DEEP EOR

DEEP SWD

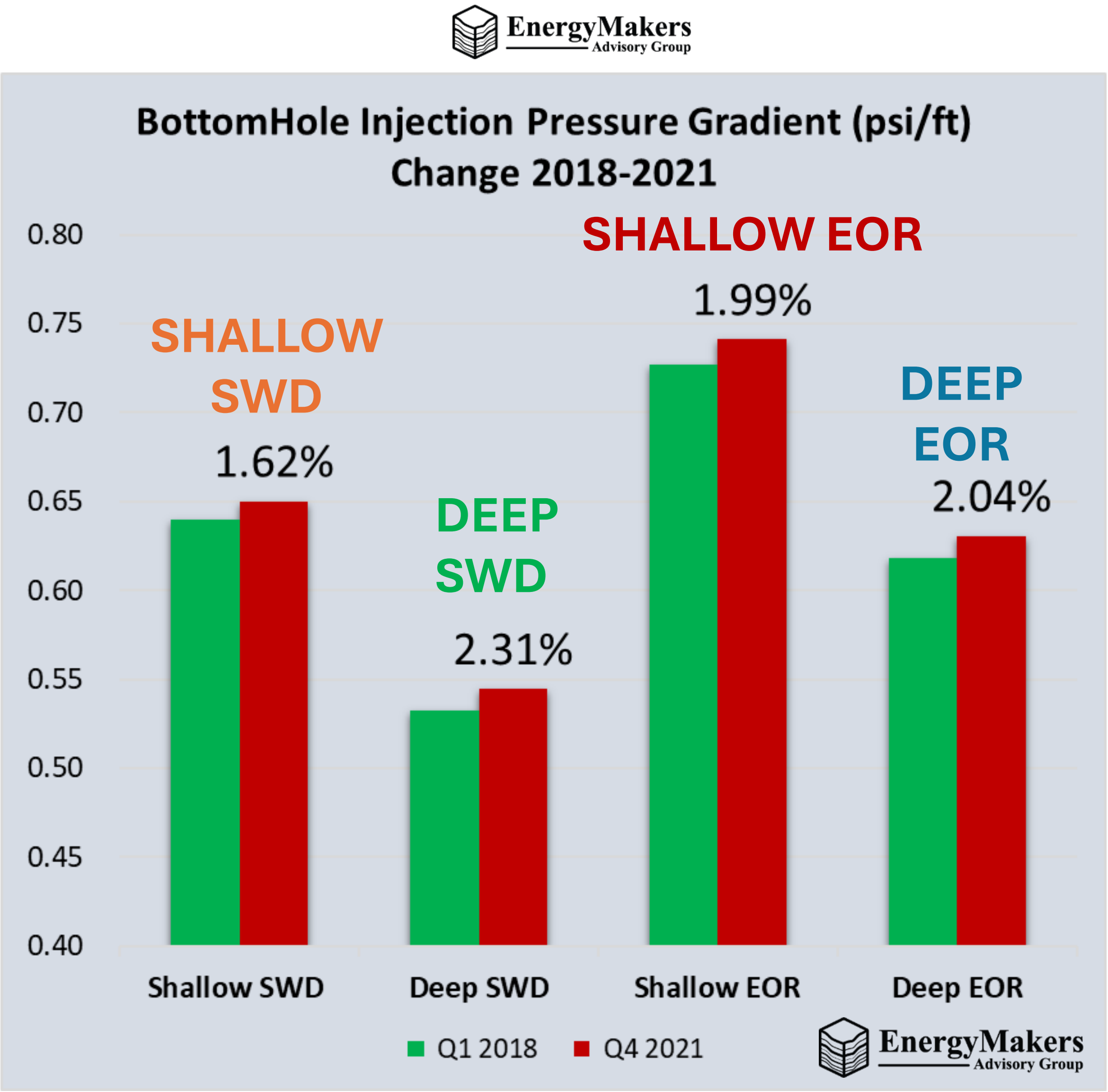
Shallow EOR formations are much higher pressured, on average, than SWD formations, but appear to "influence" nearby SWD.

Both Shallow SWD and EOR are much higher pressure on average that Deep SWD Formations.

Midland Basin Average Bottomhole Pressure Gradients (PSI/ft) are gradually increasing across the basin – all Well Types

Tip # 3: Avoid areas showing recent signs of <u>pressure increases</u>; you are likely to have more "pressure runway"

69% of active DMG blocks are increasing in BHP (Average BHP change, active blocks)



Finding Relief from High Bottom-Hole Pressures

Delaware 3P Report

Midland 3P Report

Tip # 4: Stay away from areas of high-density injection/ square mile. You are more likely to obtain more "pressure runway".

3P Report Chapters F, G, and H and I

½ Mile Radius of Review

2 Mile Radius of Review

Protection of Injection Intervals

Isolation from Base of Groundwater

Interval Integrity/Isolation & Relative Risk of AOR "Penetrations" (wells)

Prove your proposed injection Interval in 2 –Mile AOR is Isolated…
(else lower allowable BHP)

Score's "highest risk" well in terms of:

- ❑ Age of well
- ❑ Active Responsible Operator
- ❑ Proximity to Injection
- ❑ Completion / isolation / integrity of interval
- ❑ Plugged or abandoned wells

- ❑ Also check Freshwater protected

The proposed Texas RRC Algorithm identifies "worst well" in the 2-Mile AOR

We applied algorithms to each Block, generally **2.5 X** larger than a 2 mi radius AOR.

Any (single) high risk from the list, associated with one (1) well in the AOR,
could result in a deducted .05 psi/ft. imposed pressure "buffer" from MSIP.

Therefore, the number of AOR penetrations also correlate with risk metrics

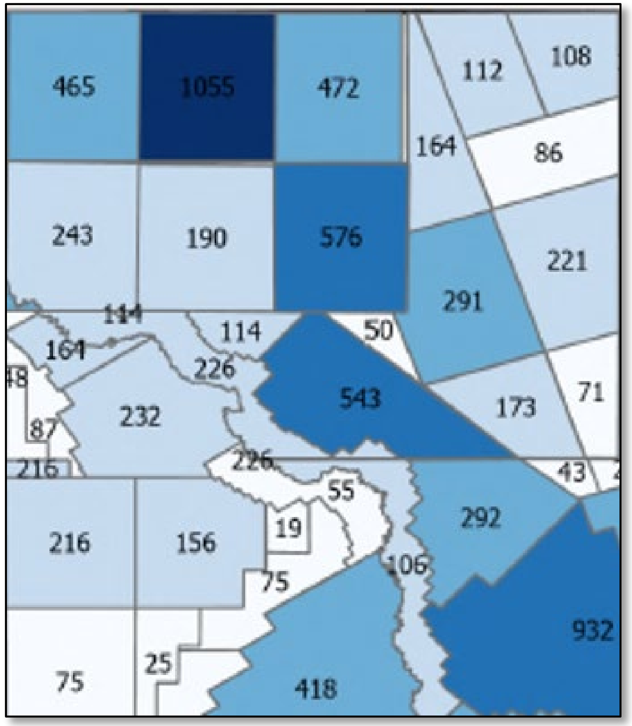
Likelihood of .05 psi/ft "buffer" – **# of Penetrations is a Factor**

Because the algorithm considers the "highest risk" well in the AOR, a higher number of penetrations is more likely to have at least one high risk well.

Even (1) risk factor is likely to result in a .05 psi/ft BHP pressure buffer requirement.

Delaware 3P Report

See Map Details at Conference



Data Completeness and Interval Protection

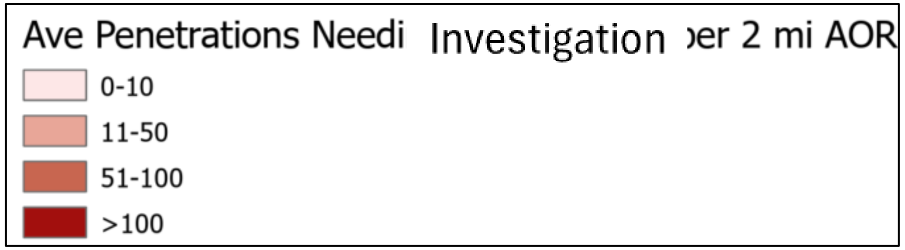
Algorithms require **Data Completeness** for every Penetration in 2 and ½ Mile AOR:

- Cement Data
- Casing Data
- Perforations
- ID of Base of Freshwater

If one or more fields are incomplete, this will flag the algorithm.

The 3P Report checks for Data Completeness, Every Penetration.

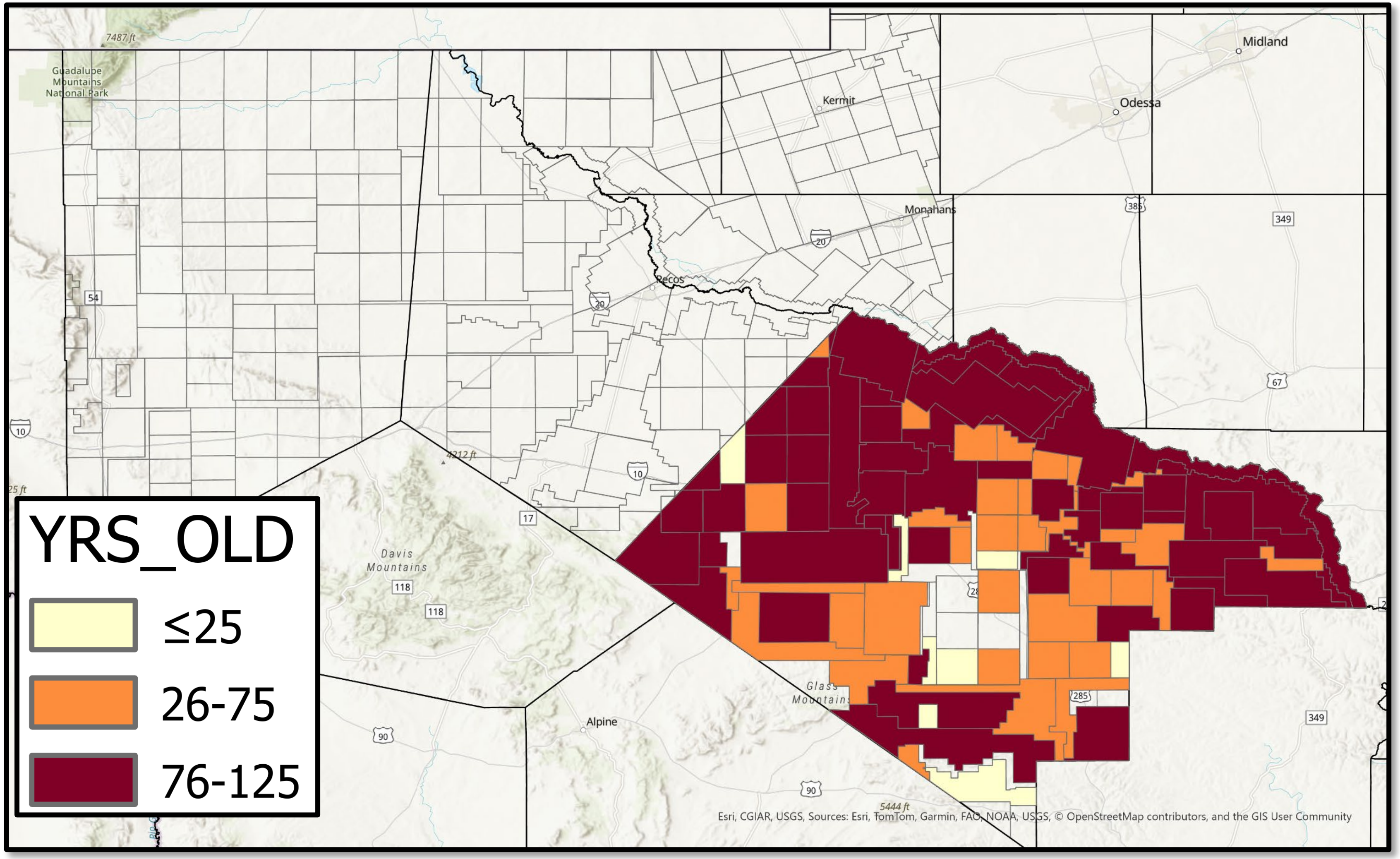
See Map Details at Conference



Likelihood of .05 psi/ft "buffer" – **from Old(est) wells***

Age of Well also drives the algorithm.

Even (1) really old well, (or a well without completion date*) is likely to result in a .05 psi/ft BHP pressure buffer requirement.



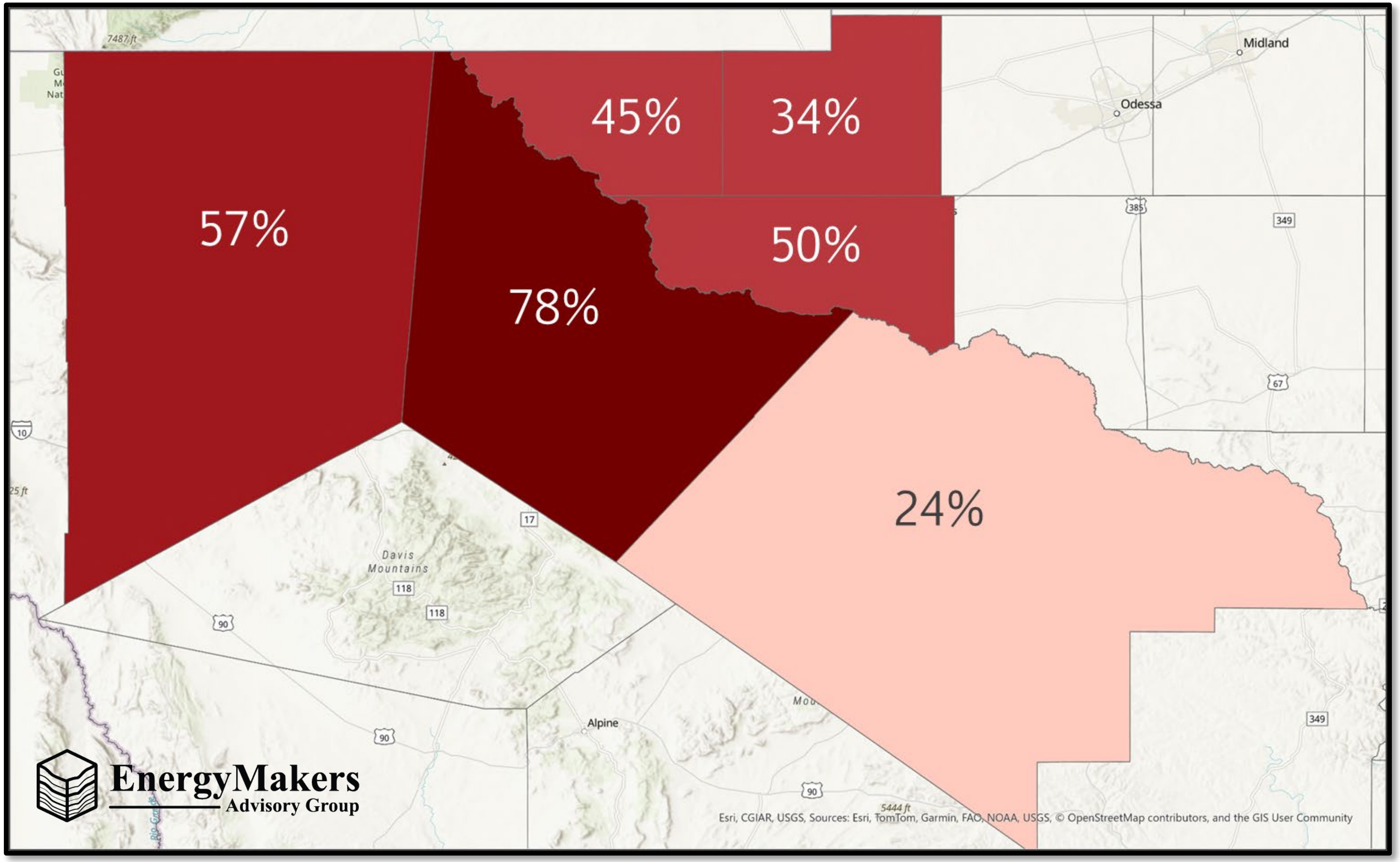
If completion date not available or data missing, algorithm assumes 125 years.

Likelihood of .05 psi/ft “buffer” – Active Operator Unknown

Percent of Blocks per county with one or more wells missing “active operator”.

Within the AOR, if a (single) well is identified without a known Active Operator, the algorithm will be impacted;

likely to result in the .05 psi/ft BHP pressure buffer requirement.



Likelihood of .05 psi/ft “buffer” – **Orphan Wells**

Texas RRC Orphan Wells as of January 2025.

Concentration is in /near Central Basin Platform and NW Shelf

Orphans in East Delaware, mainly

See Map Details at Conference

Orphan Wells and “Parallels” with old EOR Plays

See Map Details at Conference

EOR Well Density **Orphan Well Density**

Chapter J

Environmental Risks and Considerations

3P Report: Best to Avoid (The Laundry List!)

- ❑ Faults
- ❑ Earthquakes
- ❑ Known Surface Anomalies
- ❑ Plugged and Abandoned Wells
- ❑ Inactive Unplugged Wells
- ❑ Wells with no Active Operators
- ❑ Orphan Wells
- ❑ Wells lacking Cement, Casing, Perforations, or base of Freshwater
- ❑ Older Penetrations
- ❑ Areas with High BHP

- Areas with Increasing BHP*
- Areas with Low and Decreasing BHP*
- Areas of High Density Injection*
- Old EOR Wells*
- Heavily faulted / karsted / heterogeneous / unknown confinement Zones*

*(*not regulatory factors, Energy Maker's advises consideration)*

Screening for SWD $Performance (3P Considerations)

AI Interpretation of O&G business…swimming in cash

- ❑ Margin between BHP and Confinement Frac Gradients
- ❑ <u>Moderate</u> Reservoir BHPs (not too high, or too low…)
- ❑ Interval Thickness
- ❑ Injection Density in AOR (Proves capacity…but if very high, can be a concern…)
- ❑ Average BPD for Area SWDs (Low, High, Average)
- ❑ Permitted Pressure & Volume Utilization for SWDs in area – is there runway?
- ❑ Texas RRC MDIV Calculations
- ❑ Texas RRC MSIP Calculations
- ❑ Area Surface Pressures relative to predicted MSIP
- ❑ Avoidance of Risk (previous slide)

Summary

Industry consultants estimate a full SWD Permit application will cost 10X what it did a decade ago, due to rigorous permitting and extensive data gathering & mining requirements.

Rapid Screening approaches can alleviate most of the timeline and resource cost:

quickly rule out target locations:

* unlikely to be permitted, or,

* likely to have poor overall performance.

We recommend THREE sets of Screening Thresholds:

1) RRC Permitting Requirements

2) Company consideration of possible environment / litigation Risks

3) Company consideration of desired SWD Financial Performance

For penetrations within the ½ mile of Review needing remediation, your Company now has the option of paying the RRC for remediating activities, without incurring liability (a win-win).

For areas requiring Seismic Reviews, establish a monitoring and safety program to improve MDIV / potential financial performance for the SWD Asset.