GWPC Produced Water Report – Update 2023

Mark Kidder / ALL Consulting

September 13, 2023

ALL CONSULTING
GOVERNMENT RELATIONS · ENERGY · PLANNING · TECHNOLOGY
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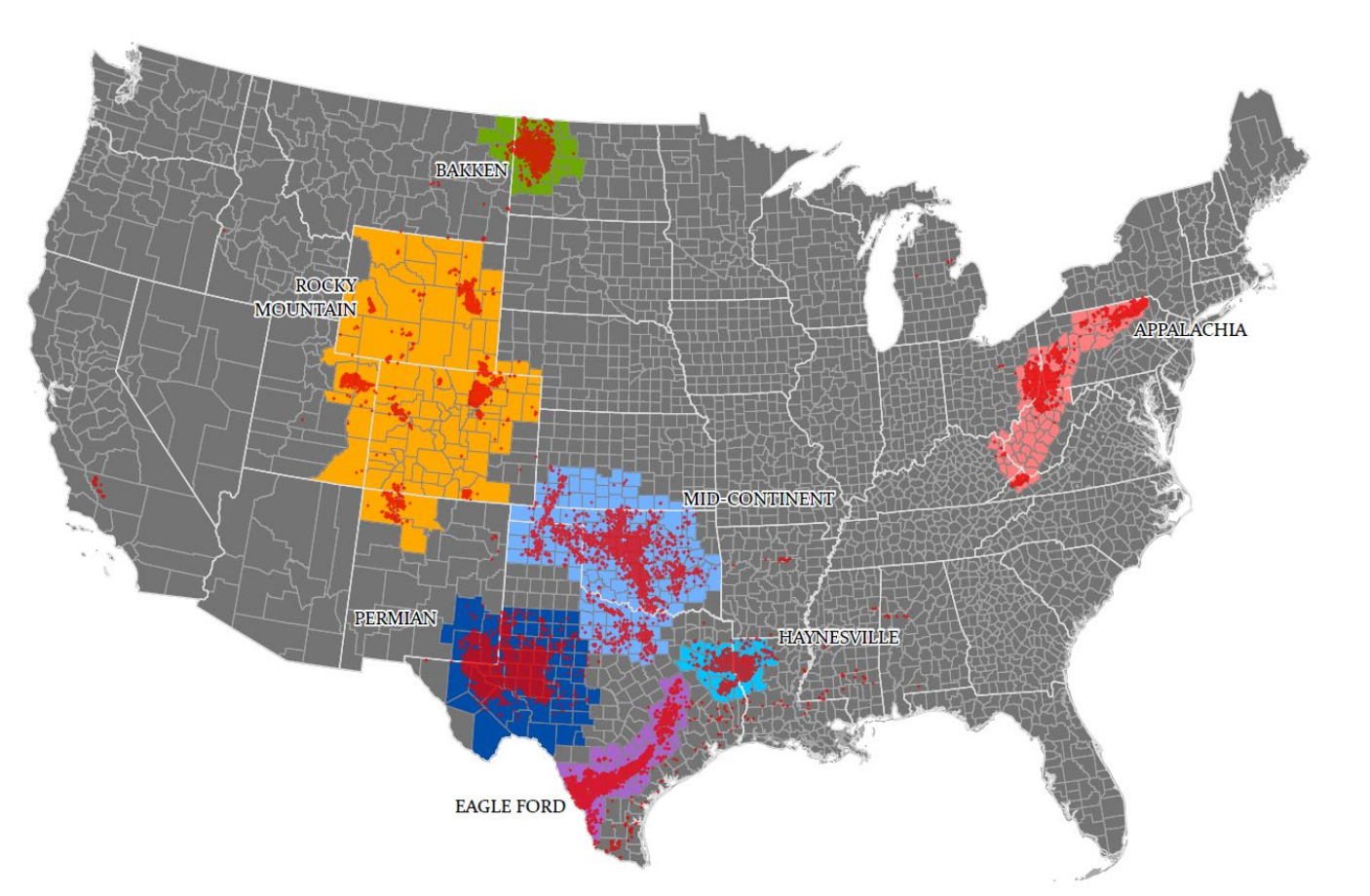
UPDATED GWPC DOCUMENT: PRODUCED WATER REPORT – UPDATE 2023

- **Focused Solely on Key Updates**
  - ~100 pages
  - Legislative and Regulatory
  - Produced Water Operational and Management Practices
  - Produced Water Reuse Technologies and Associated Research Needs

CONTINUED FOCUS:
TOP 7 OIL AND GAS DEVELOPMENT REGIONS



1. **Permian** (Including Midland and Delaware Basins) – TX, Southeast NM
2. **Eagle Ford** – TX (includes S. Texas)
3. **Appalachian** (Including Utica and Marcellus Basins) – PA, OH, WV
4. **Bakken** – ND, MT
5. **Mid-Continent** – OK, Southern KS, North Texas
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7. **Haynesville** – AR/LA/Northeast TX

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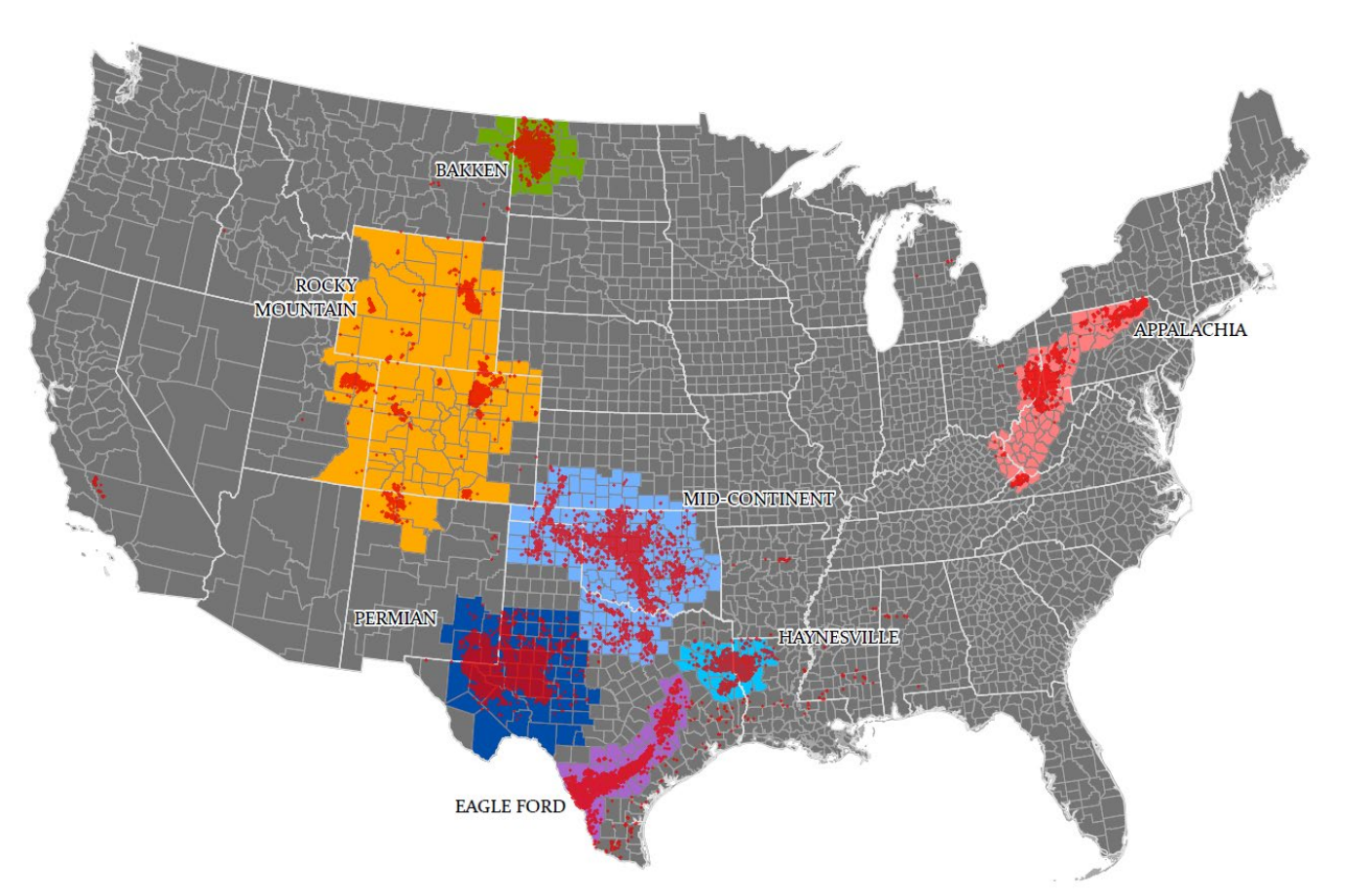

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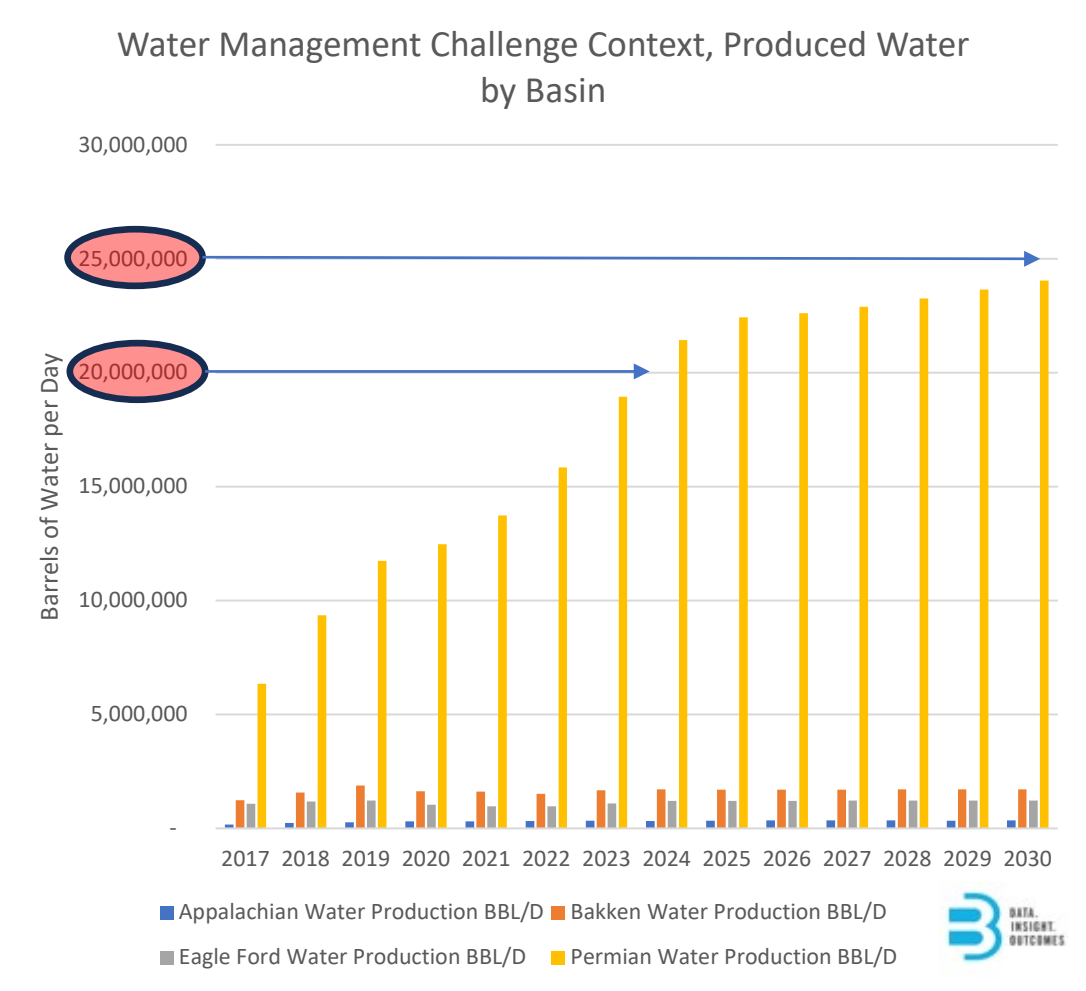
Top 4 Development Regions

PW Data More readily available

KEY DISCUSSION POINTS / FINDINGS

- **Permian Emerges as Focal Point of PW**
  - Of 7 Largest O&G Dev. Regions
    - **#1** - U.S. in Oil Production (>50% of US Production)
    - **#1 -** Produced Water Volumes /Challenges
- **Focus - 3 Key Discussion Points**
  - **Induced Seismicity** – Greatest Risk to E&P Growth
  - **PW Recycling** (Completions)
    - Highlight: Treatment Spec Emerging
  - **PW Reuse** (Beneficial)
    - Highlight - High Salinity Desalination
    - Practical Limits on Disposal of Highly Concentrated Brine

PUTTING PERMIAN PW CHALLENGES INTO CONTEXT



- **CURRENT:** Permian current produced water volumes generated are:
  - 11x > Bakken
  - 16x > Eagle Ford
  - **49x > Appalachian**
- **BY 2030:** Permian expected to outpace these basins even further:
  - 14x > Bakken
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- **Permian: Currently Approaching Practical Injection Volume Capacity**

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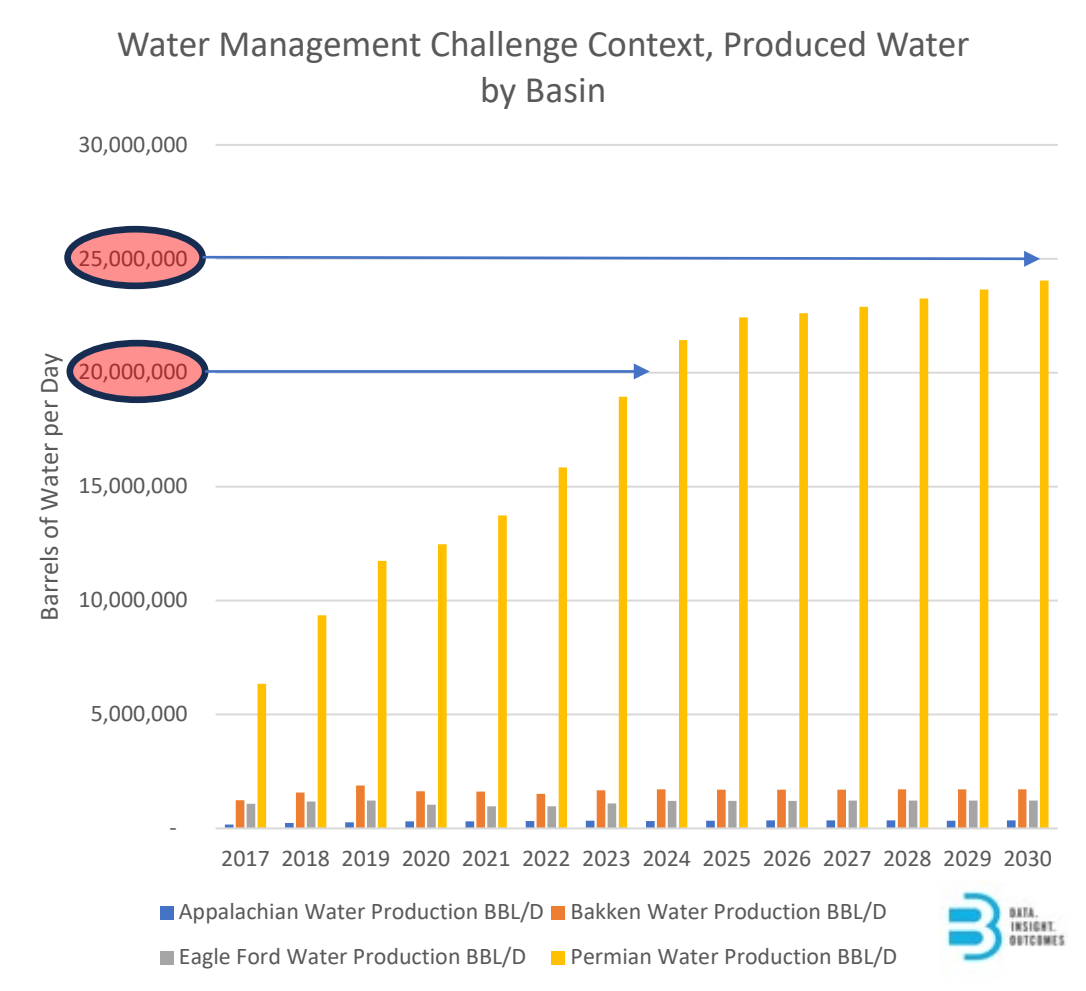

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SOLUTION: More Injection Capacity Required / More SWD's!

INDUCED SEISMICITY
GREATEST RISK TO PERMIAN E&P GROWTH

Significant Increases in Induced Seismic Events

- **Reducing Injection Volume in High-Risk Areas**
- **Regulatory Agencies (NM/TX) Want More Seismic Monitoring**

Compels the Question….

- **EVER WONDER *Why?***

  Frac-ing with 100,000's bbls of water…
  pumped at >8,000 psi… over a few days…
  is RARELY directly connected to induced seismicity?

  - **Largely because of monitoring and mitigation!**
  - **Frac crews intensely measure for microseismic events**
  - **When events become problematic, frac crews reduce pressures**
  - **Frac companies - driving advances microseismic technology**

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SOLUTION: Inject Less PW (Reduce Pressure) / Increase PW Recycling / Reuse!

GREATER RECYCLING OF PW - COMPLETIONS IMMEDIATE FOCUS: REDUCE INJECTION VOLUMES BY

- Completions –Min. Quality Expectations of PW - Key Parameters:
  - **TSS**
  - **TOG**

CLARIFICATION: Prominent Practices

Physical: Settling / Separation **Mechanical/Physical/Chemical**: DAF

- **H2S**
- **Total Iron**
- **Bacteria**

OXIDATION: Prominent Practices

Physical: Aeration **Chemical:** H_2O_2 , Bleach (NaClO), Ozone

Key Performance Measurements:

- ORP (determines oxidation efficiency/residual)
- ATP (Bacteria)*

RECYCLED PW – COMMON TREATMENT SPEC EMERGING!

		High-Spec Treatment	Mid-Spec Treatment	Low-Spec Treatment
TOG	*mg/L*	< 10	< 30	< 100
TSS	*mg/L*	< 50	< 200	< 1,000
Total Fe	*mg/L*	< 5	< 10	n/a
H_2S	*mg/L*	*ND*	*ND*	*ND*
ORP	*mv*	> 300	> 150	> 0
pH	*n/a*	6-8	6-8	6-8
Bacteria/ ATP	*pg/ml*	< 50	< 100	< 500
Typical processes		• Oil/water separation • Aggressive oxidation • Filtration and/or flocculation	• Oil/water separation • Mild oxidation • Solid settlement	• Oil/water separation • Minimum oxidation • Specific process tailored to the needs

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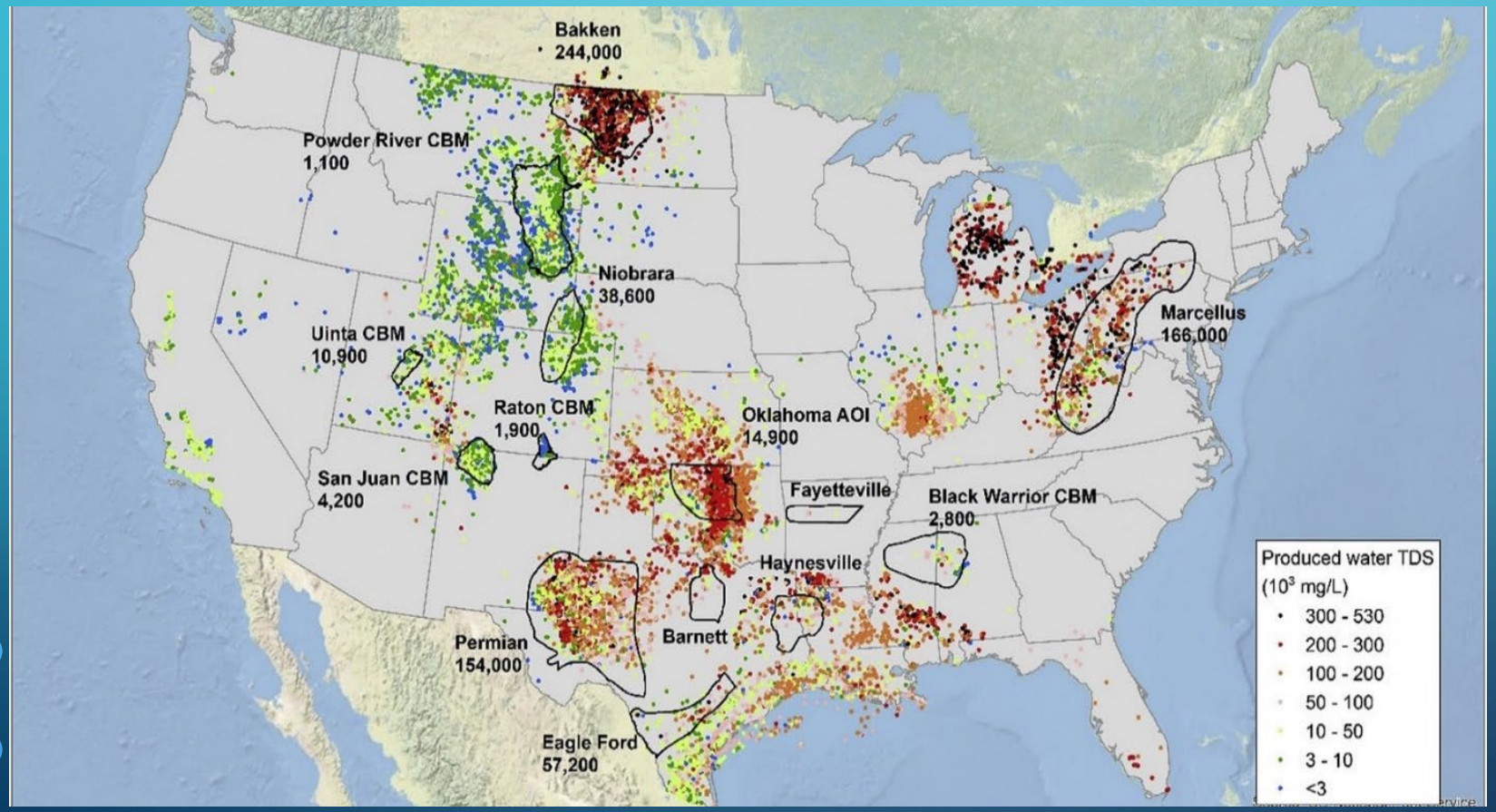
- Most Challenging PW Treatment Goal? Keeping a positive ORP (>0) before used at next frac
- Driver for intensity of oxidation (ORP) Levels?

  EXPECTED STORAGE TIME of PW between fracs = greater residual ORP – constantly decreasing target based on storage times

PW REUSE –CHALLENGE COMPOUNDED BY HIGH TDS AND INLAND LOCATION



Average TDS Per Basin

3 Areas with TDS > 6 figures

- **Bakken – 244,000 ppm**
- **Marcellus – 166,000 ppm**
- **Permian – <u>154,000 ppm</u>**

PW FOR BENEFICIAL REUSE – CHALLENGE COMPOUNDED BY HIGH TDS AND INLAND LOCATION

Why is desalination so challenging in the Permian?

- **High TDS** – >40,000 ppm – No RO
  - Permian - 154,000 ppm
  - Limits treatment options - Distillation
- **Inland Location** – Limits Disposal Options
  - Most desalination facilities – Coastline placement
  - Source of water to treat = the disposal zone
    - Concentrated brine back pumped back into the sea
  - Inland Desalination Locations – 2 Disposal Options
    - Injection wells
    - Crystallization

THE OPTIMAL BENEFICIAL REUSE SCENARIO: CREATE FRESH WATER + DISPOSE OF CONCENTRATED BRINE IN SWDS

ANALYSIS:

Establish FW Treatment Levels and Maximum Brine Concentration (TDS)

- **FW Treatment Level** = 500 ppm TDS (Max)
  - Authorities accept 500 ppm as max TDS concentration for "fresh water"
    - Tap water – 350 ppm avg
- **Concentrated Brine Treatment Level** for *Ongoing* Disposal:
  - Max. Acceptable Limit Identified: 260,000 ppm TDS*
    - Concentration slightly below the Spontaneous Nucleation Point (SNP)
      - SNP – Solids begin to form

**Ambient temp /pressure*

Fresh Water Recovery / Disposal Volume Reduction Ratios

Incoming Water TDS (ppm)	Incoming Volume (bbl)	Heavy Brine Volume (bbl) at 260,000 ppm	Distillate Volume Recovered (bbl) at <500 ppm	Percent Distillate (Fresh) Water Recovered
100,000	16,250	6,250	10,000	61.54%
110,000	17,333	7,333	10,000	57.69%
120,000	18,571	8,571	10,000	53.85%
130,000	20,000	10,000	10,000	50.00%
140,000	21,667	11,667	10,000	46.15%
150,000	23,636	13,636	10,000	42.31%
160,000	26,000	16,000	10,000	38.46%
170,000	28,889	18,889	10,000	34.62%
180,000	32,500	22,500	10,000	30.77%
190,000	37,143	27,143	10,000	26.92%
200,000	43,333	33,333	10,000	23.08%

Note: Heavy brine is concentrated to 260,000 ppm TDS, and distillate is <500 ppm TDS.

Figure 60: Expected Water Recovery and Waste Brine Volumes from High Salinity PW[114]

VAPOR DISTILLATION

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140,000	21,667	11,667	10,000	46.15%
150,000	23,636	13,636	10,000	42.31%
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VAPOR DISTILLATION

At 155,000 ppm TDS PW
(Permian Avg)

Incoming PW Volume
25,000 bbls

Post Treatment Results:
~<u>40% FW Recovery</u>
40% (10,000 bbls) fresh water
60% (15,000 bbls) conc. brine

Not so much a *TREATMENT* limitation
But..
Primarily a ***PHYSICAL*** **limitation imposed for SWD's to stay below SNP.**

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VAPOR DISTILLATION

PROS:

- Reduce Disposal Volumes

CONS:

- TDS at 260K increases bottomhole ***pressure*** gradient by ~0.09 psi/ft

Final Observations

- PRODUCED WATER: Eyes of the World On the Permian: Lessons Learned – Far Reaching!
- Current Industry Focus: **1 - 2 PUNCH - MAXIMIZE**
  - **#1 <u>RECYCLING</u> (for Completions)**
    - BIGGEST LIMITATION: Max ~ 7MM BWPD Total Demand / Trending  to 50% Recycled (Achievable)
  - **#2 <u>REUSE</u> (Beneficial)**
    - BIGGEST LIMITATION:
      - PHYSICAL LIMITATION: 40% Recovery / 60% Disposal
      - Even w/ MAJOR Expansion –
        - Treat 1 MM BWPD = <u>TWENTY TREATMENT FACILITIES</u> that treat 50K BWPD Each
      - Overall Reduction in Disposal Volume = 400K BWPD / Systemwide Inj. Volume of 20MM BWPD
      - ***Reduces Injection Volume by Only 2% (Minimal Impact)***
      - Practical Reality – Years Away

For Permian Expansion to Continue – Need MORE Injection Capacity / SWD's

Increased Risk of Induced Seismicity *seems inevitable*

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WHAT ELSE CAN THE INDUSTRY DO NOW TO BE PROACTIVE?

1-2-**3** Punch

#3 Proactively Expand Seismic Monitoring System

- **Most practical present oppty – Measure/Manage/Mitigate Induced Seismicity**
  - Focus on SRAs and Expand Outward
  - Learn from Frac Crews
    - Where microseismic trends upward, dial back *pressure*
  - Establishes Baseline in Microseismic Activity
  - For PW – Allows for Active Management
    - Divert Volumes / *Pressure* to other areas
    - Before larger events occur!
  - Opportunity For Industry/Consortiums/Service Providers/Legislators
    - PROACTIVE – To mitigate the biggest risk to the Permian's future

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For Full Report - **www.GWPC.org**

Key Contributors - SPECIAL THANKS TO:

Groundwater Protection Council (GWPC)
Maggi Young – Chesapeake Energy
Rick McCurdy – Select Energy Services
Kelly Bennett and Pat Patton – B3 Insight
Apoorva Sharma – Crystal Clearwater Resources
Zac Sadow – KMX Technologies
Markus Drouven: PARETO

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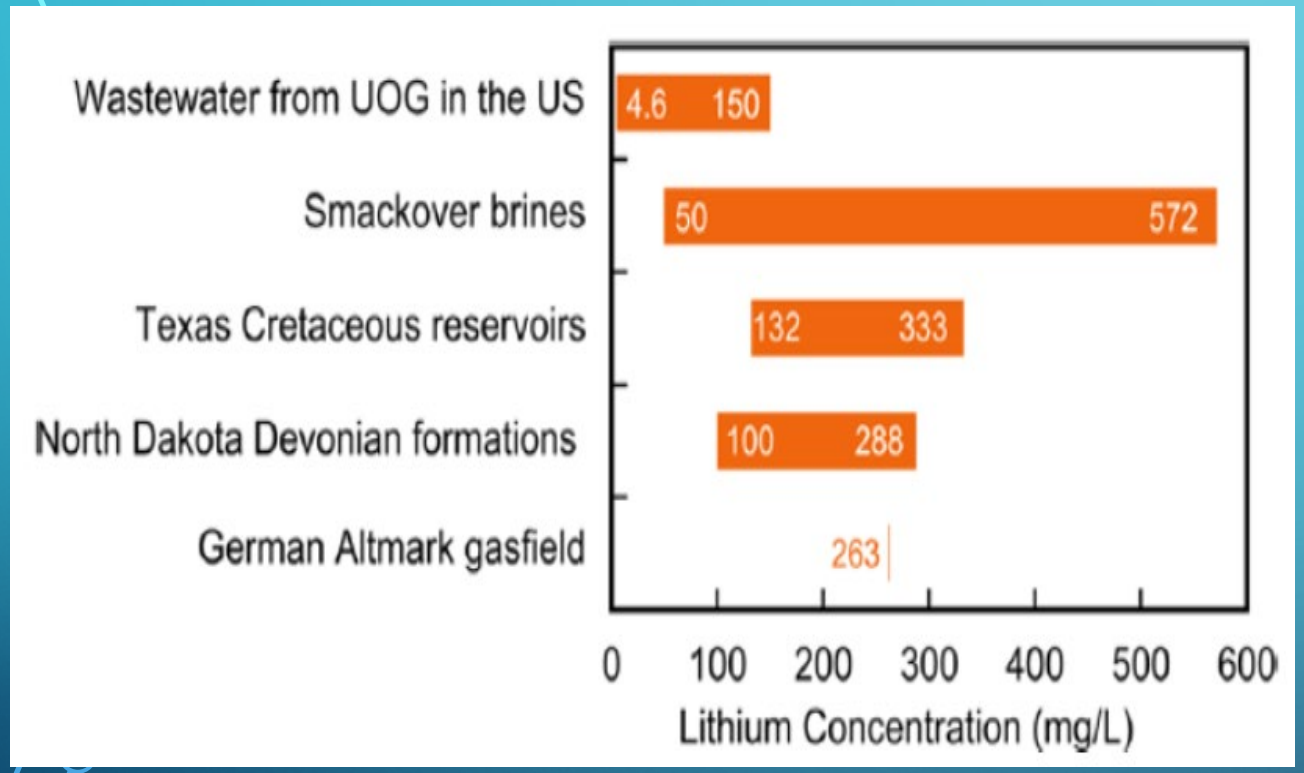
EXTRA SLIDES

Lithium Extraction Opportunity



Lithium Chloride Concentrations in Produced Water

- Current Extraction Technologies – Economic Viability Requires
  - Adequate Volumes of Water
  - Lithium Chloride >100ppm
  - LiCl concentration in the Permian
    - Averages 20-40 ppm