

Flowback and Produced Water ReUse

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Produced Water Beneficial Uses

- *Recycling Frac Fluid for Drilling: Encana (Suffield, Alberta)*
- *Potable Water Aquifer Storage and Retrieval: use of 500 – 1350 TDS CBM water (Gillette, Wyoming)*
- *Irrigation Water Production: Treatment of 6000 TDS produced water (Castaic Lake Water Agency, California)*
- *Irrigation Water Production: bio-treatment of produced water for crops (Nexen, Yemen)*
- *Livestock Watering: >1000 TDS CBM water (Gillette, Wyoming)*
- *Engineered Forest: Ecolotree® farms in Iowa (Licht, 2006)*

F&PW ReUse Strategy

#1 Frack water specifications

#2 F&PW variability

#3 Life-cycle strategy

#4 Treatment technology

#5 Risk management

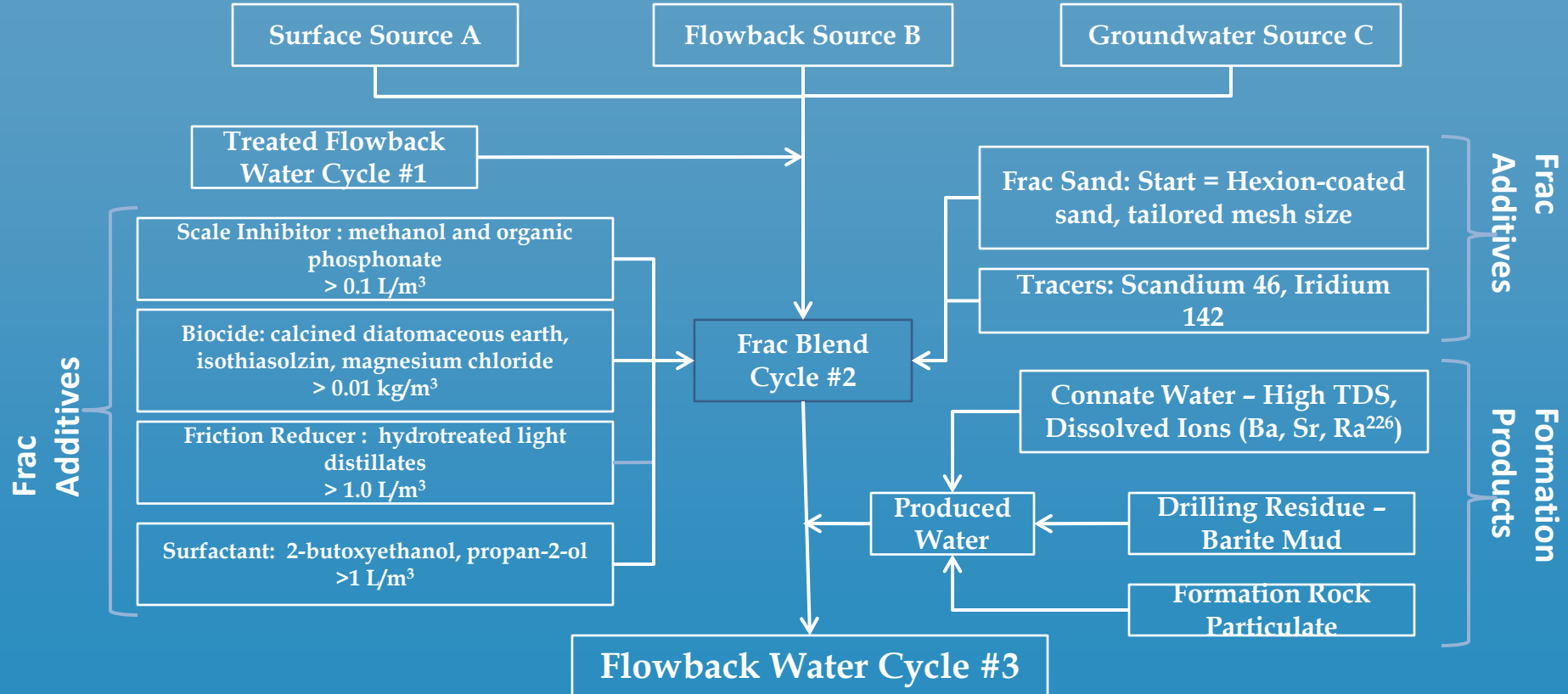
Typical Frack Water Specification

- *Low sulfate (<500 mg/L)*
- *Moderate TDS (<100,000 mg/L)*
- *Neutral pH (6 – 8.5)*
- *Low turbidity*
- *Low bicarbonate (<400 mg/L)*

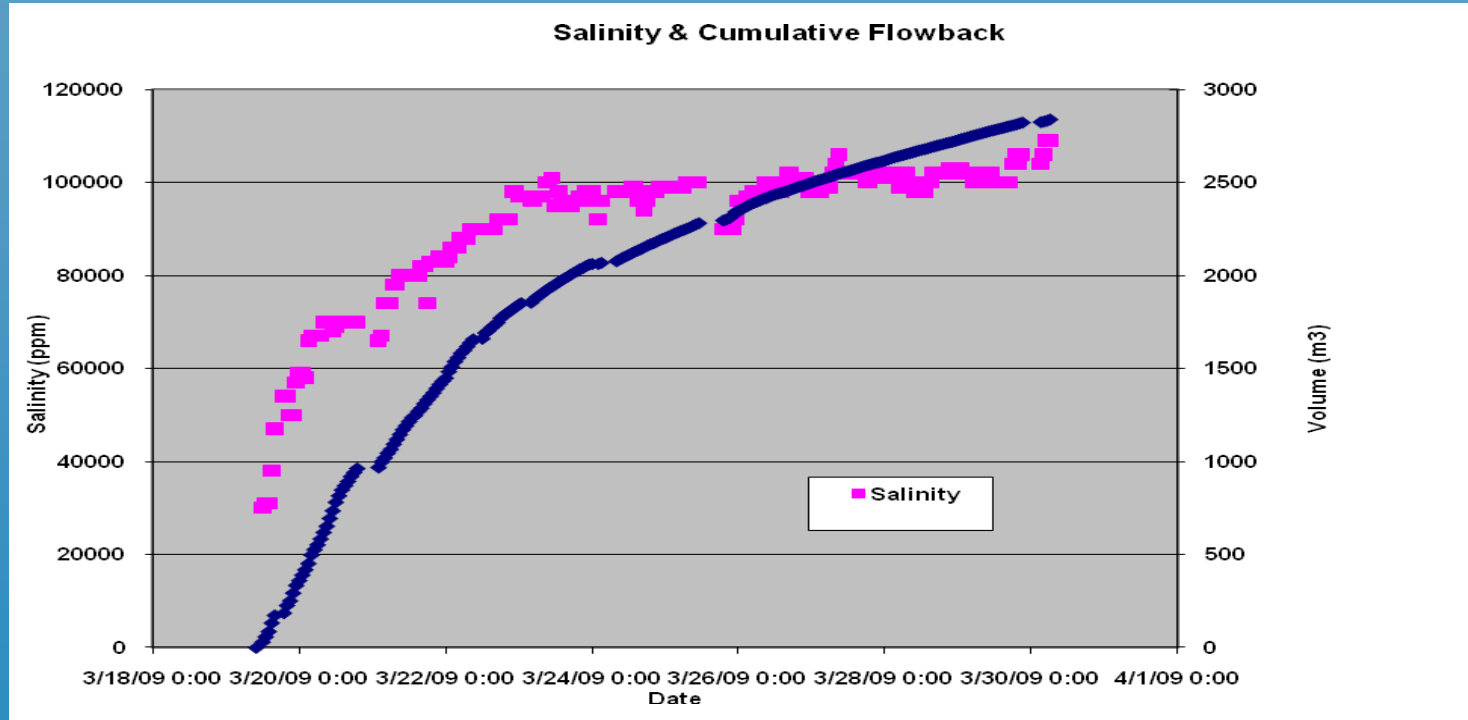
Frac Water Additives

- *Scale control*
- *Friction reducers*
- *Bacteria control*
- *Flow stimulation*
- *Oxygen scavenging*
- *Clay stabilization*
- *Surfactants*
- *Corrosion inhibition*

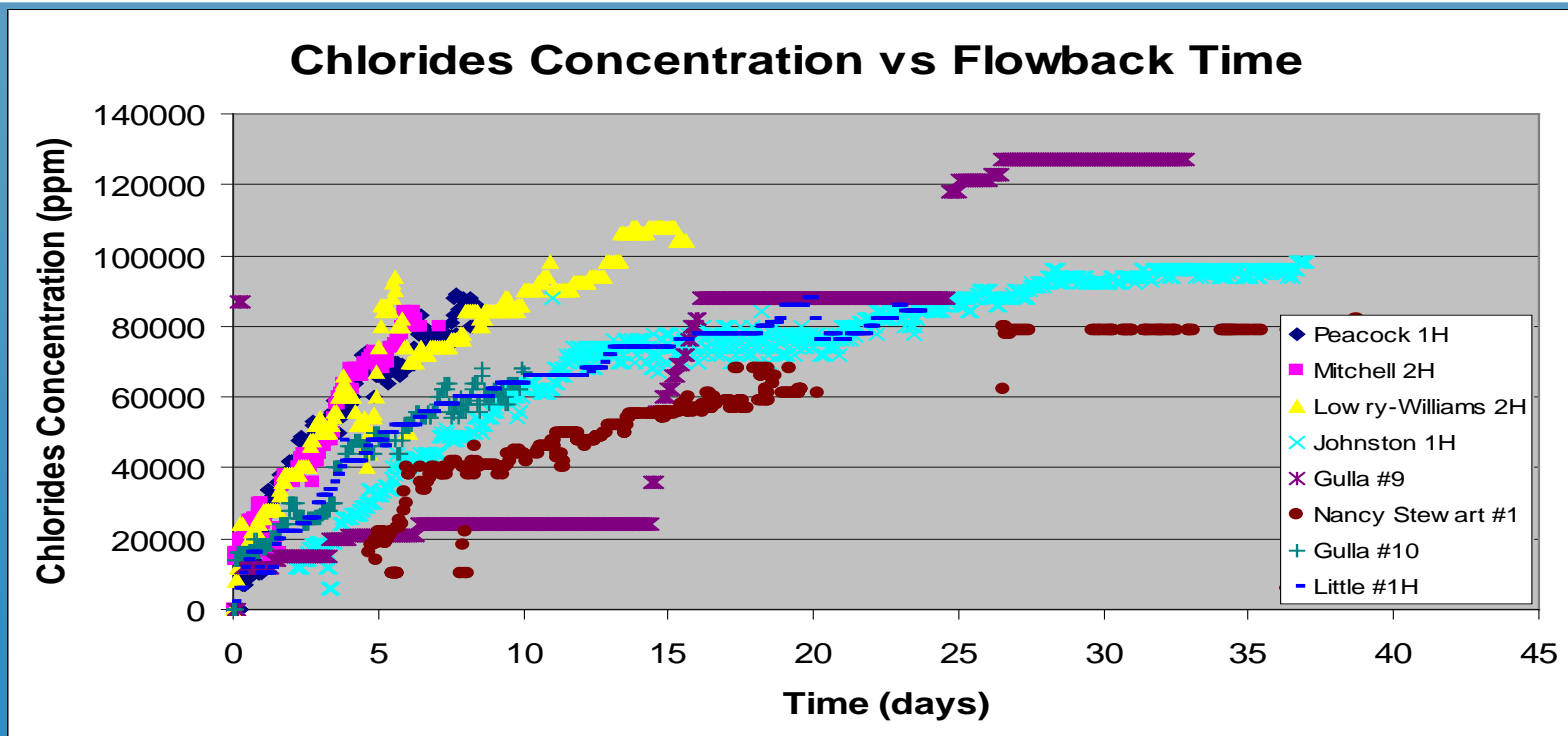
Frack Supply and Flowback Composition



Flow/Salinity Variation Montney



Salinity Variation - Marcellus



Marcellus v. Montney Scaling

	Barium (mg/L)		Strontium (mg/L)		Ra ²²⁶ (Bq/L)	
	Median and Max		Median and Max		Median and Max	
Marcellus	662	15,700	821	5,841	126	891
Montney	409	546	537	10,600	190	240

1 bequerel = 27 picocuries

Scale Formation

Compound	Formula	K_{sp}
Calcium hydroxide	$\text{Ca}(\text{OH})_2$	8×10^{-6}
Strontium sulfate	SrSO_4	3.44×10^{-7}
Barium sulfate	BaSO_4	1.08×10^{-10}
Radium sulfate	RaSO_4	3.66×10^{-11}

Residuals Management

- *Potential for issues from NORM:*
 - Occupational Health and Safety - low
 - Transportation of Dangerous Goods – low to moderate
 - Leachability and Landfill Disposal – moderate to high
- *Key to management is early separation*

Scaling Implications

- *Calcium carbonate scales*
- *Sulphate scales*
 - Restricts flow
 - Affects formation characteristics
 - Residuals management
- *Avoid high sulphate source water*

Bacterial Implications

- *Microbial Influenced Corrosion (MIC)*
- *Generation of hydrogen sulfide (H_2S)*
- *Creation of iron sulfides ($Fe_x S_y$ black water)*
 - Tank bottoms/interface solids
 - Plugging
 - Under-deposit corrosion
- *Contamination of downstream equipment and pipelines*

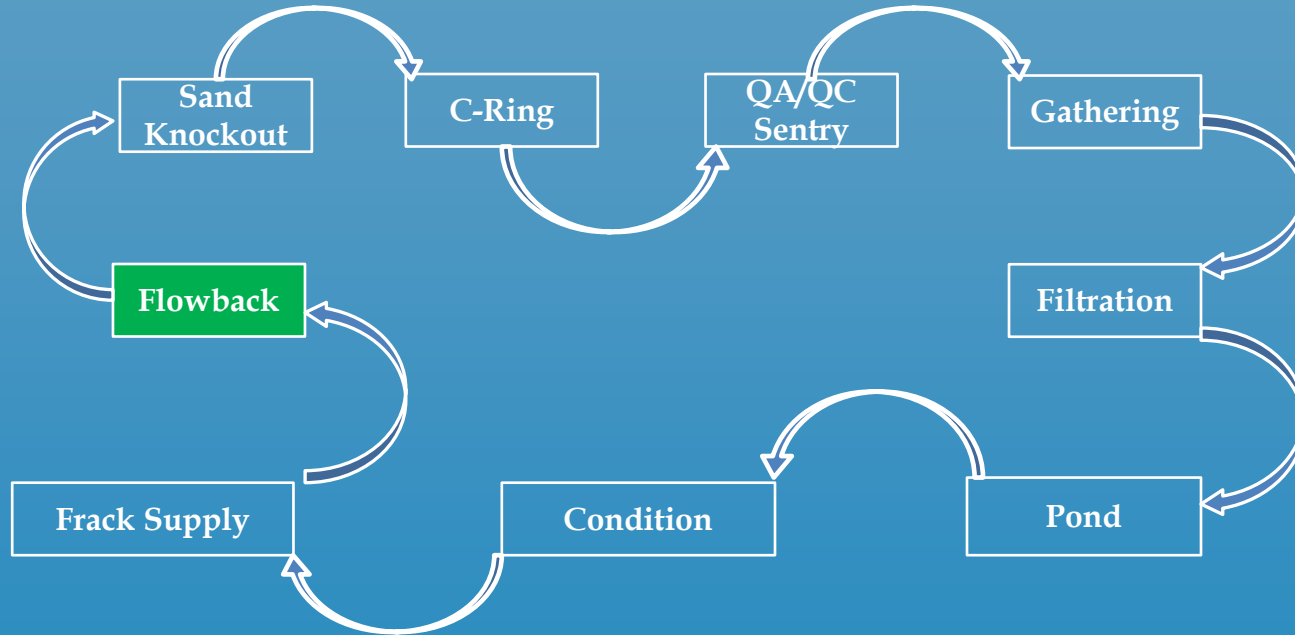
Strategic Implications

- *Residual additives – affect dosing estimates for subsequent re-use*
- *Scale inhibitor – leachability of solid residuals*
- *Bacteria control – aquatic and terrestrial toxicity*
- *Friction reducer – effectiveness progressively lower with higher TDS*

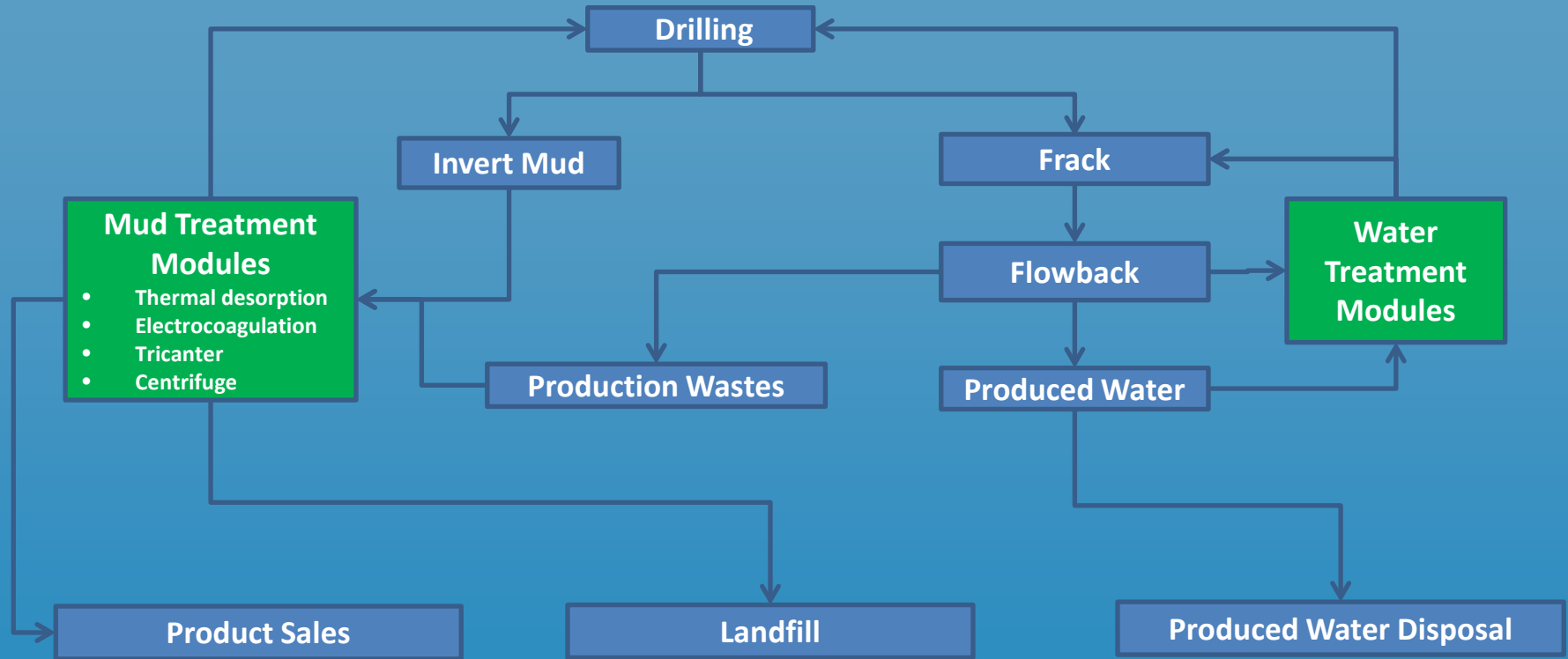
Optimizing F&PW Re-Use

- *Fit-for-purpose, modular systems for online analysis, blending and conditioning of frac fluid*
- *Optimizing water management system*
 - Minimize fresh-water requirements
 - Solids removal to protect reservoir
 - Precipitate removal to prevent fouling and scaling
 - Minimize additives
- *Advanced treatment where deep well disposal is not available*

Well-to-Well Cascading Strategy



Modular Strategy for Water and Waste Management



Flowback Treatment Technologies

- *A - Aqua-Pure NOMAD – Mechanical Vapour Recompression*
- *B - 212 Resources – Hybrid Flash Evaporation and Distillation*
- *C - Veolia – Mechanical Vapour Recompression*
- *D - GE – Falling Film Mechanical Vapour Recompression*
- *E - Lundberg – Flood-force Crystallizer*
- *F - Ecosphere – Ozonix ozone and ultrasound sonoluminescence*
- *G - VSEP – Nanofiltration and High-Pressure Spiral RO*
- *H - Veolia – Clarification, Softening and ElectroDialysis Reversal*
- *I - CoMag – Magnetite Flocculation*
- *J - Powell – ElectroCoagulation, Ultrafiltration and Solids Concentrator*
- *K - Toray – High Pressure Membranes*
- *L – ozonation-electrocoagulation*
- *M - tomorrow*

Advanced Treatment

- *May be required due to:*
 - Raw water scarcity
 - Blend specifications
 - Discharge restrictions
- *Considerations:*
 - Operating cost favors mechanical or chemical over thermal
 - Carbon footprint
 - Robustness due to variable feedstock

Keys to Technology Selection

- *Modular to adapt to changes in flow and composition*
- *Cascading strategy*
- *Manage risk of upsets*
- *QA/QC Sentry at point of generation*

Simplest Strategy – Water Conditioning



High-vol, high-p cartridges



Low-vol, low-p bags

Blending Pod – Water Re-Use



- Blending high-TDS with low-sulphate source water to meet friction reducer spec
- Conductivity-TDS correlation used to fine-tune

Key Considerations

- *Blending – in-field characterization*
- *Maximize re-use – achieve TDS target – common maximum of 65,000 TDS*
- *Control of residuals throughout life cycle for disposal*
- *Optimizing water inventory to maximize reuse using on-line, in-field systems*

Optimum Flowback Re-Use

- *Proactive stakeholder strategy*
- *Maximize re-use of flowback with fit-for-purpose, modular systems for online analysis, blending and conditioning of frac fluid*
- *Optimizing water management system*
 - Minimize fresh-water requirements
 - Solids removal to protect reservoir
 - Precipitate removal to prevent scaling
 - Minimize additives
- *Advanced treatment where deep well disposal is not available*

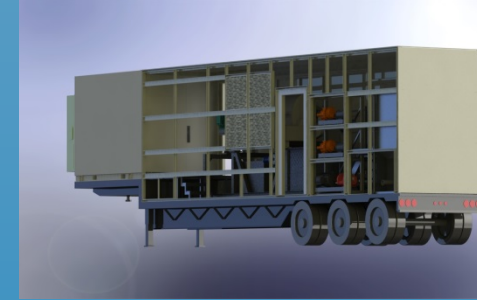
Modular and Mobile – Technology Agnostic



Flowback
Recycle

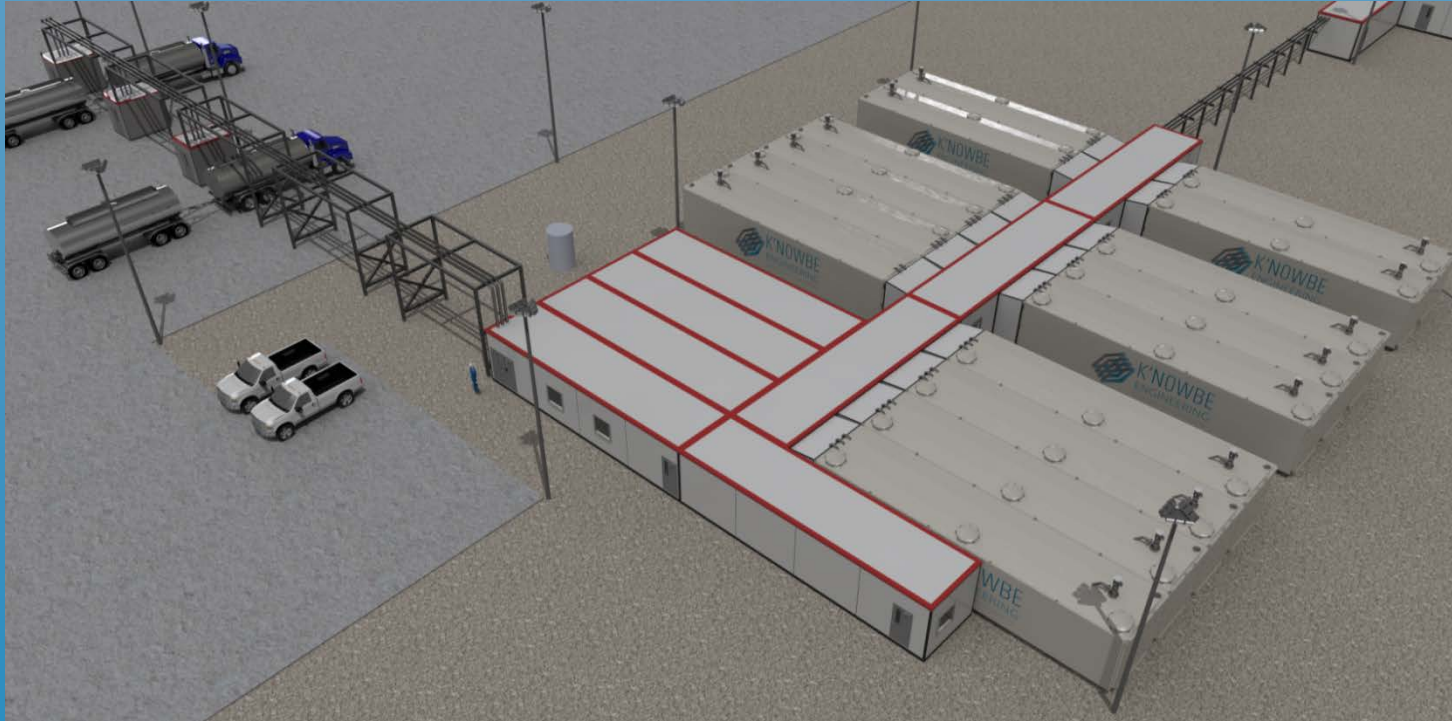


Produced Water
Disposal



Drilling Mud
Recycle

Fully Modular Strategy



Summary

- *Life-cycle strategy*
- *Cascading system*
- *Risk management*

Questions?

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