Treatment of Shale Gas Produced Water for Discharge

Technical Workshops for the Hydraulic Fracturing Study

Water Resources Management

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- Part of NETL's program to promote domestic natural gas production by providing technologies to overcome the technical and environmental challenges associated with unconventional resources.

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INTRODUCTION

- Managing produced water from shale gas wells can be a challenge
- Management and treatment decisions depend on many variables and are inter-related
- Treatment can alleviate some disposal issues
- Treatment options are limited by cost, treatment capabilities, and availability

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PW Management Options

- Three Basic Options
  - Injection
  - Surface Discharge/Beneficial use
  - Reuse in HVHF
- All options have challenges
- All options may require some level of treatment

Treatment Goals

- Three primary treatment goals
  - Reduce TDS (desalination) for discharge/beneficial use
  - Reduce volume for disposal
  - Reduce TDS, scaling, and/or bio-fouling for reuse or UIC

Treatment Challenges

- Shale gas produced water quality varies
  - Between plays
  - Within plays
  - Over time
- High Total Dissolved Solids (TDS) concentrations limit treatment options
- All treatment processes result in a waste stream – may be liquid, solid, or both
- Treatment in the field is very different than the lab
- All of the PW management options and treatment goals may be inter-related

SHALE GAS PW QUALITY/VARIATION

Play	Range of TDS (mg/L)*
Barnett	500 – 200,000
Fayetteville	3,000 – 80,000
Haynesville	500 – 250,000
Marcellus	10,000 – 300,000

** TDS Concentrations gathered from a combination of various published reports and personal conversations with operators.*

LOGISTICS/PRACTICAL CONSIDERATIONS

- Sources of PW change over time as new wells are drilled and development expands over an operator's lease-holdings
- Treatment facility location:
  - Mobile?
  - Permanent?
  - Semi-permanent? - Most common
- Treatment facility ownership:
  - Commercial?
  - Owned and run by operator?
  - Contracted by operator? - Most common

Management/Treatment Drivers

- Social/Community
- Environmental
  - Conservation of Resources
  - Aquatic Impacts
- Regulatory
- Economic
  - Cost of withdrawals
  - Cost of transportation
- Technical
  - Lack of injection capacity
  - Treatment limitations
  - Treatment availability
- Company policies

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Injection

Benefits:

- Can be a low-cost option
- Well-established and (mostly) widely accepted disposal method
- Several States encourage as the preferred option

Challenges

- Limited UIC well capacity/locations in some shale plays
- Lack of near-by wells creates transportation issues

Discharge/Beneficial Use Benefits

- Returns water to the local ecosystem
- Reduces disposal volume
- Can help community relations
- Can be a cost-effective management option

Discharge/Beneficial Use Challenges

- Treatment required
- Shale gas produced water not conducive to most beneficial uses
  - Small volume/well with scattered sources
  - Water production is episodic and moves over time
- Disposal of treatment concentrate
- Changing regulatory requirements
- Potential environmental/liability issues

Reuse

Benefits:

- Reduced withdrawals (and associated concerns)
- Reduced Disposal needs
- Reduced environmental concerns

Challenges

- Blended water must be suitable for fracture fluid
- May require treatment for TDS, scale, microbes
- Not necessarily a “no-treatment” option

Mixing and Scale Affinity Model

- Predicts chemical composition of mixed waters, allowing the user to see how waters will react when mixed
- Analyzes the mixing of multiple source waters, identifies the affinity for scale formation and the potential species of scale that will be formed

- Identify the most favorable mix ratio of available waters to meet specified targets for quality parameters – create an engineered water
- **www.all-llc.com/projects/produced_water_tool/**

Treatment for Discharge

Available Technologies

- Thermal Distillation
- Reverse Osmosis
- Will also briefly mention Thermal Evaporation

Pre-Treatment/Conditioning

- Remove suspended solids and organics, adjust pH, etc.
- Each of these technologies require some pre-treatment
  - Handled by vendors as part of their system
  - Discussed in other presentations

Thermal Distillation

- Mechanical Vapor Recompression (MVR)
- Condenses steam for reuse
- Corrosion/scale can be problems
- TDS up to about 200,000 mg/L
- Fresh water recovery rates of 50 – 90 %
- Costs range from$3.00 to $5.00/Bbl

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Reverse Osmosis (RO)

- Force water through an osmotic membrane
- Pre-treatment to prevent premature membrane fouling is critical
- Membrane replacement costly
- TDS up to about 50,000 mg/L
- Fresh water recovery rates of 40 – 90%
- Costs range from $0.42 to $3.50/Bbl

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Vendor Costs and Capabilities

- Vendors have limited operating experience/data for shale gas produced water
- Cost and capability data developed in the lab or in other industries may not be valid
  - Produced water quality variability
  - High TDS
  - Field Conditions
- Even when there is no intent to deceive, lack of consistent information on what is included in a quoted cost makes cost comparisons difficult
  - CAPEX/OPEX, Transportation, Disposal of reject water, etc.
- Vendors are constantly improving their processes as they gain experience

Volume Reduction

May want to reduce the volume that must be transported to UIC wells

- Thermal Distillation
- Reverse Osmosis
- Thermal Evaporation
  - Reduce liquid volume
  - Dispose of concentrate
- Crystallization
  - No limit on TDS
  - Zero Liquid Discharge
  - Dispose of solids

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Treatment Availability

- Availability varies by basin
- New vendors entering the market almost daily
- Several pilots underway/planned

- Treatment for shale gas PW remains in it's infancy

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THERMAL AVAILABILITY

Treatment Vendor	Thermal Distillation/ Evaporation	Shale Gas Play				
		Marcellus	Barnett	Haynesville	Fayetteville	Woodford
	212 Resources	✓	✓			
	Fountain Quail	✓	✓		✓	
	Aquatech	✓	✓		✓	
	Veolia	✓				
	INTEVRAS	✓	✓			
	GE Water & Process Tech.		✓		✓	
	Total Separation Solutions			✓		

RO AVAILABILITY

Treatment Vendor	Reverse Osmosis	Shale Gas Play				
		Marcellus	Barnett	Haynesville	Fayetteville	Woodford
	GeoPure		✓			
	Siemens	✓			✓	
	GPRI		✓			
	Auxsol		✓		✓	
	Veolia	✓				
	MI SWACO	✓				
	Ecosphere		✓		✓	✓
	GE Water & Process Tech.		✓		✓	
	Innovative Water Solutions		✓			

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Key Points

- The decision to treat shale gas produced water for surface discharge is based on many inter-related considerations
- Shale gas PW has high TDS concentrations that require desalination prior to discharge
- Treatment for discharge options are effectively limited to Thermal Distillation and Reverse Osmosis.
- Cost data for many vendors is limited/unproven
- Technology Availability is limited/unproven
- Treatment technologies are advancing and changing

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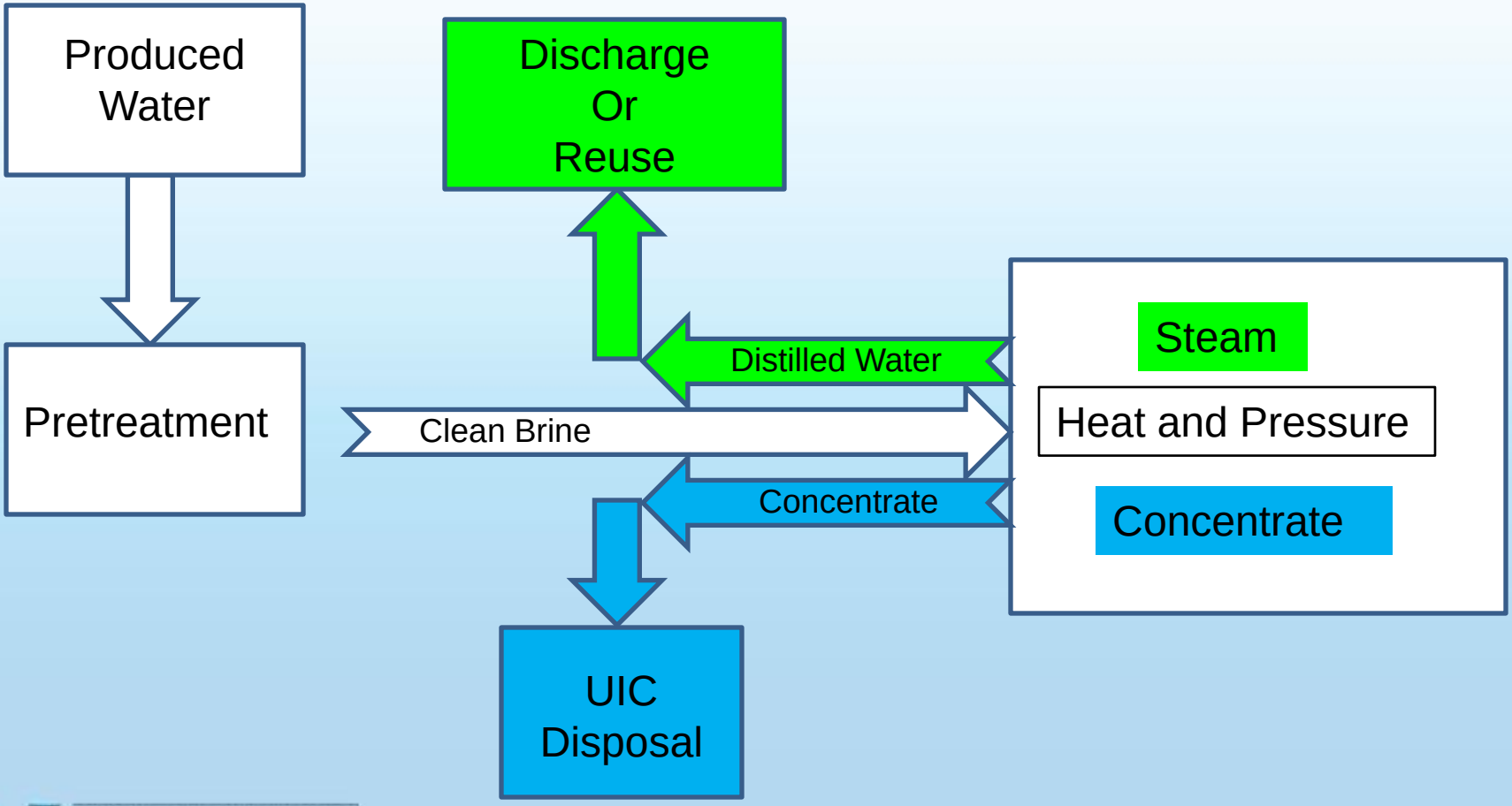
Thermal Distillation



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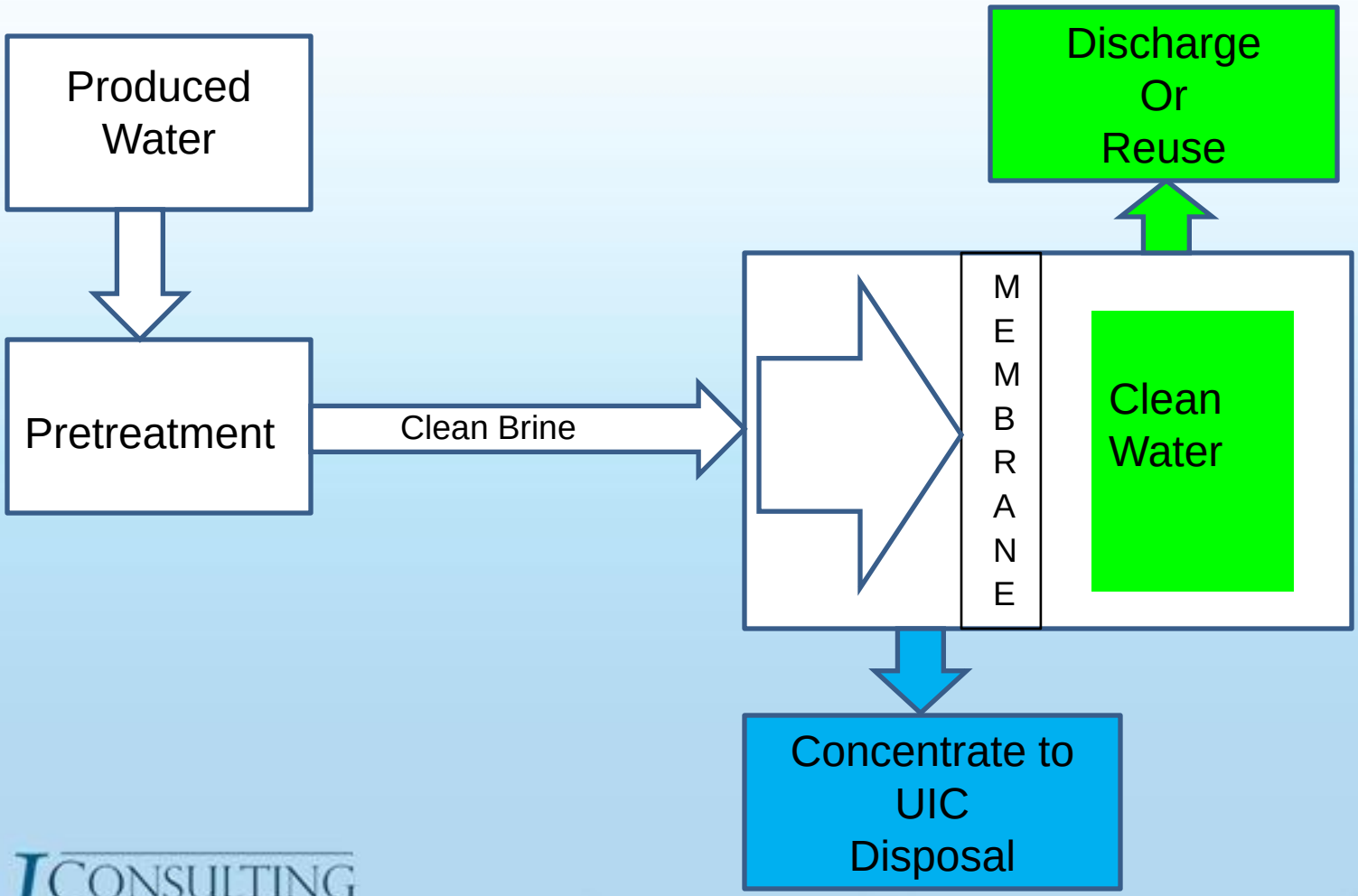
Reverse Osmosis (RO)



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