PATRICK HORNER, P.Eng

AQUAPURE
CLEAR SOLUTIONS

SHALE GAS
WATER MANAGEMENT

PATRICK HORNER, P.Eng

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SHALE GAS

WHY WATER MANAGEMENT?

• US Shale Gas Reserve: 353 Trillion Cubic Feet
• Shale Gas made up 19% of total US NG Consumption in 2009 and expected to rise to 45% by 2035.
• Shale Gas Requires Horizontal Wells and Hydraulic Fracturing
• Hydraulic Fracturing of Horizontal Wells requires 275 times the water of Fracturing Conventional Vertical Wells.

WATER MANAGEMENT IS CRITICAL TO SHALE GAS
NATURE OF FLOWBACK FACTORS → QUALITY AND QUANTITY

1 – SOURCE WATER CHEMISTRY
2 – FRAC CHEMICAL PROGRAM
3 – FORMATION GEOCHEMISTRY
4 – FRAC COMMUNICATION WITH ADJACENT AQUIFERS
5 – TIME ON SURFACE + BLENDING

FLOWBACK ANALYSIS = 1 + 2 + 3 + 4 + 5
(VARIABLES ARE NEVER EXACTLY THE SAME)
NATURE OF FLOWBACK

FLOWBACK TDS vs VOLUME PROFILE

TOTAL DISSOLVED SOLIDS (mg/L)

VOLUME (bbl/day)

AVERAGE TDS
COMPOSITION

- Dissolved Salts
- Dissolved Minerals
- Frac Chemicals
- Polymers (0 – 500 mg/L)
- Bacteria: (BOD 0 - 100 mg/L)
- TSS (200 – 1000 mg/L)
- NORM (0 – 15 pCi/L gross A)
- VOC (0 – 10 mg/L)
- SVOC (0 – 100 mg/L)
- Hydrocarbons (0 – 50 mg/L)
- Ammonia (0 – 150 mg/L)
- Carbonate Scales
- Sulphate Scales
- Silica Scales

CHANGES FROM PLAY TO PLAY
WELL TO WELL
DAY TO DAY

<table>
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<th></th>
<th>Fayetteville</th>
<th>Marcellus</th>
<th>Barnett</th>
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<tbody>
<tr>
<td>Na (mg/L)</td>
<td>5362.6</td>
<td>24445.0</td>
<td>12453.0</td>
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<td>Mg (mg/L)</td>
<td>77.3</td>
<td>263.1</td>
<td>253.0</td>
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<td>Ca (mg/L)</td>
<td>256.3</td>
<td>2921.0</td>
<td>2242.0</td>
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<tr>
<td>Sr (mg/L)</td>
<td>21.0</td>
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<td>357.0</td>
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<td>Ba (mg/L)</td>
<td>0.8</td>
<td>679.0</td>
<td>42.0</td>
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<td>Mn (mg/L)</td>
<td>0.5</td>
<td>3.9</td>
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<td>Fe (mg/L)</td>
<td>27.6</td>
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<td>SO4 (mg/L)</td>
<td>149.4</td>
<td>9.1</td>
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<td>HCO3 (mg/L)</td>
<td>1281.4</td>
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<td>Cl (mg/L)</td>
<td>8042.3</td>
<td>43578.4</td>
<td>23797.5</td>
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<td>TDS (mg/L)</td>
<td>15,219</td>
<td>72,533</td>
<td>39,570</td>
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<td>S.G.</td>
<td>1.010</td>
<td>1.050</td>
<td>1.030</td>
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WATER MANAGEMENT DECISION FACTORS

THE BALANCING ACT

- PUBLIC SAFETY
- COMMUNITY RELATIONSHIPS
- REGULATORY CLIMATE
- ENVIRONMENTAL RISK / LIABILITY
- SHARED ACCESS TO WATER AND DISPOSAL
- WATER MANAGEMENT COSTS
- FRAC FLUID QUALITY
- LONG TERM WELL PERFORMANCE
WATER MANAGEMENT
DECISION FACTORS

KEY CRITERIA

- FLOWBACK CHEMISTRY
- SOURCE WATER
- DISPOSAL
- STORAGE
- TRANSPORTATION
- TREATMENT TECHNOLOGY
- FRAC WATER SPEC

? AVAILABILITY / OPTIONS / COST / RISKS ?
WATER MANAGEMENT

STRATEGIES

DISPOSAL

FRAC WATER

FRAC

FLOWBACK
10 - 40% OF FRAC WATER

DISPOSAL
WATER MANAGEMENT STRATEGIES

RE-USE

FRAC WATER

FLOWBACK
10 - 40% OF FRAC WATER

FRAC

RE-USE TREATMENT
LEVEL 0 - 4

NEXT FRAC

LEVEL 0: NO TREATMENT
LEVEL 1: TSS REMOVAL (< 50 ppm)
LEVEL 2: TSS REMOVAL (< 5 micron)
LEVEL 3: TSS REMOVAL (< 1 micron)
LEVEL 4: TSS + 2+/− ION REMOVAL

MAKE-UP WATER
WATER MANAGEMENT STRATEGIES

RECYCLE

FRAC WATER

FLOWBACK 10 - 40% OF FRAC WATER

MAKE-UP WATER

FRAC

RECYCLE TREATMENT LEVEL 5

NEXT FRAC / DISCHARGE

LEVEL 5: TSS + TDS REMOVAL (0 ppm TSS, <100 ppm TDS)

CONCENTRATED BRINE (DISPOSAL OR RE-USE)
BARNETT: RECYCLE → FRAC

- 10,000 BPD LEVEL 5 INFIELD RECYCLING FACILITY (PRE-TREATMENT + NOMAD MVR EVAPORATOR)
- FLOWBACK RECYCLED AND BLENDED WITH MAKE-UP FOR NEXT FRAC.
- KEY DRIVERS:
  - REDUCE WATER USE (LIMITED AVAILABILITY)
  - REDUCE TRUCKING (COMMUNITY IMPACT)
  - REDUCE ENVIRONMENTAL LIABILITY (LOW TDS TRANSPORT AND STORAGE)

LIMITED FRESH WATER + URBAN COMMUNITY
CASE STUDY 2

MARCELLUS: RECYCLE → DISCHARGE

- 7,500 BPD LEVEL 5 NEAR FIELD DISPOSAL FACILITY (PRE-TREATMENT + NOMAD MVR EVAPORATORS)

- FLOWBACK AND PRODUCED WATER TREATED FOR DISCHARGE TO MUNICIPLE WWTP (TDS <100 ppm)

- KEY DRIVERS:
  - REDUCE HIGH DISPOSAL COSTS (HIGH TRANSPORT COSTS TO OUT OF STATE DISPOSAL WELL)
  - NO LOCAL DISPOSAL OPTION

NO LOCAL DISPOSAL OPTION
EAGLEFORD: RE-USE → FRAC

- 10,000 BPD LEVEL 1 IN FIELD MOBILE TREATMENT UNIT (ROVER)
- FLOWBACK AND PRODUCED WATER TREATED AND BLENDED WITH MAKE-UP WATER FOR RE-USE
- KEY DRIVERS:
  - LIMITED TRANSPORATION
  - REDUCE DISPOSAL
  - REDUCE FRESH WATER CONSUMPTION

HIGH TRANSPORATION COSTS
THE AQUA-PURE ADVANTAGE:

- 16,000,000 bbls of Commercial Shale Gas Water Treatment Experience
- Over 12 different technology pilots (what works where)
- Commercial experience in 4 different shale plays
- Over 16 Commercial Facility Installations
- Operational equipment ready for deployment
- Third Party Technology Performance Validation (by GTI)
- Engineering services to adapt and customize solutions
- Full Service Water Management Solutions
FOLLOW-UP

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