Water Management For Shale Plays

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Water Management Began With Oil and Gas Production

- Water is produced along with oil and gas from nearly every well since petroleum was discovered.
- Water is the most common and heavily used fluid in the petroleum industry.
- Water is used as a base fluid in drilling, completion, and production operations.
- Water is mixed, produced, cleaned, recycled, and injected.
- *Water’s use, protection, and disposal are emotionally charged subjects in many communities.*

Drake Well 1859
Source: PA Department of Conservation and Natural Resources
History of Water Disposal

• Into the middle of the 20\textsuperscript{th} century produced water was flowed:
  – Onto the ground
  – Into lakes and streams
  – Into unlined evaporation pits (Lined evaporation pits are still in use today)

• Today in the US over 98\% of produced water is disposed of in disposal wells or used for waterflooding

• Waterflooding
  – The first waterflood in the US was accidently started at Pithole City, PA in 1865
  – Started in Oklahoma and Texas in 1930’s
  – Became wide spread in the 1950’s
Water Management Cycle

- **Water source**
  - Subsurface aquifers
  - Rivers, lakes or ponds
  - Rural or urban water supplies
  - Gray Water
  - Acid Mine Drainage

- **Water transport**
  - Pipeline
  - Trucking

- **Water storage**
  - Frac Tanks (500 BBLS)
  - Modular Tanks (up to 60,000 BBLS)
  - Portadam (size as required)
  - Pits or ponds (100,000+ BBLS)

- **Water treatment and reuse**
  - Biocides
  - Aeration
  - Aerobic bacteria
  - Settling
  - Filtration
  - Flocculation
  - Distillation
  - Crystallization

- **Water disposal**
  - Evaporation
  - Water disposal wells
Significance of Water to Shale Completions

More than ever, water is an integral part of the success of oil and gas operations in Shale Plays.

Consider this:

– No Water
– No Hydraulic Fracturing
– No Oil and Gas Resource Plays
Water Management Plan Components

- Water Management Plan
  - Company’s acreage position
  - Water sources
  - Regulatory constraints
  - Environmental constraints
  - Cultural constraints
  - Fracturing fluids
  - Water volumes required
  - Storage capacity required
  - Refill time required
  - Layout infrastructure
  - Geotechnical investigation
  - Design facilities
  - Construction plan

Source: B. Pribish, 2015 private communication
Infrastructure

• Infrastructure planning
  – Plan placement of
    • Fresh water storage
    • Produced water treatment facilities
    • Disposal facilities
    • Buried HDPE pipelines
  – Practical limit of lay-flat is about 3 miles

• Flexibility
  – Move fresh water to any storage facility
  – Move treated and produced water from any treatment and disposal facility to any other facility
  – Delivery to and from each facility by both pipelines and trucks
Primary Water Sources

- Subsurface Aquifers using water wells
- Ground Water from naturally occurring or man made ponds
Water Needs and Costs

• Increased water demand due to
  – Drilling extended lateral lengths to 12,000 ft. or longer
  – Pad drilling
• Fracture fluid volumes
  – 300,000 to 1,000,000 BBLS per well
• Fresh water cost
  – Permian Basin
    • $0.50 to $0.75 per BBL
  – Anadarko Basin
    • $0.25 to $0.50 per BBL
• Costs for produced water treatment
  – $0.25 to $1.00 per BBL using aerobic bacteria and aeration
  – Other treatment costs may be higher

Source: ALL Consulting, 2016
Produced Water Storage Facilities

- Preferred designs - 1 to 6 lined 300,000 to 500,000 BBL impoundments
- Recommended Produced Water Impoundment liners:
  - Gas vent strips made of geotextile material
  - Geotextile layer
  - Secondary 40 mil black liner
  - Geotextile layer
  - Leak detection system (sump)
    - Geocomposite layer
    - Washed pea gravel
    - Perforated Pipe
  - Primary 40 mil white liner
- Pits connected by 12” HDPE equalization pipes
- Suction pipes installed in the clean brine impoundment
Impoundment Sizing and Design

- Impoundment designs based on operators needs:
  - Type of water stored
  - Completion schedule/water forecast
  - Water volume from production
  - Water recycling/treatment plan
  - Disposal capacity

- Ideal Design:
  - Can store fresh or produced water
  - Effective solids and bacteria removal
  - Designed for lowest cost
  - Combined storage volume from 300,000 to 2 million BBL

Source: ALL Consulting, 2018
Impoundment Construction

Source: ALL Consulting, 2018
Water Pit Liner Installation

Source: ALL Consulting, 2018

Source: ALL Consulting, 2018
Liner Installation/Completed Pits

Source: ALL Consulting, 2018

Source: ALL Consulting, 2018
Pipeline Design and Installation

• Water transport by pipeline to or from
  – Water source(s)
  – Existing water storage
  – Planned storage and treatment facilities
  – Salt water disposal wells
• Multidirectional water flow is a necessity
  – To move either fresh or salt water
  – To transport water from multiple facilities
• Benefits of developed pipeline systems
  – Reduced trucking
  – Decreased long-term costs
  – Increased safety & reduced risk of spills
• Automation
  – Allows control of water remotely
  – Decreases in-field man power

Source: ALL Consulting, 2018
Frac Water – Recycling Objectives

- Economically produce clean brine water from produced water that can be used as a base fluid for hydraulic fracturing
  - Process must be able to remove hydrocarbons, gelling agents, metals, $\text{H}_2\text{S}$, iron sulfide, bacteria, boron, and suspended solids
  - Process must be able to handle variable qualities and quantities of inlet water
  - For most operations equipment must be mobile and have a compact footprint
  - Water treatment must be economical when compared to the acquisition and disposal of fresh water
Before Recycling Water

• What Do We Need to Know
  – Type of fracturing fluid that is being used
    • Slickwater
    • Linear gel
    • Cross linked gel
  – The chemical analysis
    • For fresh water
    • For flowback/produced water
    • For treated water
  – Regulations governing
    • Produced water transportation
    • Produced water storage
    • Treated water storage
    • Waste stream disposal
  – Economic constraints
    • Cost of water storage (approximately $2.00/BBL for initial installation)
    • Cost of water transportation ($0.50/BBL to move water from storage to frac)
    • Cost of water processing
    • Cost of waste stream disposal
Drivers for Recycling

• Reduce demand on limited freshwater resources

• Reduce injection volumes
  – Reduce injection costs
  – Limited disposal zones for salt water disposal wells
  – Induced Seismicity concerns

• Reduce water costs

Source: ALL Consulting, 2018
Recycling Challenges

• Produced water
  – Treatment must be economically feasible
  – Minerals can interfere with friction reducers or frac gel
  – Quality varies widely
  – Minerals can cause scale

• Environmental regulations
  – Have become more stringent
  – In most states flowback, recycle or produced water pits have to be permitted in some fashion
  – Oklahoma requires design, certification, permitting, and construction supervision by a registered professional engineer
A Basic Approach that Works

- Combine at the same facility
  - Produced water treatment
  - Water storage
  - SWD well

- Separate pipelines
  - For fresh water
  - For produced water
  - For clean brine

- Tank battery to remove solids and separate oil

- Treatment system to provide a clean brine

- Injection well for produced water that cannot be recycled

- Multiple facilities strategically placed

Source: ALL Consulting, 2017
Treatment System

• Treatment system consists of:
  – A tank battery
  – A series of lined impoundments
    • Improves treatment
    • Provides ample storage
  – Aeration and microbial treatment
  – Equalization pipes
• Results in a clean brine suitable for reuse

Source: ALL Consulting, 2016
Treatment/Disposal Tank Battery

• Located adjacent to
  – Injection wells
  – Treatment pits

• Removes
  – Solids
  – Oil (down to 30 ppm)

• Automated to send water to
  – Treatment pits
  – Injection well
  – Both

• Typically coupled with 2 H-pumps controlled by variable speed drives (VSDs)

Source: ALL Consulting, 2017
• Aeration
  – Increases dissolved oxygen levels in water
  – Sustains aerobic bacteria
  – Eliminates hydrocarbons and other organics from the water
  – Prevents water from “Flipping”
  – Reduces the proliferation of Anaerobic Bacteria

• Aerobic bacteria
  – Control anaerobic bacteria
  – Managed with biocides during frac operations

• Anaerobic bacteria
  – More problematic (e.g., SRB’s - H₂S producing bacteria and APB’s - acid producing bacteria)
  – More expensive to manage with biocides

Source: ALL Consulting, 2017
Salt Water Disposal Considerations

• Increase in seismicity
  – Decreased injection allowables
  – Operators are choosing to limit injection
  – Alternate disposal zones are limited
  – Operators are exploring recycling as a way to reduce injection volumes

• Trucking produced water for disposal
  – Expensive
  – Can create adverse community impacts

• Transporting produced water through pipelines
  – Cost effective
  – Environmentally sound

Source: ALL Consulting, 2017
Benefits of Good Water Management Plan

• Ensures adequate water for completions
• Allows for
  – Unexpected changes in the completion schedule
  – Changes in frac water volumes
• Reduces fresh water demand
• Provides options for managing produced water
• Provides options for water treatment
• Reduces SWD well injection volumes
• Limits trucking for produced water disposal

Source: ALL Consulting, 2018
Keys to Success

• Provide a cost-effective approach to water management that
  – Supplies sufficient water supply for completions
  – Reduces fresh water demand
  – Recycles produced water
  – Disposes of excess water

• Provide flexibility to respond to unexpected changes in
  – Schedules
  – Need to move water from one facility to another
  – Injection well use or problems
  – Equipment

• Provide simple operations using
  – Automated controls
  – Uncomplicated treatment systems
  – Limited operator involvement in day-to-day operations
  – Minimal operator training

• Provide a process that recovers capital investment in three years or less.
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Citation Information: