

Practical Management of Produced Water From Onshore Oil and Gas Operations

Prepared For:



Industry Trends

- Oil & Gas prices have risen to unprecedented levels
 - Many previously uneconomic fields are being revitalized – often resulting in large water volumes to handle
 - Managing high-quality water in arid regions, mainly in western states, are becoming increasingly challenging – largely with unconventional development
- Water management remains a primary concern to successful development of fluid minerals
- Technology is becoming a significant aspect to water management

Objectives

- Identify existing and emerging practices used to manage of produced water from onshore oil & gas operations
- Transfer technologies and tools to industry, regulatory agencies, landowners, and other stakeholders
- Use research findings to aid in improving produced water management planning, alternative selection, and practices
- Aid farmers/ranchers in understanding how produced water can be used as a benefit

Introduction to Produced Water Management Alternatives



Water Rights & Classifications

Total dissolved solids (ppm)*	Comments
Less than 1,000 (EC < 1.5 mmhos/cm)	Excellent for all classes of livestock.
1,000 to 2,999 (EC = 1.5-5 mmhos/cm)	Very satisfactory for all classes of livestock. May cause temporary and mild diarrhea in livestock not accustomed to them.
3,000 to 4,999 (EC = 5-8 mmhos/cm)	Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to them.
5,000 to 6,999 (EC = 8-11 mmhos/cm)	Can be used with reasonable safety for dairy and beef cattle, sheep, swine, and horses. Avoid use for pregnant or lactating animals.
7,000 to 10,000 (EC = 11-16 mmhos/cm)	Considerable risk in using for pregnant or lactating cows, horses or sheep, or for the young of these species. In general, use should be avoided although older ruminants, horses, poultry, and swine may subsist on them under certain conditions.
Over 10,000 (EC > 16 mmhos/cm)	This water is considered unsatisfactory for all classes of livestock.

Water Management Alternatives

- Injection Group
 - Class II Injection
 - Class V Injection
- Surface Discharge Group
 - Land Surface Discharge
 - To a Water Body
 - Non-Point Source Discharge
- Impoundments Group
 - Wildlife Watering
 - Fisheries/Fish Ponds
 - Recharge
 - Recreation
 - Evaporation ponds
 - Wetlands

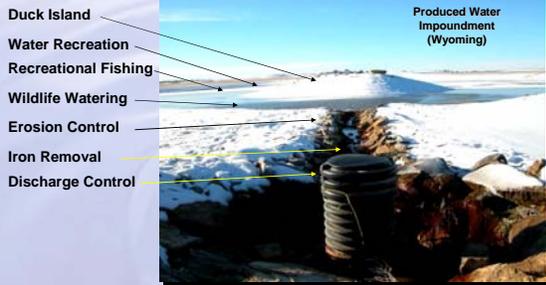



More Water Management Alternatives



- Industrial Use Group
 - Dust Control
 - Drilling/Development Fluids
 - Power Generation
 - Field Wash
 - Others
- Agricultural Use group
 - Irrigation
 - Livestock Watering
 - Soil Remediation
- Public Water Use
 - Domestic Use
 - Municipal Water Supply
 - Potable Use
 - Non-potable Use

Delineating Beneficial Uses



Produced Water For Agricultural Purposes

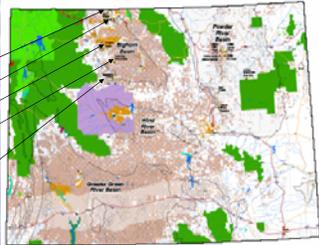


- Common Alternatives
 - Irrigation
 - Center Pivot
 - Side (Wheel) Roll System
 - Big Gun System
 - Flood Irrigation
 - Stock Watering



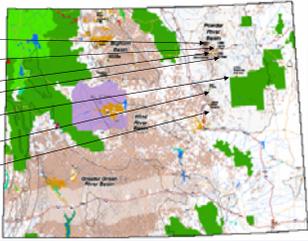
Representative Wyoming Sites

- Wyoming Site Visits
 - Big Horn Basin - All sites had oil/water separation and then discharge for beneficial use
 - Elk Basin
 - Garland Field
 - Oregon Basin
 - Little Bighorn Basin
 - Hamilton Dome

A map of Wyoming showing various oil and gas basins. Lines connect the text labels to specific locations on the map: Big Horn Basin (northwest), Elk Basin (west), Garland Field (west), Oregon Basin (west), Little Bighorn Basin (southwest), and Hamilton Dome (southwest).

More Wyoming Sites

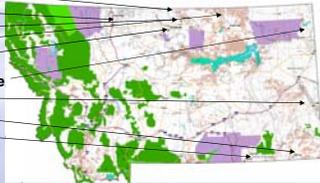
- Powder River Basin
 - Several CBNG sites
 - EMIT plant
 - Zeolite Plant
 - Retail Water Station
 - RO Plant
 - Beneficial Uses
 - Salt Creek Field
 - Teapot Naval Reserve

A map of Wyoming showing various oil and gas basins. Lines connect the text labels to specific locations on the map: EMIT plant, Zeolite Plant, Retail Water Station, RO Plant, Beneficial Uses (all in the Powder River Basin), Salt Creek Field (east), and Teapot Naval Reserve (southwest).

Representative Montana Sites

- **Montana**

- Battle Creek North
- Sunburst Field
- Rabbit Hills
- Bowdoin Field
- Tiger Ridge
- Sydney/Medicine Lake Are
- Cedar Creek Anticline
- Bell Creek Oil Field
- Big Horn County CBNG



Representative Kansas Sites

- **Kansas Sites**

- Western Kansas, Hugoton Basin
 - Stewart Field
 - Several (small) commercial disposal facilities



Representative Oklahoma Sites

- **Oklahoma Sites**

- OKC Field – Deep Injection into horizontal injection well in a highly developed residential area
- Red Oak Field – Surface flood irrigation



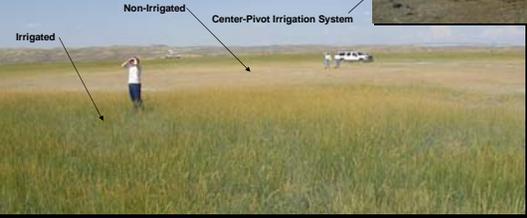






Wyoming Powder River Basin

Kingsbury Produced Water Irrigation Project
Powder River Basin, Wyoming (Williams Companies)



Oklahoma: Red Oak Field

- Surface flood irrigation in the Red Oak Field



Montana Bowdoin Field

- Large evaporation pit (lined) for gas production in Bowdoin Field north of Saco, MT



Kansas: Stewart Field

- **Western Kansas**

- Efficient water flood using brine water in Stewart Field



Wyoming: Garland Field



Garland Field
Big Horn Basin
Garland, WY



Wyoming: Prairie Dog Creek CBNG Field



Coal Bed Natural Gas
Development in the
Powder River Basin

Shallow Class V
injection wells have
been used for aquifer
storage/recovery of
produced water



Wyoming: County Line CBNG



Water Treatment Practices



Produced Water Treatment Technologies

- Packed Bed Adsorption
- Constructed Wetlands
- Ion Exchange
- Electrodialysis (ED)
- Electrodialysis Reversal (EDR)
- Capacitive Deionization Technology
- Electrochemical Activation Technology
- Electro-deionization

Produced Water Treatment Technologies, Cont'd

- Evaporation
 - Rapid Spray Evaporation (RSE)
 - Freeze Thaw Evaporation
 - Falling Film Vertical Tube Evaporators
- Pressure Driven Membrane Separation Technologies
- High Efficiency Reverse Osmosis (HERO™)
- Oxidation Reactor
- NORM Treatment

Watershed Analysis Tool



Planning Water Management and Production Operations

- Remote Data Collection
- Irrigation with PW
- Small Pad
- Cattle Protection
- Underground utilities
- Well house Color



Water Management Considerations



Irrigation is one of the produced water management practices used more commonly to manage CBNG produced water



Wildlife watering is an important local beneficial use of CBNG produced water in the PRB. Wildlife, such as Antelope, are attracted to CBNG reservoirs.

Watershed Analysis Tool

- Provides water management demands over time (increases or declines)
- Aid in the selection and conceptual design of produced water management alternatives
- Provide water balance analysis required for planning alternatives to water management
- Facilitate water analysis for alternative selection
 - Surface discharge mixing model, enhanced evaporation, agricultural uses, etc.

Water Balance Model

- PWM alternatives balance with production volumes over the life of the project and account for project peak production rates
- Types of alternatives modeled for water balance
 - Agricultural uses (e.g., managed irrigation)
 - Livestock/wildlife watering
 - Storage and evaporation
 - Industrial uses
 - Underground injection (various types)
 - Use of various water treatment technologies
 - Surface discharge

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