



COLORADO ENERGY RESEARCH INSTITUTE



Penn State

PVES



Produced Water Management and Beneficial Use

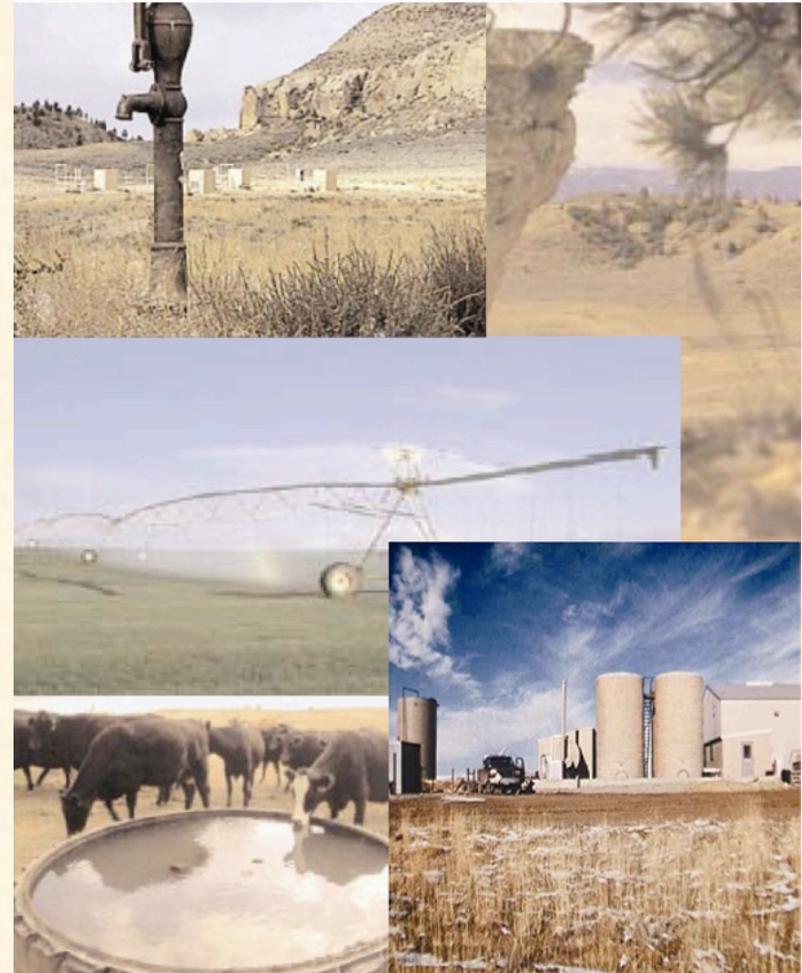
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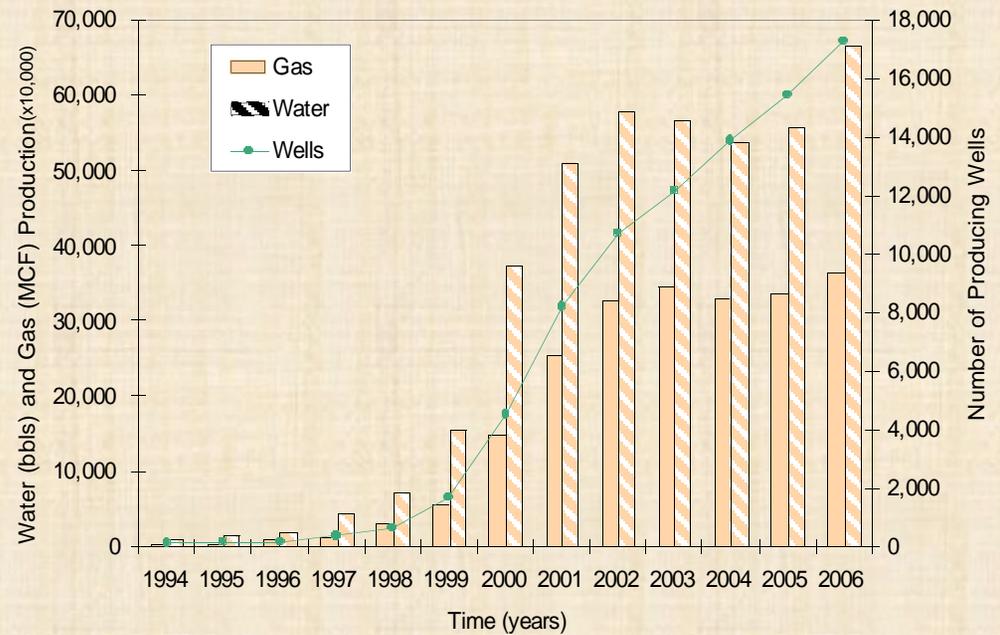
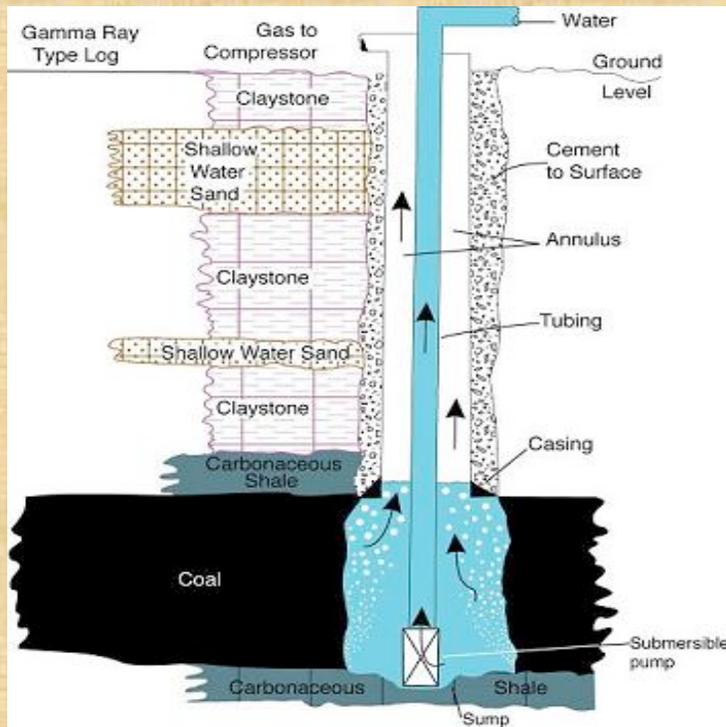
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Powder River Basin CBM Water



Estimated 650,000,000 bbl/yr water produced in 2006

Discharge of CBM water is of significant environmental concern

Research Areas

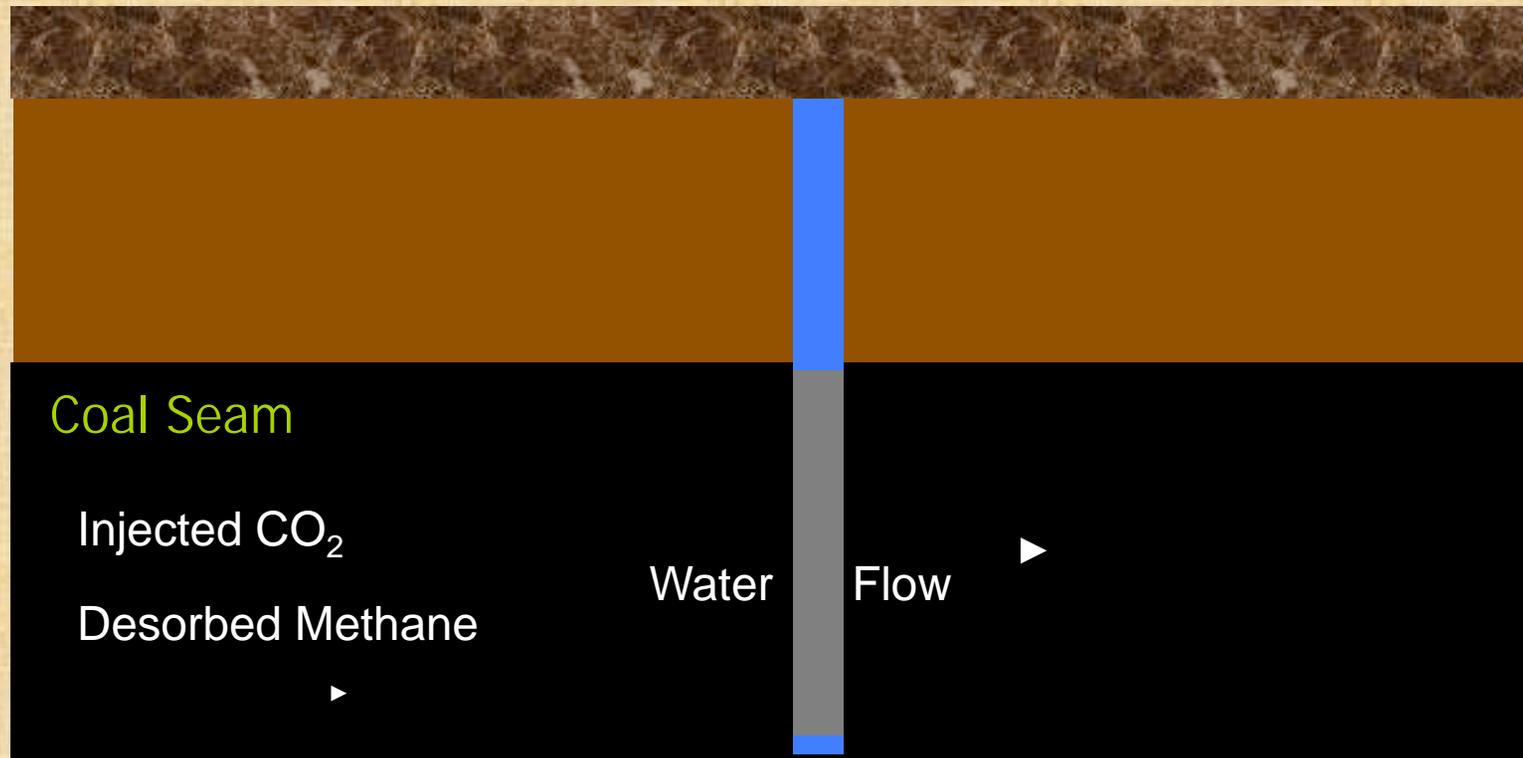
- Water Minimization (membranes and completion techniques)
- Surface Disposal (streams and infiltration ponds)
- Re-Injection
- Agricultural Application
- Treatment

Water Minimization Membrane-Enhanced CBM

1. Flow-through: CO_2



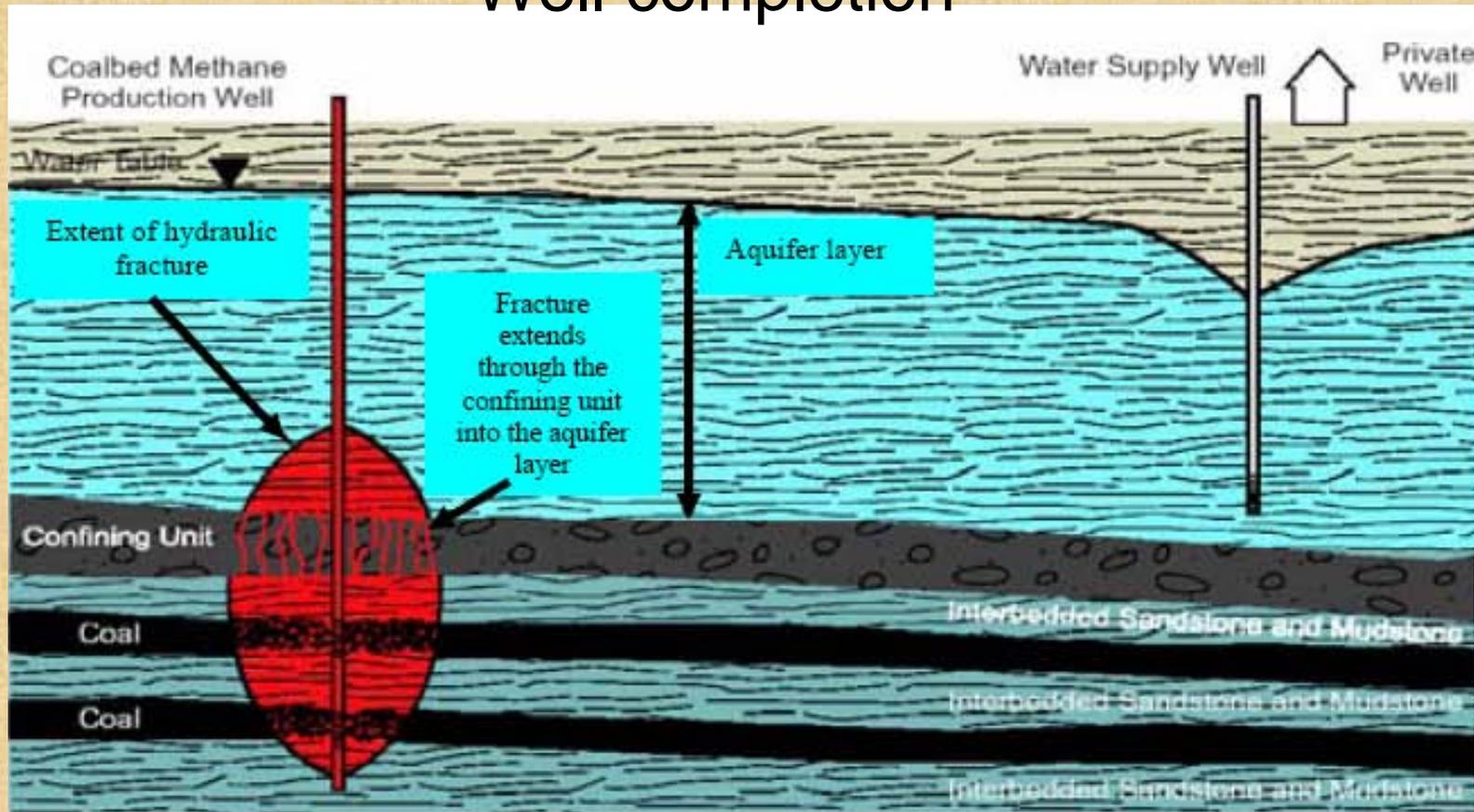
CH_4 , $\text{H}_2\text{O}_{(g)}$, etc.



Gas Permeable membranes minimize water production

Water Minimization

Well completion



Water Enhancement Tests - used to clean wellbore of drilling fines but may fracture formation.

Big George Coal

Water and Gas Production by Fracture Orientation

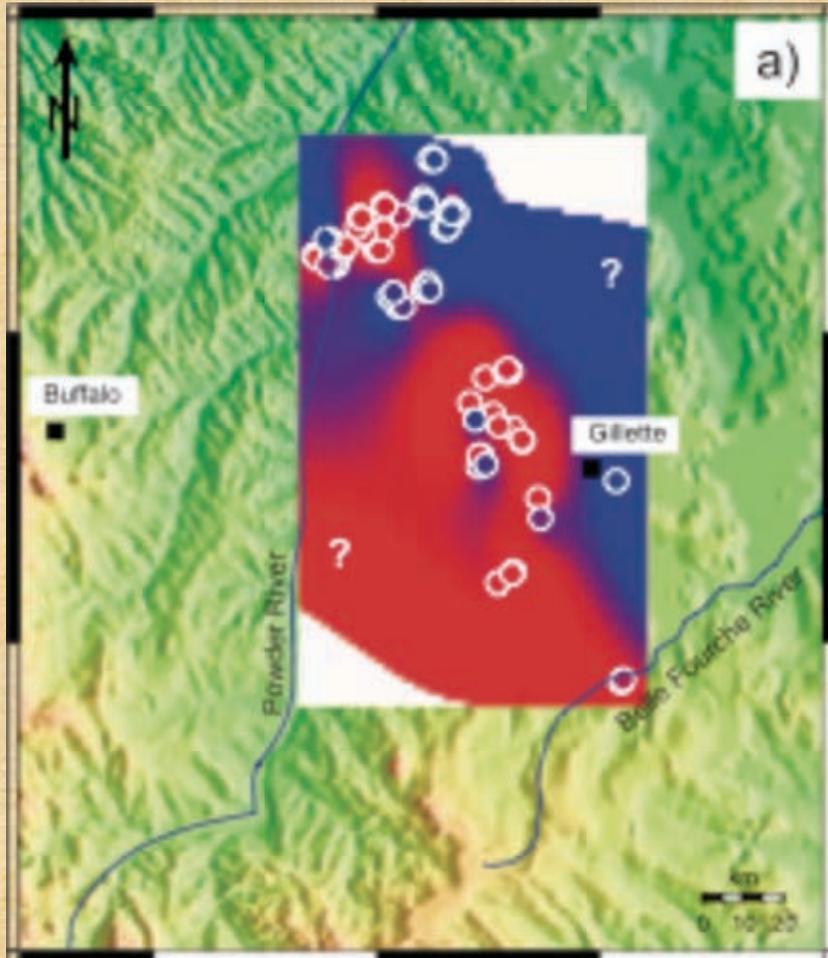
Wells with Vertical Fractures

- 71% of total water from 1/3 of total wells and very little gas production
- Wells with vertical fractures and low water are excellent gas producers

Wells with Horizontal Fractures

- Low water production but typically also low gas producers

Recommended Best Practices for Well Completion



Fracture Map

Purple: inferred horizontal fractures

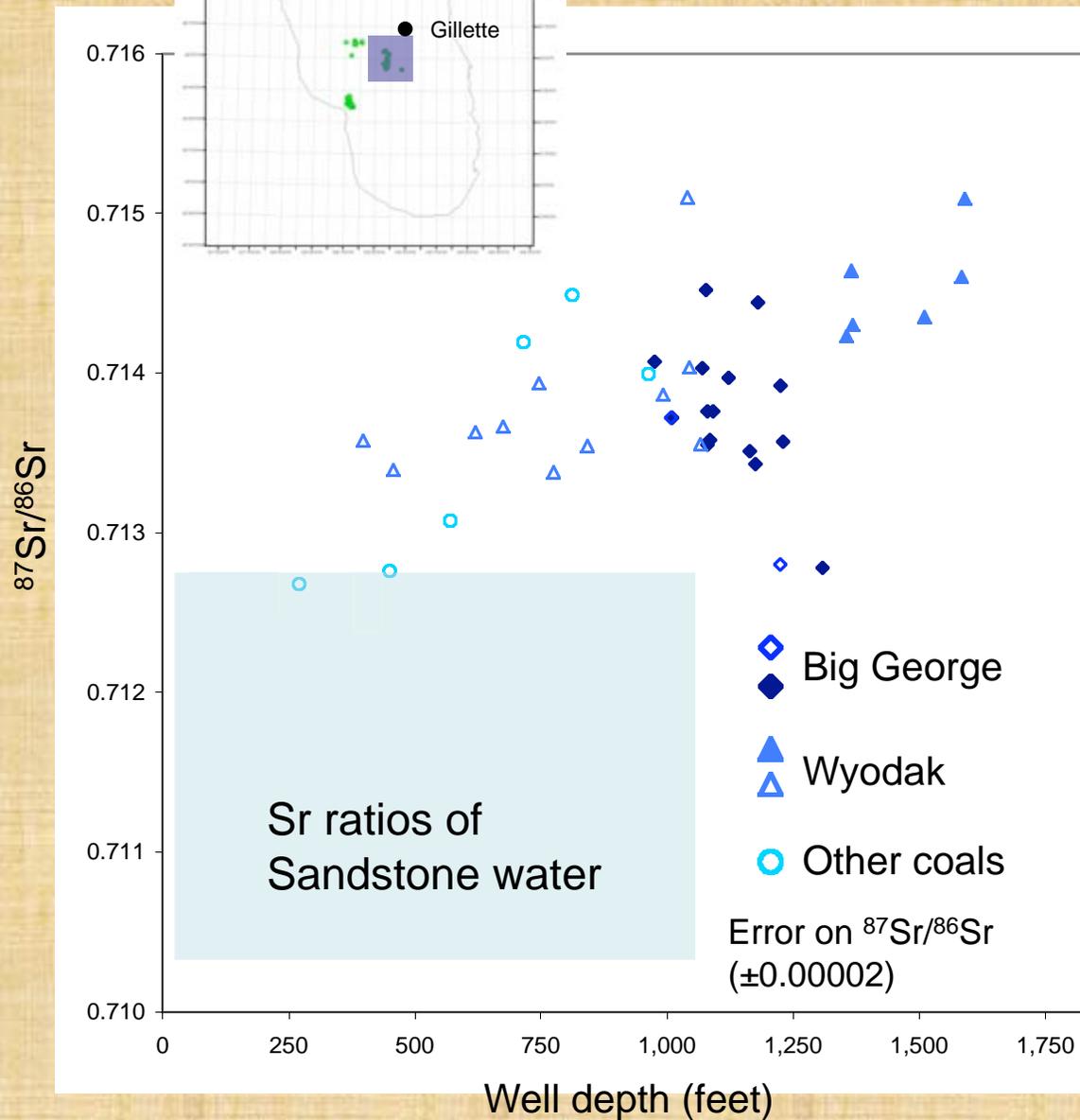
Red: inferred vertical fractures

Expect Vertical Fractures: limit extent of water enhancement test.

Expect Horizontal Fractures: conventional fracturing techniques?

Unknown Orientation: Minifrac to evaluate fracture orientation.

Water Sourcing: Gillette Area



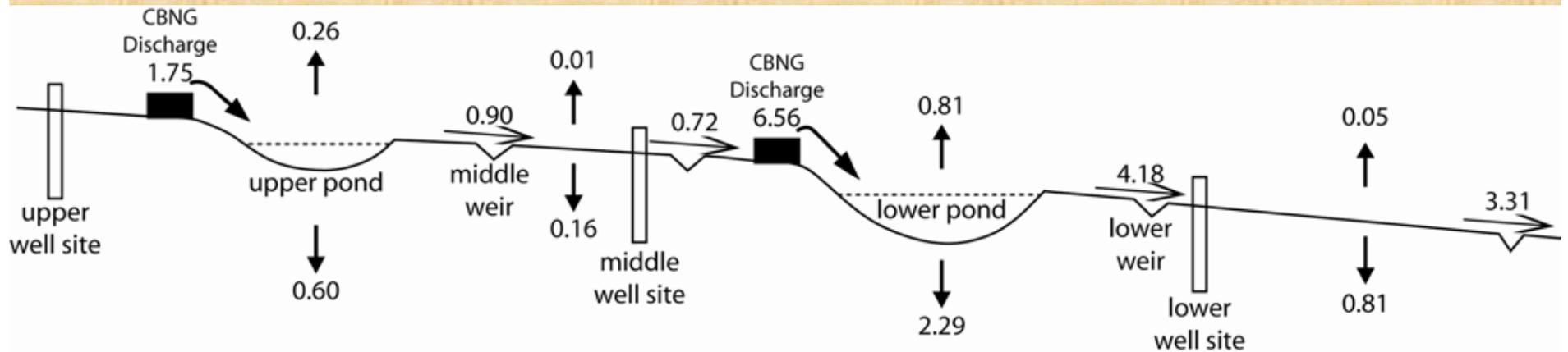
- $^{87}\text{Sr}/^{86}\text{Sr}$ from sandstone aquifers is lower than coal, especially for deep coal wells

- 2 wells have unusually low $^{87}\text{Sr}/^{86}\text{Sr}$

- One improperly cased

- One has sandstone directly below coal

Surface Discharge



Cross Section of Study Site

Channel Conveyance Losses:

Long-term trend due to vegetation increase

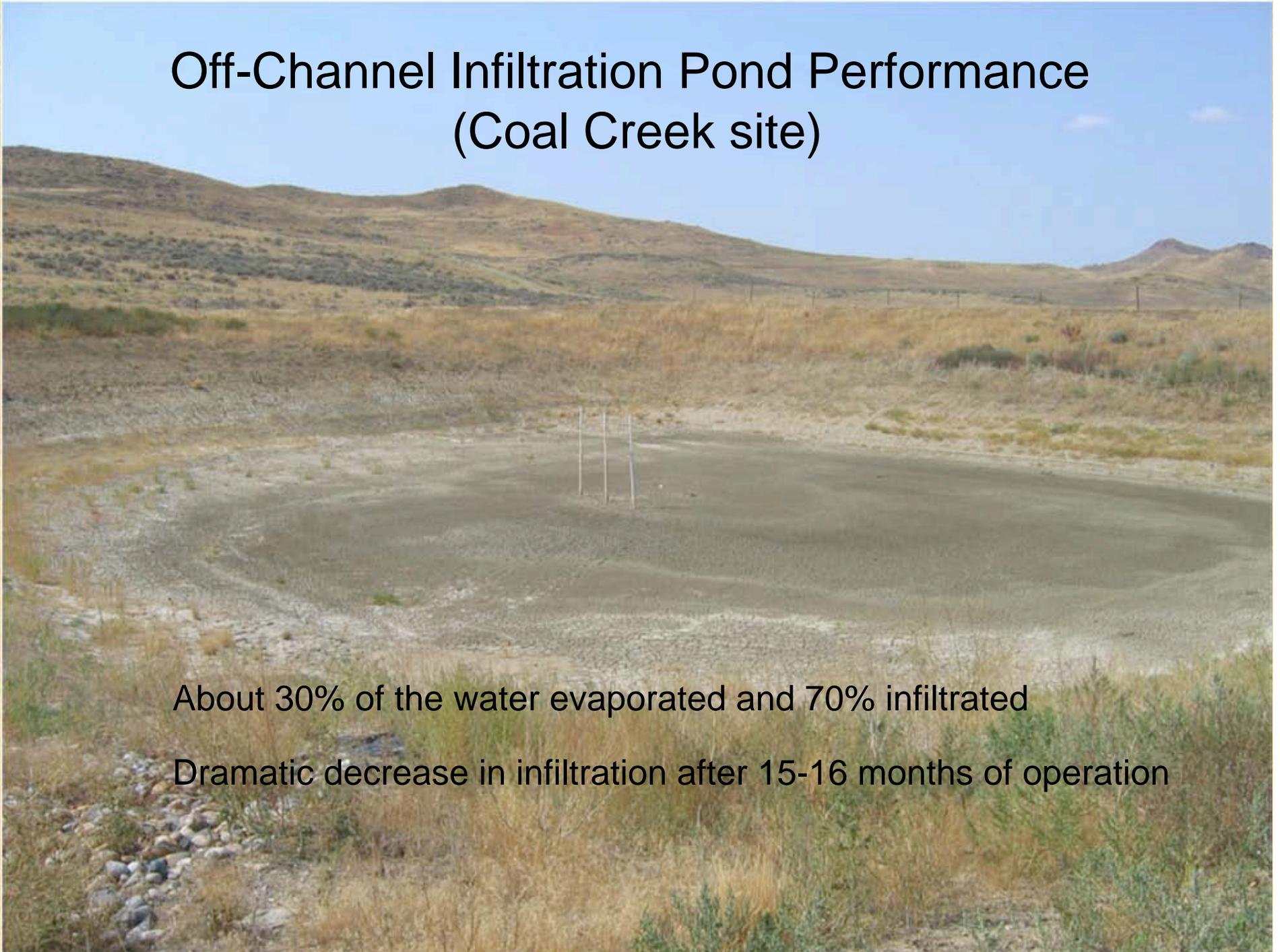


- Summer plant transpiration losses increased 6 fold by the third summer.
- Simulated summer discharge dropped from 20 gpm to 0 gpm 2 miles downstream by the second summer.
- Seasonality and temporal trends are important in predicting downstream discharge.

Off-Channel Infiltration Pond Performance (Coal Creek site)

About 30% of the water evaporated and 70% infiltrated

Dramatic decrease in infiltration after 15-16 months of operation



Beneficial Use

CBM water for Agricultural Application



Sulfur & gypsum application





Results

Untreated Plot

- Soil is crusted
- Soil structure lost
- Ponding occurring

Treated Plot

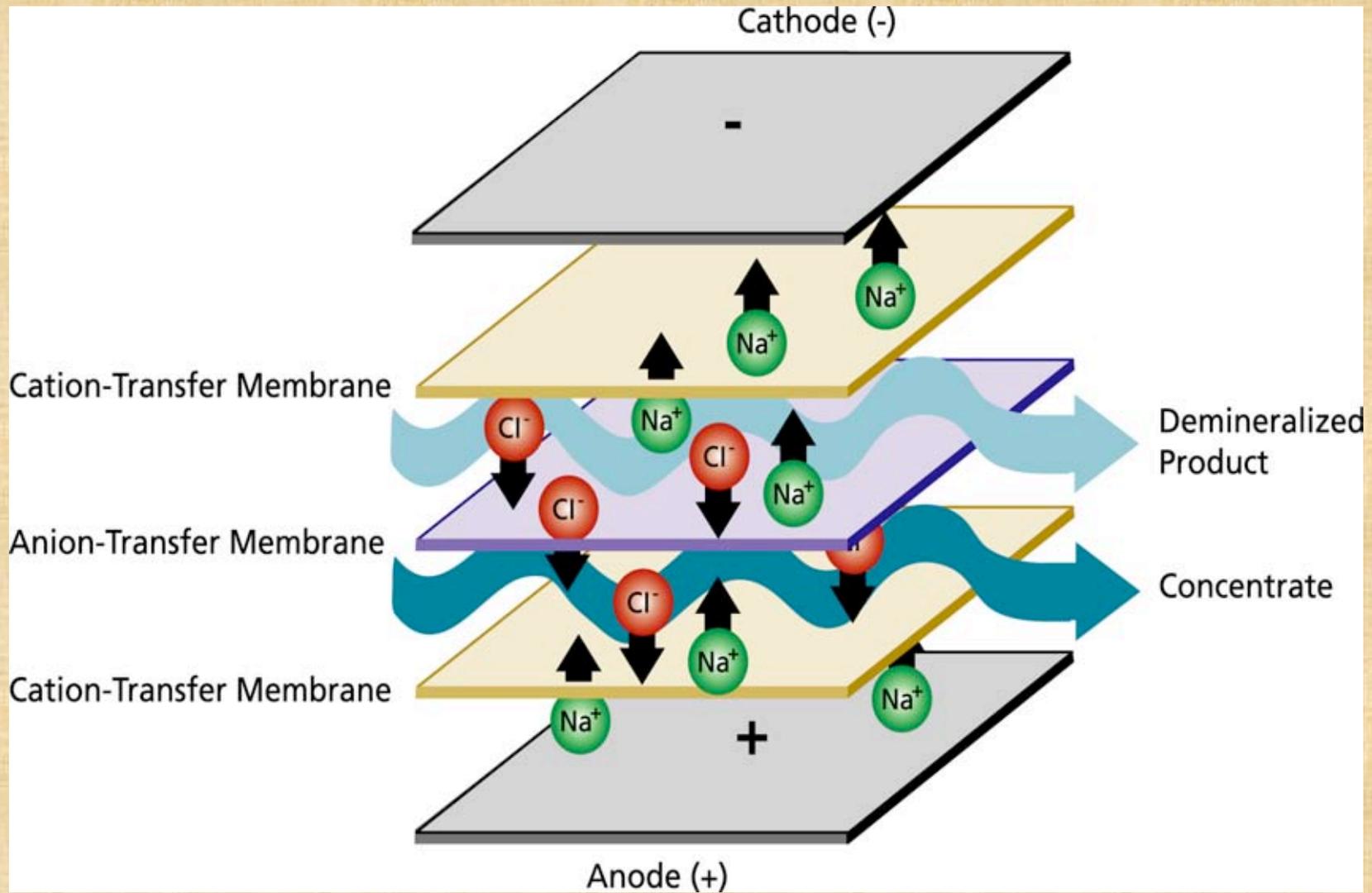
- Soil aggregation maintained
- Good water infiltration

Conclusions:

Amendments protect & reclaim soil.

Monitoring of amendments is critical.

Water Treatment



Electrodialysis Technology

Performance Characteristics of ED

Strengths

- High water recoveries
> 92%
- Low pressure operation
< 25 psi
- Resistant to fouling
- Long membrane life

Limitations

- Applicable to low to moderate TDS
- Energy costs excessive at TDS above 20,000 mg/l
- Does not remove hydrocarbons (e.g., BTEX or PAH's)

Comprehensive Investigation of the Biogeochemical Factors Enhancing Microbially Generated Methane in Coal Beds

Stimulate the microbial conversion of coal to natural gas (methane) in-situ.

- 1) No need to mine coal
- 2) Heavy metals associated with coal are left in place
- 3) CO₂ emissions decrease relative to burning coal

Thank You

