

Beneficial use of coal bed natural gas produced water through managed irrigation in the Powder River Basin of Wyoming

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June 16, 2014

Outline

What is managed irrigation?

The managed irrigation process

Evaluation, design, permitting, operations, monitoring,
and closure

Case study

Conclusions

What is Managed Irrigation?



Managed irrigation is defined as:

The application of established soil science, water chemistry, agronomic, and agricultural engineering principles to utilize CBNG produced water in a beneficial manner to grow forage for livestock and wildlife while protecting soil physical and chemical properties.

What is CBNG produced water?

In the Powder River Basin:

Groundwater pumped to the surface to recover CBNG

Rich in naturally occurring sodium and bicarbonate minerals

Why is the water a concern?

Natural sodicity (and less so, salinity) reduces the suitability of the water for crop irrigation

Managed irrigation process

Evaluation

Design

Permitting

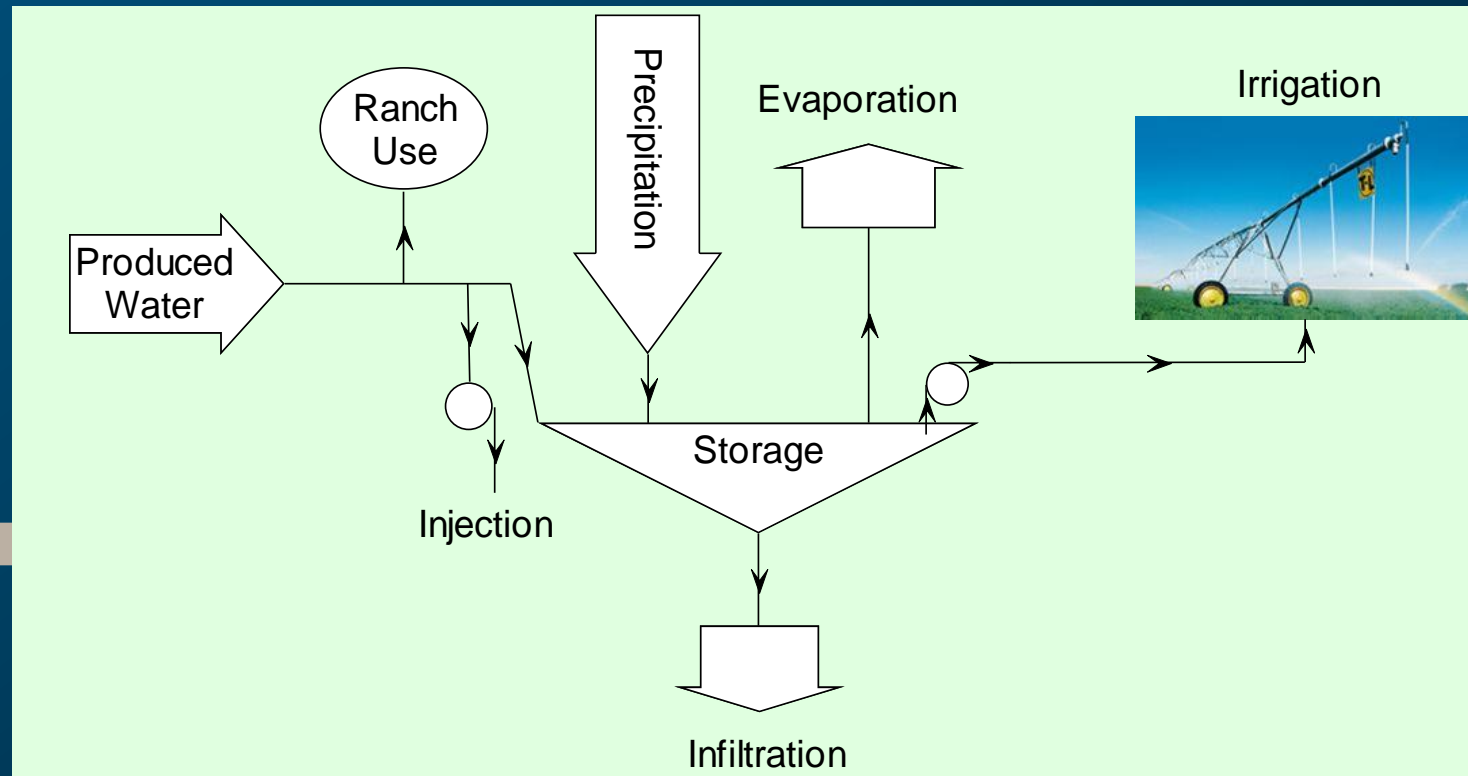
Operations

Monitoring

Closure

Phase 1: Irrigation Feasibility Evaluation

- Water quality suitability
- Soil/water conditioning prescription
- Water balance
- Site selection
- Permitting requirements
- Feasibility report



Phase 2: Irrigation Design and Permitting



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Phase 3: Operations and Monitoring



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Phase 4: Closure



Managed irrigation principles:

Work closely with landowner(s).

Select suitable sites and soils.

Understand the water balance.

Understand the chemistry of the water.

Condition soil and/or water to mitigate sodicity.

Select suitable crops.

Irrigate based on crop and leaching requirements.

Prevent runoff.

Monitor water, soil and vegetation.

Plan for site closure.

Managed Irrigation in the PRB



Managed Irrigation in the PRB

Program initiated in early 2000's

Evaluation, design, & permitting

Grew to nearly 90 fields covering 3,000 acres

Operations & monitoring

**Recent decrease in production reduced need for
water disposal**

Closure

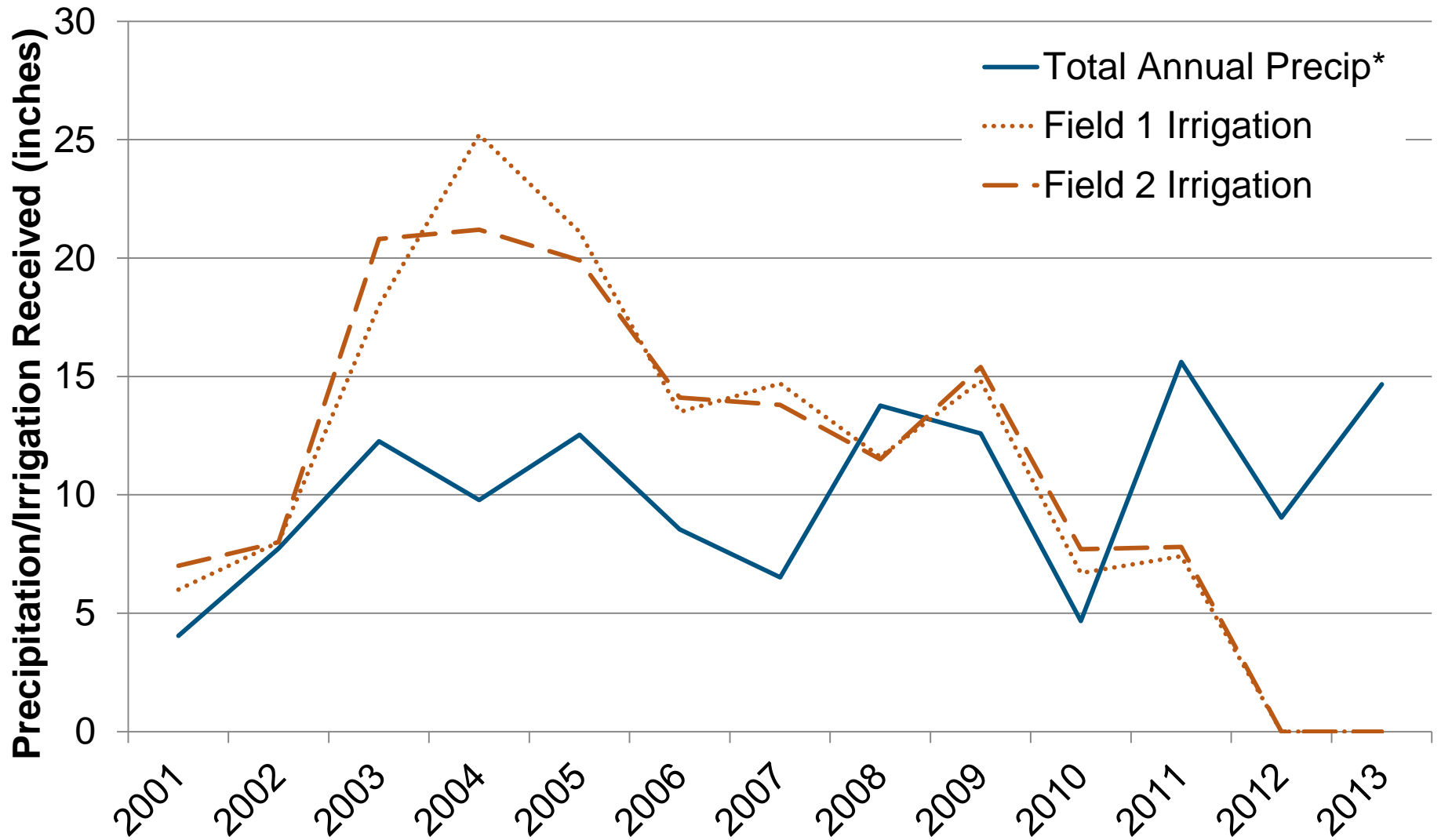
Case study

- **Two center pivot fields near Sheridan, WY**
- **49 acres each**
- **CBNG produced water first applied in 2001**
- **Final application of CBNG produced water in 2011**
- **Alfalfa fields from 2002-2009, sorghum in 2010, native grasses and alfalfa from 2011-present**

Average water quality

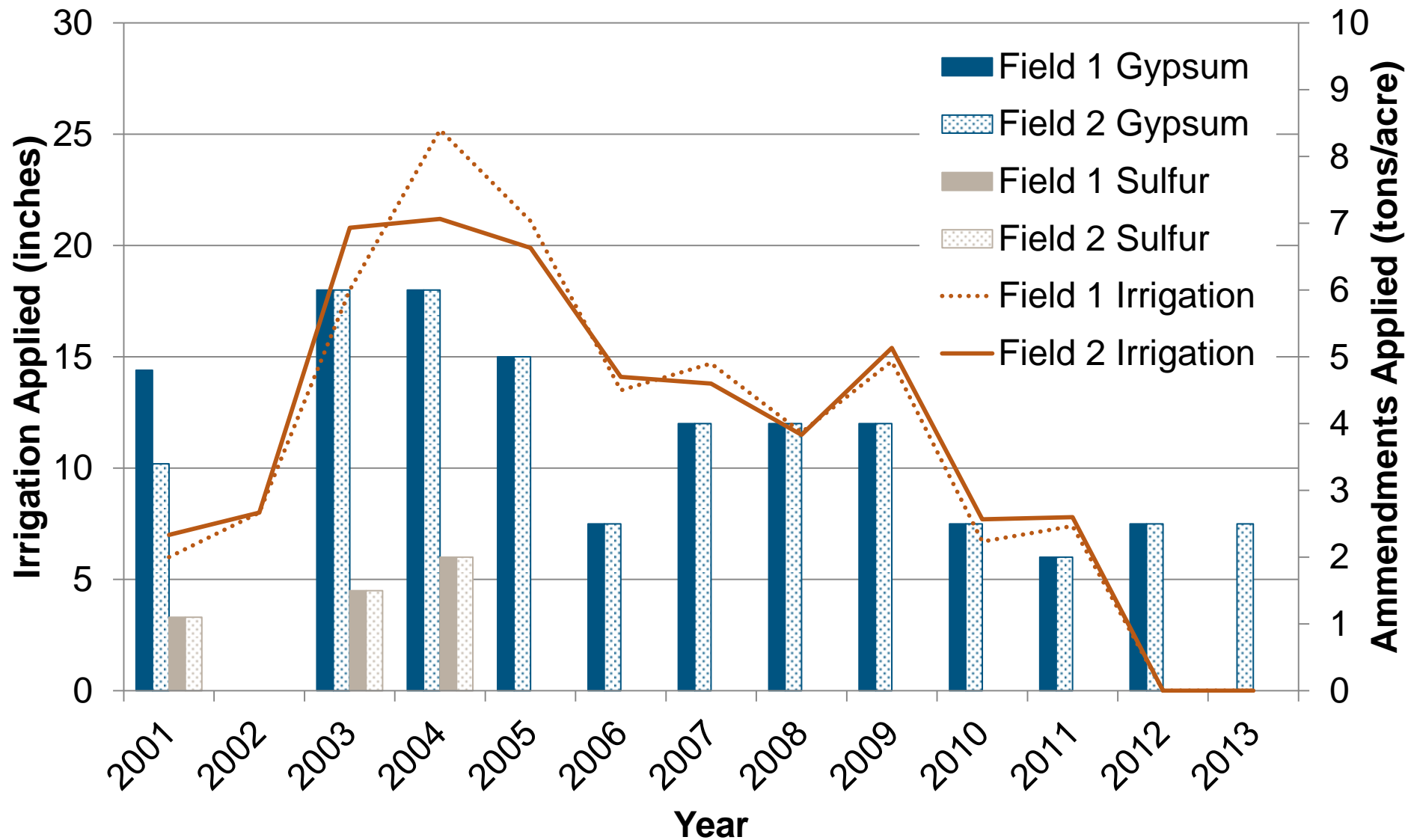
Analyte	Units	Average Value
pH	s.u.	8.8
Electrical Conductivity (EC)	µmhos/cm	2,386
Sodium Adsorption Ratio (SAR)	--	50
Anions		
Bicarbonate	mg/L	1,282
Chloride	mg/L	28
Fluoride	mg/L	3.4
Sulfate	mg/L	72
Cations		
Calcium	mg/L	5.5
Magnesium	mg/L	3.8
Potassium	mg/L	8.1
Sodium	mg/L	617

CBNG produced water applied



*Precipitation data from the Western Regional Climate Center; Boyd Ridge station

Applied irrigation and amendments



Closure requirements

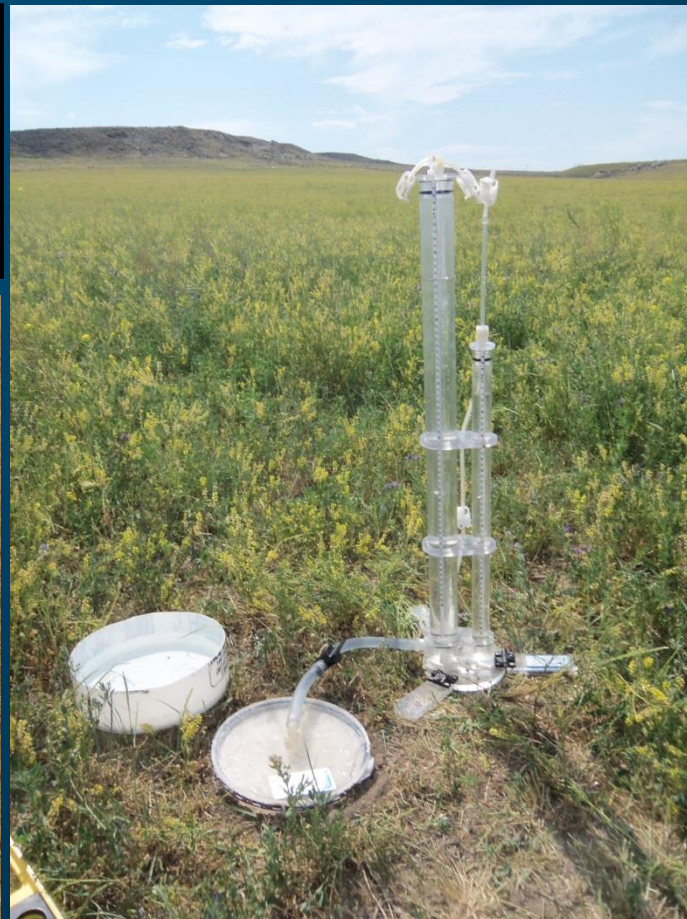
- ✓ Apply up to two tons/acre gypsum after final irrigation event
- ✓ No more than a 25% reduction in infiltration from baseline
- ✓ Root zone salinity < 3.0 dS/m and ESP $< 8\%$
-OR-
Root zone salinity > 3.0 dS/m and ESP $< 15\%$

Site closure soil conditions

Parameter	Field 1		Field 2	
	0-6"	6-12"	0-6"	6-12"
pH	7.4	7.6	7.5	7.4
EC (dS/m)	3.0	3.3	1.8	2.6
SAR	5.1	6.6	2.3	7.6
ESP (%)	5.7	6.9	2.6	10.4
Saturation Percentage (%)	51.5	44.4	50.8	43.8
Lime Content (%)	1.8	4.8	9.0	17.1

Infiltration rates

Location	Soil Infiltration (inches/hour)	
	2002	2012
Field 1	0.24	1.6
Field 2	0.23	1.7



Closure root zone salinity and sodicity

inches	Field 1				Field 2			
	EC (dS/m)		ESP (%)		EC (dS/m)		ESP (%)	
0 to 6	3.0	3.1	5.7	8.6	1.8	2.3	2.6	7.6
6 to 12	3.3		6.9		2.6		10.4	
12 to 24	3.3		11.7		3.0		10.8	
24 to 36	2.4		19.1		1.8		13.3	
36 to 60	5.7		9.2		2.2		11.2	

Closure requirements

- ✓ Apply up to two tons/acre gypsum after final irrigation event
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Conclusions

Over 370 million gallons of produced water applied over 10 years

Continually adjusted recommendations based on actual soil data, water quality, and applied irrigation

2 years after final irrigation, both fields met final reclamation criteria



Questions?

