Managed Irrigation with Coalbed Natural Gas Produced Water

Presentation by Kevin Harvey to the
Water Policy Interim Committee, January 14, 2009

KC HARVEY
Soil & Water Resource Consulting

AN ENERCREST COMPANY

Who am I?

- President of KC Harvey, Inc.
- EVP and Chief Scientist of EnerCrest, Inc.
- M.S. Land Rehabilitation/Soil Science (MSU) and B.S. Resource Conservation/Soil Science (UM)
- Board Certification in Soil Science
- 28 years worldwide experience
- 12 years CBNG experience – MT, WY, CO, UT
- Several 100 CBNG water management projects
- Invited by Wyoming DEQ to participate on CBM water policy committee
- Received national SSSA award for CBNG managed irrigation work

Overview

- What is Managed Irrigation?
- Soil and Water Chemistry 101
- Evaluation, Design, Permitting, Operations, Monitoring and Closure
- Project Examples

What is Managed Irrigation?

Managed irrigation is defined (by me) 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.

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.

Soil and Water Chemistry 101

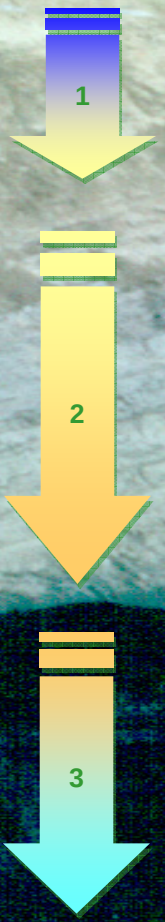
What CBNG Produced Water Is and Is Not:

- CBNG water is naturally occurring groundwater.
- Chemicals and salts in CBNG water result from natural processes.
- No chemicals or salts are added to CBNG water by the production process.
- Coalbed water is classified as a sodium-bicarbonate type water.

Analyte	Units	Min.	Max.
pH	*s.u.*	6.8	8.0
Total Dissolved Solids (TDS)	*mg/L*	270	2720
Electrical Conductivity (EC)	*dS/m*	0.42	3.7
Sodium Adsorption Ratio (SAR)	*unitless*	5	69
Bicarbonate	*mg/L*	289	3134
Chloride	*mg/L*	5.1	65
Fluoride	*mg/L*	0.4	4.1
Sulfate	*mg/L*	<0.3	17
Calcium	*mg/L*	1.8	69
Magnesium	*mg/L*	0.6	46
Potassium	*mg/L*	3.1	48
Sodium	*mg/L*	109	1000

How did the water get this way?

Evolution of Coalbed Water



1 – as water infiltrates through soil, natural salts comprised of calcium, magnesium and sulfate dissolve.

2 – sodium replaces calcium and magnesium because of ion exchange that occurs in buried shale layers .

3 – decomposition of carbon causes sulfate reduction that removes sulfate and adds bicarbonate to the water. coalbed groundwater is a sodium-bicarbonate type.

Why is the water a concern?

- 100% untreated CBNG produced water may impact soils and plants if used for irrigation.
- The natural sodicity of produced water is the primary factor most likely to affect the suitability of the water for irrigation.
- The salinity of produced water is less of a problem than the sodicity.

Salinity and Sodicity as it Relates to Irrigation Water Suitability

- **Excessive salinity (EC) in irrigation water can impact crop growth.**
  - ✓ Excessive salt in soil make it harder for plants to pull water out of soil
- **Excessive sodicity (SAR) in irrigation water can impact soil structure and infiltration / permeability.**
  - ✓ The higher the salt content of the irrigation water or soil, the less impact from SAR

Salinity and Sodicity

- **Effects seen long term (chronic exposure)**
- **Occasional contact:**
  - ✓ No measurable change to soil infiltration
  - ✓ No measurable change to plant production


Managed Irrigation with SBNS Produced Water

Evaluation, Design, Permitting, Operations, Monitoring, and Closure

Phase 1: Irrigation Feasibility Evaluation

- Assess water quality suitability for irrigation.
- Develop soil/water conditioning prescription.
- Analyze project water balance.
- Select candidate irrigation sites.
- Review permitting requirements.
- Prepare feasibility report.

Phase 2: Irrigation Design and Permitting

- Site and Soil Characterization
- Selection and Design of Irrigation Systems
- Crop Selection.
- Soil Water Balance Modeling and Irrigation Scheduling.
- Development of Site Monitoring Plan.
- Development of Irrigation Management Plan.
- Development of Site Closure Plan.

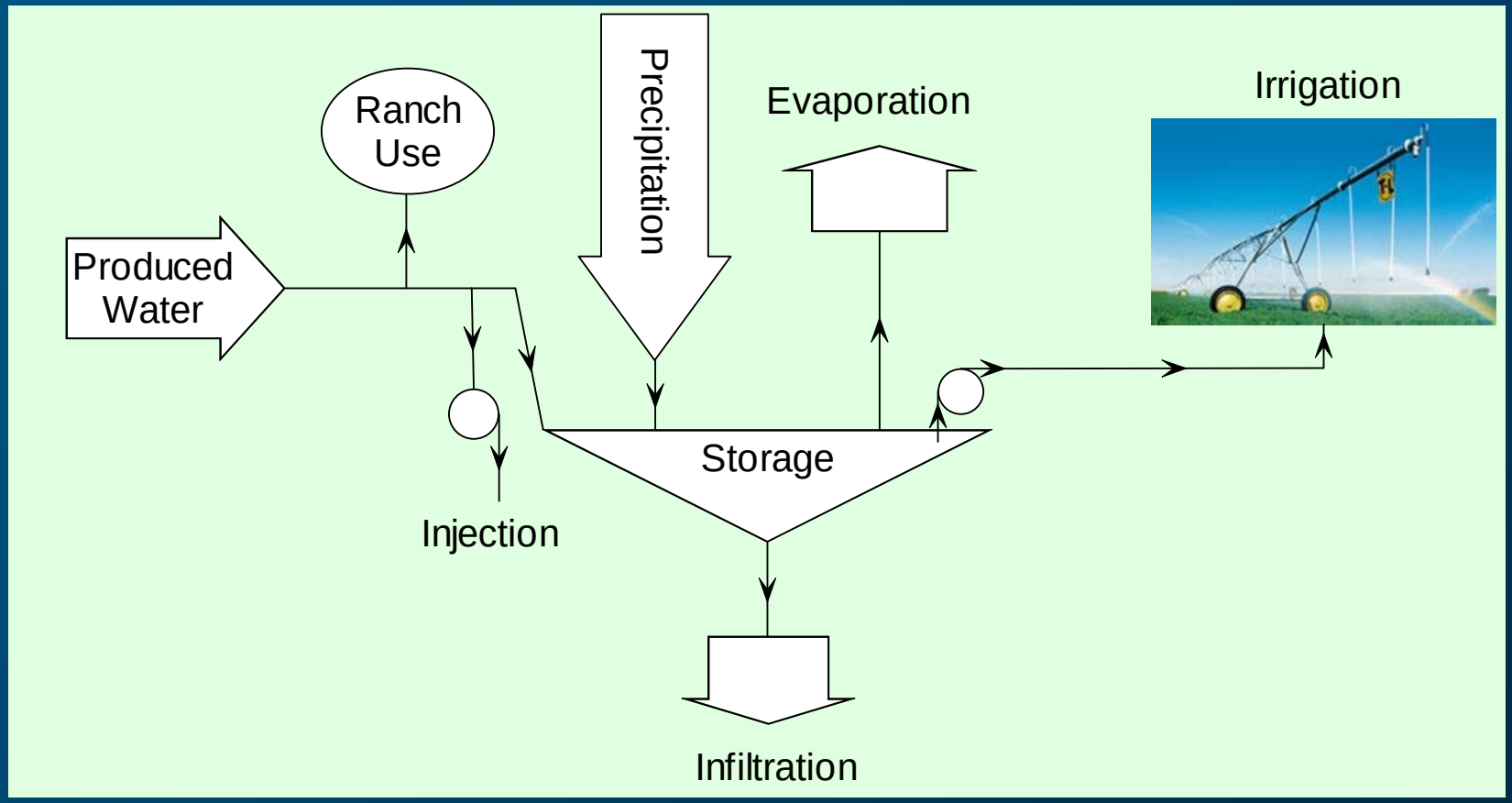
Phase 3: Operations and Monitoring

- **Site Operations**
  - ✓ Planting
  - ✓ Irrigation Operations
  - ✓ Amendment Spreading
  - ✓ Harvesting
- **Irrigation and Crop Management Plans**
  - ✓ Cropping Sequences
  - ✓ Irrigation Scheduling
- **Monitoring Plan**
  - ✓ Soil
  - ✓ Crop
  - ✓ Water

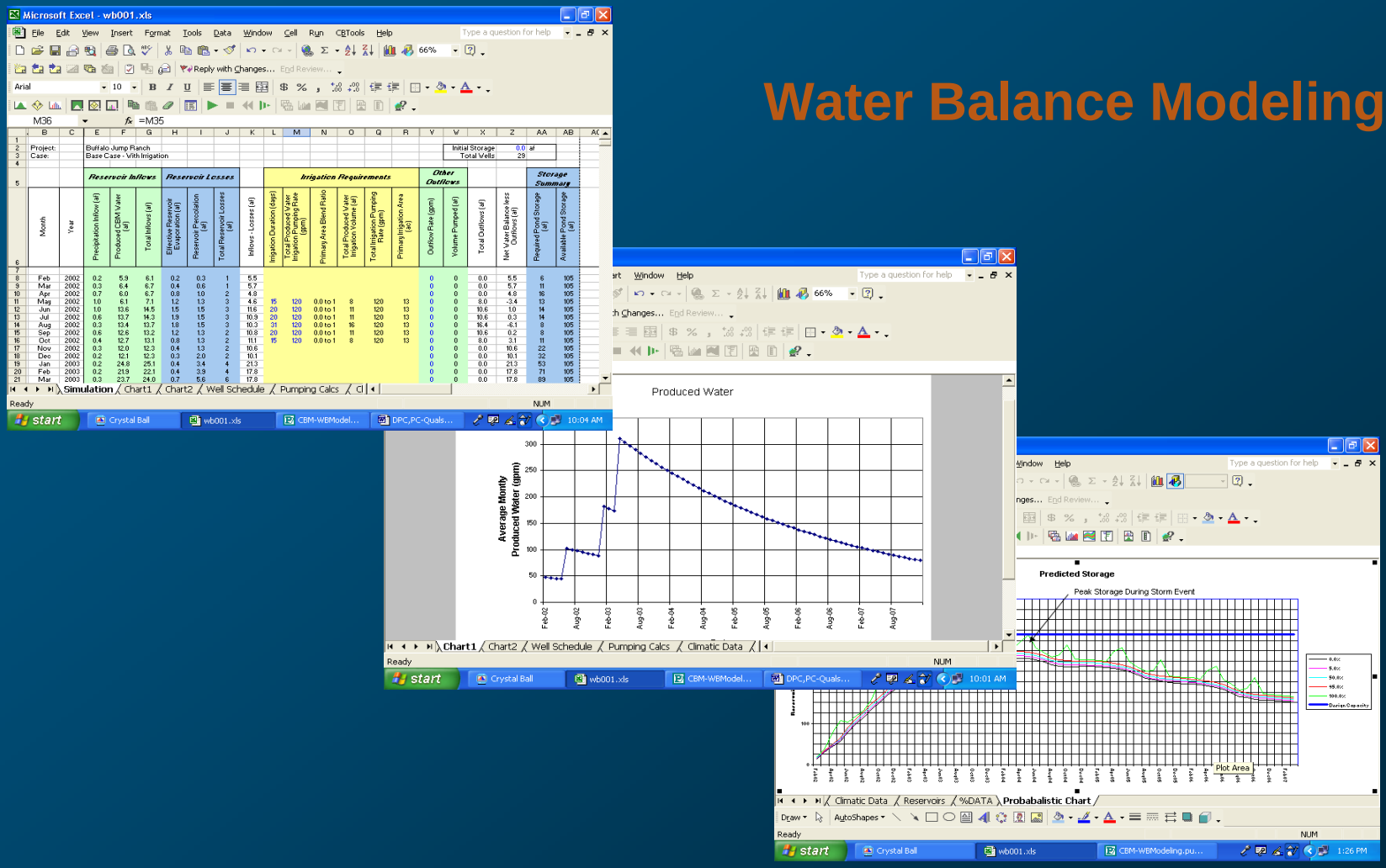
Conditioning CBNG Produced Water for Irrigation

- **Sodium Removal (e.g. RO, IX, etc.)**
  - ✓ Remove sodium to lower SAR
  - ✓ Remove salts and bicarbonate
- **Calcium Addition**
  - ✓ Gypsum, or other calcium addition to water
  - ✓ Gypsum soil amendments
- **Bicarbonate neutralization**
  - ✓ Calcium addition to lower SAR
  - ✓ Agricultural grade sulfur soil amendments
- **Blending**
  - ✓ Untreated produced water + treated water
  - ✓ Untreated produced water + other water

Project Water Balance Projections

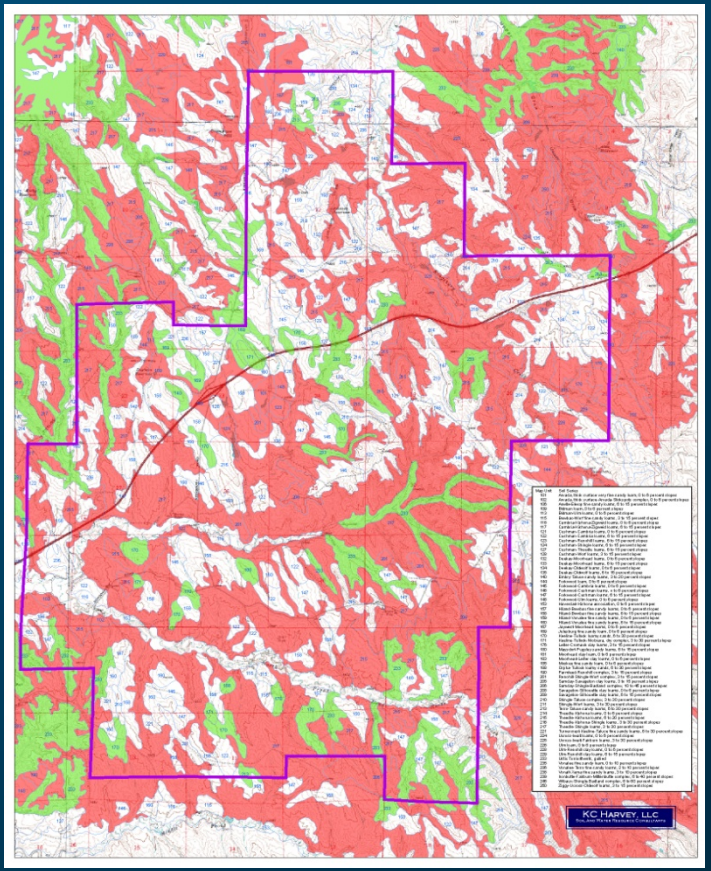


Water Balance Modeling

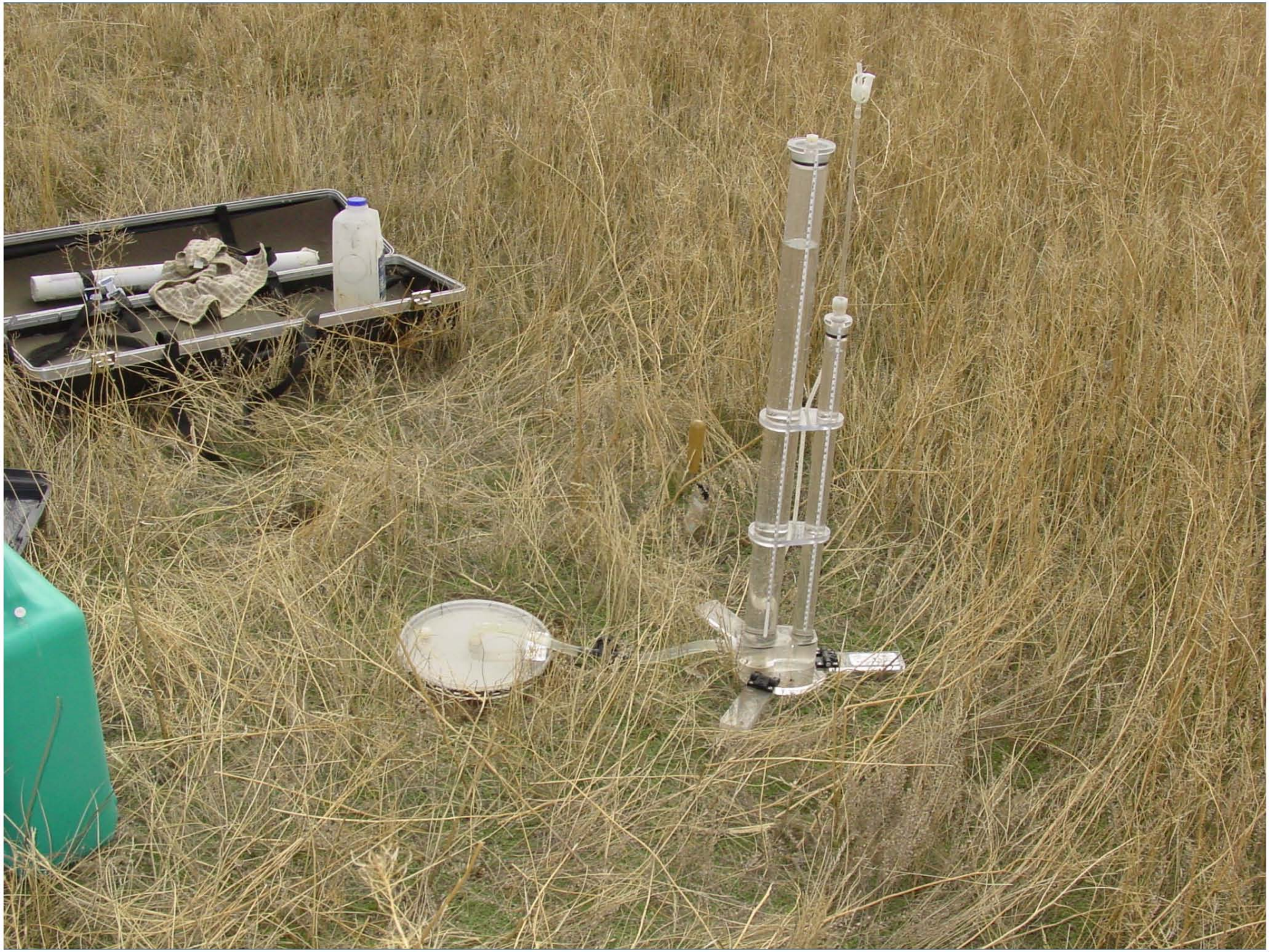


Selecting Candidate Irrigation Sites

- **Topography**
  - ✓ Slopes < 10%
- **Landowner Preferences**
- **Site Proximity**
  - ✓ Well field
  - ✓ Storage pits/reservoirs
- **Soil Suitability**
  - ✓ GIS Screening



Site and Soil Characterization



Irrigation System Selection

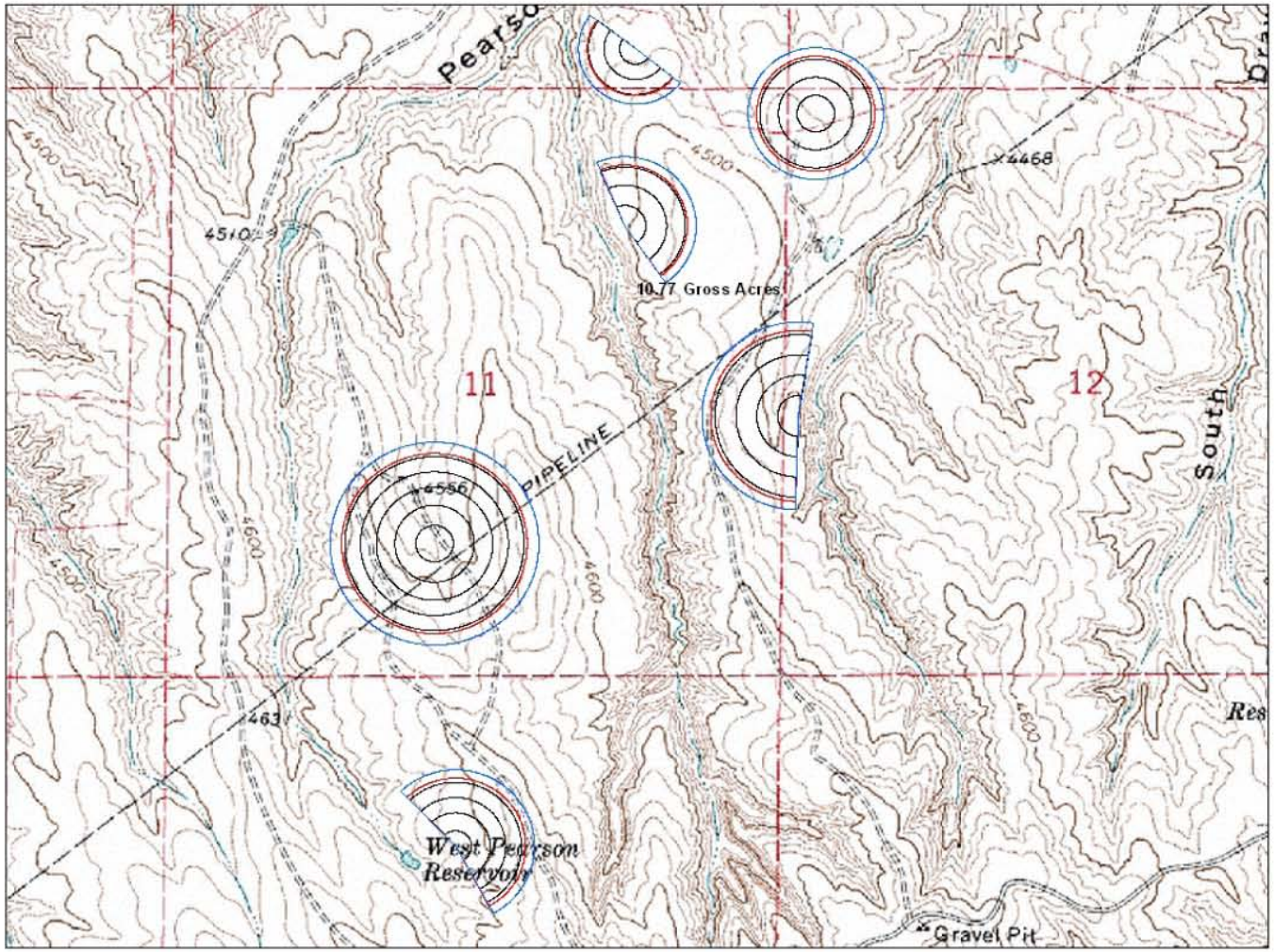
Wheellines

Center Pivot

Flood Irrigation

Solid Set

Irrigation Layout



Crop Selection

- Water Quality
- Landowner Preferences
- Season
- Water Balance
- Prior Site Conditions
- High Water Uptake

Soil Water Budgeting/Irrigation Scheduling

Table 6. 2003 Soil Water Balance Calculations (data in inches)

Field: **Tongue River West** **Soil Type:** Loam/Sandy loam **Soil Water Holding Capacity:** [6] 8.0

Crop: Alfalfa hay **Acres:** 49 **Initial Soil Water Content:** [7] 8.0

Month	Precipitation [1]	Gross Irrigation [2]	Irrigation Efficiency	Net Irrigation [3]	Total Input [4]	Evapotranspiration [5]		Soil Water Content [8]	Surplus [9]
						Potential	Estimate		
Apr	0.55	0.0	0%	0.0	0.6	2.4	2.4	6.2	0.0
May	2.81	0.0	0%	0.0	2.8	5.1	4.5	4.5	0.0
Jun	2.5	2.7	85%	2.3	4.8	6.4	4.8	4.5	0.0
Jul	0.07	3.3	85%	2.8	2.9	8.0	6.0	1.4	0.0
Aug	0.34	8.2	85%	7.0	7.3	6.8	2.8	5.9	0.0
Sep	1.54	3.5	85%	3.0	4.5	3.8	3.3	7.1	0.0
Oct	0.26	3.1	85%	2.6	2.9	0.9	0.8	8.0	1.2
Nov	0.74	0.0	0%	0.0	0.7	0.0	0.0	8.0	0.7
Dec	0.51	0.0	0%	0.0	0.5	0.0	0.0	8.0	0.5
Jan	0.51	0.0	0%	0.0	0.5	0.0	0.0	8.0	0.5
Feb	0.48	0.0	0%	0.0	0.5	0.0	0.0	8.0	0.5
Mar	0.94	0.0	0%	0.0	0.9	0.0	0.0	8.0	0.9
Total (in)	9.8	20.8		17.7	28.9	33.4	24.6		4.4
								Leaching Fraction [10]	0.150

Project Examples

- Fidelity Exploration & Production Company
- Williams Production RMT Company

Fidelity Exploration & Production Company

Tongue River Project Area

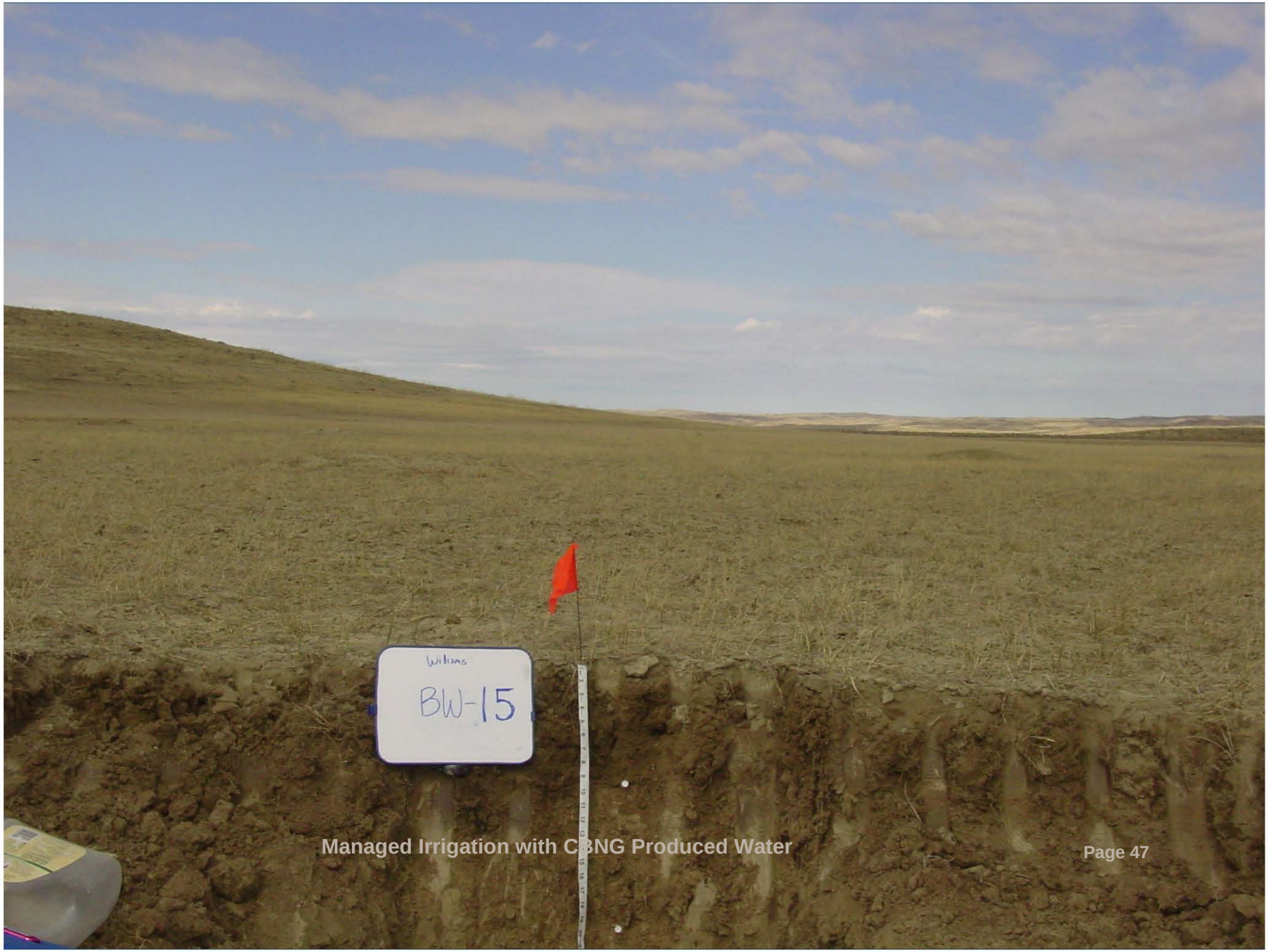
Wyoming


Zimmatic

Williams Production RMT Company

Powder River Project Area

Wyoming


Williams
BW-15

Forage Production

- Grass Yields range from 1.25 to 2.0 tons per acre.
- Alfalfa yields range from 2.0 to 3.0 tons per acre.
- Cattle graze the sites during the winter
- Not managed to maximize yield – harvest is not optimally timed.

Thank you.