Managed irrigation with coalbed natural gas produced water: Planning, design, operations, monitoring, and closure

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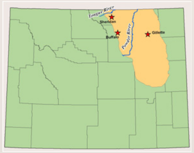
Introduction



- Coalbed natural gas (CBNG) production continues to increase in the Powder River Basin (PRB) of Wyoming
- The PRB has ~ 713 billion m^3 of recoverable CBNG[1]
- CBNG production will extract ~ 700,000 ha-m of ground water[2]
- CBNG produced water is unaltered groundwater rich in:
  - Soluble salts
  - Sodium
  - Bicarbonate
- Direct land application of CBNG produced water poses a potential sodicity and salinity hazard
- Several water management strategies are necessary – one strategy available is managed irrigation
- Managed irrigation is the application of soil science, water chemistry, agricultural engineering, and agronomic principles to utilize CBNG-produced water in a beneficial manner to produce forage for livestock and wildlife while protecting soil physical and chemical properties

Managed Irrigation Objectives

- Beneficially use CBNG produced water
- Maintain soil salinity at levels suitable for crop growth
- Prevent excessive sodium accumulation in the soil profile
- Produce a forage crop

Managed Irrigation Planning

Project water balance

- Production volume
- Production rates
- Crop water use estimates
- Water storage requirements
- Project duration
- Alternative water management strategies

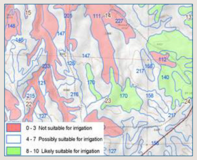
CBNG water quality assessment

- Assess salinity, sodicity, alkalinity, and specific ion toxicity[3]
- Determine soil amendment rates with geochemical models[4]

Objective	Technique
Neutralize HCO_3^-	Elemental S addition
Reduce SAR	Gypsum addition supplies Ca

Initial soil screening

- GIS-based screening utilizes soil survey data:
  - Soil map unit
  - Texture
  - Hydraulic conductivity
  - Soil depth
  - Slope



Managed Irrigation Design

Site characterization

- Soil profiles described with standard NRCS field methods[5]
- Similar to an Order 1 soil survey
- Samples collected and analyzed from each genetic horizon
- Hydrology, topography, and land use are also evaluated
- Site characteristics are used to determine the overall suitability for managed irrigation with CBNG produced water

Agronomic planning and design

- Crop selection: salinity tolerance and landowner preference
- Irrigation system design suitable for topography, soils, and project economics

Managed Irrigation Operations

Soil water balance and irrigation scheduling

- Leaching requirement calculated to maintain soil salinity levels suitable for plant growth
- Water application rates not to exceed soil infiltration capacity

Irrigation and crop management plans

- Satisfy landowner and land use goals
- Schedule operational activities:
  - Amendment application
  - Seeding
  - Harvesting
  - Monitoring

Managed Irrigation Monitoring

Monitoring objectives

- Maintain soil physical and chemical conditions at levels supportive of plant growth
- Ensure successful forage crop production
- Incorporate monitoring data into management practices

Water, soil, crop, and meteorological monitoring

Medium	Timing	Monitoring Point	Method	Parameters[1]	Conducted By
Soil Chemistry	Spring - prior to the irrigation season	Samples collected along a defined transect.	Composite soil samples will be collected from two depths: 0 to 6" and 6 to 12".	pH, EC, SAR, ESP, % Lime, Sulfate, and bicarbonate. Organic Matter will be analyzed in the 0 to 6" depths. N,P,K,Zn as required.	Contractor and a certified laboratory. It is recommended that the sampling be performed by a certified professional soil scientist.
	Fall - after the irrigation season	Samples collected along a defined transect.	Composite soils samples will be collected from six depths utilizing a Giddings soil probe: 0 to 6" 6 to 12" 12 to 24", 24 to 36", 36 to 60", and 60 to 96".	pH, EC, SAR, ESP, % Lime, sulfate, and bicarbonate. Organic Matter will be analyzed in the 0 to 6" depth.	Contractor and a certified laboratory. It is recommended that the sampling be performed by a certified professional soil scientist.
Soil Infiltration	Baseline and periodically after irrigation begins	Defined monitoring locations	Tension infiltrometer	Soil infiltration rates	Contractor.
Soil Structure	Spring and Fall	Along a defined transect	Visual to a depth of 24"	Soil stucture	Certified Professional Soil Scientist
Water Quality	Annually (beginning of irrigation season)	Irrigation water intake	Grab sample	pH, EC, major ions	Contractor and a certified laboratory.
Water Quantity	Weekly during the irrigation season.	Each pivot	Meter reading	Meter reading	Contractor
Crop Monitoring	Monthly during the irrigation season.	Along a defined transect	Visual	Germination, emergence, vigor, and weed infestations	Contractor
	After each harvest	Each crop type	grab samples of bale cores	Sulfate, nitrate, calcium, magnesium, sodium, crude protein, and percent moisture	Contractor and a certified laboratory.
Climate	Weekly during the irrigation season.	ETGage, rain gauge or from nearest meteorological monitoring station	Visual	Reading	Contractor

Site Closure Planning

- Determine long-term land use goals
- Predict soil chemical conditions
- Make closure amendment recommendations, as necessary
- Create a post-closure monitoring strategy

Discussion

- Managed irrigation requires active, responsive management
- Soil physical and chemical conditions are maintained at targeted levels

Soils

- Soil EC increases due to water and amendment applications
- Soil structure and hydraulic conditions are maintained

Potential benefits

- Beneficial use of CBNG produced water
- Increased crop production during a period of on-going drought
- Successful crop establishment improves range condition in irrigated areas
- Managed irrigation techniques may be useful in other situations where industrial waters are available for irrigation

References

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4. Parkhurst, D. L. and C.A. Appelo. 2005. User's guide to PHREEQC (Version 2)—A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations: U.S. Geological Survey Water-Resources Investigations Report 99-4259, 310 p.

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