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An Integrated Framework for Treatment and Management of CBM Produced Water

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and Dean Heil

Colorado School of Mines

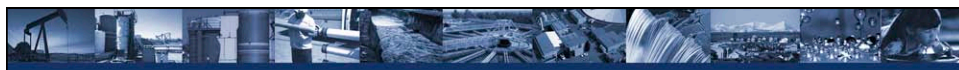

Jim Graydon, Jean Debroux, Dawn Taffler
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John Veil, Seth Snyder, Bob Sullivan, YuPo Lin
Argonne National Laboratory

Bob Raucher and Jim Henderson, Stratus Consulting
Wayne Buschmann, Eltron Research

17th International Petroleum and Biofuels Environmental
Conference (IPEC)

San Antonio, TX, September 1st, 2010



Outline

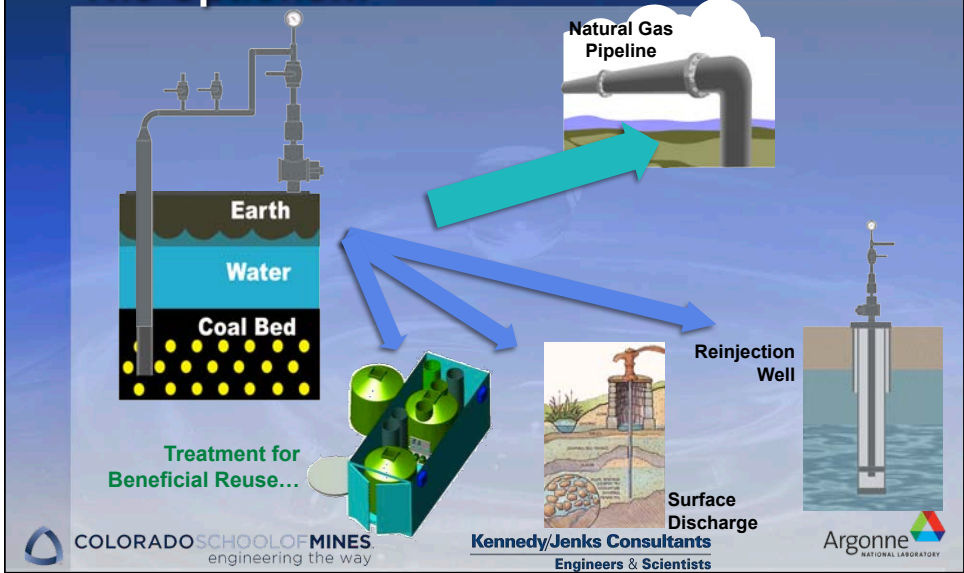
- ▶ Current practices and challenges associated with management and beneficial use of produced water
- ▶ Opportunities and technical challenges
- ▶ Guidance needed for beneficial use
- ▶ An integrated framework approach to facilitate beneficial use
- ▶ Concluding remarks

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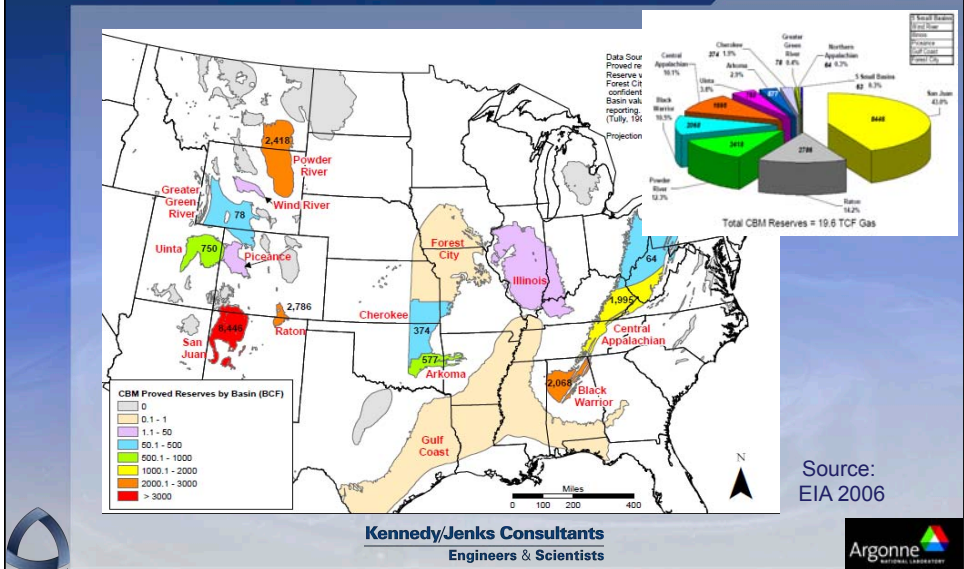
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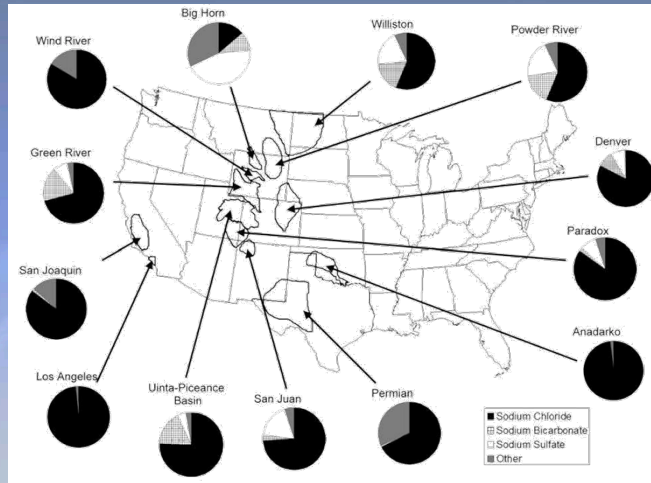
Coal Bed Methane (CBM) Produced Water: The Options...



CBM Proved Reserves (BCF) By Basin



Produced Water Quality: Salt Composition

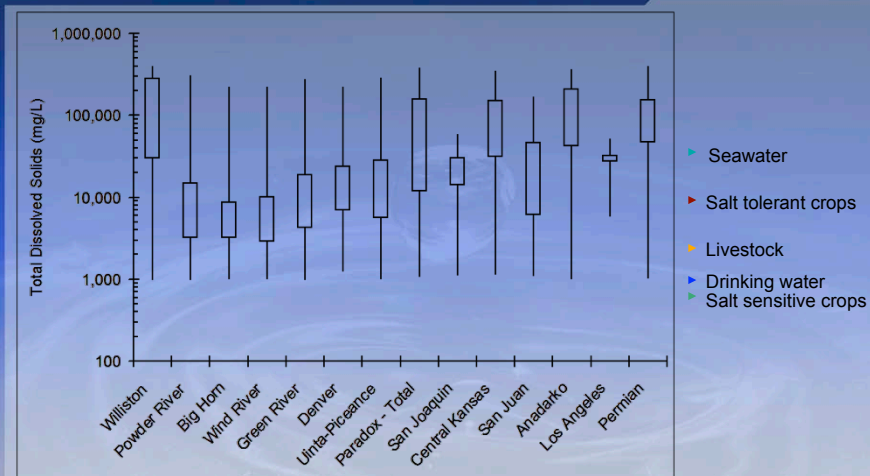


Benko and Drewes (2008), Env. Eng. Science 25, 2, 239

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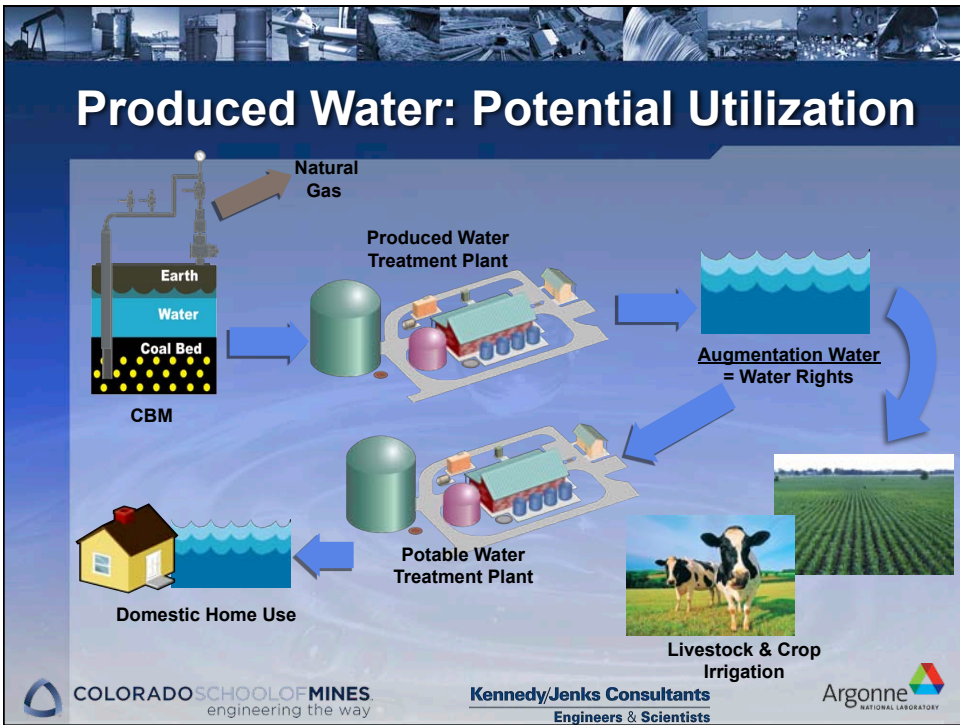
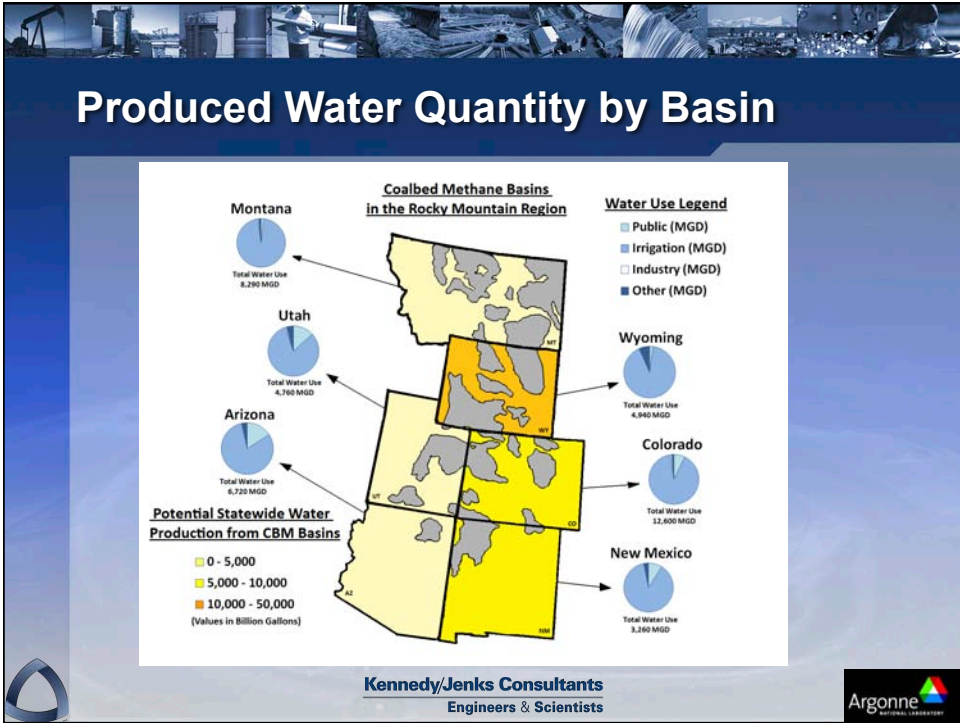
Produced Water Quality



Benko and Drewes (2008), Env. Eng. Science 25, 2, 239

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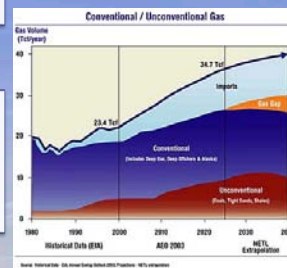
Produced Water as a Water Supply

Reliable Resource

- Drought-proof
- Presently unused
- Non-tributary water not subject to water right limitations

Long Term Supply

- Oil and gas development 30-70 more years
- Water resource could continue to be mined



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Challenges for Widespread Beneficial Use

Geographic Challenges

- Long distances between produced water sources and end users
- High cost of water conveyance infrastructure

Gas Market Challenges

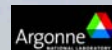
- Fluctuating gas prices might deter investments in treatment technology

Regulatory Challenges

- Complex water rights
- Interstate variations in environmental regulations and permits
- Difficult to assess the quantity and scope of mitigation and compensation owed to 3rd parties
- Liability and uncertainties associated with conveyance and end use
- Institutional boundaries between private management of oil and gas resources and public management of water resources












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An Integrated Framework for Treatment and Management of Produced Water

- Colorado School of Mines / AQWATEC**
 • Principal Investigators: Jörg Drewes, Tzahi Cath, Pei Xu
- Kennedy/Jenks Consultants**
 • Principal Investigators: Jim Graydon and Jean Debroux
- Argonne National Laboratories**
 • Principal Investigators: John Veil and Seth Snyder
- Stratus Consulting**
 • Bob Raucher, Jim Henderson
- Eltron Research**
 • Wayne Buschmann
- Technical Advisors**
 • Dave Stewart, Stewart Environmental Consultants
 • Jeff Cline, Cline Energy Consultants






An Integrated Framework for Treatment and Management of Produced Water




Project Goal

- ▶ *Develop an integrated guidance framework that links the composition of produced water to beneficial use applications and identify the most cost-efficient, environmentally sound, and most beneficial strategies for management and treatment of produced water from CBM operations*

Project Schedule:
September 2008 - March 2011

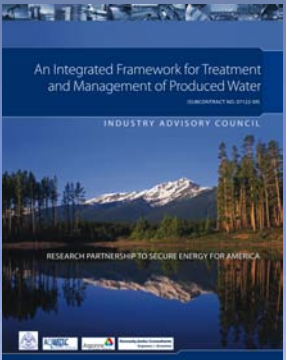





Rocky Mountain Region Major Coalbed Methane Basins

An Integrated Framework for Treatment and Management of Produced Water

- ▶ **Industry Advisory Council (IAC):**
 - 10 medium- and large-size gas producers
 - Major CBM players in the Rocky Mountain region
- ▶ **Technical Experts/Advisors:**
 - Jeff Cline, Cline Energy Consultants
 - Dave Stewart, Stewart Environmental Consultants


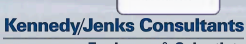



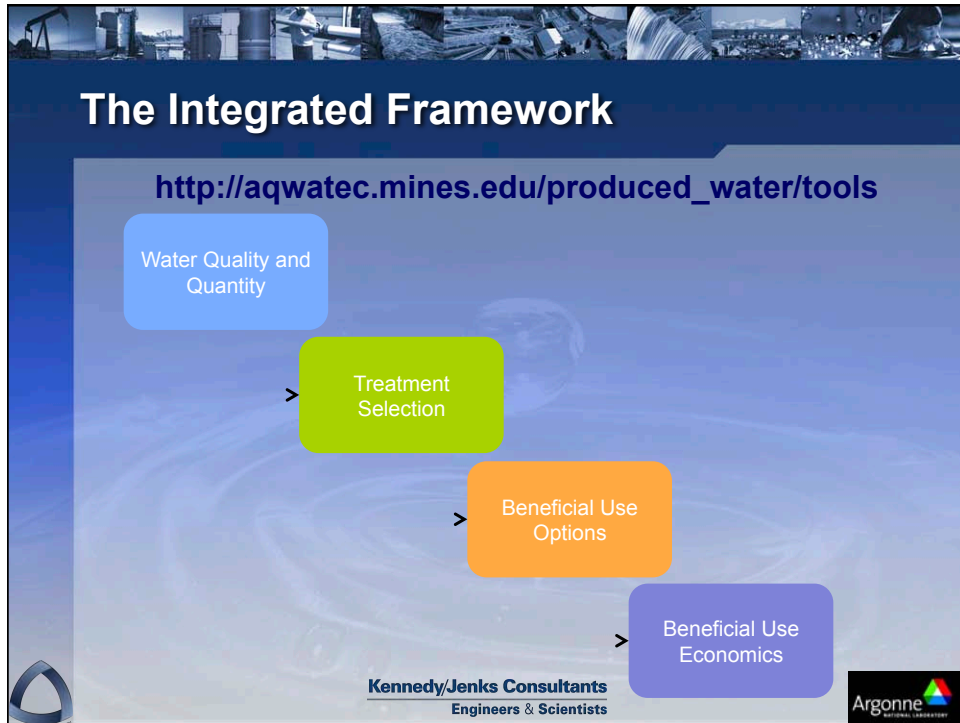




An Integrated Framework for Treatment and Management of Produced Water

▶ **Stakeholder Advisory Committee (SAC):**

Federal Government	Private Industry	Non-Governmental
U.S. Bureau of Reclamation (BOR)	Cline Energy Consulting	Awwa Research Foundation (AwwaRF)
U.S. Environmental Protection Agency (EPA)	Petroglyph Operating Company	Colorado Energy Research Institute (CERI)
Bureau of Land Management (BLM) – Colorado	Stewart Environmental Consultants	WaterReuse Association (WRA)
	Veolia Water	Western Governors' Association
		Family Farm Alliance
		Trout Unlimited
		Southern Nevada Water Authority
		Black Hills Center for American Indian Health
		Colorado Oil and Gas Conservation Commission



An Integrated Framework for Treatment and Management of Produced Water

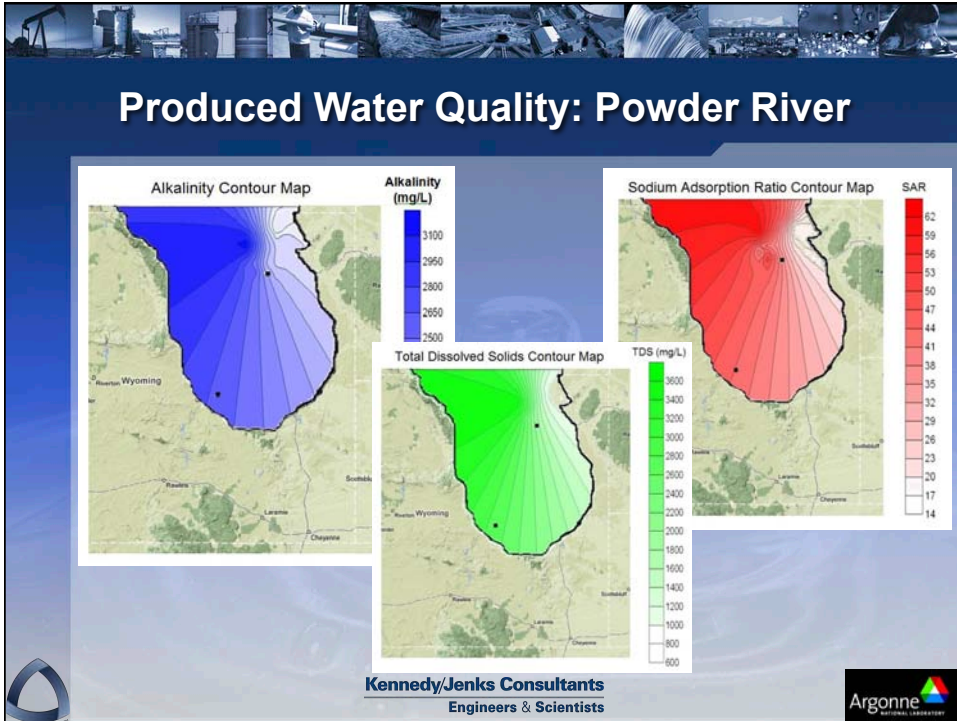
Project Overview

- ▶ **Task 1 - Classification of Produced Water Qualities and Management Strategies**
 - Characterize and classify produced water qualities across different basins/formations: Water Quality Module (WQM)
 - Determine produced water quantities (by basin and resource; gas/water ratios; current disposal/use strategies; etc.)
 - Develop a beneficial use matrix considering natural and engineered conveyance systems, water qualities of beneficial non-potable and potable uses, and quantity and quality of residuals generated
 - Address regulatory requirements among different locations

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An Integrated Framework for Treatment and Management of Produced Water

► **Task 2 - Selection and Testing of Treatment Technologies for Produced Water**

- Identification and evaluation of robust, low-maintenance, modular pre-treatment and desalination technologies as well as brine management and disposal strategies (considering both well-established conventional as well as emerging desalination technologies):
Treatment Technology Assessment Report
- Explore most appropriate and cost-efficient technologies for treatment of produced water considering water quality of produced water and targeted beneficial use: Treatment Selection Module (TSM)
- Pilot-scale treatment trains are currently being designed, assembled and tested at laboratory setting and representative production sites for field-scale validation
- Develop cost modules for management options

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Technology Assessment Report

An Integrated Framework for Treatment and Management of Produced Water

TECHNICAL ASSESSMENT OF PRODUCED WATER TREATMENT TECHNOLOGIES

1st EDITION

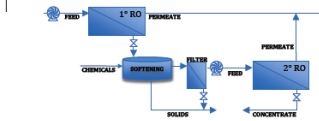
RPSEA Project 07122-12



November 2009

Dual Reverse Osmosis with Chemical Precipitation

Dual reverse osmosis (RO) with chemical precipitation employs both physical (purification through a semi-permeable membrane) and chemical precipitation methods to enhance water recovery beyond that of a single stage RO process. This method is used when high recovery is desired when desalinating hard water. Concentrated brine generated from the first stage RO is treated (softened) with lime (Ca(OH)_2) or caustic soda (NaOH), and/or soda ash (Na_2CO_3) to precipitate calcium as CaCO_3 , magnesium as Mg(OH)_2 , and to a lesser extent co-precipitate colloidal and dissolved silica. Specific chemicals can be used to precipitate targeted sparingly soluble salts. Precipitation of these constituents reduces the likelihood of membrane scaling in the second stage RO. RO membranes are capable of achieving high removal of monovalent ions (e.g., sodium, potassium, chloride, etc.), divalent and multivalent ions (e.g., calcium, magnesium, sulfate, iron, arsenic, etc.), and many organic constituents from the feed stream. The dual RO with chemical precipitation technology is primarily used for brackish water desalination, where a removal of multivalent ions and increased water recovery are desired. An illustration of the process is shown below.



Summary of technical assessment of dual RO with chemical precipitation

Criteria	Description/Remarks
Status of technology	Pilot tested at municipal desalination plants. Not previously employed for CBM produced water treatment.
Feed water quality	Total dissolved solids application range from 1,000 mg/L to 35,000 mg/L. High removal of monovalent and divalent ions, metals, and organics is achievable. System is likely to achieve additional silica removal through co-precipitation.
Product water quality	Permeate water quality depends on feed water salinity and operating conditions. Pilot studies reported 94% rejection of total dissolved solids.
Recovery	Product water recovery is estimated to exceed 90%.
Energy use	No data is currently available.
Chemical use	Chemical demand of lime (Ca(OH)_2) or caustic soda (NaOH) depends on water chemistry and the quantity of calcium and magnesium targeted for removal. Chemical cleaning rates depend on feed water quality. Membrane cleaning will be triggered when certain operating conditions are exceeded, and may require the use of NaOH , Na_2EDTA , or HCl .



An Integrated Framework for Treatment and Management of Produced Water

► Task 3 - Assessment of Management Options

- Explore through cost/benefit analyses the multiple conditions that have to be fulfilled in order to establish beneficial use from a technical, regulatory, political, environmental, economic, and legal standpoint:
Beneficial Use Screening Module (BSM)
- Develop a structured decision process that identifies, evaluates, and, where possible, quantifies benefits, risks, and costs of each management option:
Beneficial Use Economic Module (BEM)



Integrated Framework Screening Tools

WQM

TSM

BSM

BEM

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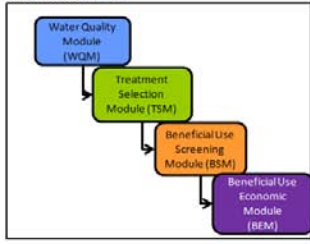
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Produced Water Treatment and Beneficial Use Screening Tool

Main Menu

TOOL ORGANIZATION

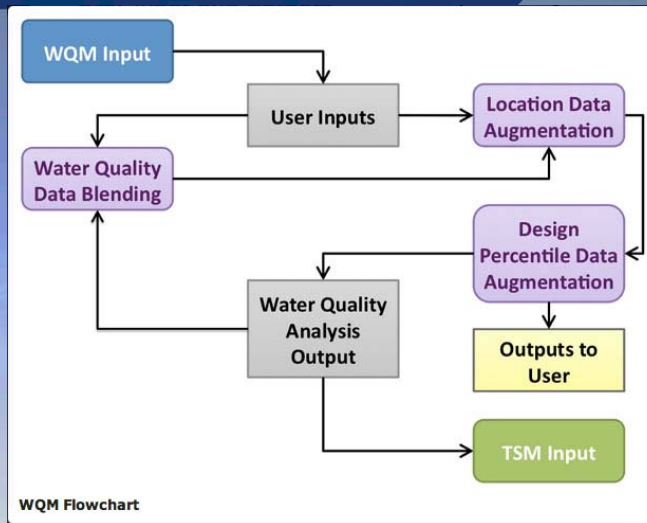


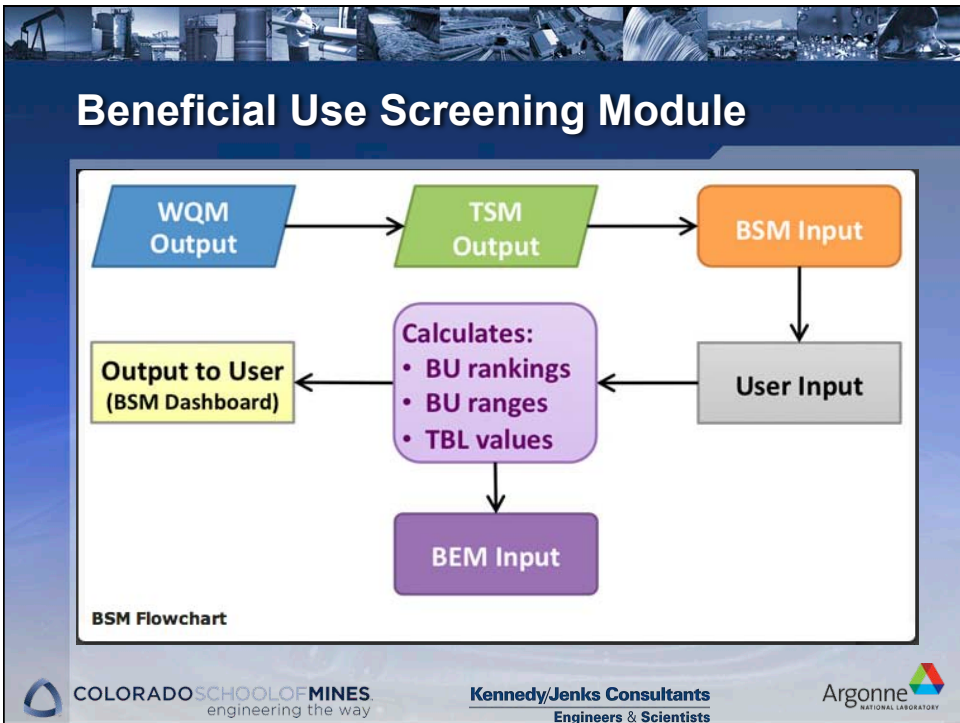
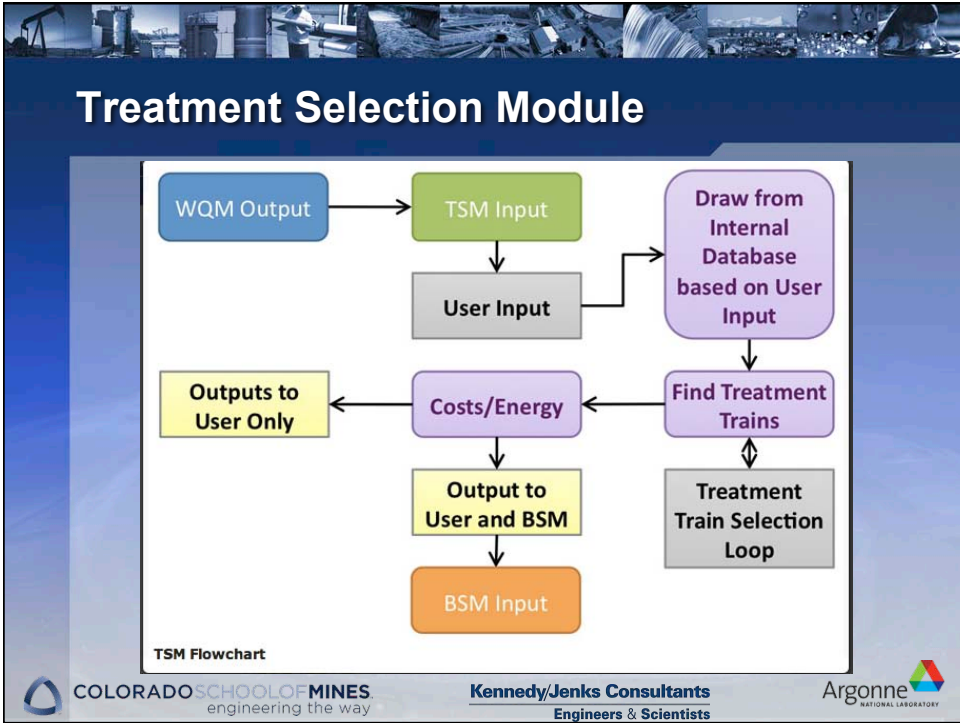
LEGEND CATEGORIES AND USEFUL LINKS

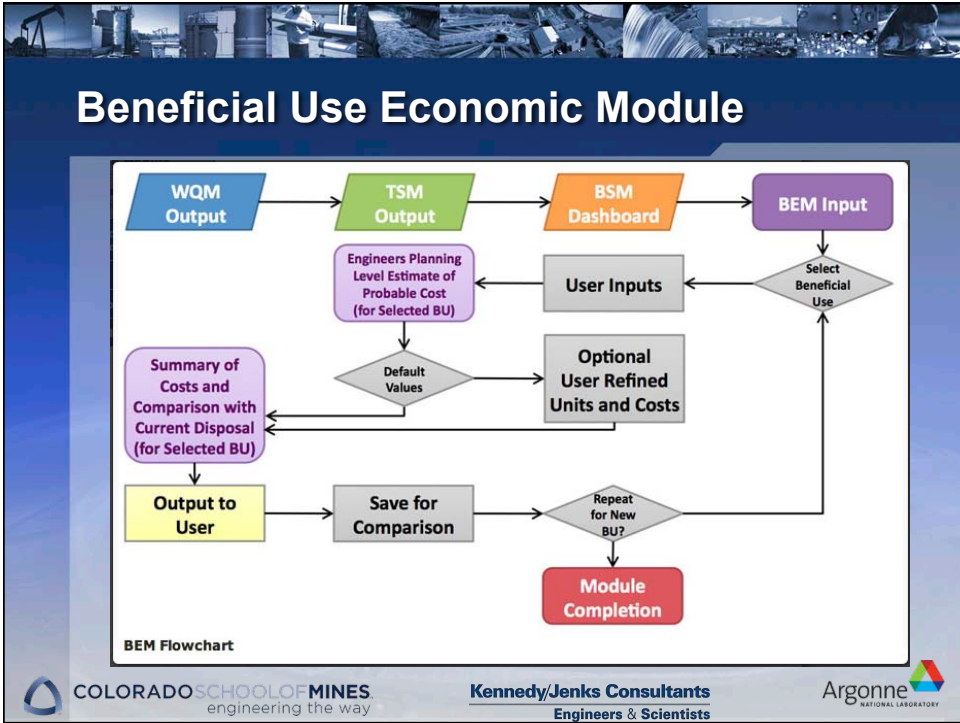
MODULES		USER ACTIONS	
WQM	Link to WQM module	← Back	Back to previous page/menu
TSM	Link to TSM module	Next →	On to next page/menu
BSM	Link to BSM module	[]	User input
BEM	Link to BEM module	[]	Clear all inputs Clears all user inputs in this workbook
SUPPORTING INFORMATION		[]	Restore all inputs Restores all defaults in this workbook
USER MANUAL	Manual for all modules	<div style="background-color: black; color: white; border-radius: 50%; padding: 5px; display: inline-block;"> START! (click here) </div>	
TOOL DESCRIPTION	Description of the tool		

Disclaimer: The outputs and results obtained from this Integrated Decision Framework are meant for project screening purposes only as relevant information gathered for these modules are based on limited projects and best engineering judgment. Actual projects will contain details not captured in this analysis that may affect the treatment of produced water, regulatory compliance, project feasibility, and overall cost of the project.

Water Quality Module







http://aqwaterc.mines.edu/produced_water

Project Website

Produced Water Treatment and Beneficial Use Information Center
Sustainable and beneficial use of produced water from coalbed methane resources

Home Introduction Assessing Beneficial Uses Treatment Options Tools Documents Regulations

The Produced Water Treatment and Beneficial Use Information Center is an online resource for technical and regulatory information on quantity, quality, and treatment technologies for produced water from coalbed methane (CBM) resources in the western United States.

This site provides information on location and quality of CBM produced water, current and potential future treatment and use of CBM produced water, state and federal regulations pertaining to discharge and use, and guidelines and tools for selection of treatment technologies for optimal management practices.

Site Contents

- Introduction: Introductory information on beneficial uses and produced water
- Assessing Beneficial Uses: Beneficial use matrix, key criteria, and case studies
- Treatment Options: Summaries of treatment options and related fact sheets
- Tools: Tools for water quality, treatment technology, costs, key elements
- Documents: Service provider/broker list, model contract
- Regulations: Regulatory requirements for produced water management for selected states

News

- February 12, 2010: [Call for Papers for IPEC](#)
- February 12, 2010: [2010 Ground Water Summit and Ground Water Protection Council Spring Meeting](#)
- November 5, 2009: [Presentation at IPEC](#)

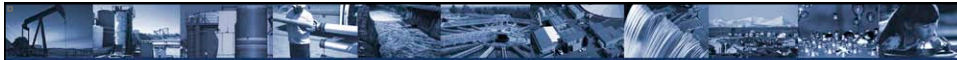
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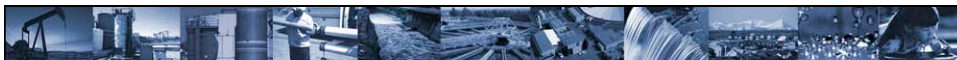
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▶ Task 4 - Field Validation of Viable Treatment Processes for Produced Water

- Bench/pilot-scale treatment trains were designed, constructed and being tested at representative production site for field-scale validation
- Data is being analyzed to determine the effectiveness, robustness, and ease of operation of treatment strategies
- Testing results will provide validation of the integrated decision making framework



Concluding Remarks

- ▶ Unconventional natural gas production will increase
- ▶ CBM produced water represents significant unconventional freshwater resource for the next 20-70 years
- ▶ Treatment, conveyance, and storage are needed
- ▶ Water rights and liability are biggest issues
- ▶ Third parties might function as water purveyors
- ▶ Integrated Framework Tools can assist in facilitating beneficial use



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Acknowledgment

- ▶ **RPSEA Stakeholder Advisory Committee (SAC) and the Industry Advisory Council (IAC)**
- ▶ **Industry Sponsors**
- ▶ **U.S. Bureau of Reclamation**
- ▶ **RPSEA**

