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The Treatment Selection Module: An Excel Application to Select Optimal Water Treatment Trains for Reuse of Coal-bed Methane Produced Water

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Colorado School of Mines

The 17th International Petroleum & Biofuels Environmental Conference (IPEC)
September 1st, 2010 - San Antonio, TX



Outline

- ▶ **The Challenges of CBM produced water**
 - Site conditions
 - Assessing the merit of treatment technologies
- ▶ **Introducing the Treatment Selection Module**
 - Attributes
 - Methodology
 - Preview
- ▶ **Conclusions**

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Site Specific Technical Challenges

- ▶ **Remote sites**
 - Chemicals
 - Personnel
- ▶ **Environmental conditions**
- ▶ **Variable flow**
- ▶ **Challenging water quality**



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Technical Assessment of Produced Water Treatment Technologies

- ▶ **Review identified 34 fundamental treatment technologies and 21 integrated systems/processes**
 - Commercial status of technology
 - Feed and product water quality
 - Removal efficiencies
 - Infrastructure considerations
 - Energy consumption
 - Chemical demand
 - Life cycle
 - O&M considerations



Fundamental Treatment Technologies

Pretreatment (Selected)

Basic Separation

- Settling
- Coagulation
- Hydrocyclone

Adsorption

- Activated carbon
- Zeolite
- Ion exchange

Advanced

- Chemical oxidation
- Microfiltration
- Ultrafiltration



Submerged Ultrafiltration Membrane System by Zenon



Desalination Treatment Technologies

Membrane Separations (selected)

High Pressure Membrane

- Reverse osmosis
- Nanofiltration
- VSEP

Electrically Driven Processes

- Electrodialysis
- Electrodionization


Novel Membrane Processes

- Membrane distillation
- Forward osmosis

Thermal Technologies

- Thermal Distillation
- Dewvaporation






Post Treatment and Brine Management


Post Treatment (selected)

- pH adjustment
- SAR adjustment
- Blending

Brine Management (selected)


- Evaporation basins
- Injection wells
- Crystallizer






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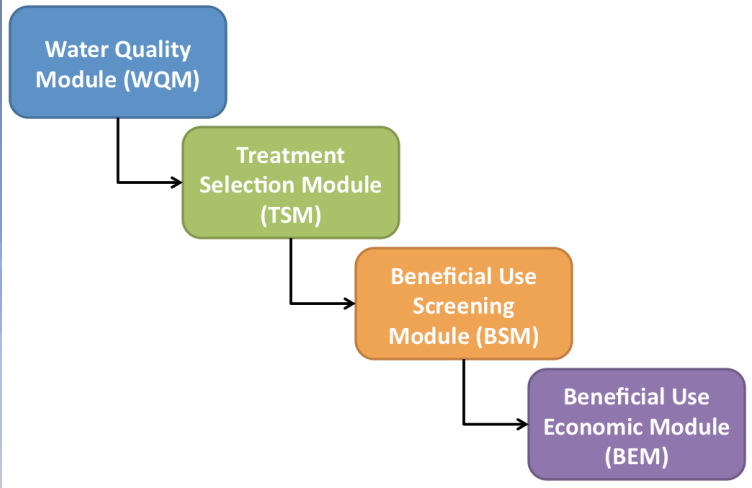
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The Integrated Framework




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graph TD
    WQM[Water Quality Module (WQM)] --> TSM[Treatment Selection Module (TSM)]
    TSM --> BSM[Beneficial Use Screening Module (BSM)]
    BSM --> BEM[Beneficial Use Economic Module (BEM)]
    
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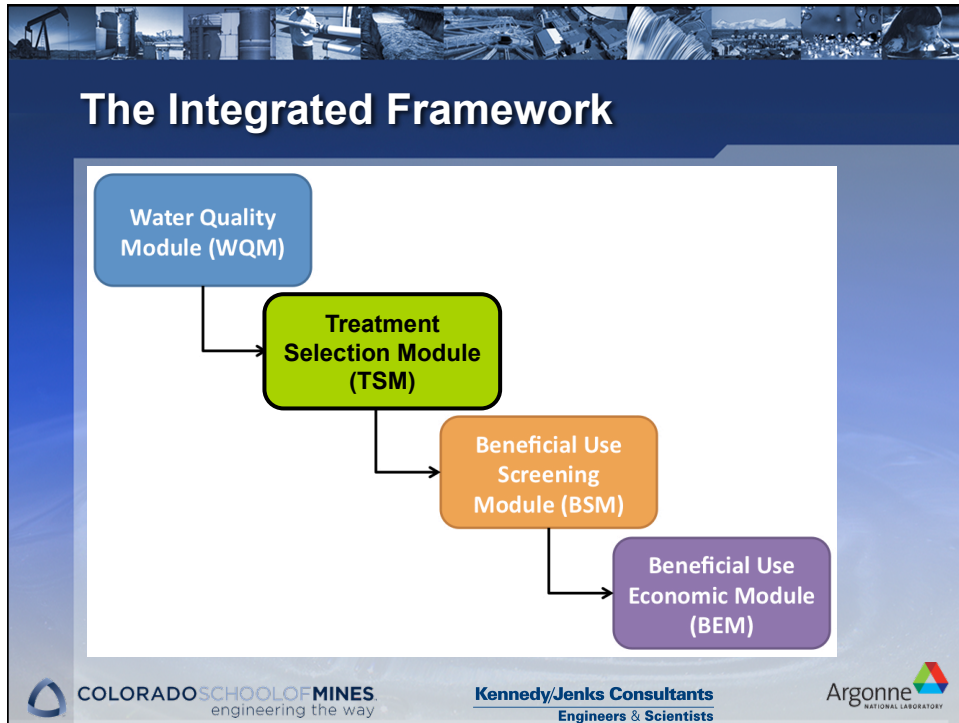





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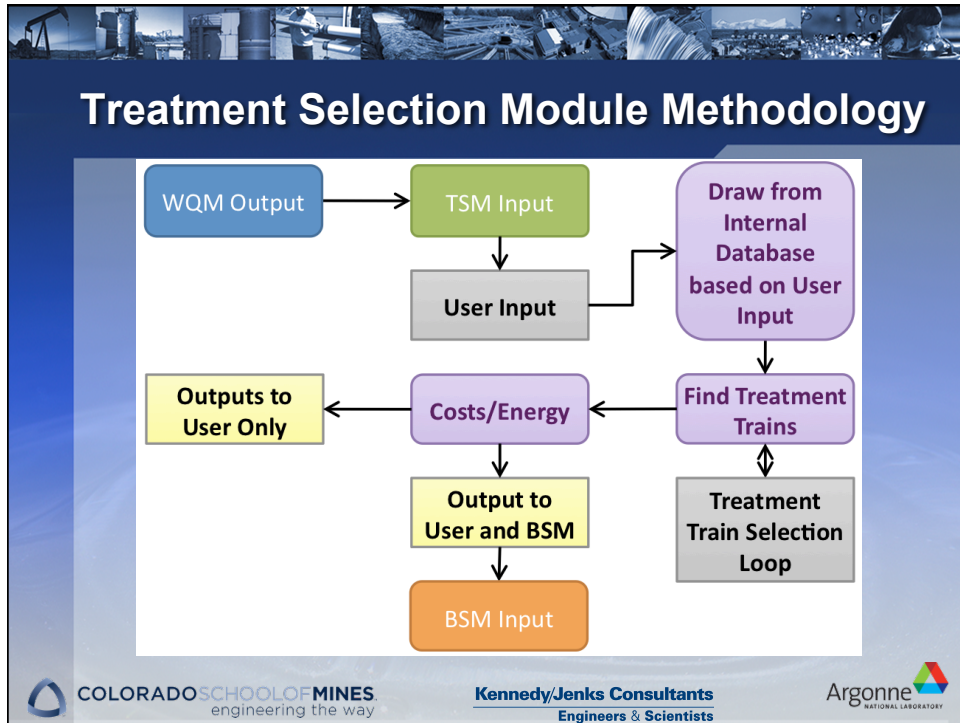
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-
- Attributes of the Treatment Selection Module**
- ▶ **Suggests suitable treatment trains that:**
 - Achieve a specific product water quality (e.g., livestock watering)
 - Are appropriate to site conditions
 - ▶ **For each treatment train provides:**
 - Product and brine water quality
 - Broad capital cost estimate
 - Chemical demand estimate
 - Energy consumption estimate
- 
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Treatment Selection Module: Development Challenges


- ▶ **Very large permutations**
 - 32 treatment processes
 - 46 water quality parameters
 - Intelligent process selection
 - On the fly data trimming


- ▶ **Data, Selection Criteria, Validation**
 - Treatment Technology Assessment Document
 - Input from academia & industry
 - Beta testing



8 corners, 12 edges
> 3 billion combinations


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A Decision Framework to Assess Beneficial Use Opportunities for CBM Produced Water

Treatment Selection Module

MAIN MENU ⓘ

Module Input

Water recovery ⓘ

Selection criteria ⓘ

Additional Information ⓘ

More options...

View water quality ⓘ

Module Output

Previous output ⓘ

RUN
(click here) ⓘ

← Main Menu WQM → TSM → BSM → BEM Next Module →

Supporting Information

User Manual

Module description

Treatment Technology Assessment Document

Conversions

Assumptions

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.

A Decision Framework to Assess Beneficial Use Opportunities for CBM Produced Water

Treatment Selection Module

Water Quality Data

← TSM Menu

Component	Water Quality Data	Beneficial use category 1 +	Units
		Livestock, impoundments, dust control	
Alkalinity (as CaCO3)	1220		mg/L
Alkalinity-Bicarbonate	1260		mg/L
Alkalinity-Carbonate	0		mg/L
Aluminum	0.1	5.00	mg/L
Arsenic	0.053	0.20	mg/L
Barium	2.3		mg/L
Benzene	6.5		µg/L
Boron	0.57	5.00	mg/L
Bromide	10.75		mg/L
Calcium	27		mg/L
Chloride	1765		mg/L
Chromium, total	0.06	1.00	mg/L
Conductivity	3180		uS/cm
Copper	0.1	0.50	mg/L
Cyanide, free	0.09		mg/L
Ethylbenzene	14		µg/L
Fluoride	5.1	2.00	mg/L
Iron	15.70		mg/L
Lead	0	0.10	mg/L
Lithium	0.51		mg/L

WQM

TSM

BSM

BEM

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Treatment Selection Module

MAIN MENU i

Module Input

Water recovery i

Selection criteria i

Additional Information i

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WQM

TSM

BSM

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A Decision Framework to Assess Beneficial Use Opportunities for CBM Produced Water

Treatment Selection Module

Selection criteria scoring

← TSM Menu

Instructions: Please score the criteria using a number from 1 to 5 in the boxes below, where 5 indicates that the item is extremely important and 1 indicates that the item is not very important at all.

Score	Description	Explanation	Example:
5	Limited operator oversight	The degree of operator oversight required.	i
1	Easy to operate	This includes the use of hazardous chemicals and the level of operator skill required to manage the system	i
1	Flexible	The ability of the technology to withstand highly varying water quality	i
1	Small footprint	The size, in land area, that the process takes up	i
1	High industrial status	Market maturity of technology, frequency of use in similar situations, competitiveness of vendors	i
5	Low chemical demand	The volume of chemicals required at the site	i
1	Low energy demand (specific)	The specific energy required by the technology	i
1	Mobile	The ease with which the technology can be moved from one part of the site to another	i
1	Modular	Ability to implement technology as a unit process and accommodate changing influent volume	i
1	Low capital cost	The cost of installing the technology	i
1	Robust	Ability to withstand varying environmental conditions.	i
1	Low waste management	The degree of waste management required including the volume of waste and the technical skill to handle it	i

WQM TSM BSM BEM

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MAIN MENU ⓘ

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WQM TSM BSM BEM

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Treatment Selection Module

TSM Output - Treatment Train

← TSM Menu

Select 1 treatment train per beneficial use.

Options	Treatment train	Detailed Water Quality
<p>Potable use, aquifer recharge, storage & recovery</p> <ul style="list-style-type: none"> <input type="radio"/> UV disinfection - Hydro cyclone - Greensand filter - Cation IX - GAC - BWRO - Evap ponds <input type="radio"/> Wetland - UV disinfection - Chemical softening - Cation IX - GAC - BWRO - Evap ponds <input type="radio"/> Wetland - UV disinfection - Greensand filter - MF/UF (ceramic) - GAC - BWRO - Evap ponds 		<input type="button" value="Detailed Water Quality"/>
<p>Livestock, impoundments, dust control</p> <ul style="list-style-type: none"> <input type="radio"/> UV disinfection - Greensand filter - Anion IX <input type="radio"/> UV disinfection - Cation IX - Anion IX <input type="radio"/> UV disinfection - Chem Oxidation - filtration - Anion IX 		<input type="button" value="Detailed Water Quality"/>
<p>Crop irrigation, non-potable use</p> <ul style="list-style-type: none"> <input type="radio"/> UV disinfection - Hydro cyclone - Cation IX - BWRO - Evap ponds <input type="radio"/> Wetland - UV disinfection - Chemical softening - Cation IX - BWRO - Evap ponds <input type="radio"/> Wetland - UV disinfection - Greensand filter - MF/UF (ceramic) - GAC - BWRO - Evap ponds 		<input type="button" value="Detailed Water Quality"/>

A Decision Framework to Assess Beneficial Use Opportunities for CBM Produced Water

Treatment Selection Module

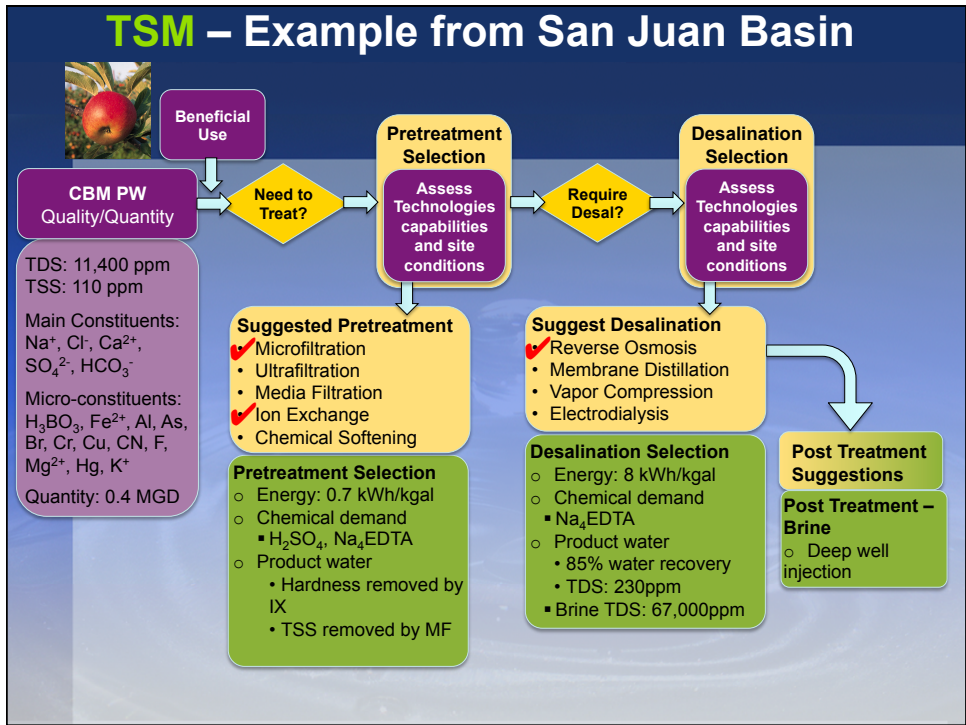
← Main Output

TSM Output - Permeate and Brine Water Quality

Potable use, aquifer recharge, storage & recovery

Treatment Train: UV disinfection - Hydro cyclone - Greensand filter - Cation IX - GAC - BWRO - Evap ponds

Component		Feed Water Quality	Product Water Quality	Brine Water Quality	Potable use, aquifer recharge, storage & recovery
Alkalinity (as CaCO ₃)	mg/L	1220.0	24.4	1518.90	
Alkalinity-Bicarbonate	mg/L	1260.0	25.2	1568.70	
Alkalinity-Carbonate	mg/L	0.0	0.0	0.00	
Aluminum	mg/L	0.1	0.0	0.15	
Arsenic	mg/L	0.1	0.0	0.07	0.01
Barium	mg/L	2.3	0.0	2.85	2.00
Benzene	µg/L	6.5	0.0	8.12	5.00
Boron	mg/L	0.6	0.2	0.66	
Bromide	mg/L	10.8	0.1	13.41	
Calcium	mg/L	26.5	0.0	33.12	
Chloride	mg/L	1765.0	17.7	2201.84	
Chromium, total	mg/L	0.1	0.0	0.07	0.10
Conductivity	µS/cm	3180.0	3180.0	3180.00	
Copper	mg/L	0.1	0.0	0.09	1.30





Conclusions

- ▶ **Produced groundwater presents unique treatment challenges**
- ▶ **Developed Treatment Selection Module**
 - Suggests treatment trains based on water quality, beneficial use & site characteristics
 - Provides broad cost, energy and chemical demand estimates



Future Work & Other Applications

- ▶ **Future work on Treatment Selection Module**
 - Field testing validation of selection results
 - Beta testing
 - Publicly available by the end of 2010
- ▶ **Other Applications**
 - Other ground water applications
 - Surface waters
 - Reclaimed water