Decision support tool for management of produced and frac-flowback water

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Abstract A decision support tool (DST) was developed for technology selection and decentralization of treatment facilities in the exploration and production oil and gas industry. Selection of water treatment processes is a complex task and has to consider many parameters including water quality and quantity and overall economics. Produced water quality is widely variable, and water may contain contaminants from diverse groups. The DST can help designers, utilities, and regulators to evaluate options for beneficial use of flowback and produced water from oil and gas production and select effective treatment trains that can be implemented for treatment of these streams.

Keywords Produced Water, Frac-flowback, Beneficial Reuse

Introduction

Beneficial Use refers to the use of reclaimed or impaired water for a secondary purpose that has a positive value. This may apply to produced water from oil or gas wells or other impaired water from industrial or domestic sources. Potential beneficial use options for produced water include domestic potable use, livestock watering, industrial, commercial, agriculture irrigation, fisheries and wildlife maintenance and enhancement, recreation, fire protection, dust suppression, and more. The determination of a specific beneficial use depends on federal and state jurisdiction and the circumstances of each case, and the availability and feasibility of conventional and advanced water treatment technologies.

Large volumes of produced water are pumped to the surface during production of oil and gas, including coalbed methane (CBM) and shale gas, throughout the United States. CBM basins are shown in Fig. 1. Water must be pumped out of the coal layers (referred to as dewatering) in order to reduce the hydrostatic head (*i.e.* reservoir pressure) and allow the release of methane. The produced water generated during these operations is by far the largest byproduct or waste stream associated with gas production. The quantity of water produced during the life of a well is typically from 1 to 3 barrels (bbl; 120–360 L) of water per thousand cubic feet (bbl/mcf; 28 m^3) of gas (4–13 L/m^3). Water production is greatest in the early stages of well production, and it diminishes over time.

Produced water is an inextricable part of the natural gas recovery process. If an operator cannot reduce water production rates or sufficiently minimize water management costs, CBM fields cannot be efficiently developed, and a valuable energy resource may be lost or diminished.

The costs of produced water management vary extensively depending on the location, disposal method, the type of waste (quality and quantity), and the extent of competition in the local or regional area. Direct discharge and impoundment/evaporation are the least expensive management options, while commercial hauling of water or brine disposal are

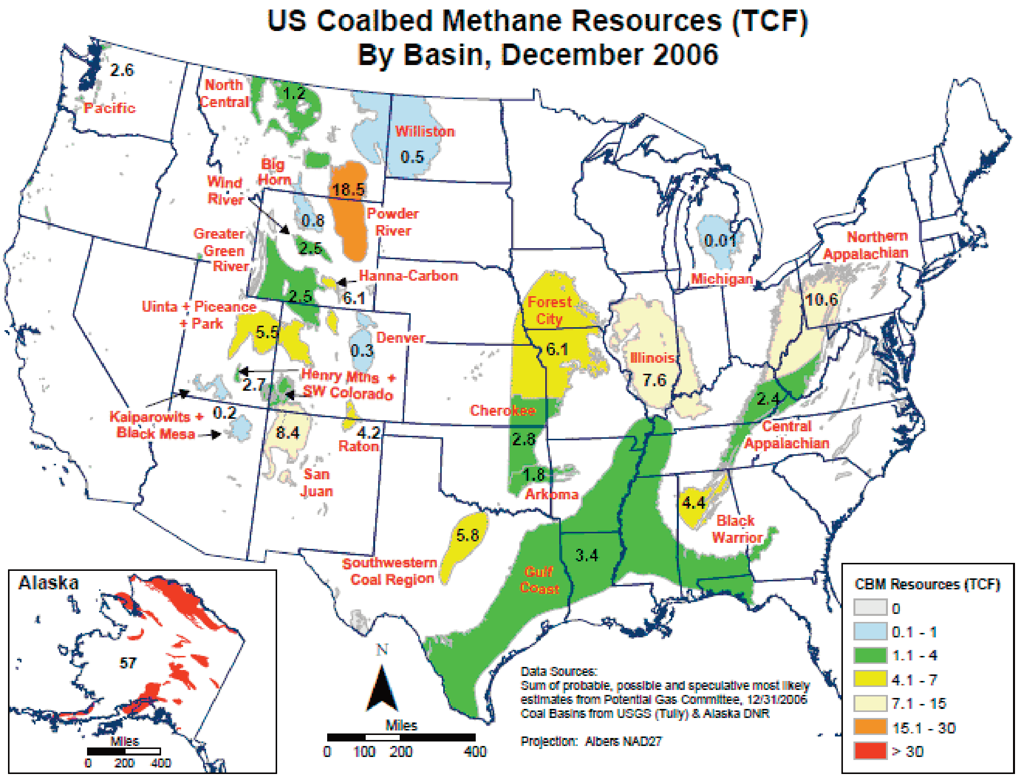

Figure 1 *Map of US coalbed methane resources by basin in trillion cubic feet of natural gas (eia 2013).*

the most expensive options for management of produced water.

Today, freshwater resources in the Western United States are fully allocated. Population forecasts suggest that the majority of U.S. population growth by 2020 will occur in western states, representing regions already lacking sufficient water resources. Increasing water demands associated with energy production and use exacerbate the situation in the West. While this scenario represents enormous challenges, it also provides opportunities for beneficial use of new water resources such as produced water. There are clear needs and strong economic drivers to develop integrative approaches to improve treatment, handling, disposal, and beneficial use of water brought to the surface during production of CBM, shale gas, and other unconventional gas resources.

Methods

In this project we have developed a computerized tool that can help users, including gas producers, water utilities, governments, and the public to learn about the characteristics of produced water and the major steps, costs, technologies, and environmental issues associated with production of water for beneficial use from coalbed methane produced water.

The CBM Produced Water Management Tool is a macro-enabled Excel workbook that contains four modules: Water Quality Module (WQM), Treatment Selection Module (TSM), Beneficial Use Screening Module (BSM), and Beneficial Use Economic Module (BEM). A flow diagram of the Tool is illustrated in Fig. 2.

The development of the decision support tool (DST) at CSM started in 2009 with the establishment of a comprehensive water quality and quantity database for CBM produced water for several major basins in the Rocky

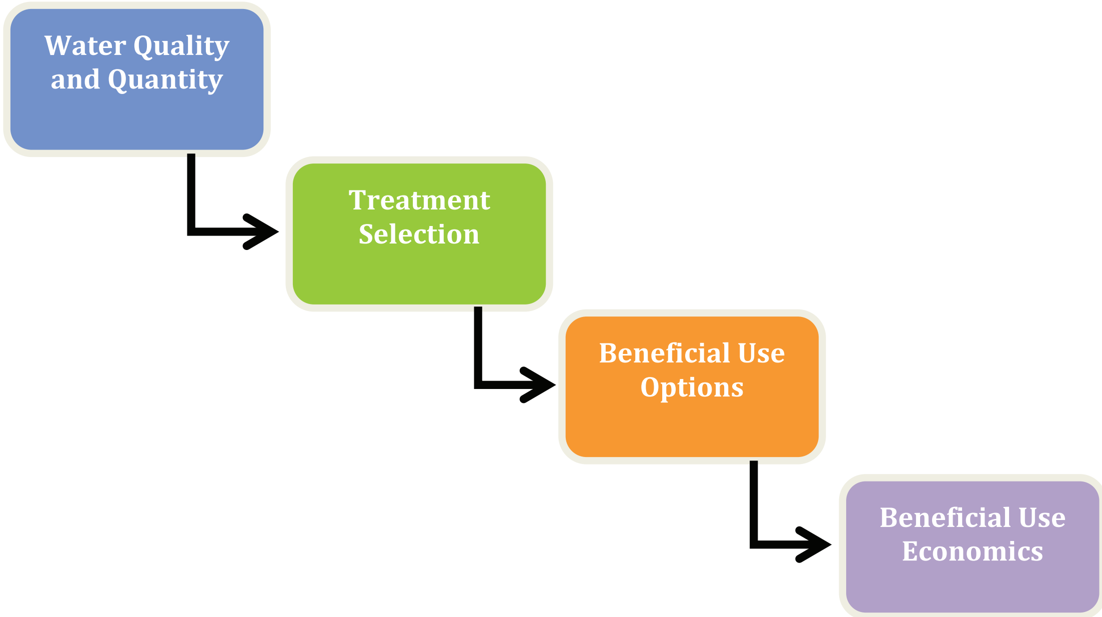

Figure 2 *The four internal modules of the DST for produced water treatment and beneficial reuse.*

Mountains region. The WQM enables access to this data (CSM/AQWATEC 2013b). To predict the water quality of wells based on location, the module incorporates known water quality information from a combination of public and private sources. Data is currently available for three major producing basins in the Rocky Mountain Region, including the Powder River, Raton, and San Juan basins.

The WQM (Fig. 3) is amenable to a broad range of user inputs, from limitation (location and basin of interest) to substantial (validation of user observed constituent concentrations). The WQM is capable of estimating produced water quality based on different levels of data available to the user.

The TSM (Fig. 4) is designed to suggest three treatment trains capable of treating produced water to a quality suitable for each of pre-programmed or user defined beneficial uses. The user inputs criteria such as water quality, water quantity, desired water recovery,

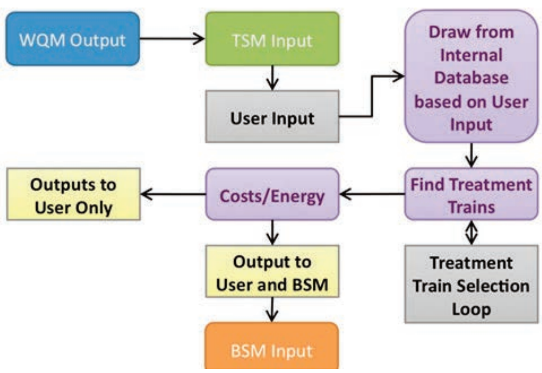

Figure 3 *Flow diagram of the WQM.*

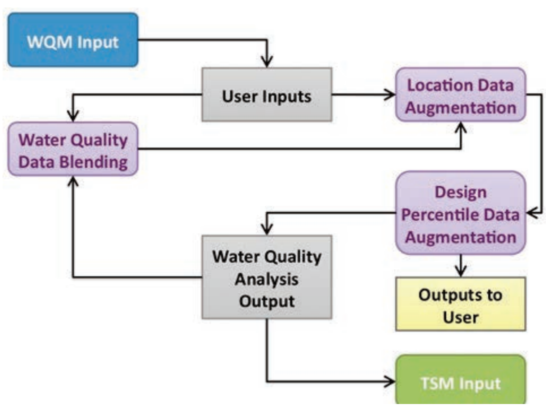

Figure 4 *Flow diagram of the TSM.*

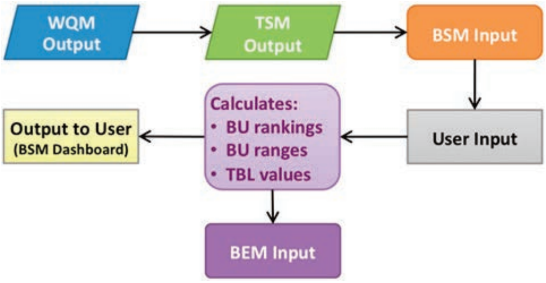

Figure 5 *Flow diagram of the BSM.*

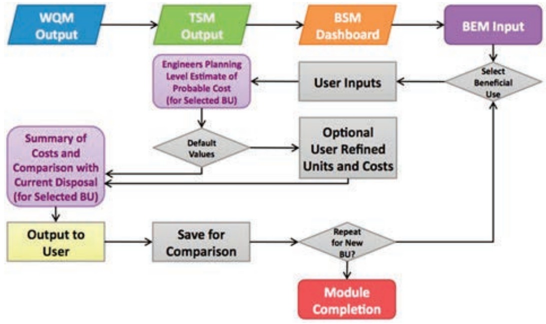

Figure 6 *Flow diagram of the BEM.*

and other site-specific operational objectives to assist in the selection of an integrated treatment process. Using these inputs, along with a robust selection methodology, the tool generates potential treatment trains from a set of >40 technologies (CSM/AQWATEC 2013a). The TSM preferentially selects the minimum number of processes, in a most logical order, required to treat a given feed water stream to either predefined or user defined beneficial uses. The TSM generates a report detailing three suggested treatment trains, estimated water quality and quantity, chemical and energy requirements, estimated brine quality and quantity, and a proposed brine management strategy for each beneficial use predefined or defined by the user.

The purpose of the Beneficial Use Screening Module (BSM; Fig. 5) is to help produced water generators, potential beneficial users, and other stakeholders identify key issues regarding different potential beneficial use projects. The user inputs information about water quantity, reliability and duration of flows for a potential project. Based on this information, the module screens potential beneficial uses and ranks them qualitatively. The rankings are output in a Screening Matrix, which provides a color-coded assessment of the feasibility and relative complexity between beneficial use categories. This can help the user to identify the top 2 or 3 beneficial uses that have a greater potential for feasibility or economic return. The user then can focus on these beneficial uses for additional assessment in the BEM.

The purpose of the Beneficial Use Economic Module (BEM; Fig. 6) is to help produced water generators, potential beneficial users, and other stakeholders identify estimated, planning-level capital and O&M costs for potential beneficial use projects. The evaluation can be performed for multiple beneficial use categories or variations on a single beneficial use category to allow for comparison of the relative costs between scenarios. Potential social, environmental and other benefits are also estimated quantitatively and/or qualitatively in the BEM to provide a non-economic assessment of beneficially using produced water (CSM/AQWATEC 2013b).

The BEM is the last module in the series of linked modules; it builds off of the output information from the WQM, TSM, and BSM. The BEM also uses scenario-specific user input variables (such as estimated project life, project area, and terrain) to build a cost estimate. The costs are outputted in both a detailed, line-item cost estimate table and a general cost summary. Default variables can be adjusted as necessary to refine the cost estimate or to change the basic scenario.

Results from the First Phase of the Study

During the first phase of the study the DST was developed and tested by operators and stakeholders. Then two hypothetical case studies were simulated on the DST to determine site-specific produced water treatment technologies and beneficial use options, using realistic conditions and assumptions. Case studies were located in the Powder River (WY) and San Juan (NM) Basins. Potential beneficial uses evaluated include crop irrigation, on-site use, potable use, and instream flow augmentation. The screening tool recommended treatment trains capable of generating the water quality required for beneficial use at overall project costs that were comparable to or less than existing produced water disposal costs, given site-specific conditions and source (produced) water quality. In this way, the tool may be used to perform a screening-level cost estimate for a particular site to determine whether the costs per barrel for beneficial use are more or less than site-specific disposal costs. The demonstrated technical and economic feasibility provide incentive to address the institutional and legal challenges associated with beneficial use of produced water.

The two comprehensive case studies were previously reported and can be accessed on the web at http://aqwatec.mines.edu/produced_water/tools/RPSEA_CBMPW_CaseStudies.pdf

Further Development of the DST

Encouraged by the results from the first phase of development, upgrade of the current version of the DST with more functions and user choices is being pursued. The DST is being further developed and enhanced beyond the CBM produced water management, and will incorporate databases and treatment of shale gas and tight sand. A comprehensive water quality database (including compositions of fracturing fluids, flowback, produced water, baseline groundwater and surface water) and a thorough examination of produced water and flowback water qualities are critical to evaluate the environmental impacts, alleviate public and regulatory concerns, and select pretreatment and treatment processes to meet beneficial use or disposal requirements.

The new version of the DST will include decentralization of treatment, enabling modeling and optimization of treatment for a wider variety of beneficial uses. Decentralized treatment refers to the implementation of water treatment for a single of a small cluster of wells, whereas centralized treatment refers to the collection and treatment of water from the entire basing of a large section of the basin. A decentralized system could be beneficial because it provides localized water reuse opportunities and reduces conveyance costs and could be cost effective when produced water sources are very scattered. On the other hand, there might be benefits from using a centralized system, driven by economy of scale. The decentralization module accounts for economic and environmental factors to make appropriate decisions on whether a decentralized or centralized system is more efficient for a specific basin or user and to make an optimal distribution of treatment plants at selected sites.

In the new version of the DST the user will have higher flexibility to define and include/exclude specific treatment technologies. This will open up the DST for use by other industries and by process developers.

DST for Urban Infrastructure Development

A third version of the DST is now being developed for selecting technologies and redesigning urban water infrastructure. The new DST includes new features that are critically needed in urban settings, but also in rural and industrial settings. These include (in addition to decentralization capabilities) selection of energy recovery systems and nutrient recovery systems. Thus, the third version of the DST can optimize water systems to facilitate net-positive energy use.

Conclusions

Computerized decision support tools are critical to better understanding water resources quality and quantity and improving the infrastructure through optimization of treatment processes and maximization of beneficial reuse of impaired water. In parallel to other

DSTs currently developed by other institutions, the Produced Water DST will enable better utilization of resources in critical industries and new urban settings.

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