Oil & Natural Gas Technology

DOE Award No. DE-FE0000888

Progress Report

Water Management Strategies for Improved Coalbed Methane Production in the Black Warrior Basin

Submitted by:
Geological Survey of Alabama
P.O. Box 869999
Tuscaloosa, AL 35486-6999

Prepared for:
United States Department of Energy
National Energy Technology Laboratory

July 25, 2013

Office of Fossil Energy

EXECUTIVE SUMMARY

The primary objective of this research is to analyze and develop strategies for water management in coalbed methane reservoirs of the Black Warrior basin. Management of produced waters is a subject of increasing environmental scrutiny, and the Geological Survey of Alabama (GSA) is developing a large, high-quality database and GIS that will provide a basis for the development of efficient regulatory frameworks that will protect the environment while ensuring that coalbed methane will be delivered to the marketplace. The Black Warrior basin provides a wealth of data and experience that can be used to evaluate water management practices across a spectrum of reservoir conditions and operational situations. Accordingly, the concepts and methods developed during this study will be applicable to other regions. These concepts and methods include optimizing water and gas production throughout the operational life cycle, forming strategies to minimize environmental impact, and identifying beneficial uses for produced water.

This project is employing an integrated, multidisciplinary approach to the evaluation and development of water management strategies for coalbed methane reservoirs. Work has commenced with an evaluation of reservoir geology and basin hydrology, which control fluid composition and yield. This project considers the full range of geologic and hydrologic variables that affect coalbed methane reservoirs, including stratigraphy, structural geology, petrology, fluid chemistry, reservoir pressure, and basin hydrodynamics. As the hydrogeologic framework is developed, work will shift toward characterizing reservoir performance and the life cycle of coalbed methane operations. The study will conclude by developing a comprehensive approach to produced water management that emphasizes environmental protection, optimization of reservoir performance, and beneficial use of produced water. A vigorous technology transfer program will be conducted throughout the study that will include assembly of a project advisory committee, development of a project web page, and dissemination of project results through the internet, publications, presentations, and workshops.

Technology transfer activities last quarter (Task 2.0) included the acceptance of manuscripts for publication in the International Journal of Coal Geology and the proceedings of the Unconventional Resources Technology Conference. Project results also will be presented in a keynote lecture, which will be delivered at the International Conference on Coal Science and Technology. Work last quarter focused on Water Management Strategies (Task 9.0). Complex interrelationships among initial reservoir pressure, water yield, and water chemistry present distinct challenges for produced water management. Wells producing nearly potable water provide the simplest opportunities for beneficial use, but low yield limits options for widespread application. Variable water chemistry in areas with high yield wells, moreover, makes water quality difficult to predict and thus requires careful scrutiny when selecting options for processing, disposal, and reuse.

RESULTS OF WORK DURING REPORTING PERIOD

Approach

The Black Warrior basin is a cradle of the modern coalbed methane industry that has provided a wealth of experience and has guided coalbed methane development around the globe. More than 2.2 Tcf of coalbed gas has been produced from the basin, and 4,869 wells are active in 17 coalbed methane fields (fig. 1). Annual gas production has been between 105 and 121 Bcf since 1993, and although the basin is considered mature, exploration and drilling operations are highly active. Cumulative water production now exceeds 1,340 MMbbl, and annual production was higher than 78 MMbbl in 2007. Water production has been rising since 2001 in response to renewed expansion of the coalbed methane industry in Alabama, and so water management issues continue to be of high concern.

The hydrologic and geochemical complexity of coalbed methane reservoirs in the Black Warrior basin favors the application of diverse technologies for produced water management, yet the coalbed methane industry is reliant mainly upon instream disposal, which is a subject of increasing environmental scrutiny. Currently, no integrated system for water management exists that can be used to optimize production operations, manage instream and subsurface disposal, and identify opportunities for beneficial use. A basic need is an integrated analysis of water chemistry, basin hydrology, and operational infrastructure that can be used to make decisions about produced water management. GIS technology, moreover, is an ideal vehicle for the synthesis of this analysis that facilitates the construction of a robust and effective water management plan.

To assist the coalbed methane industry in filling this need, the Geological Survey of Alabama (GSA) is conducting a three-year study that provides a conceptual framework for the management of produced water from coal. This study employs an integrated, life-cycle approach that draws on a spectrum of geologic disciplines (fig. 2). This investigation employs a spectrum of geologic, hydrologic, geochemical, petrologic, GIS, and other computational techniques to characterize the reservoir geology and basin hydrology of the Black Warrior basin to develop new water management strategies that ensure environmental protection, foster beneficial use of produced waters, and improve reservoir performance. The wealth of data and the geological diversity of the Black Warrior basin provides an unparalleled opportunity to evaluate water management strategies across a spectrum of reservoir conditions. Accordingly, this research will help natural gas producers develop basic geologic, hydrologic, and water management concepts that can be applied to coalbed methane plays throughout the world.

Results and Discussion

Work on this project is coordinated into a series of tasks aimed at project management, technology transfer, and the performance of technical activities (fig. 3). Task 1.0 focuses on project management, whereas Task 2.0 encompasses all technology transfer activities associated with this project. Tasks 4.0 through 9.0 include all technical activities required to meet the goals of this research. Work on most tasks is complete, and efforts last quarter focused on Technology Transfer (Task 2.0) and Water Management Strategies (Task 9.0).

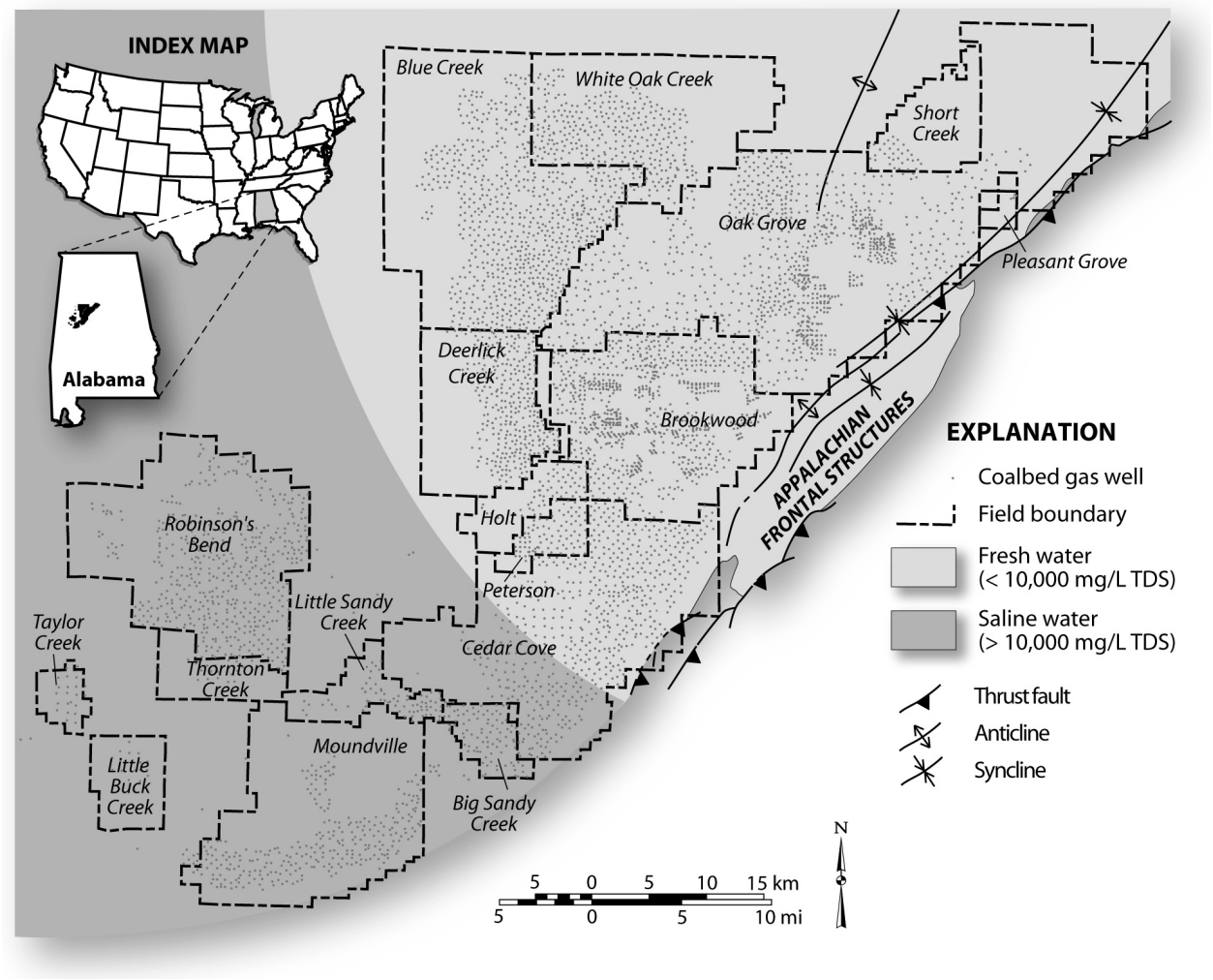

Figure 1.—Coalbed methane fields of the Black Warrior basin, west-central Alabama.

Technology transfer activities last quarter included manuscript submission and preparation. A manuscript has been accepted for publication in a special volume of the International Journal of Coal Geology that is being edited by Daniel Soeder of the U.S. Department of Energy National Energy Technology Laboratory and Mark Engle of the U.S. Geological Survey. The volume focuses on the potential environmental impacts of unconventional fossil energy development. The paper is entitled, "Interrelationships Between Water and Gas Chemistry in Mature Coalbed Methane Reservoirs of the Black Warrior Basin" and is authored by Jack Pashin of Oklahoma State University, Marcella McIntyre-Redden and Steve Mann of the Geological Survey of Alabama, and Matthew Varonka and Bill Orem of the U.S. Geological Survey.

Another manuscript has been accepted for publication in the proceedings of the Unconventional Resources Technology Conference, which will be held in Denver during August 2013. The paper is entitled, "Dynamics of Thermogenic and Late-Stage Biogenic Gas Generation in Coalbed Methane Reservoirs of the Black Warrior Basin," and considers the effects of burial,

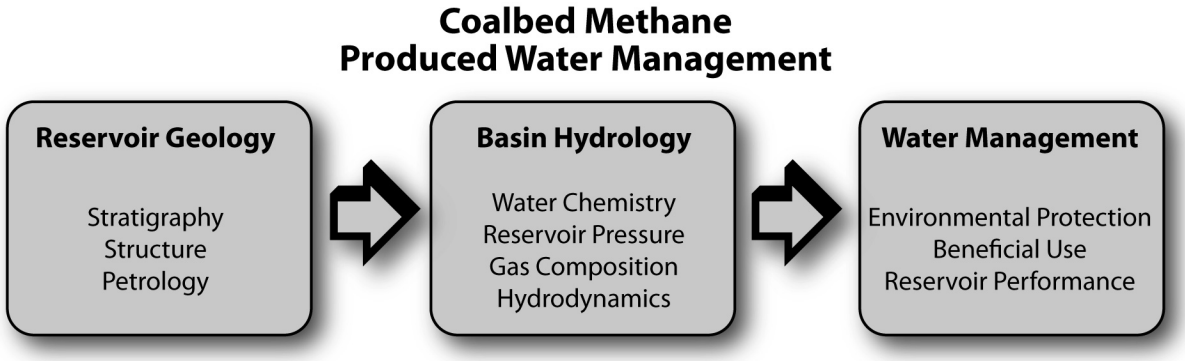

Figure 2.—Conceptual framework outlining proposed study of the relationships among reservoir geology, basin hydrology, and water management strategies in coalbed methane reservoirs.

unroofing, and changing water chemistry on the generation, migration, and chemistry of hydrocarbons in bituminous coal. Dr. Pashin will make a presentation in a workshop on produced water issues that is being organized by the Petroleum Technology Transfer Council. The workshop will be held in Morgantown, West Virginia, and is scheduled for August 22, 2013. Dr. Pashin also has been invited to deliver a keynote lecture on coalbed methane at the International Conference on Coal Science and Technology, which will held at Penn State University from September 29 to October 3, 2013.

Work continued last quarter on Water Management Strategies (Task 9.0). The Black Warrior coalbed methane industry is currently dependent solely on instream disposal of produced water, which limits production in some areas where coalbed methane reservoirs yield large volumes of hypersaline brine. The project team is associating discharge points along the Black Warrior River with the wells and treatment facilities that feed into those discharge points.

An outcome of this work shows distinct contrasts between the volume of produced water and water quality. Throughout the coalbed methane fields, production volume corresponds closely to initial reservoir pressure. Specifically, wells with peak production exceeding 100 barrels per day (bbl/d) are concentrated where the initial hydrostatic pressure gradient was near normal; that is, greater than 0.30 pounds per square inch per foot (psi/ft). Wells with lower peak water production rates lower than 50 bbl/d, by comparison, are concentrated where reservoirs are substantially underpressured; that is, the initial hydrostatic pressure gradient was less than 0.20 psi/ft.

Reservoirs in which initial reservoir pressure was near normal are concentrated at the periphery of the fresh-water plumes along the southeastern basin margin and in areas where thick Cretaceous overburden has been preserved above the Pottsville Formation. The total dissolved solids (TDS) content of formation water in these areas is highly variable, ranging from less than 5,000 milligrams per liter (mg/L) to more than 20,000 mg/L.

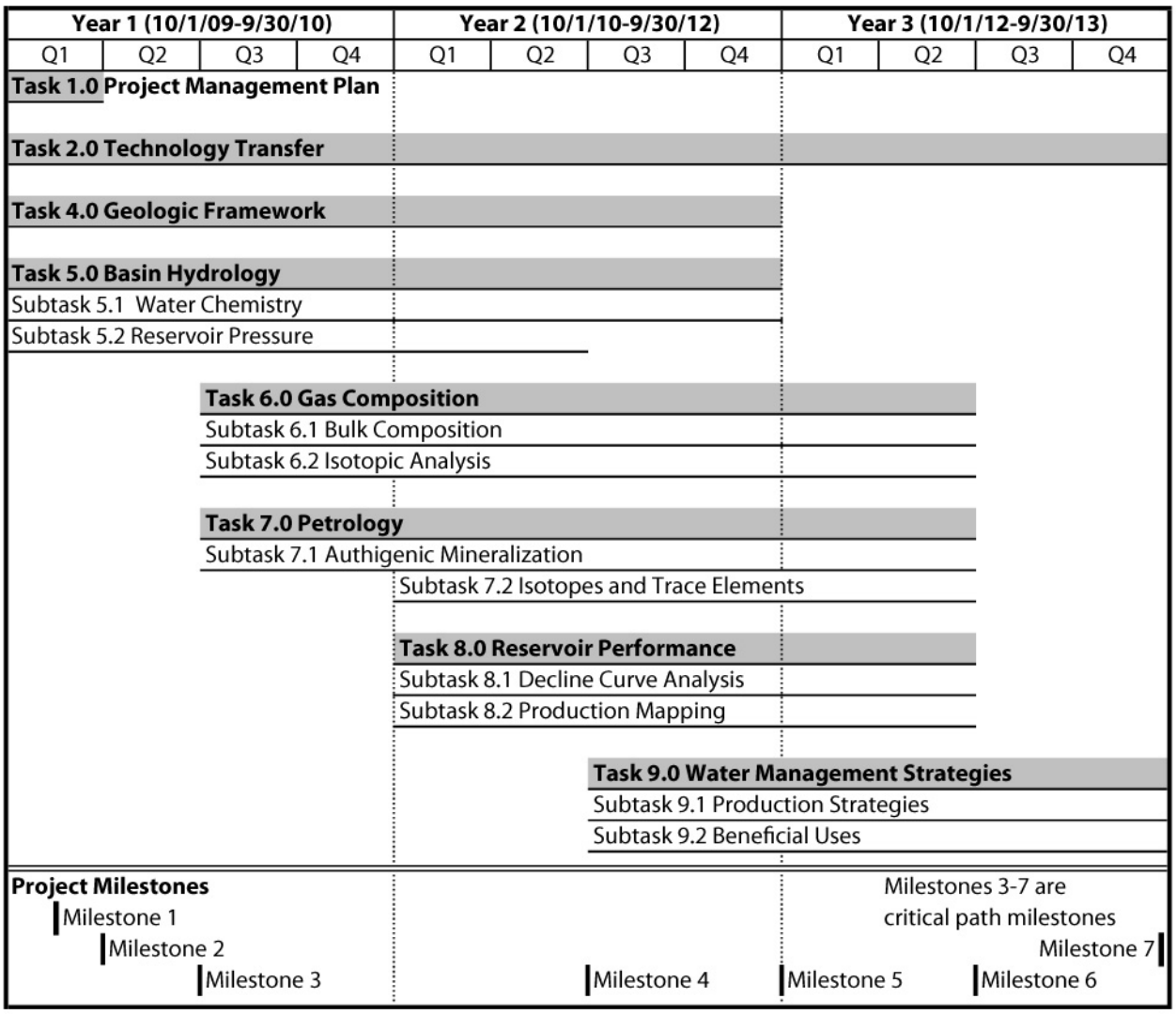

Figure 3.—Gantt chart showing scheduling and relationships among project tasks and milestones.

The initially underpressured reservoirs are principally located in the heart of the fresh-water plumes and in the interior of the basin beyond the fresh-water plumes. In the heart of the plumes, initial reservoir pressure was depleted by deep longwall coal mining that commenced more than a decade before coalbed methane development. In this area, the plumes contain the freshest water that is produced from the coalbed methane reservoirs. Beyond the fresh-water plumes, by contrast, is the highest salinity water that is produced from these reservoirs.

This variation in water yield and chemical composition poses significant challenges for produced water management. For example, fresh water is most easily processed for beneficial use, but low yield limits the available volume. And the variable chemistry of the water produced from high yield wells makes water quality difficult to predict and thus requires careful scrutiny when selecting options for processing, disposal, and reuse.

Next quarter, research will continue on Technology Transfer (Task 2.0) and Water Management Strategies (Task 9.0). All other project tasks have been completed. An instrumentation problem has delayed the receipt of the final set of geochemical analyses of produced water, and so the project team is contemplating requesting a 1-month no-cost extension so that maps can be finalized and the proposed produced water management strategies can be refined.

Conclusion

Technology transfer activities last quarter (Task 2.0) included the acceptance of manuscripts for publication in the International Journal of Coal Geology and the proceedings of the Unconventional Resources Technology Conference. Project results also will be presented in a keynote lecture, which will be delivered at the International Conference on Coal Science and Technology. Work last quarter focused on Water Management Strategies (Task 9.0). Complex interrelationships among initial reservoir pressure, water yield, and water chemistry present distinct challenges for produced water management. Wells producing nearly potable water provide the simplest opportunities for beneficial use, but low yield limits options for widespread application. Variable water chemistry in areas with high yield wells, moreover, makes water quality difficult to predict and thus requires careful scrutiny when selecting options for processing, disposal, and reuse.

COST STATUS

Table 1. Comparison of costs budgeted for Budget Period 3 and actual expenditures through June 30, 2013.

	Budgeted Costs			**Actual Expenditures**		
Category	**DOE***	**Participant**	**Total**	**DOE**	**Participant**	**Total**
Personnel	$77,180	$41,592	$118,772	$13,038.35	$13,038.34	$26,076.69
Fringe Benefits	26,241	14,141	40,382	4302.65	4302.64	8605.29
Travel	6,197	0	6,197	0	0	0
Equipment	0	0	0	0	0	0
Supplies	968	0	968	360.89	0	360.89
Contractual	0	0	0	0	0	0
Construction	0	0	0	0	0	0
Other	51,460	0	51,460	68,940.45	0	68940.45
Total Direct Charges	162,046	55,733	217,779	86,642.34	17,340.98	103,983.32
Indirect Charges	46,802	25,221	72,023	7819.09	7819.09	15,638.18
Totals	$208,848	$80,954	$289,802	$94,461.43	$25,160.07	$11,9621.50

SCHEDULE STATUS

This project has thus far moved ahead according to schedule and budget (fig. 3, tables 2 and 3). Critical Path Milestones 1 through 6 (table 3) have been met on schedule, and most project tasks are now complete. Accordingly, the remainder of the project will focus on completing Tasks 2.0 and 9.0. An instrumentation problem has delayed the receipt of the final set of geochemical analyses of produced water, and so the project team is contemplating requesting a 1-month no-cost extension until October 31, 2013 so that maps can be finalized and the proposed produced water management strategies can be refined and incorporated properly into the Final Report.

Table 2. Status of project schedule by task and subtask.

Task	Anticipated completion	Actual completion	Status
Task 1.0 Project Management Plan	11/15/09	11/13/09	Complete
Task 2.0 Technology Transfer	9/30/13		In progress
Task 4.0 Geologic Framework	9/30/12	9/28/12	Complete
Task 5.0 Basin Hydrology	9/30/12	9/28/12	Complete
Subtask 5.1 Water Chemistry	9/30/12	9/28/12	Complete
Subtask 5.2 Reservoir Pressure	3/31/12	3/31/11	Complete
Task 6.0 Gas Composition	3/31/13	3/31/13	Complete
Subtask 6.1 Bulk Composition	3/31/13	3/31/13	Complete
Subtask 6.2 Isotopic Analysis	3/31/13	3/31/13	Complete
Task 7.0 Petrology	3/31/13	3/31/13	Complete
Subtask 7.1 Authigenic Mineralization	3/31/13	3/31/13	Complete
Subtask 7.2 Isotopes and Trace Elements	3/31/13	3/31/13	Complete
Task 8.0 Reservoir Performance	3/31/13	3/31/13	Complete
Subtask 8.1 Decline Curve Analysis	3/31/13	3/31/13	Complete
Subtask 8.2 Production Mapping	3/31/13	3/31/13	Complete
Task 9.0 Water Management Strategies	9/30/13		In progress
Subtask 9.1 Production Strategies	9/30/13		In progress
Subtask 9.2 Beneficial Uses	9/30/13		In progress

Table 3. Milestone schedule. Milestones 3 through 7 are critical path milestones.

Milestone	Description	Scheduled completion	Actual completion
1	Completion of initial Project Management Plan and Technology Status Assessment (Task 1.0)	11/15/09	11/13/09
2	Posting of project web site on internet (Task 2.0).	12/31/09	12/24/09
3	Completion of design of databases for Task 4.0, Geologic Framework, and Task and 5.0, Basin Hydrology	3/31/10	3/19/10
4	Characterization of reservoir pressure complete (Subtask 5.2)	3/31/11	2/18/11
5	Tasks 4.0 and 5.0 complete.	9/30/12	9/28/12
6	Completion of analysis of Gas Composition (Task 6.0), Petrology (Task 7.0), and Reservoir Performance (Task 8.0)	3/31/13	3/31/13
7	Completion of Water Management Strategies (Task 9.0).	9/30/13	

National Energy Technology Laboratory

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

13131 Dairy Ashford, Suite 225
Sugar Land, TX 77478

1450 Queen Avenue SW
Albany, OR 97321-2198

2175 University Ave. South
Suite 201
Fairbanks, AK 99709

Visit the NETL website at:
www.netl.doe.gov

Customer Service:
1-800-553-7681