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The 3M Coalbed Methane Reservoir Model

Prepared for:

The Southern Ute Indian Tribe, Ignacio, Colorado
Colorado Oil and Gas Conservation Commission, Denver, Colorado
Bureau of Land Management, Durango, Colorado

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Introduction

Questa Engineering Corporation has prepared a basin-wide coalbed methane reservoir model of the Colorado portion of the San Juan Basin for the Southern Ute Indian Tribe, the Colorado Oil and Gas Conservation Commission, and the Bureau of Land Management. This model, which is referred to as the 3M CBM MODEL in the rest of this report, simulates the effects of production from all existing and proposed Fruitland coal wells in Colorado. The effects of dewatering, gas adsorption and desorption, and historical production are included in the model. The 3M CBM MODEL provides a technology to evaluate coalbed methane infill drilling and gas seepage at the outcrop, which have become increasingly important topics over the last several years.

The model builds on information from a groundwater or hydrologic model covering the entire basin that has been prepared by Applied Hydrology Associates. The groundwater model simulates pre-production conditions for the reservoir model, and provides estimates of the amount of groundwater flowing through the Fruitland Coal hydrologic system.

The size, scale, and detail included in the new model are beyond any previously published model. The 3M CBM MODEL includes up to 20 years of production data from 1,060 wells, 4,870 pressures from 591 wells, thickness data from 742 wells, and water chemistry from 572 wells. The project has greatly benefited from industry cooperation, data, financial assistance and peer review.

Model Features

Because of the size and scope of the input data, it was determined that existing commercial coalbed methane simulators were not suitable for this project. A completely new model was written, and a public domain executable version of the model will be available upon completion of the project. Key features of the model include handling

50,000+ gridblocks, thousands of wells, up to 1000 years of modeling, extremely efficient solver algorithms, outcrop boundary conditions, and input and output using Excel spreadsheets and/or Access databases. The model utilizes the standard Langmuir isotherm to account for gas adsorption in the coal, and also allows for free gas in the cleat system of the coal. Matrix shrinkage as a result of production is included in the model.

A single layer was selected for the model to fit within the cost, time, and data constraints. The data on individual seams that would be necessary to accurately calibrate multiple layers in a multilayer model is lacking. Coal thickness information was incorporated in an Access database by individual seams, to allow for future expansion to a multi-layer model if desired.

The 3M CBM MODEL has been tested against a commercial simulator in more than 80 test cases, and has been shown to accurately and efficiently reproduce the results of the commercial program.

Model Results

Results to date from the 3M CBM MODEL confirm the presence of highly variable reservoir properties throughout the basin. Various specific results and inferences from the 3M CBM MODEL include:

Flow Barriers and Baffles

A number of flow barriers or baffles were known to be present in the basin, based on previous work by numerous investigators and operators. The features that had multiple lines of evidence (differences in initial pressure, water chemistry, water chemistry trends, structural faults, etc.) were included in the 3M CBM MODEL. Other barriers or baffles were introduced based on the presence or absence of water or gas seepage in particular areas. Industry representatives have suggested that many additional barriers or baffles may be present in the Fruitland. The only such features that were

directly included in the 3M CBM MODEL were those baffles or barriers that had multiple lines of evidence or incontrovertible reasons for their inclusion.

Reservoir Properties

Reservoir properties were generally estimated through analysis of historical production from wells. Permeabilities were estimated from peak gas or water rates, with assumed completion efficiencies based on completion type. Porosities were estimated from extrapolation of produced water trends. Coal thickness and structure were determined from well logs. Gas contents were compiled from public information where available, and through matching performance in some areas where sufficient data are available to allow gas content to be reliably determined.

High Water Production Wells

Analysis of the largest water producers completed in the Fruitland indicate they have produced and are connected to much more water than is contained in the Fruitland coal at those locations. Further investigation indicates the Fruitland Coal and the Pictured Cliffs are apparently in hydraulic communication in some areas through natural fracturing, and that the Pictured Cliffs is one of the main sources of additional water in certain areas. A correction for this has been made in the 3M CBM MODEL.

Gas Seepage

The 3M CBM MODEL predicts that gas seepage has occurred and will continue to occur in areas where it has already been observed: the Pine River area, South Texas Creek, and along the west side (Valencia Canyon and Soda Springs areas). Additional seeps may start east of the Pine River and in other areas to be determined, but most of the seepage in the model occurs near existing seep locations. When the outcrop was modeled with a perfect connection to the basin, the simulated gas seepage was 10 to 100 times higher than observed levels of seepage. These results indicate that such a perfect connection does not exist in nature; otherwise, there would be much higher seepage levels even in areas where no gas seepage is observed. This restricted connection may be related to the structural hingeline between the coals in the basin versus the outcrop,

stratigraphic changes in the coal, coalbed geometry, capillary pressure or relative permeability effects, multi-layer effects, high absorptive capacity in the shallow coals, or other unidentified causes. By modifying the simulated connection of the outcrop to the basin, the model has been calibrated to match observed gas seepage locations and rates.

Results of model runs with infill wells indicate that in most cases no significant change in seepage should be expected as a result of infill drilling.

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