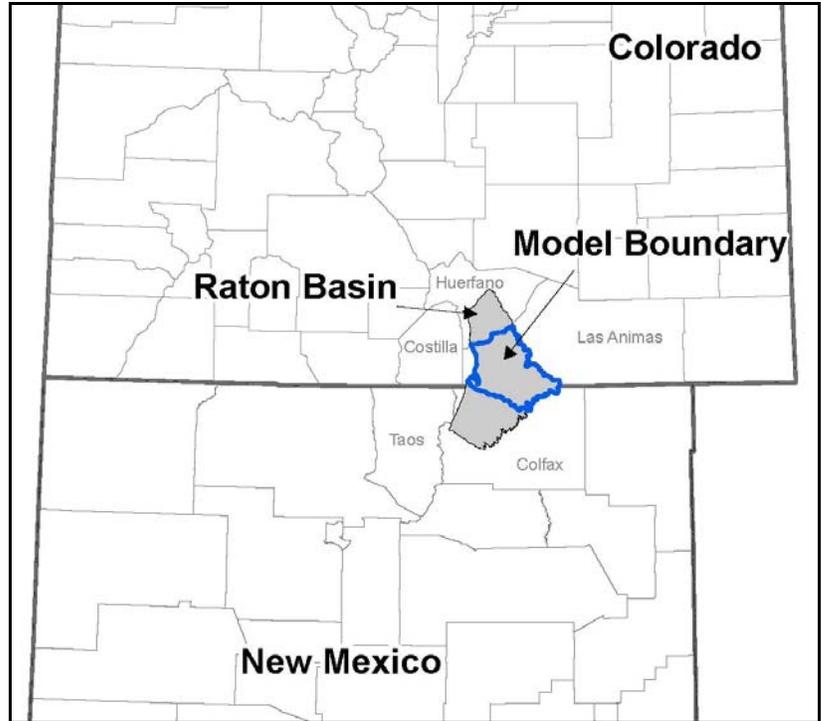




**Map of Area**



**Introduction**

The Central Raton Basin (CRB) model is a sophisticated three dimensional computer model of groundwater flow in the portion of the Raton Basin within the Apishapa, Purgatoire, and Canadian River drainage basins. The CRB model was constructed using an advanced groundwater modeling code (MODFLOW) developed and maintained by the United States Geological Survey. The objective of the CRB modeling project was to produce a calibrated model that could be used to evaluate depletions to surface water from the pumping of groundwater as part of coal bed methane (CBM) development.

**CRB Model**

The CRB model encompasses an area greater than 650,000 acres. CBM development occurs on approximately 350,000 acres. The model includes natural features controlling the groundwater flow system including geology, basin structure, groundwater recharge, evapotranspiration, and topography. The model is the most complete representation to date of the groundwater flow system in the CRB.

The CRB model includes the coal-bearing Raton and Vermejo Formations, the overlying formations and the underlying Trinidad Sandstone and Pierre Shale. The formations in the CRB area are a mixture of coal, sandstone, siltstone and shale. Groundwater predominately flows horizontally. The coal and sandstone have a greater ability to transmit groundwater than siltstone and shale. However, coal and sandstone comprise less than one-third of the overall thickness in the CRB. Coals tapped by CBM wells are discontinuous. The less permeable siltstone and shale impede groundwater flow both vertically and horizontally.

The source of groundwater in the CRB is recharge from rain or snow. Only a small fraction of rain and snow (about 5%) recharges the groundwater system.

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The majority of the drainages in the CRB have ephemeral surface water flow response to storm events. Perennial stream flow occurs where groundwater provides a constant source of water to a stream. The Purgatoire River is the principal perennial river in the CRB.

Natural gas (methane) production in the CRB requires the pumping of some groundwater from coal to reduce pressure. Natural gas is released from the coal when the water pressure is reduced. The gas moves through the coal, and is produced from CBM wells. There are approximately 2,900 CBM wells in the CRB. The water production from a CBM well drops over time as pressure is reduced in the coal and the coal cleats become filled with gas instead of water. CBM wells are constructed to minimize the amount of water produced. This is done by cementing the well bore and producing only the most productive coals.

## CRB Model Run Results

The CRB model was run to determine in what areas pumping CBM for 100 years had the potential to affect surface water flow. This type of groundwater is termed “tributary”. The CBM water producer is required to make up (“augment”) depletions of surface water flows. The CRB model showed that for most of the Raton Formation and a majority of the Vermejo Formation, pumping would have a very small impact to surface water flows within 100 years. This impact is too small to be measured at stream gauging stations. The model and results were presented to and accepted by the Colorado State Engineer.<sup>1</sup>

The CRB model was run with publically available data on CBM water production to evaluate current impacts to stream flows. The modeled depletions to surface water flows are currently approximately five acre-ft/year which is roughly equivalent to the amount of water in a 0.0002 inch rainfall event over the 350,000 acre developed area.

Also, the model was run with the assumption that the CBM produced water was completely removed from the basin. In actuality, the majority of the produced water is surface discharged or placed in pits and ponds where it eventually returns to the hydrologic system. The return of produced water to the hydrologic system would buffer and reduce impacts to surface water flows. The low magnitude of the modeled surface water depletions is attributed to the depth of the CBM production intervals, isolation of discontinuous coals, temporary volumes pumped by individual wells, and the very large area over which CBM pumping is distributed.

## Model Development and Funding

The work of building a basin-wide groundwater model was initiated by Pioneer Natural Resources USA, Inc. over six years ago. Norwest was chosen as the prime contractor. Over time other CBM operators joined Pioneer in supporting this effort. During its development, the Norwest model was peer-reviewed by several experts in groundwater modeling, including professors at the Colorado School of Mines.

For More Information on the Central Raton Basin Study, please visit:

<http://www.apishapawatershed.org>

<sup>1</sup> Office of the State Engineer, March 25, 2010. Findings of Fact, Conclusions of Law, and Final Decision of the State Engineer.

<http://water.state.co.us/dwripub/produced%20nontributary%20ground%20water/findingsoffactconclusionsoflawandfinaldecisionofthestateengineer.pdf>