GIS Applications In Reservoir Modeling

Coalbed Methane Reservoirs in the Powder River Basin, Wyoming

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- GIS Applications
- Geologic Mapping and Analysis
- Advanced Reservoir Modeling Input
Wyoming Powder River Basin

Projection: Geographic
North American Datum, 1927
Resource Management Issues

- Management of coal leasing, active mine development and CBM production from the same or contiguous parcels
- Drainage of CBM resources by production from surrounding wells
Overview - Wyoming Powder River Basin

Exploratory CBM Units

Active Coal Mines

USGS/WRMG Cored Wells

Powder River Basin Boundary
(Basal Fort Union Formation Outcrop, USGS, 2000)

T. 32 – 58 N., R. 65 – 87 W.

Projection: UTM, Zone 13
North American Datum, 1927
POWDER RIVER BASIN
COALBED METHANE
DEVELOPMENT
Powder River Basin
Total Coalbed Methane Wells
(by year; includes producing and shut-in wells)

Well Data from Wyoming Oil and Gas Conservation Commission, June 2002 (www.wogcc.state.wy.us)
(Nota that WOGCC statistics include all Wyoming CBM wells, but totals outside Powder River Basin are negligible)
Powder River Basin
Total Coalbed Methane Production
1987 - 2001

Well Data from Wyoming Oil and Gas Conservation Commission, June 2002
(Note that WOGCC statistics include all Wyoming CBM wells, but totals outside Powder River Basin are negligible)
Completed Coalbed Methane Wells

Total Wells  1,014

Well Data from Wyoming Oil and Gas Conservation Commission, 2001

Projection: Geographic
North American Datum, 1927
Coalbed Methane Well Completions
Wyoming Powder River Basin
2001 (through November)

Powder River Basin Boundary
(Basal Fort Union Formation Outcrop,
USGS, 2000)

Completed Coalbed Methane Wells
Total Wells  6,758
Well Data from Wyoming Oil and Gas Conservation Commission, 2001

Projection: Geographic
North American Datum, 1927
Coalbed Methane Well Completions
Wyoming Powder River Basin
1987 – 2001 (Jan. – Nov.)

Completed Coalbed Methane Well
Total Wells 17,183

Well Data from Wyoming Oil and Gas Conservation Commission, 2001
Projection: Geographic North American Datum, 1927
GIS Applications and Programs

- Predominantly use ArcView 3.2
- Spatial Analyst based procedures
- Limited use of ArcGIS/ArcMap – technical issues
- Limited use of ArcINFO
Evaluation requires estimation of initial (i.e. pre-mining) and current (i.e. depleted) pressures and gas content.

Simplified procedures are normally used due to data constraints.

Coal mine dewatering causes extensive water drawdown which reduces hydrostatic pressure in the coal and allows methane to desorb.

Escape of methane depletes CBM resource.

Evaluation requires estimation of initial (i.e. pre-mining) and current (i.e. depleted) pressures and gas content.

Simplified procedures are normally used due to data constraints.

Assessment of CBM resource is necessary to support CBM development, coal leasing and mine development.
Geologic/Reservoir Analysis

- Raw data include CBM well data, coal drill hole data, groundwater/hydrostatic data and coal analyses
- Procedures include gridding/surface generation, contouring and map-based calculations ("map algebra")
Overview - Wyoming Powder River Basin

Powder River Basin Boundary
(Basal Fort Union Formation Outcrop, USGS, 2000)

T. 32 – 58 N., R. 65 – 87 W.

Projection: UTM, Zone 13
North American Datum, 1927
Coalbed Methane Development
South Pod Mining Area

Producible CBM Wells (Includes flowing, shut-in, and other completed wells)

Mine Areas from BLM Public Records
Well data from Wyoming Oil and Gas Conservation Commission, June 27, 2002

Projection: UTM, Zone 13
North American Datum, 1927
Geologic Structure
Wyodak – Anderson Coal Zone

Coal drill hole with elevation data
Structural Contours at coal mid-point
(Contour Interval = 50 ft.; Elevations in feet above m.s.l.)

Coal Drill Hole Data from BLM Public Drill Hole Records, 2002

Projection: UTM, Zone 13
North American Datum, 1927
Coal drill hole with elevation data

Structural Contours at coal mid-point
(Contour Interval = 50 ft.; Elevations in feet above m.s.l.)

Coal Drill Hole Data from BLM Public Drill Hole Records, 2002

Projection: UTM, Zone 13
North American Datum, 1927
Pre-Mining (1982) Groundwater Elevation Wyodak – Anderson Coal Zone

- Groundwater Monitoring Well
- Structural Contours = 1982 Piezometric Surface
  (Contour Interval = 25 ft.; Elevations in feet above m.s.l.)

Water Monitoring Well Data from Gillette Area Groundwater Monitoring Association (GAGMO) Public Records, 2001

Projection: UTM, Zone 13
North American Datum, 1927
Current (2001) Groundwater Elevation
Wyodak – Anderson Coal Zone

Groundwater Monitoring Well

Structural Contours = 2000 Piezometric Surface
(Contour Interval = 25 ft.; Elevations in feet above m.s.l.)

Water Monitoring Well Data from Gillette Area Groundwater Monitoring Association (GAGMO) Public Records, 2002

Projection: UTM, Zone 13
North American Datum, 1927
Pre-Mining (1982) Hydrostatic Head
(Feet of Water Over Coal)
Wyodak-Anderson Coal Zone

Derived by Subtracting Coal Geologic Structure Grid From 1982 Water Elevation Grid

(Contour Interval = 25 ft.)

Projection: UTM Zone 13
North American Datum, 1927
Current (2001) Hydrostatic Head
(Feet of Water Over Coal)
Wyodak-Anderson Coal Zone

Derived by Subtracting Coal Geologic Structure Grid From 2001 Water Elevation Grid
(Contour Interval = 25 ft.)

Projection: UTM, Zone 13
North American Datum, 1927
Pre-Mining (1982) Hydrostatic Pressure
Wyodak-Anderson Coal Zone

Derived by multiplying 1982 hydrostatic grid by 0.433 psi/ft. pressure gradient (12.6 atm. pressure adjustment)

(Contour Interval = 10 p.s.i.)

Projection: UTM, Zone 13
North American Datum, 1927
Current (2001) Hydrostatic Pressure
Wyodak-Anderson Coal Zone

Derived by multiplying 2001 hydrostatic grid by 0.433 psi/ft. pressure gradient (12.6 psi atm. pressure adjustment)

(Contour Interval = 20 p.s.i.)
Adsorption Isotherm Data (Near-mines core samples)

\[ y = -5 \times 10^{-5} x^2 + 0.1327x + 2.4611 \]

\[ R^2 = 0.9451 \]

Gas Content Estimation

Kennecott CBM-1 (148.5-150.0)
Kennecott CBM-1 (187.5-188.5)
Kennecott CBM-2 (190.5-191.5)
Kennecott CBM-2 (205.5-206.5)
Kennecott B19 Split (CBM-1, 169.5-171.5)
Rim CBM H11-04: 278-280'
PNG CBM 34-1: 303-305'
PNG 33-1 Can. C17: 328-330'
Gas Content Calculations:

- The predictive equation from the adsorption isotherms can be used to estimate gas content (storage capacity) based on hydrostatic pressure.

- In this example:
  
  \[-0.00005x^2 + 0.1327x + 2.4611 = \text{methane storage capacity}\]
  
  where,
  
  \[x = \text{Hydrostatic Pressure (from pressure surface maps)}\]

- Initial and depleted gas content can be mapped.
Pre-Mining (1982) Estimated Gas Content
Wyodak-Anderson Coal Zone

Projected: UTM, Zone 13
North American Datum, 1927

Calculated from 1982 pressure surface and average adsorption isotherm

Calculated gas content in scf/ton
(Contour Interval = 2 scf/ton)

West Antelope LBA

Wyodak-Anderson Coal Outcrop
(U.S.G.S. Professional Paper 1625-A, 1999)
Current (2001) Estimated Gas Content
Wyodak-Anderson Coal Zone

Calculated from 2001 pressure surface and average adsorption isotherm
Calculated Gas Content in scf/ton
(Contour Interval = 2 scf/ton)

Projection: UTM, Zone 13
North American Datum, 1927
CBM Resource Assessment Goals

- Economic evaluation of CBM drilling and production for consideration in mine planning.
- Evaluation of effects on CBM resources by coal leasing or mining.
- Economic valuation and projections for CBM resources and wells in potentially mined parcels.
- Drilling and production economics to support timely CBM drilling in mine areas.
If development does not occur uniformly, drainage or depletion of CBM reservoirs can result.

This is caused by reductions in hydrostatic pressure that result from “regional” groundwater drawdown as coal seams are de-watered.

Pressure depletion always affects the CBM reservoir.

In cases of diverse mineral ownership this can also affect production and revenues.
Typical CBM Development Patterns
July, 2002

Producing Coalbed Methane Well
Permitted well location or drilling CBM well
Other non-productive CBM well
Conventional Well

Well Data from Wyoming Oil and Gas Conservation Commission, 2002
Lease and ownership data from BLM’s “OG-Map” Program

Projection: UTM, Zone 13
North American Datum, 1927
Drainage review and evaluation:

- Requires evaluation of production from individual wells, regional depletion, reservoir communication across lease lines, flow boundaries, etc.
- Can be done on an individual well – lease basis.
- We are developing reservoir modeling/simulation programs to evaluate drainage from multiple wells or regional water drawdown.
- GIS applications can be used to develop modeling data.
Reservoir Modeling Applications

- Gridding data themes can produce input data layers for reservoir simulation.
- ArcINFO "GRIDASCII" procedure used to export grids.
- ASCII grid files support a variety of applications.
CBM Well with coal elevation data

Structural Contours on top of coal
(Contour interval = 50 ft.; Elevations in feet above m.s.l.)

Projection: UTM, Zone 13
North American Datum, 1927

Well data from Wyoming Oil and Gas Conservation Commission, 2002
Big George Area
Coal Thickness

Projection: UTM, Zone 13
North American Datum, 1927

Well data from Wyoming Oil and Gas Conservation Commission, 2002

CBM Well with coal thickness data
(Contour Interval = 10 ft.; Thickness in feet.)
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yllcorner 4871702.322379
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### Simulation Input Spreadsheet File

#### Geologic Structure

T. 48 N., R. 78 W

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Remaining % Original Pressure
Big George Coal

Simulation Based on Idealized Gas Content and Estimated Initial Hydrostatic Pressure

Production Data through June 2002

(CBM Well Data from Wyoming Oil and Gas Conservation Commission, June, 2002)

Projection: UTM, Zone 13
North American Datum, 1927
Remaining % Original Pressure
Big George Coal

Simulation Based on Idealized Gas Content and Estimated Initial Hydrostatic Pressure
Production Data through June 2002

(CBM Well Data from Wyoming Oil and Gas Conservation Commission, June, 2002)
3-D Wire Mesh Diagram Prepared from Simulation Data using “Surfer” software.
Future Challenges and Needs

- Use of the ArcGIS software.
- Input of modeling data into GIS applications.
- Interactive database.
GIS Applications In Reservoir Modeling

Coalbed Methane Reservoirs in the Powder River Basin, Wyoming

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