

# REGIONAL BEDROCK GROUNDWATER IMPACTS FROM CBM DEVELOPMENT IN THE POWDER RIVER BASIN, SOUTHEASTERN MONTANA

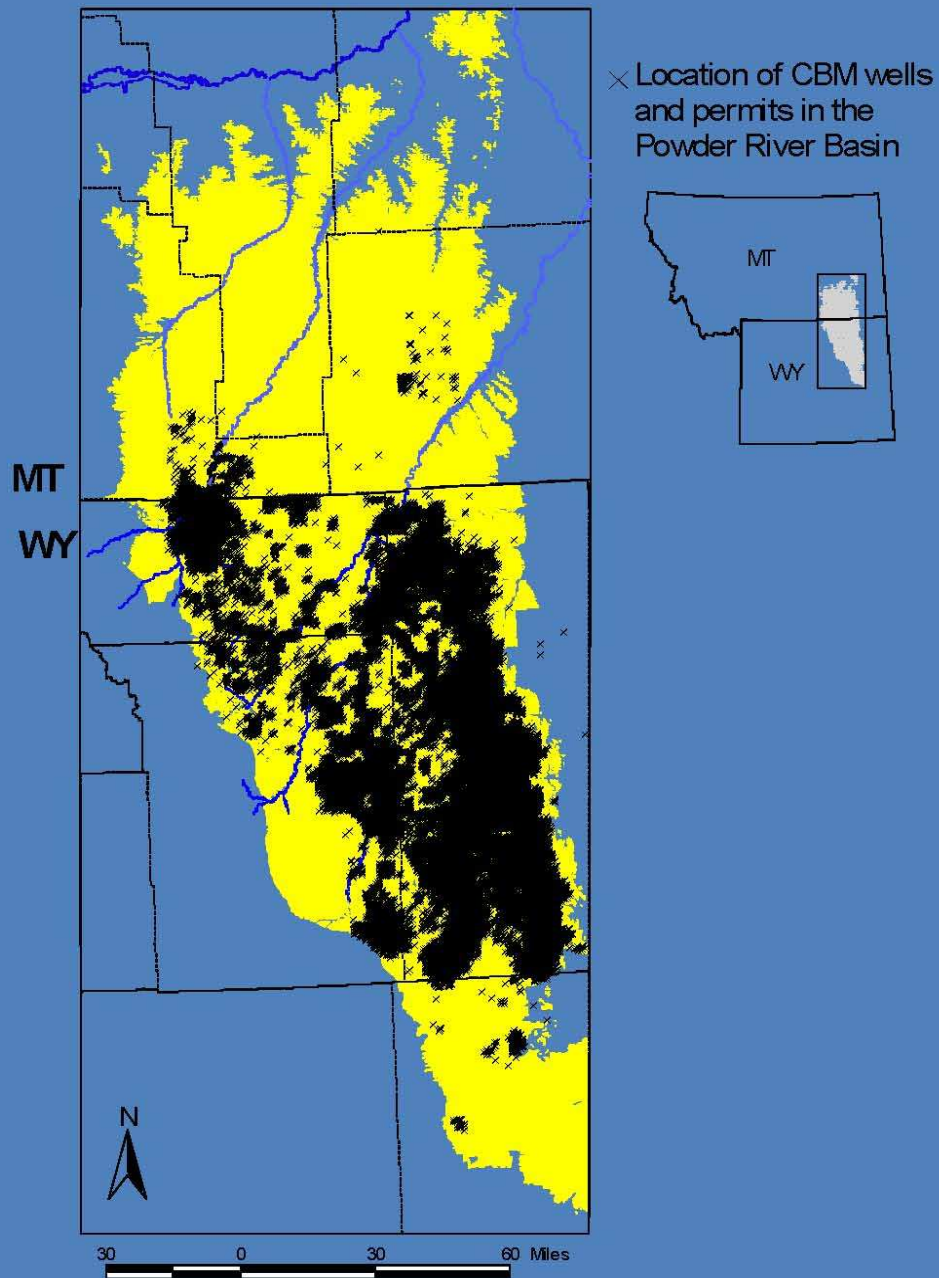
AN OVERVIEW OF CONCEPTUAL AND  
QUANTITATIVE MODELS OF GROUNDWATER  
IMPACTS, AND COMPARISON TO MONITORING DATA

Andrew Bobst  
John Wheaton  
Elizabeth Meredith  
and  
John Metesh



# Acknowledgements

- Support and organizational efforts for this monitoring program have been provided by:
  - US Bureau of Land Management
  - MT Department of Natural Resources & Conservation
  - EPA
  - US Forest Service
  - Big Horn and Rosebud Conservation Districts



As of 2008

Wells or permits in PRB

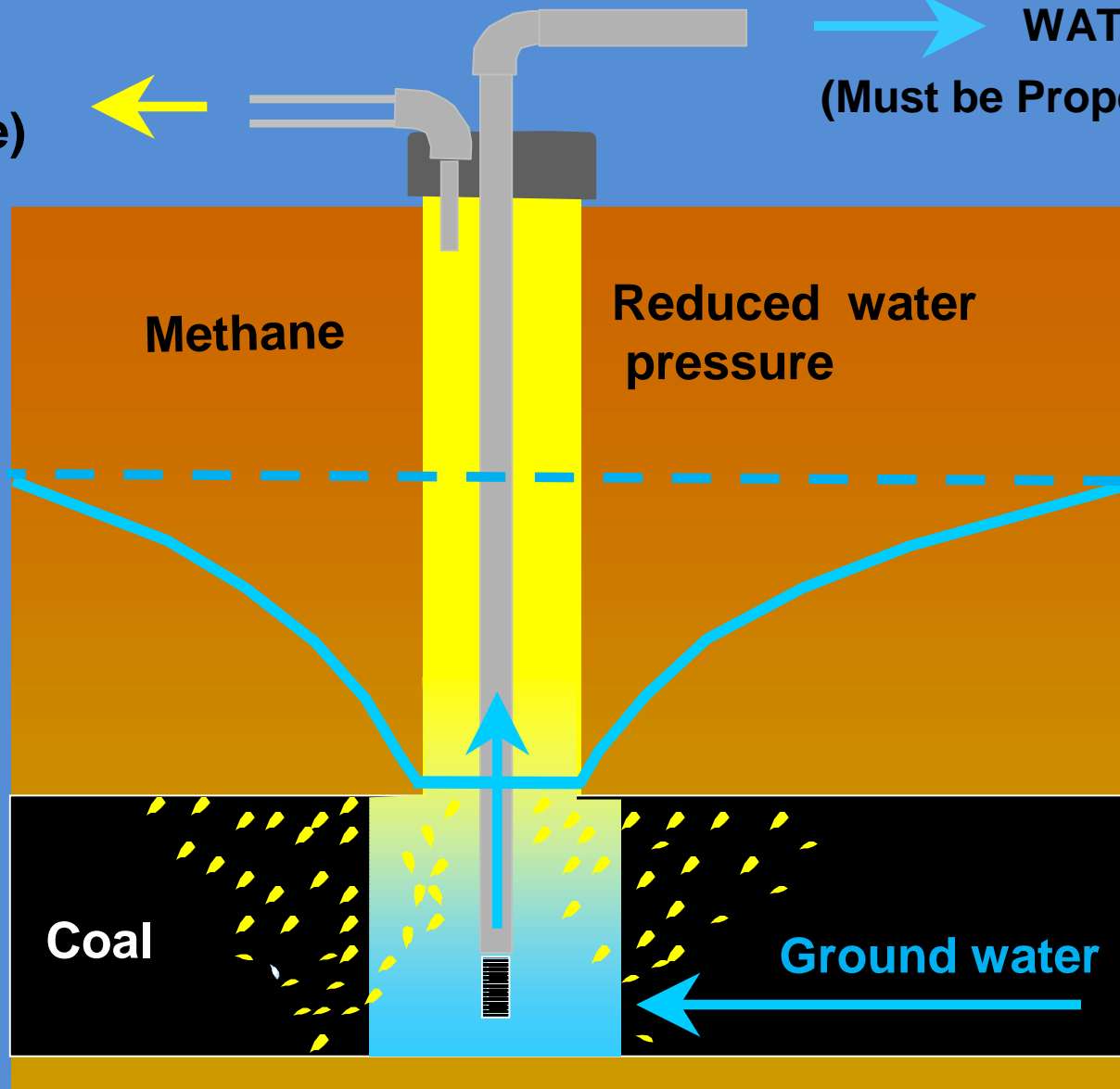
Montana: 1,686  
Producing: 827

Wyoming: 26,369  
Producing: 17,876

# TRADITIONAL CBM WELL CONSTRUCTION

**METHANE  
(to pipeline)**

**WATER  
(Must be Properly Managed)**



**Methane  
Desorbes  
from Coal**

**Coal**

**Ground water**

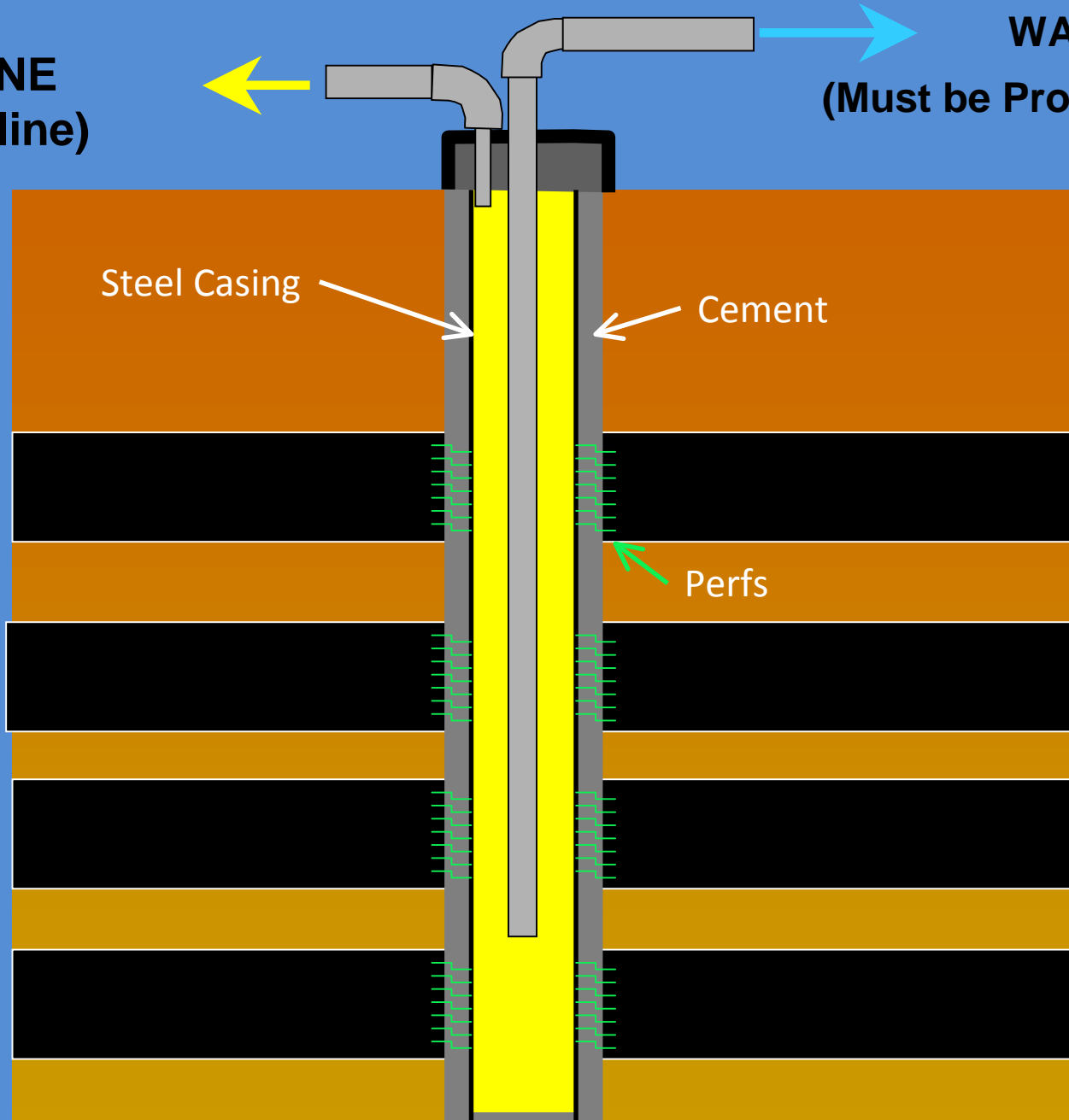
**Methane**

**Reduced water  
pressure**

## Multi-zone (Monobore) CBM WELL CONSTRUCTION

**METHANE**  
(to pipeline)

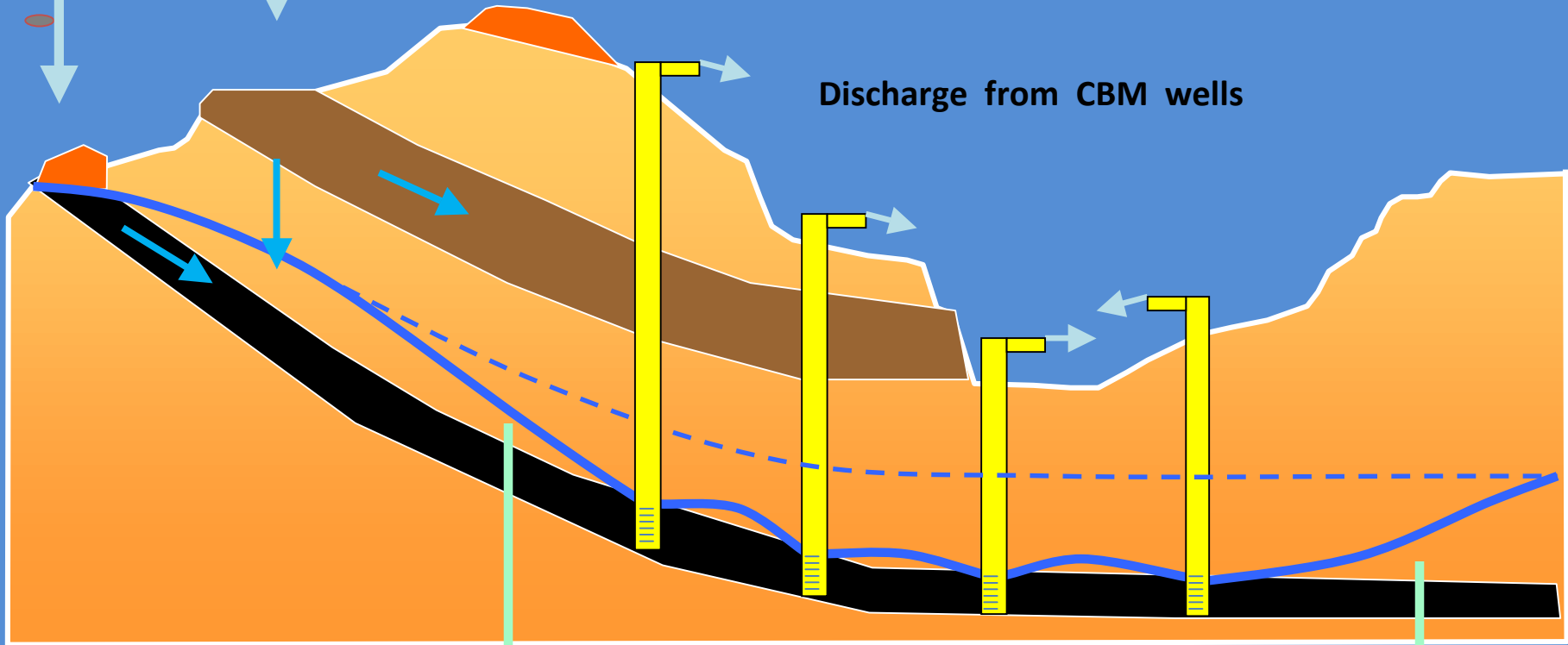
**WATER**  
(Must be Properly Managed)








# Conceptual Ground - Water Drawdown by Coalbed Methane Wells

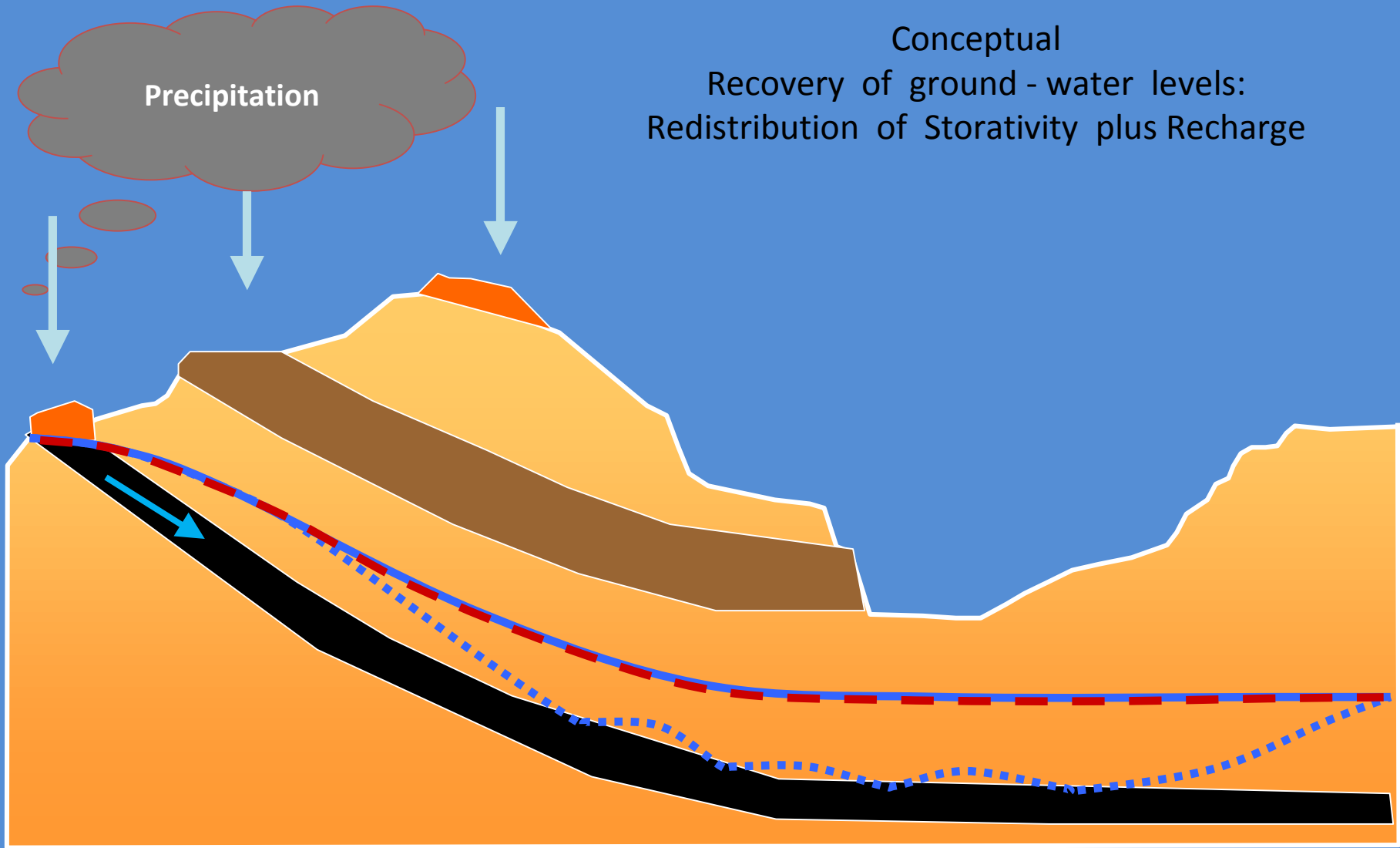
Discharge from CBM wells



CBM Producing Area

-  GROUND WATER FLOW DIRECTION
-  GROUND WATER PRESSURE
-  STARTING GROUND WATER PRESSURE

# Conceptual Recovery of ground - water levels: Redistribution of Storativity plus Recharge



GROUND WATER FLOW DIRECTION



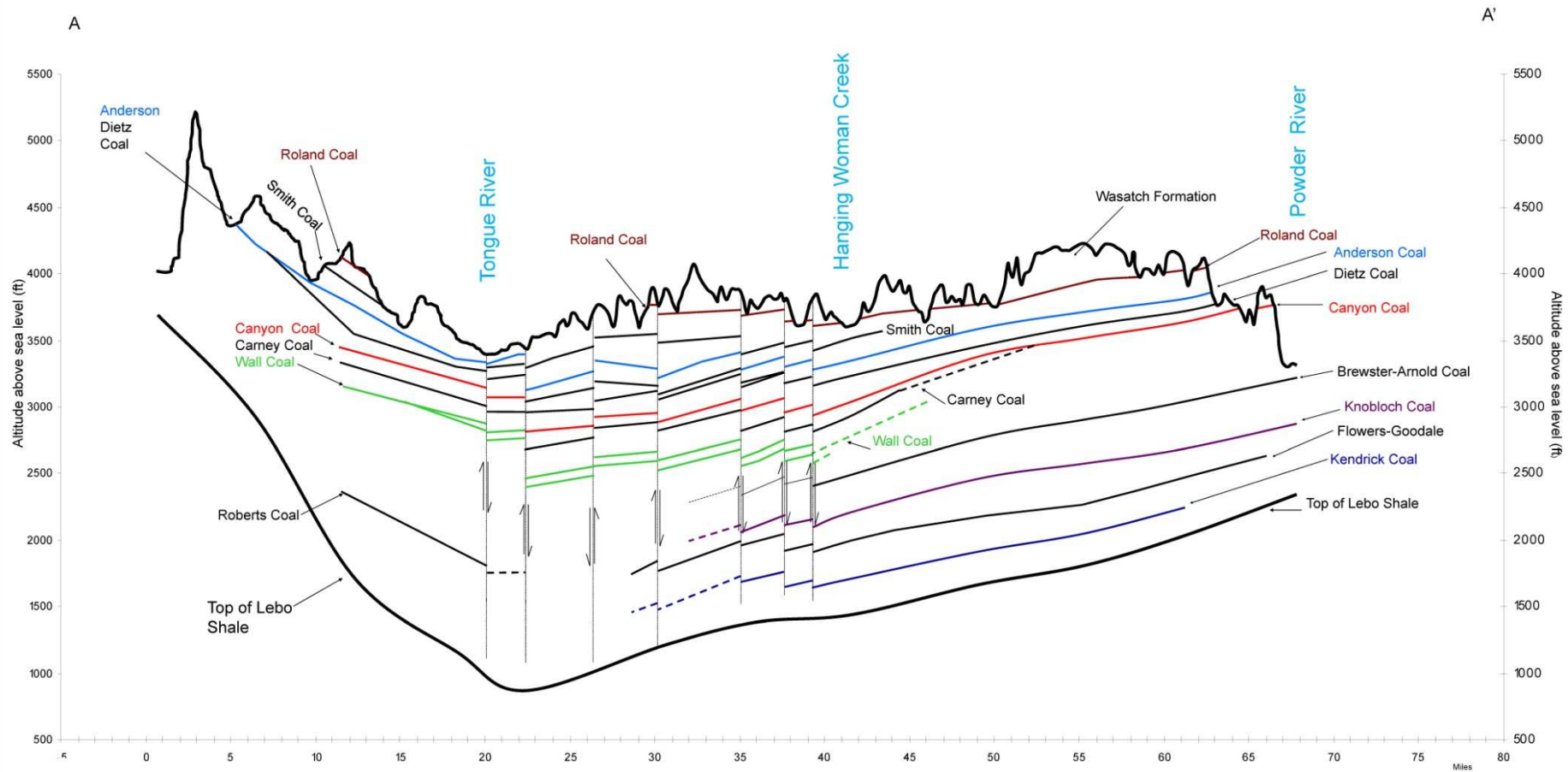
STARTING GROUND WATER PRESSURE



DRAWDOWN

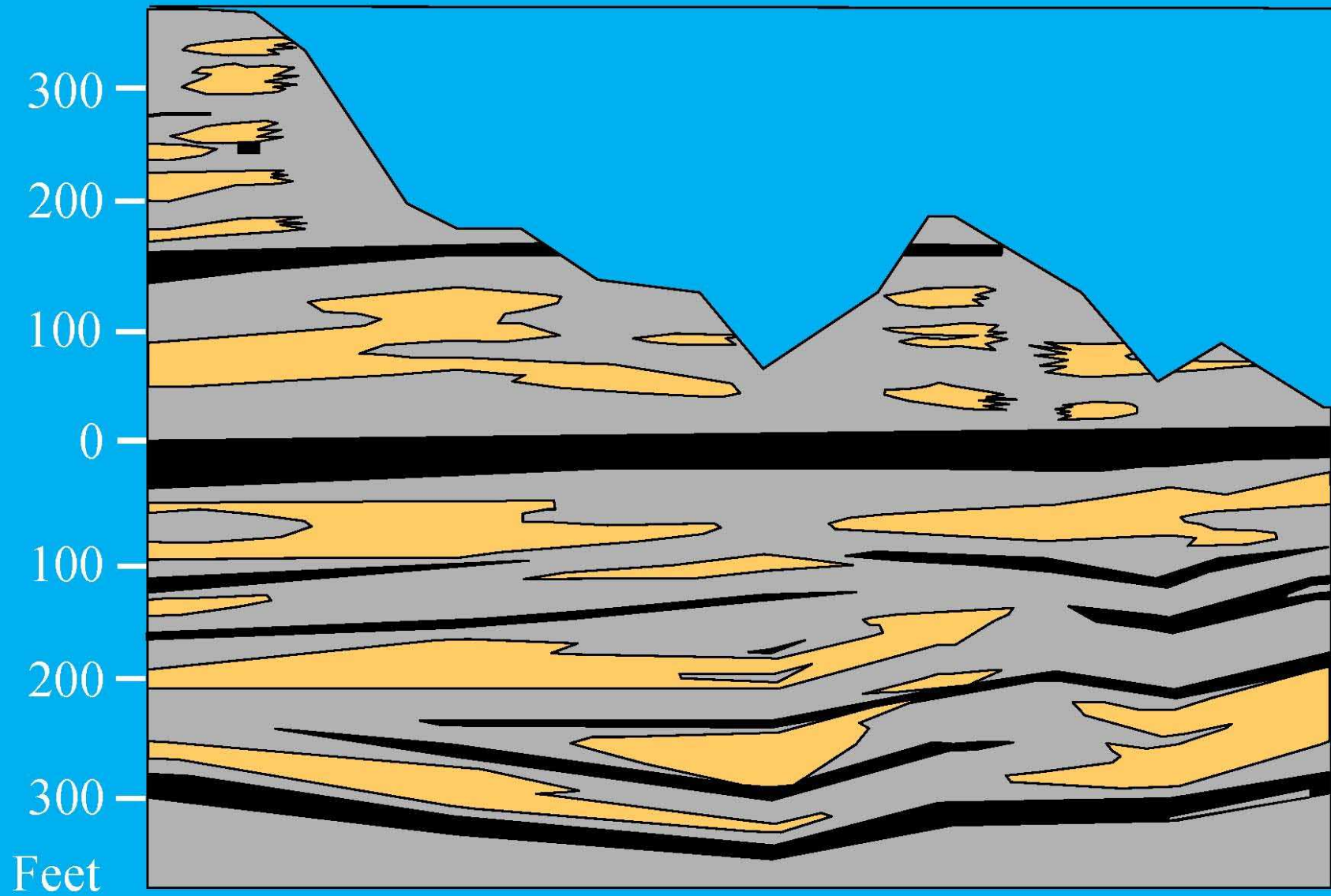


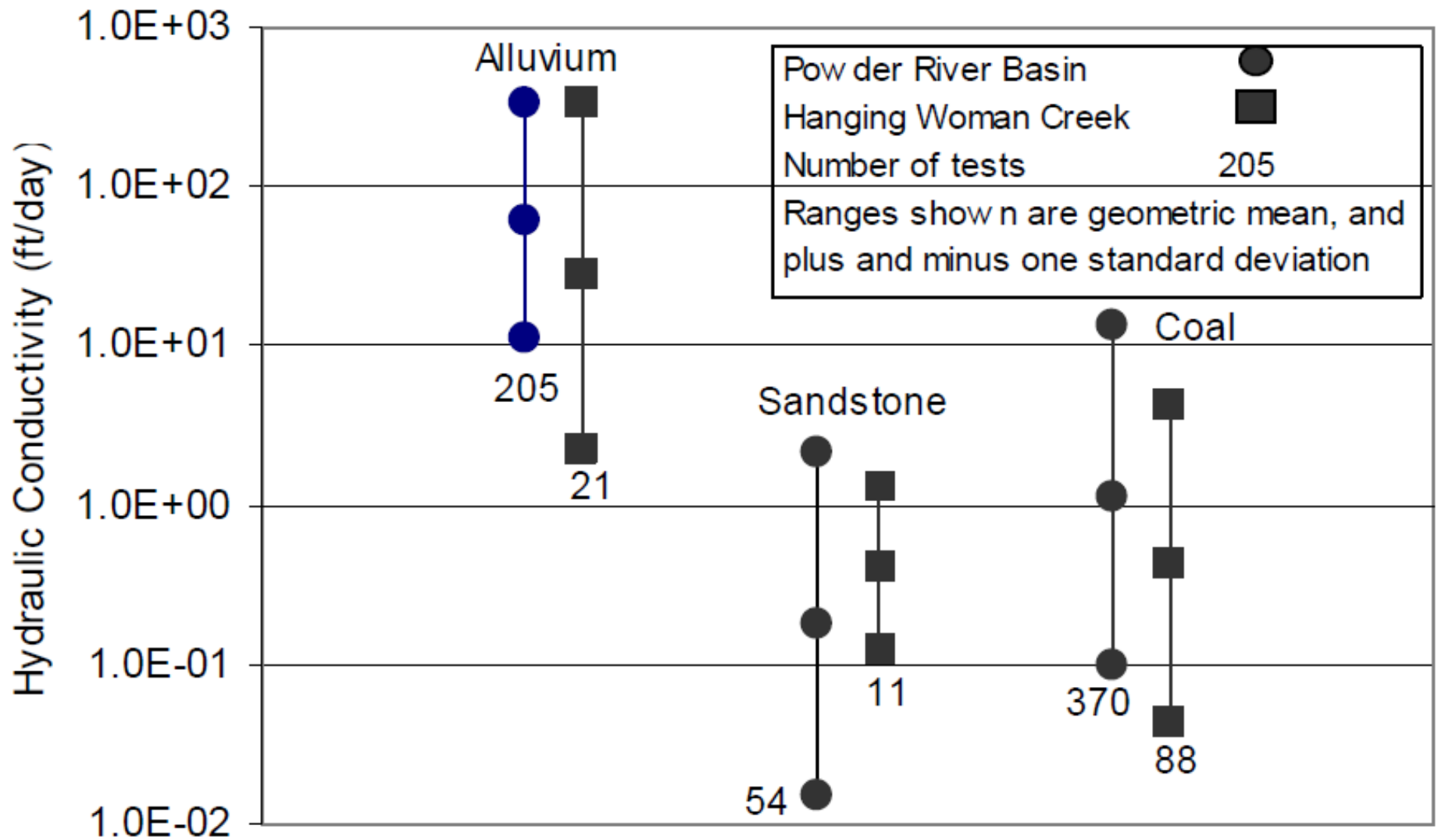
RECOVERING GROUND WATER PRESSURE





# Hanging Woman Creek Coal Field ( from USGS WRI 83-4260)



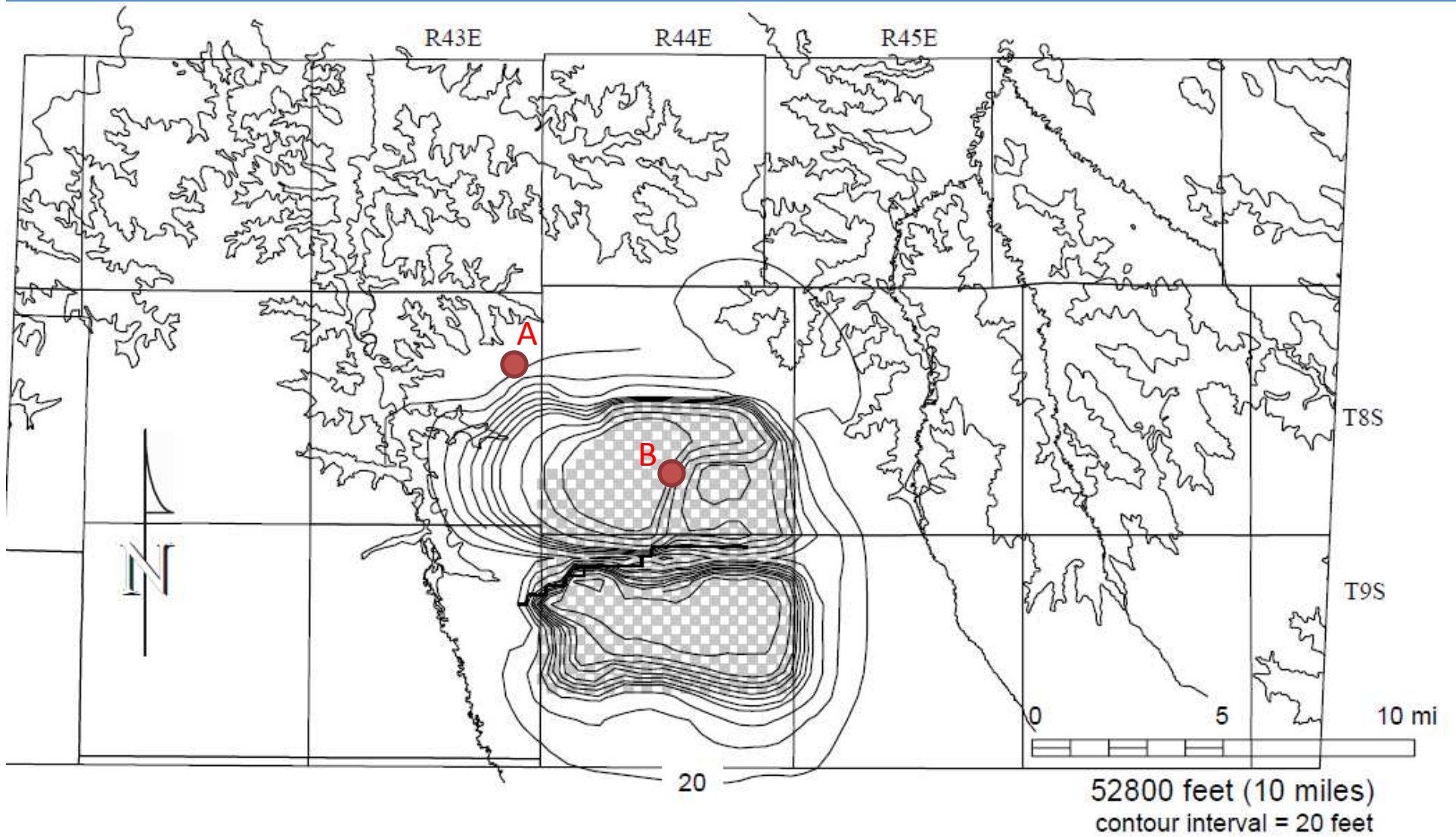


From Wheaton and Metesh, 2002

Location (number of tests) *	Hydraulic conductivity (ft/day)			Storativity (unconfined) Mean	or	Storativity (confined) Mean
	- 1 Std Dev	Geometric Mean	+ 1 Std Dev			
<b>Alluvium</b>						
PRB Wide (206)	1.1E+01	6.1E+01	3.3E+02	8.E-02		
Hanging Woman Basin (21)	2.3E+00	2.8E+01	3.4E+02	2.E-03		
<b>Sandstone</b>						
PRB Wide (54)	1.5E-02	1.8E-01	2.1E+00			5.E-04
Hanging Woman Basin (11)	1.3E-01	4.2E-01	1.4E+00			ND
<b>Coal</b>						
PRB Wide (370)	9.8E-02	1.1E+00	1.3E+01			9.E-04
Hanging Woman Basin (88)	4.3E-02	4.3E-01	4.3E+00			3.E-04

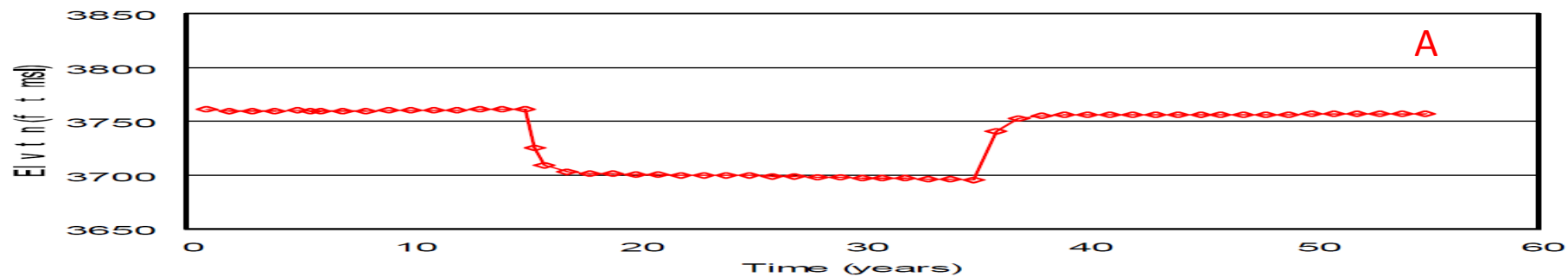
\* PRB refers to tests within the entire Powder River Basin, Montana.  
The numbers in parentheses show the number of tests for which hydraulic conductivity was calculated.  
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ND: No Data

From Wheaton and Metesh, 2002

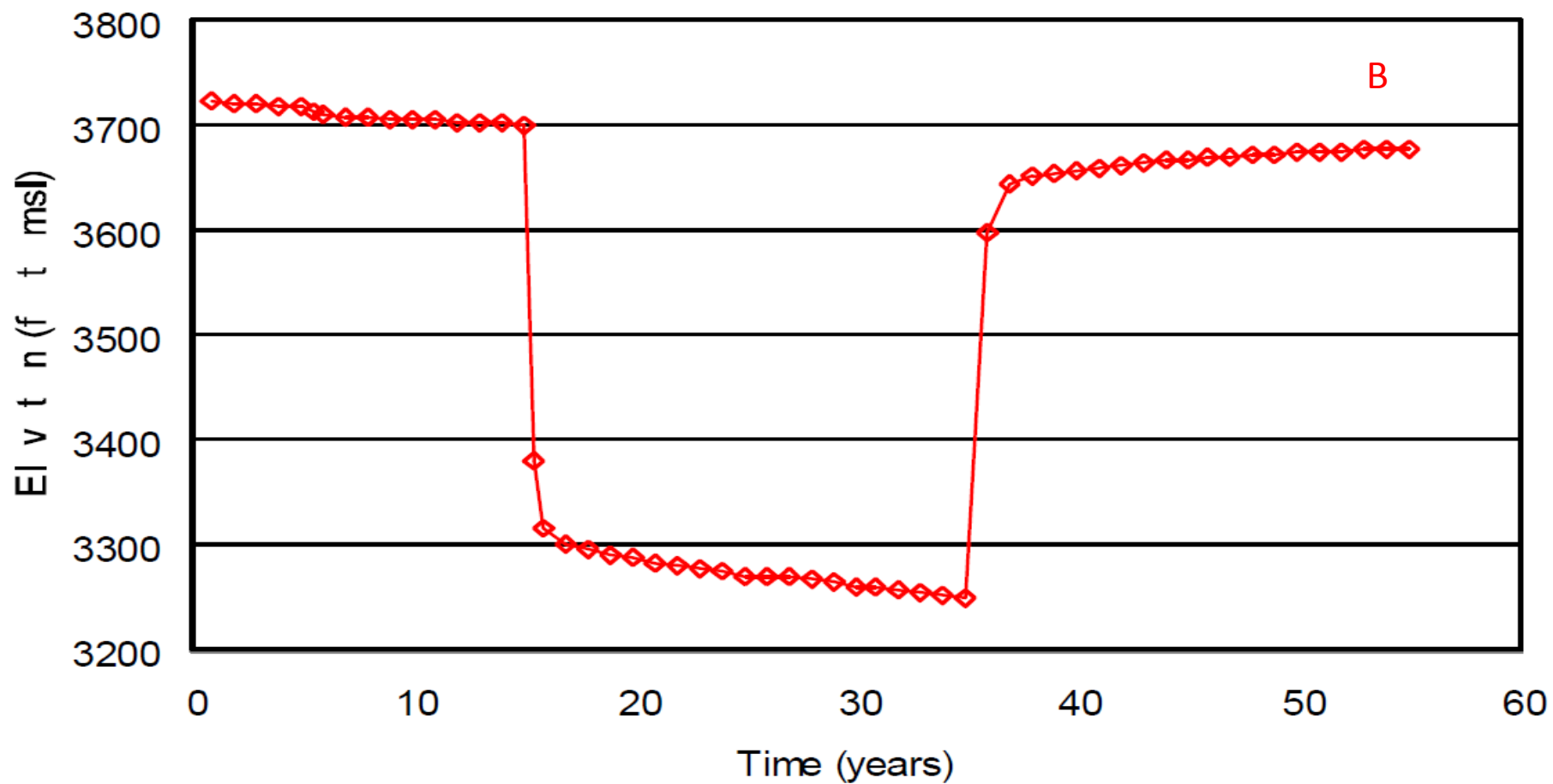


From Wheaton and Metesh, 2002

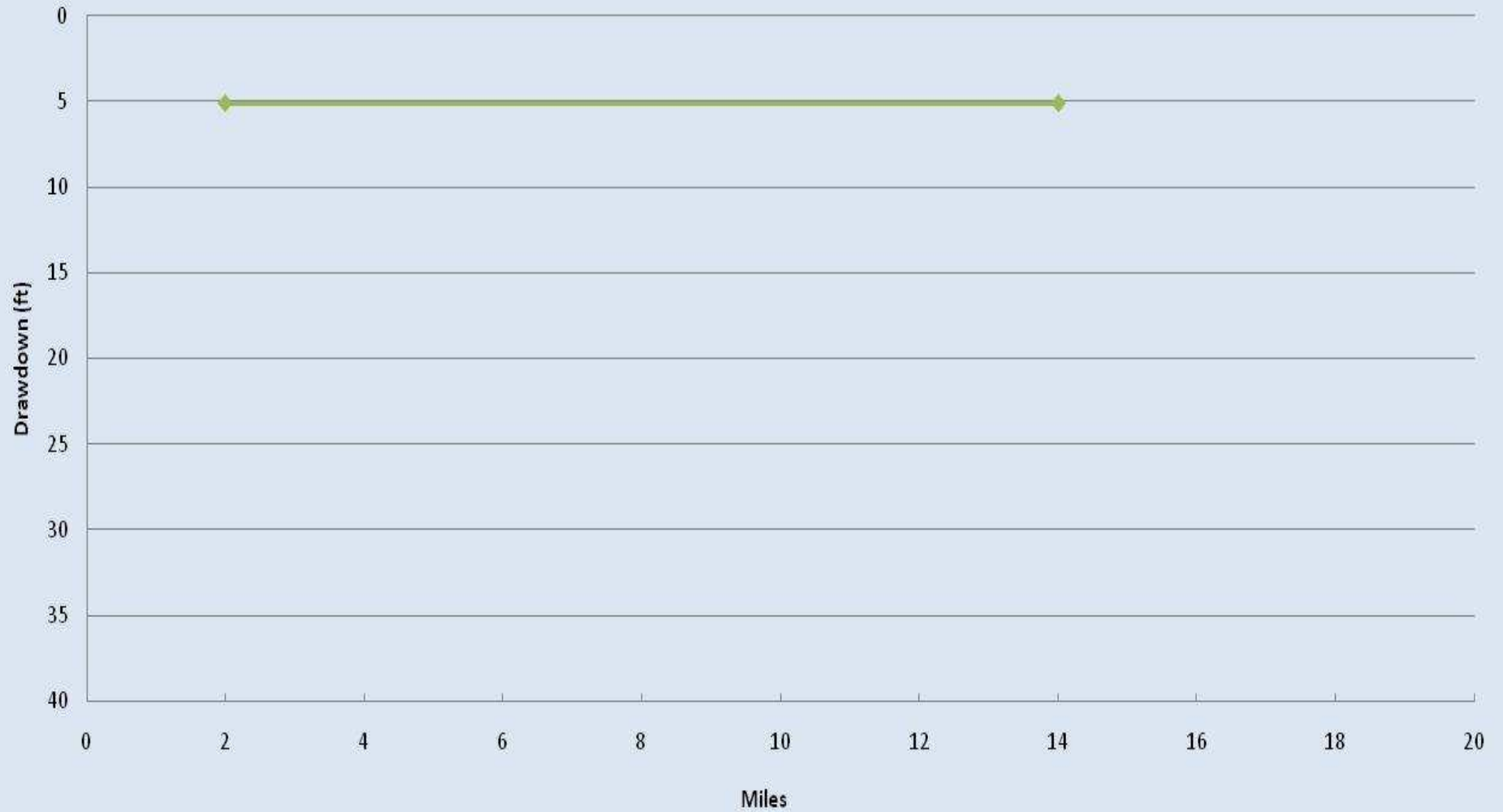
Canyon (northwest)



Canyon (north well field)

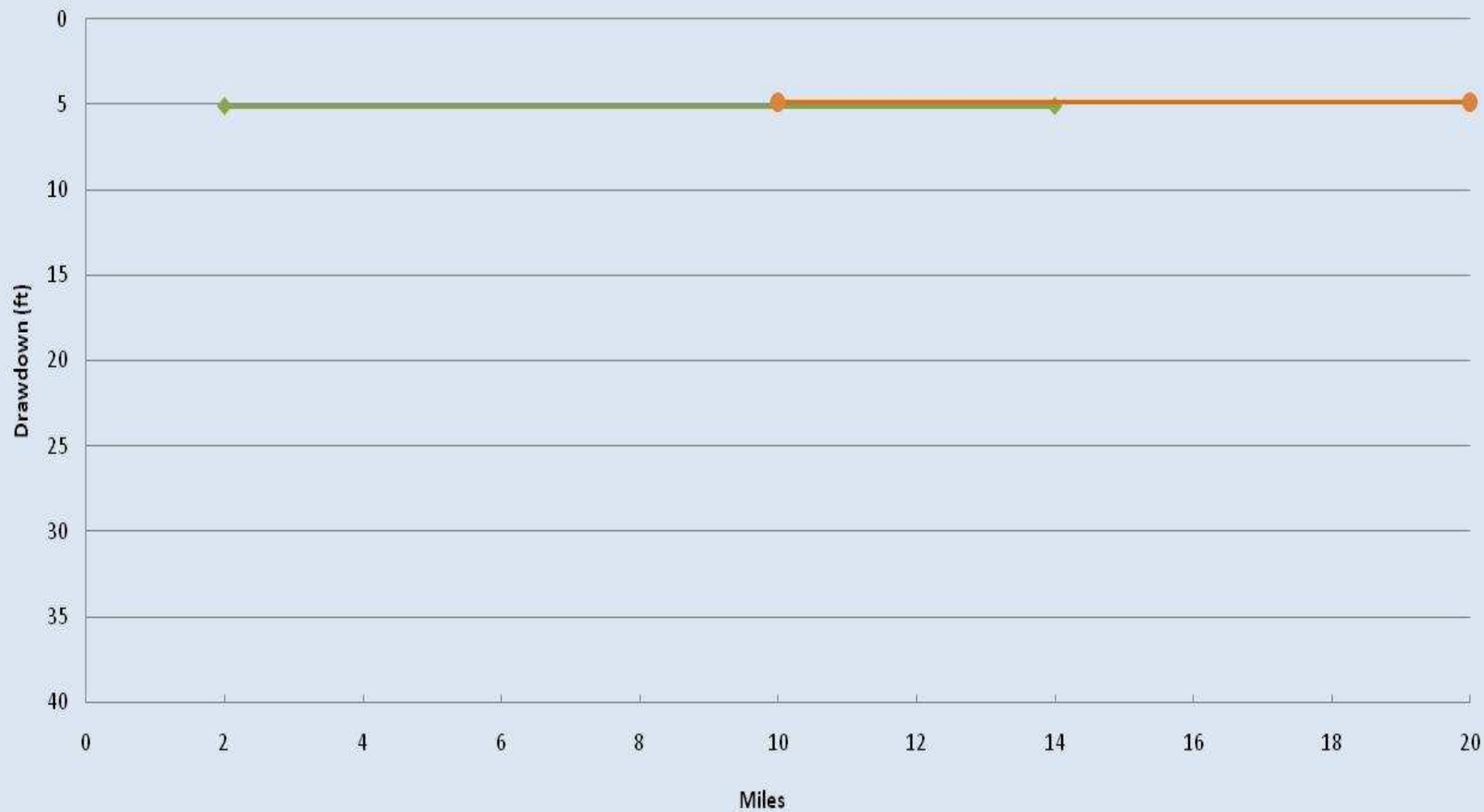


## Modeled Drawdown from CBM in the Powder River Basin



—◆— Wyodack, 1999, Coal Mine Analog, 15 yr

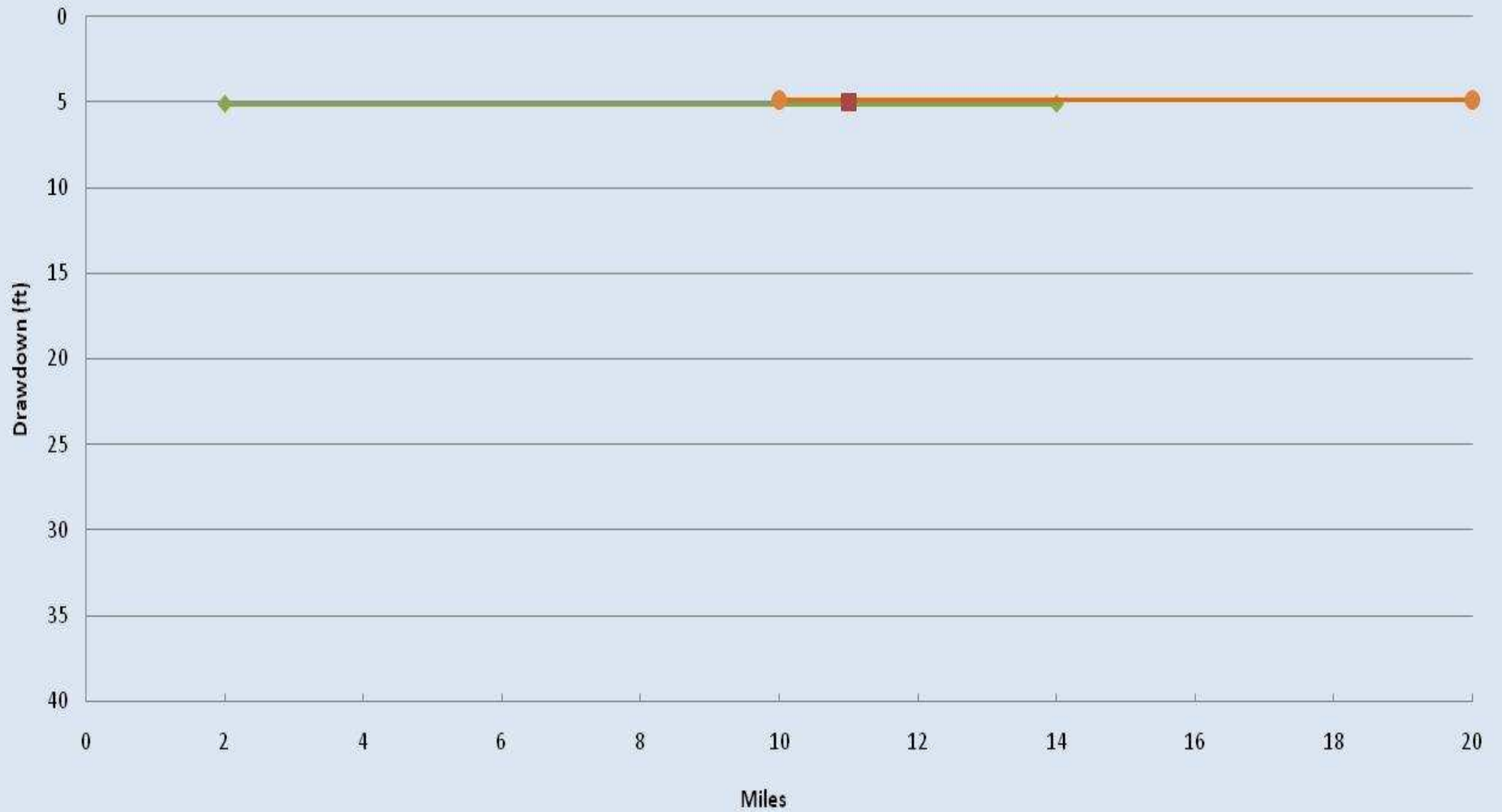
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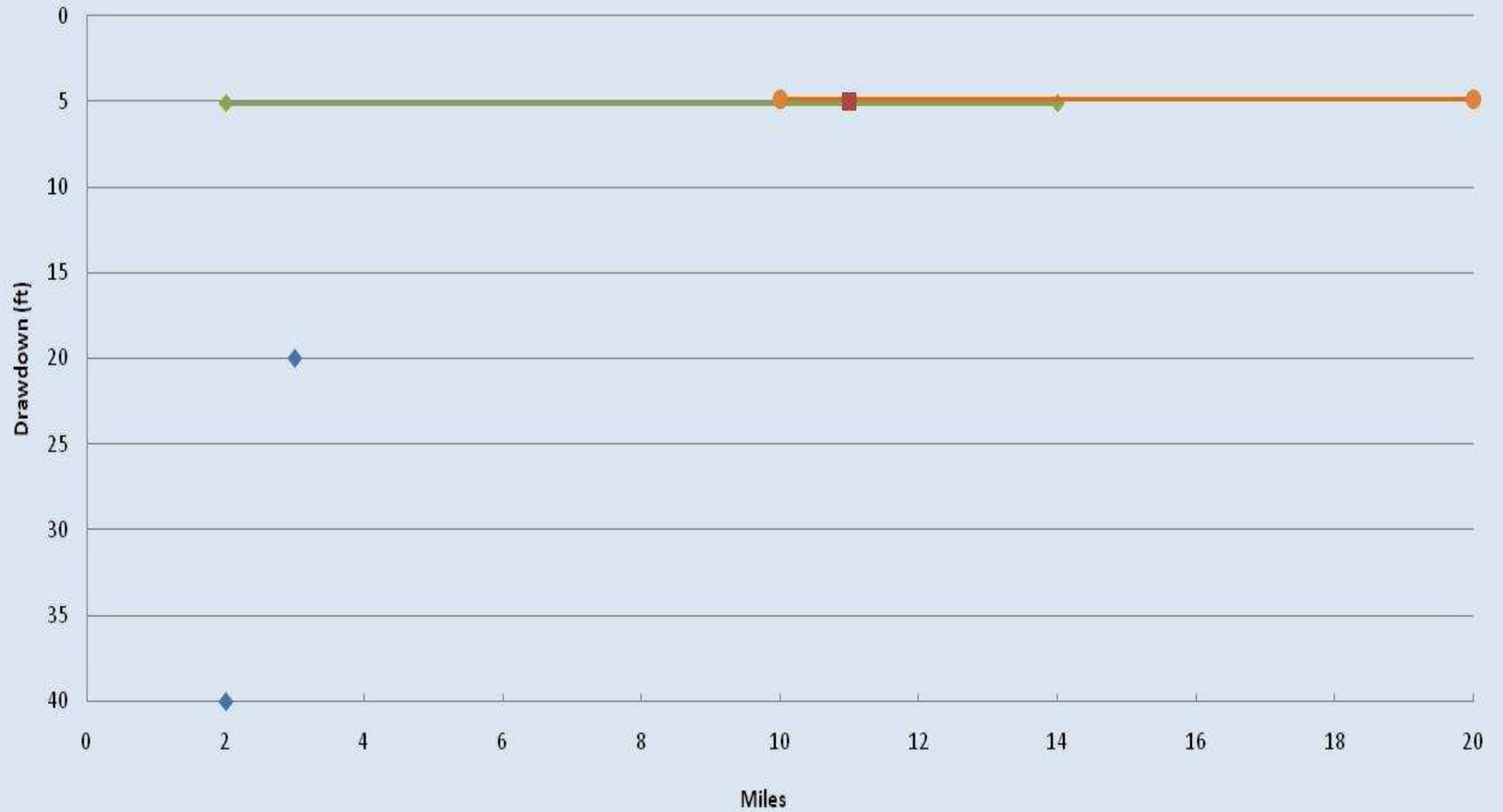
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■ Wheaton & Metesh, 2001, 2D, 5 yr

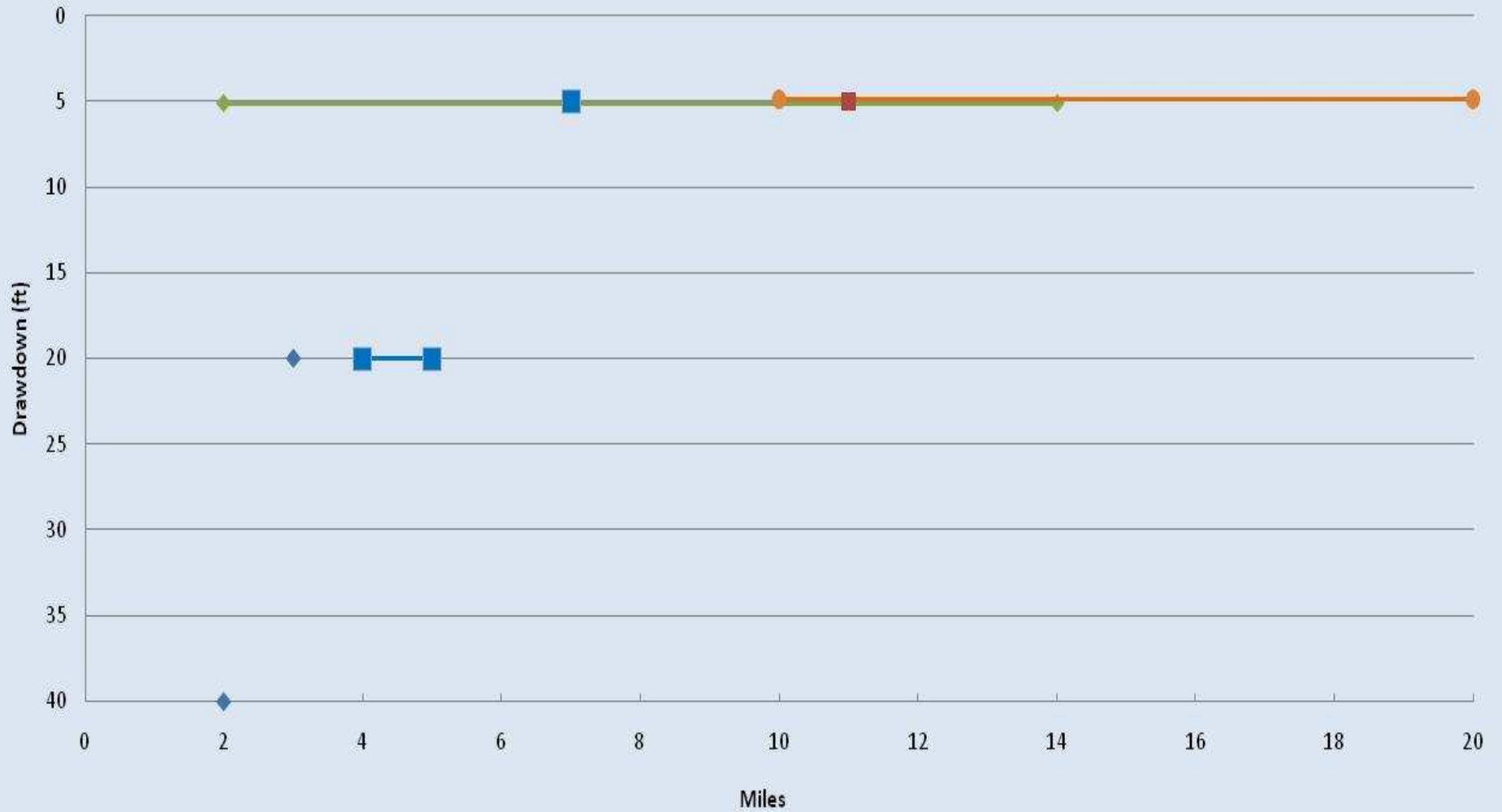


## Modeled Drawdown from CBM in the Powder River Basin



Wyodack, 1999, Coal Mine Analog, 15 yr   Wyodack, 1999, 3D, 20 years   Wheaton & Metesh, 2001, 2D, 5 yr   Wheaton & Metesh, 2002, 3D, 10 yr

## Modeled Drawdown from CBM in the Powder River Basin



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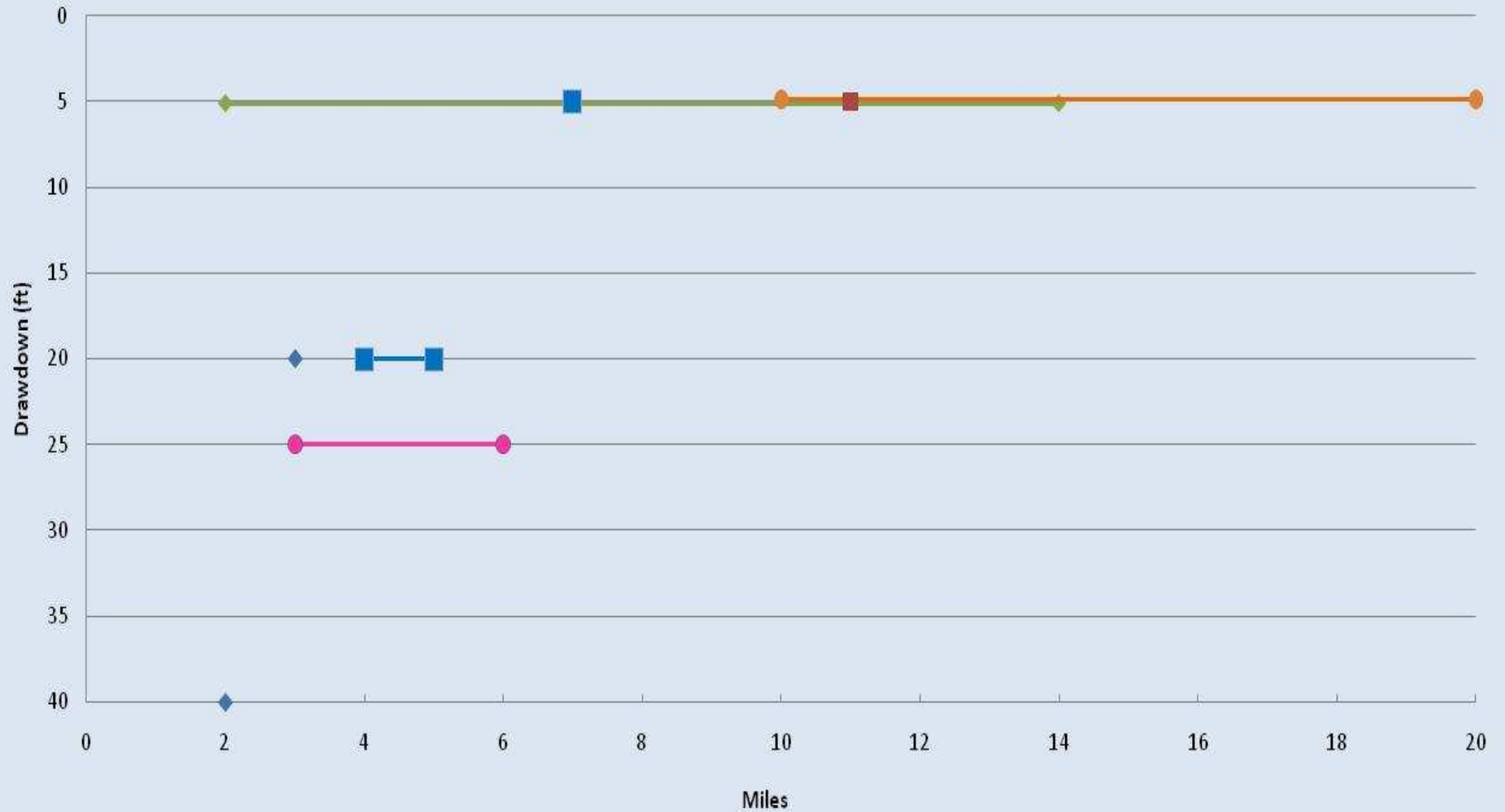
◆ Wyodack, 1999, 3D, 20 years

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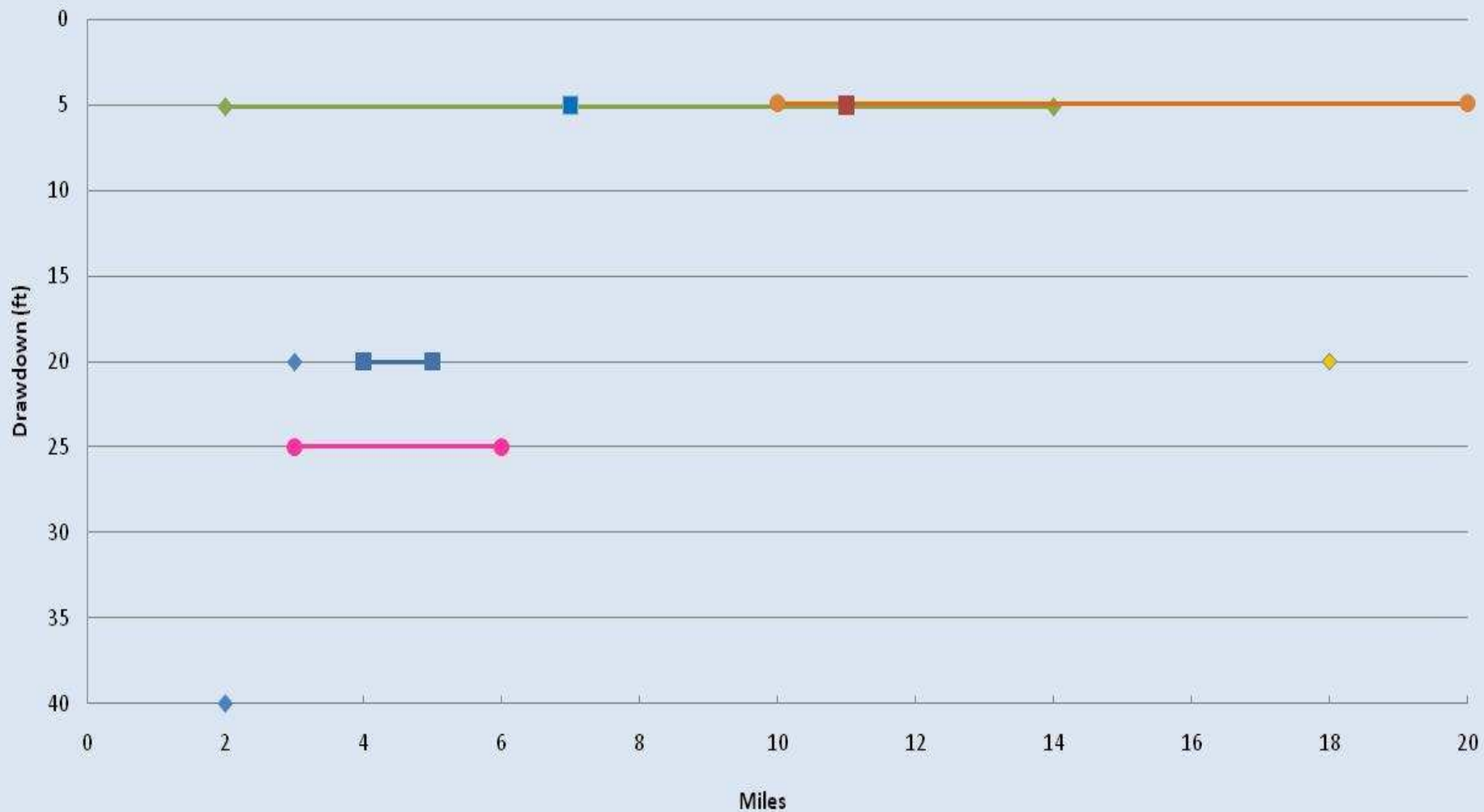
■ Wheaton & Metesh, 2001, 2D, 5 yr

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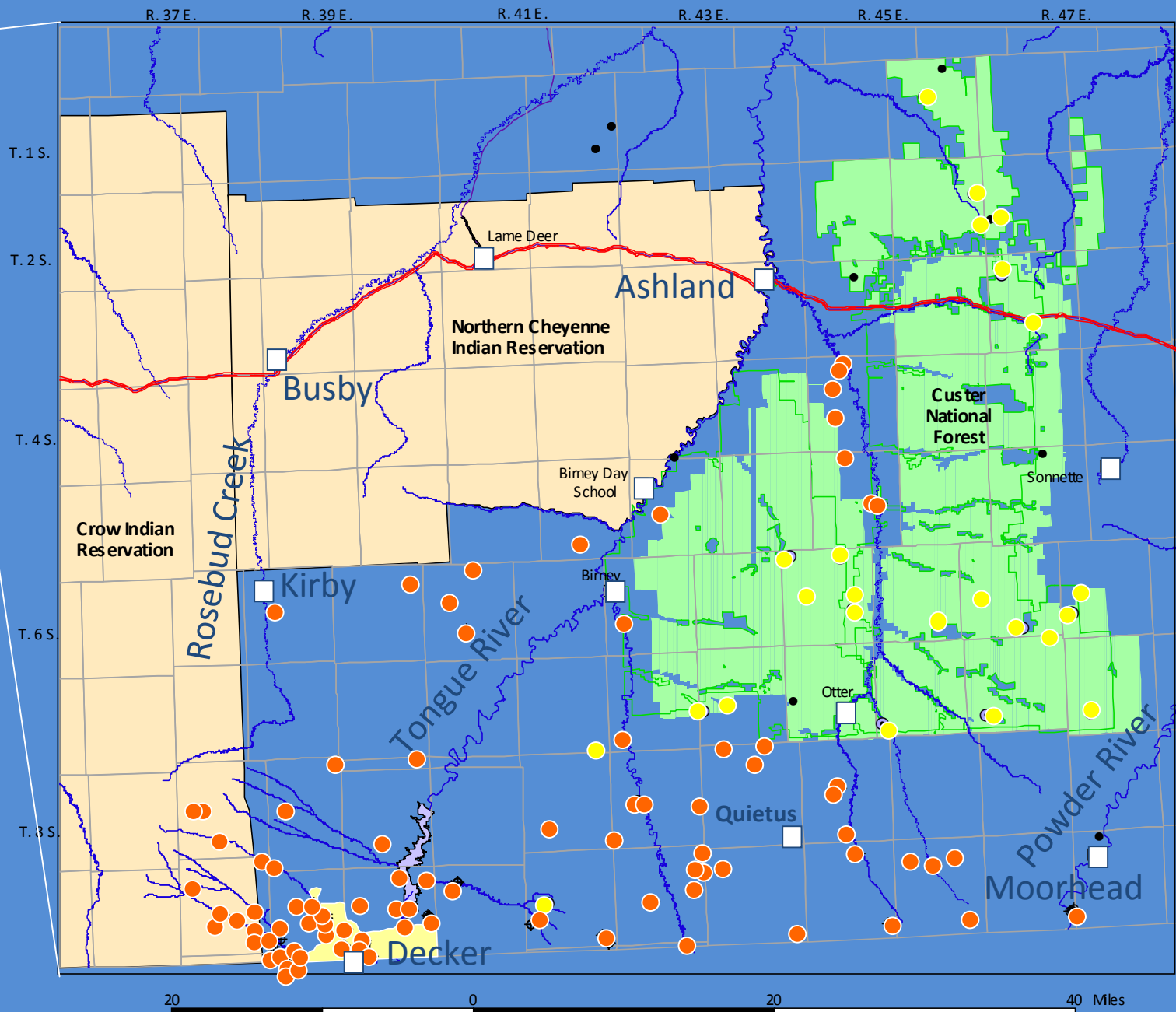
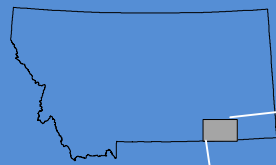
● Applied Hydrology & Greystone, 2002, 3D, 7 yrs

## Modeled Drawdown from CBM in the Powder River Basin



Wyodack, Coal Mine Analog, 15 yr  
Wheaton & Metesh, 2D, 5 yr  
Wheaton & Metesh, 3D, 20 yr  
Meyers, 3D, 15 yrs

Wyodack, 3D, 20 years  
Wheaton & Metesh, 3D, 10 yr  
Applied Hydrology & Greystone, 3D, 7 yrs



234 Wells  
15 Springs  
2 Streams

Monthly  
to Quarterly  
Gauging

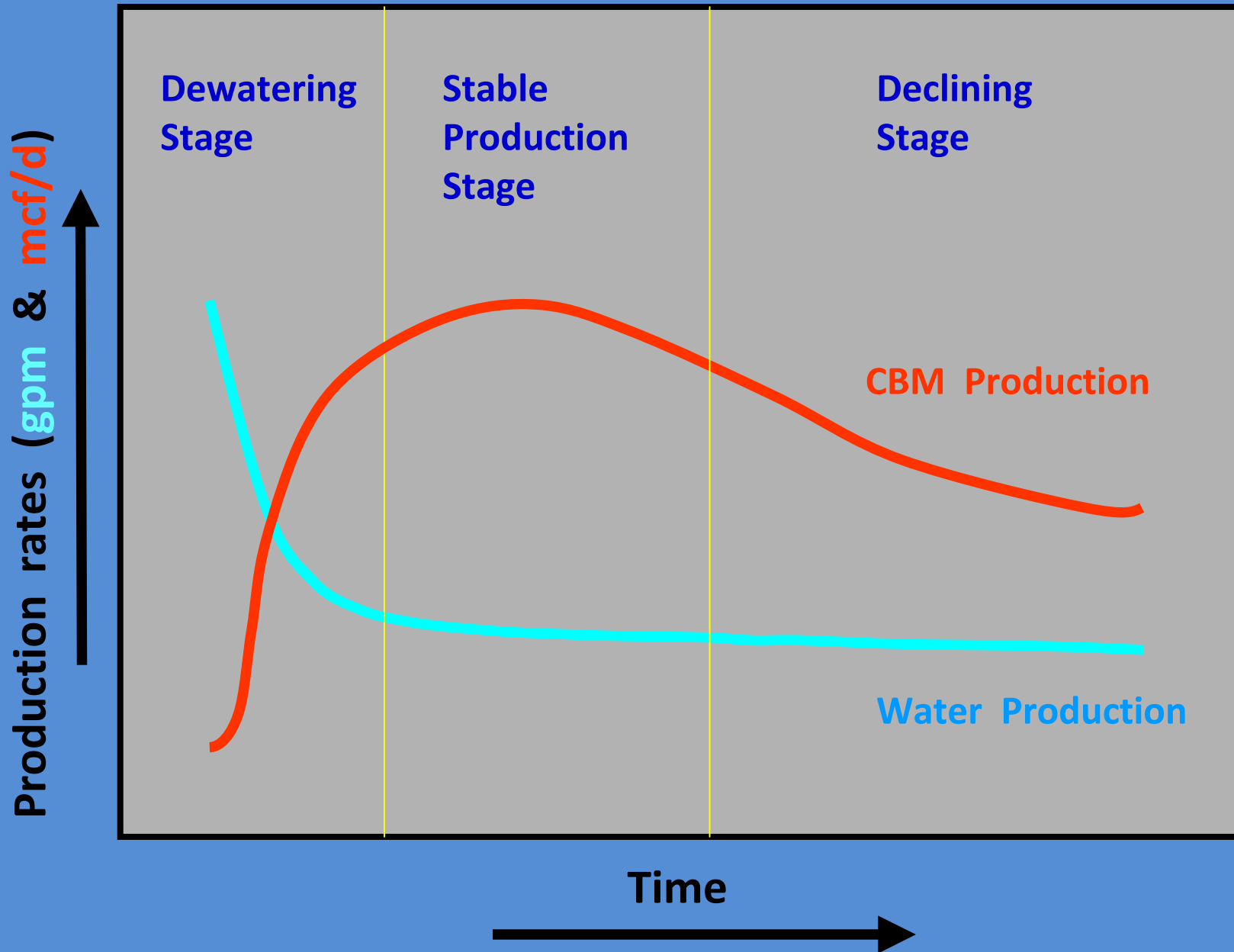
Monitor  
Sites

● Springs

● Wells

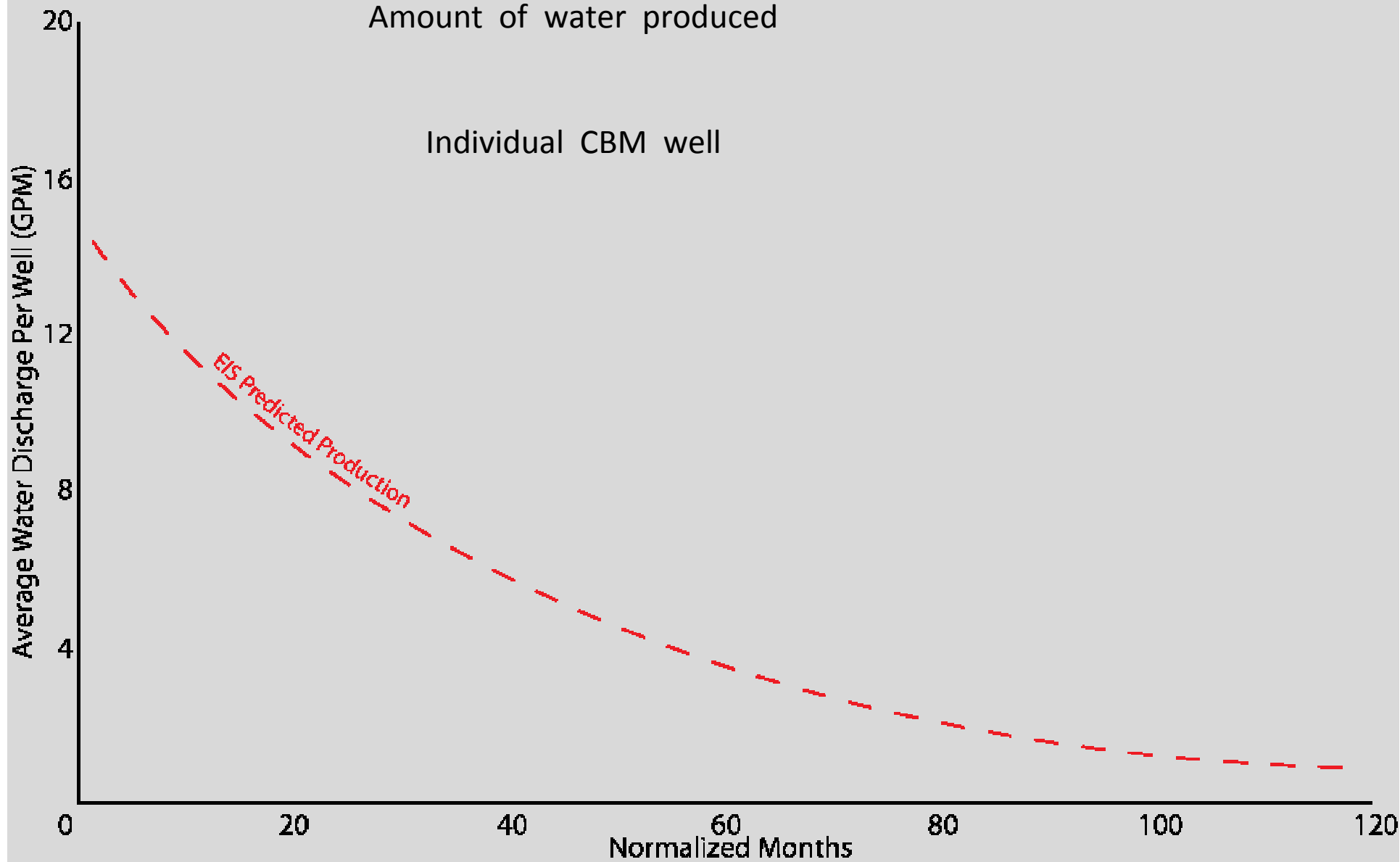
20 0 20 40 Miles

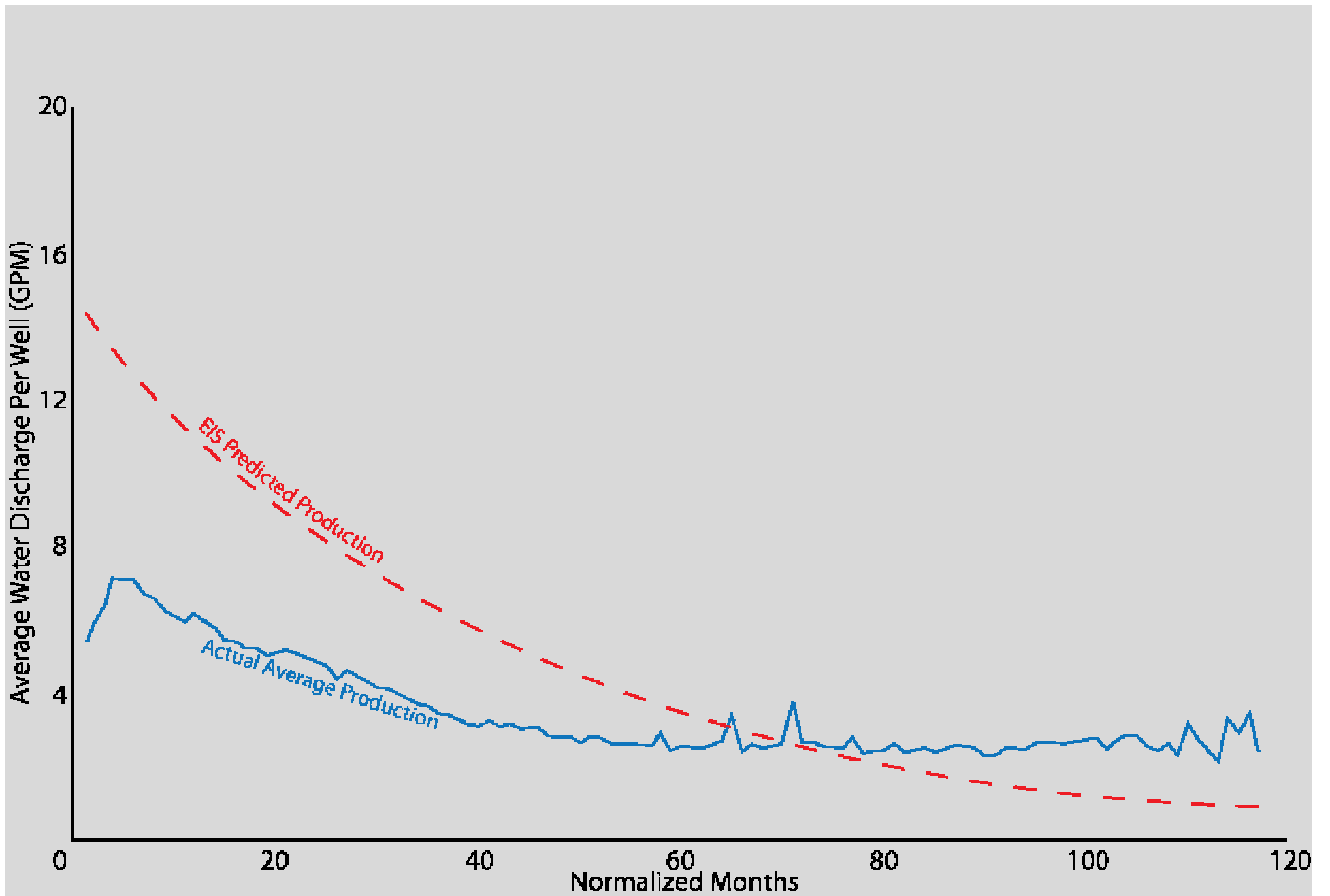
# Conceptual CBM Production Curves



Amount of water produced

Individual CBM well







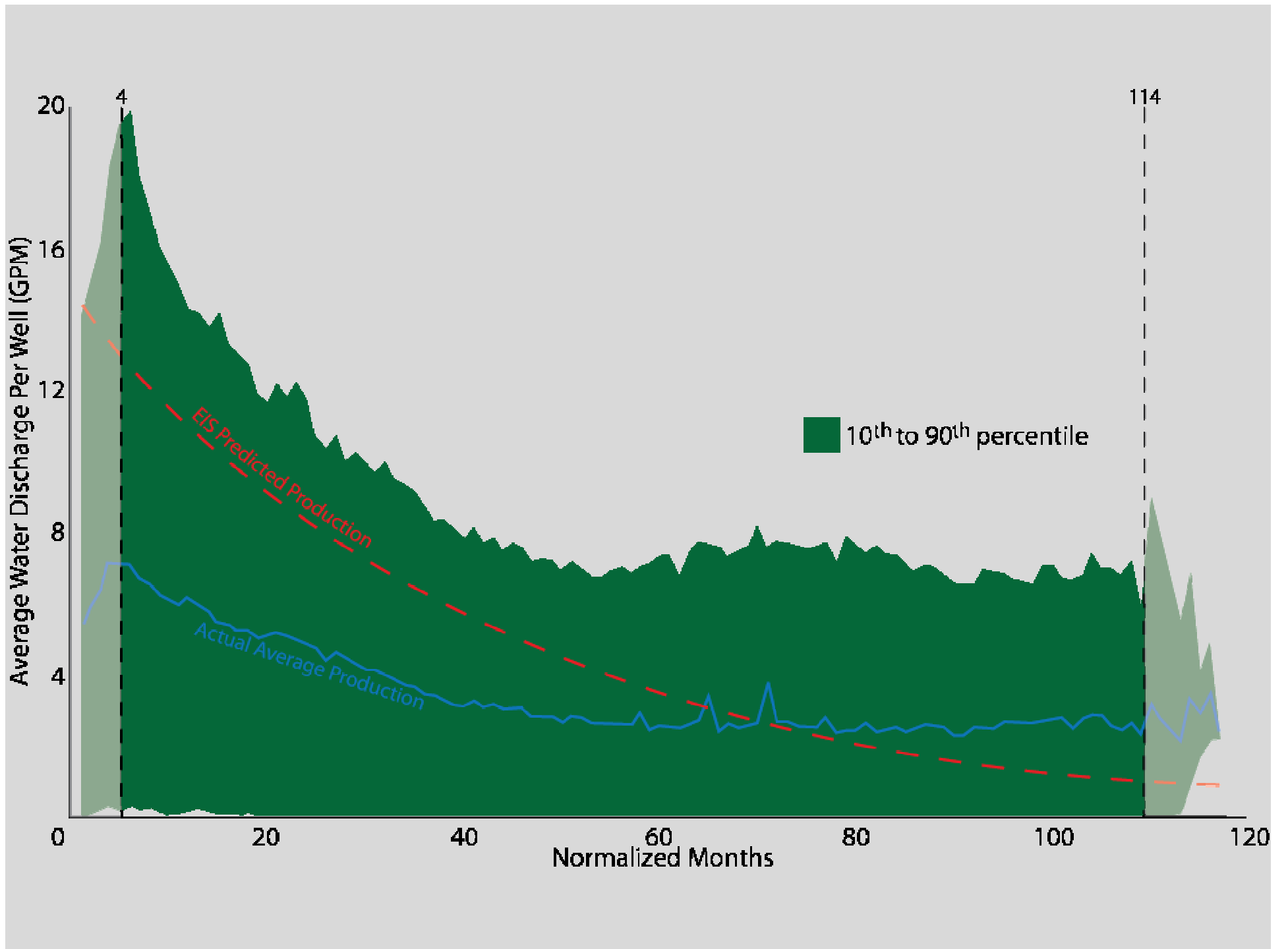


Table 2. Water quality summary for coalbed aquifers in the Montana portion of the Powder River Basin with coalbed methane potential.

	SC ( $\mu\text{mhos}/\text{cm}^2$ )	pH	TDS (mg/L)	SAR	Sulfate (mg/L)
Median	2,073	8.10	1,311	46	3
Standard Deviation	565	0.36	366	13	21
Minimum	1,082	7.56	666	4	0
Maximum	3,123	9.36	2,020	103	78

Count is 60; sample dates span June 1972 to August 2007.

SC refers to Specific Conductance, TDS refers to Total Dissolved Solids, and SAR refers to Sodium Adsorption Ratio.

# “Precipitation Index” Effects

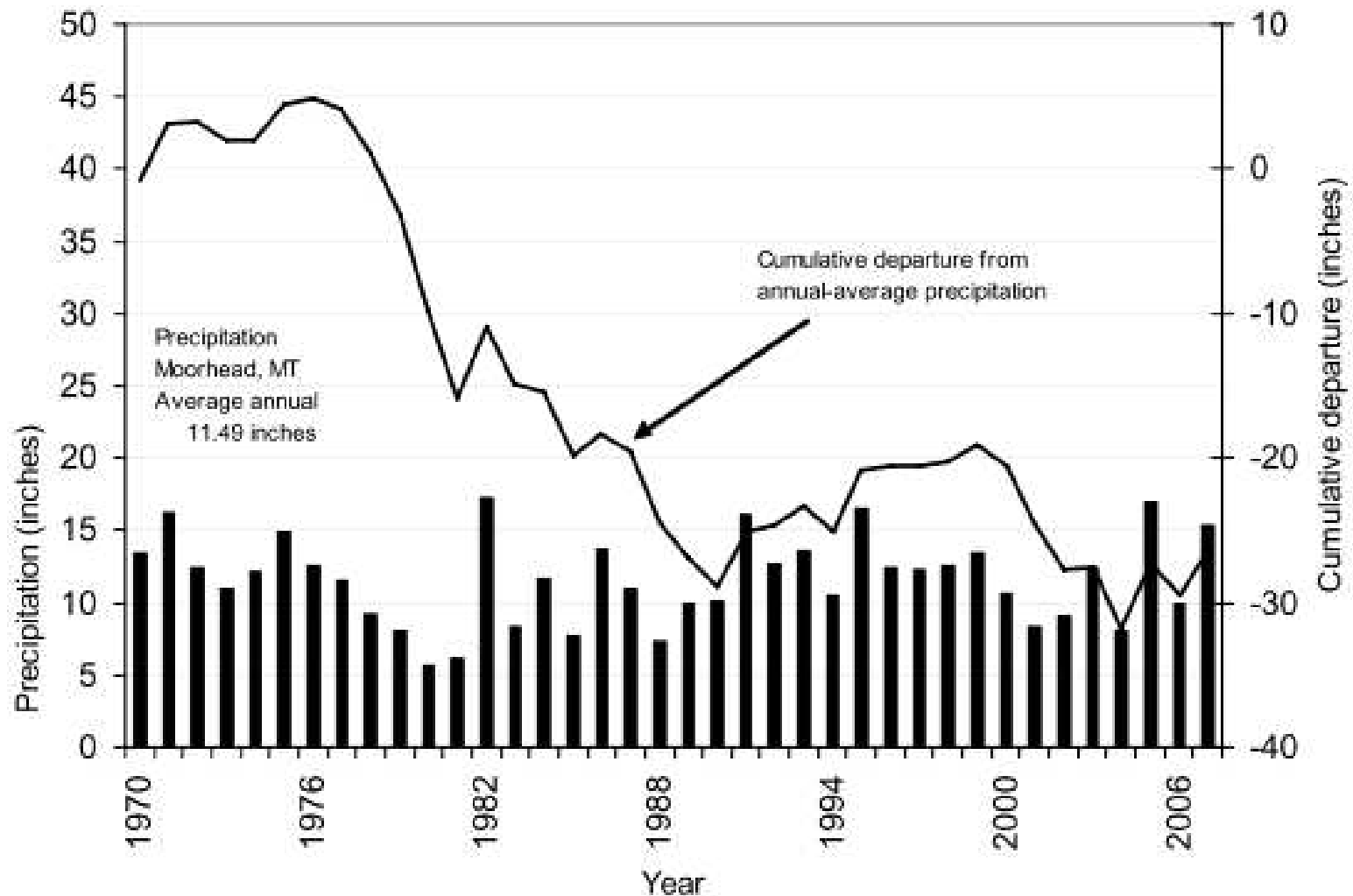
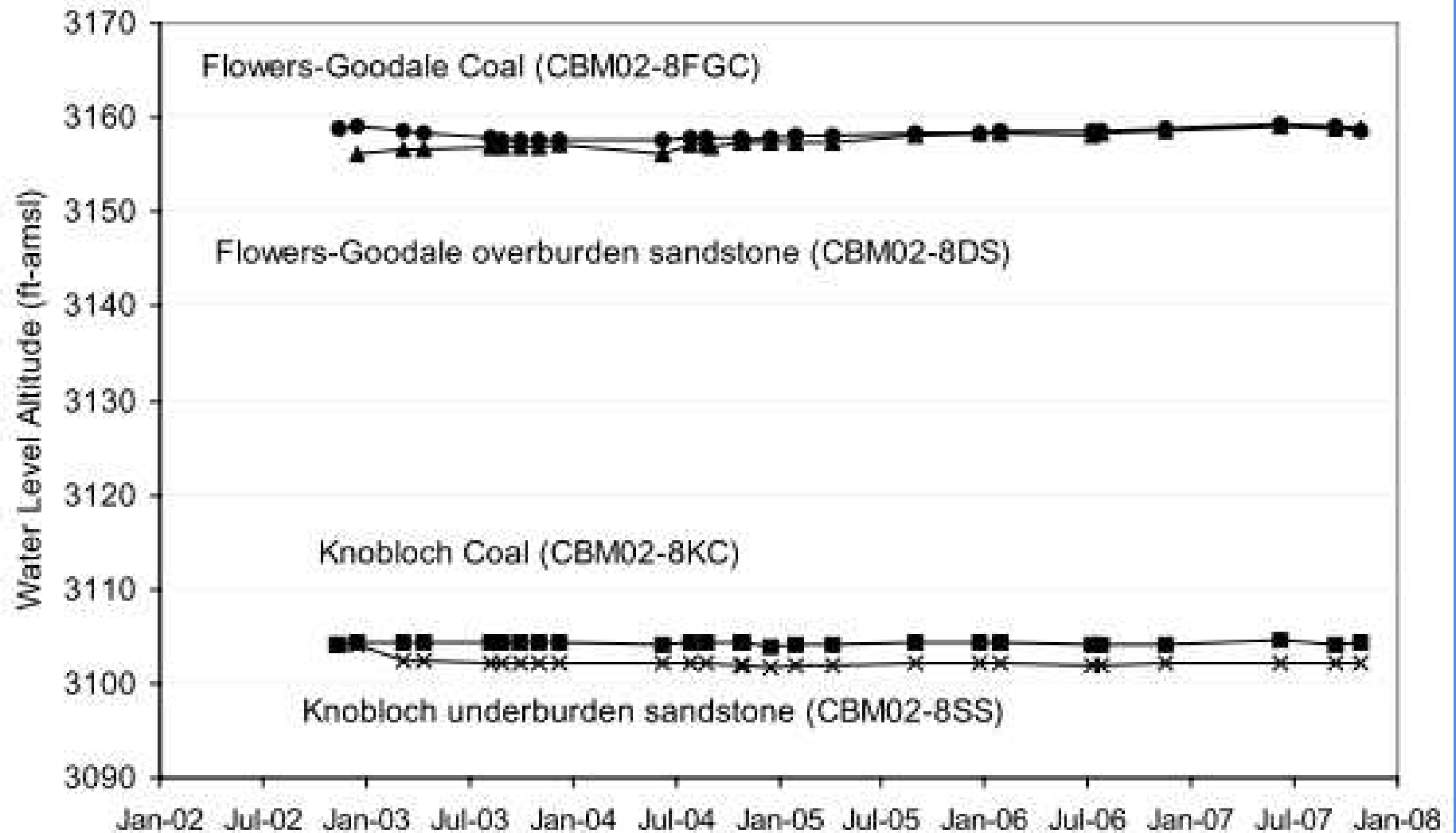
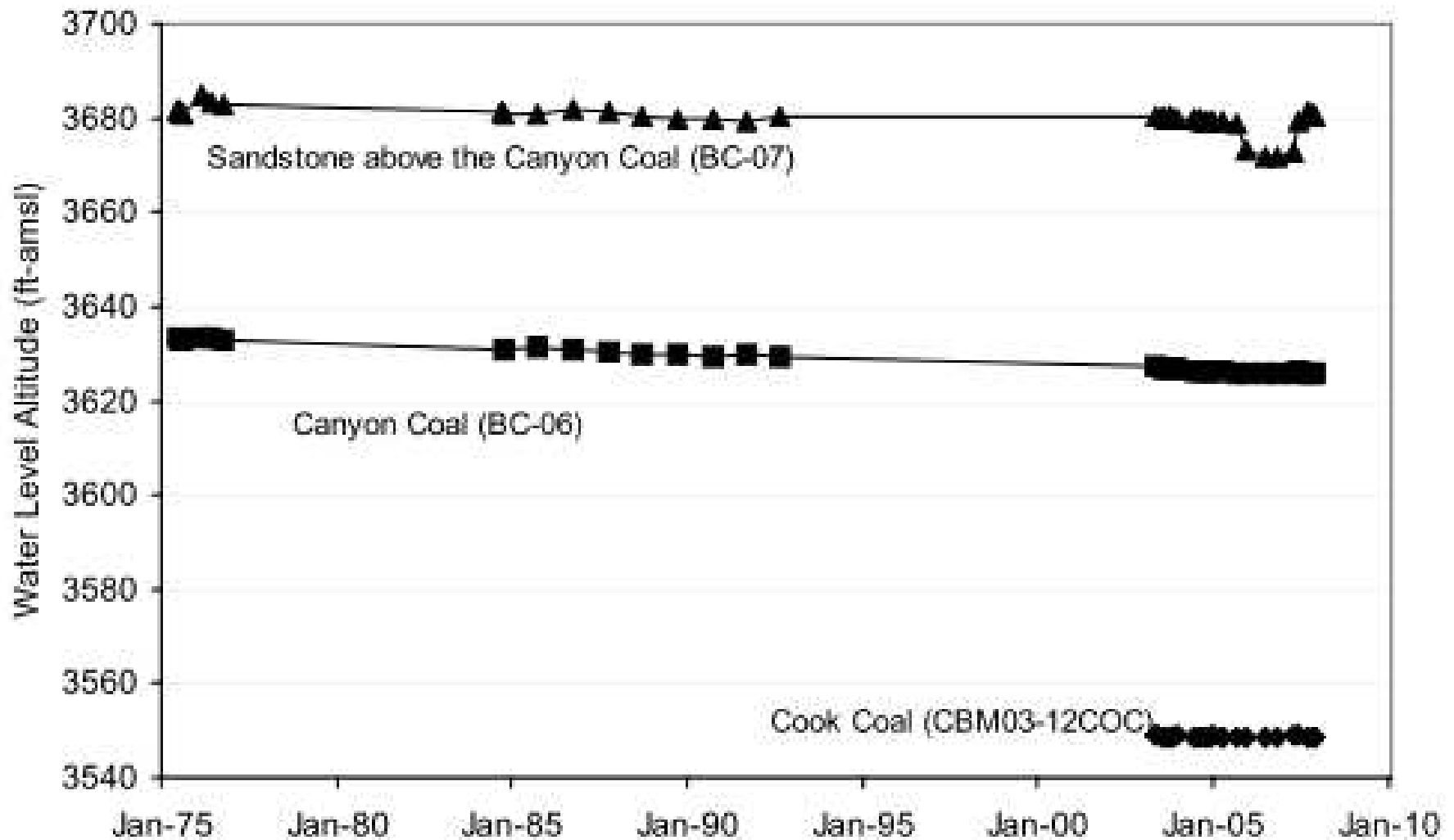


Figure 3. Annual precipitation (bar graph) at Moorhead MT. Cumulative departure from average precipitation provides a perspective on the long-term moisture trends that may effect ground-water recharge.

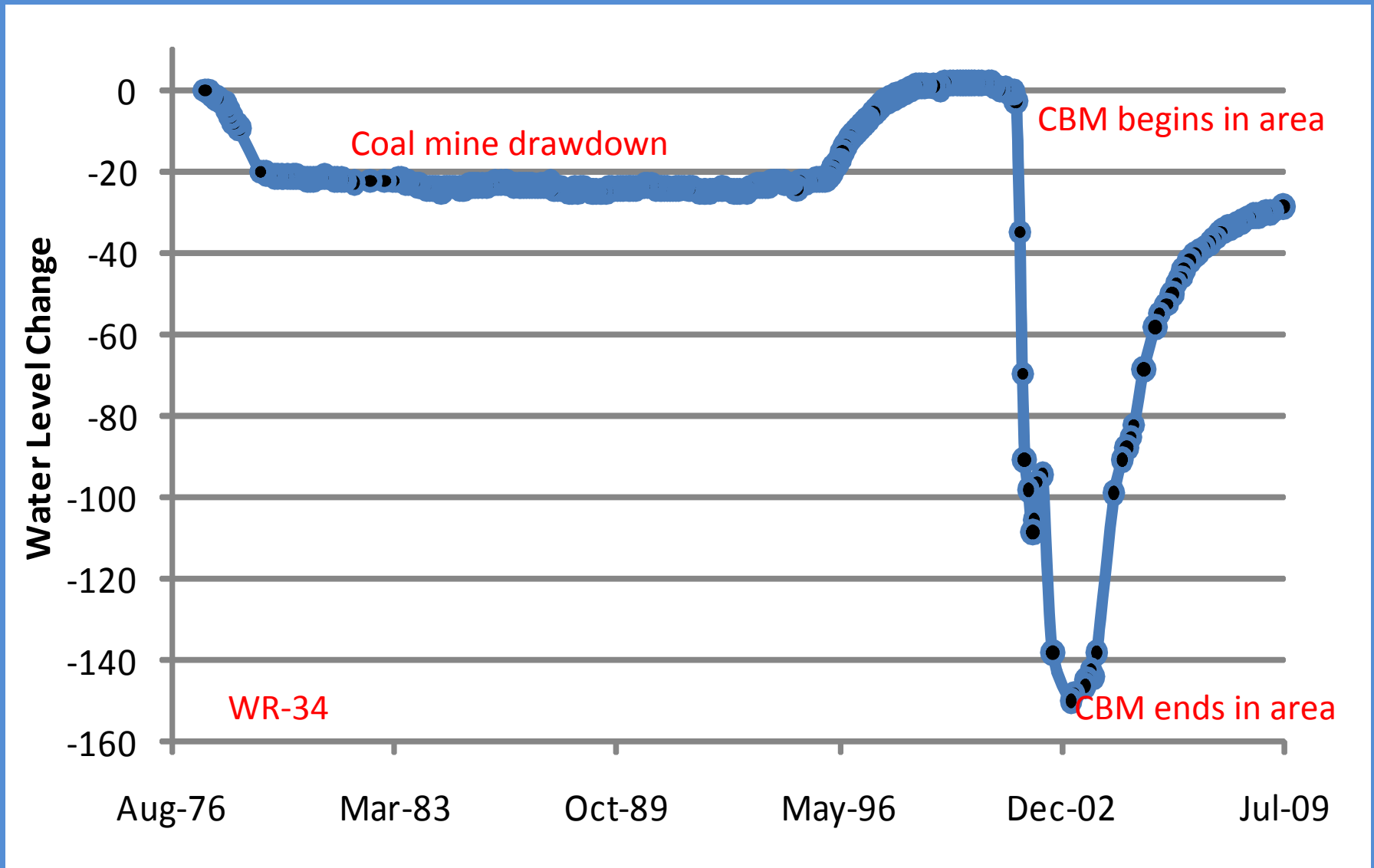
# Water Levels near Zook Creek WSA ~3 miles North of Birney (~15 Miles From the nearest CBM development)

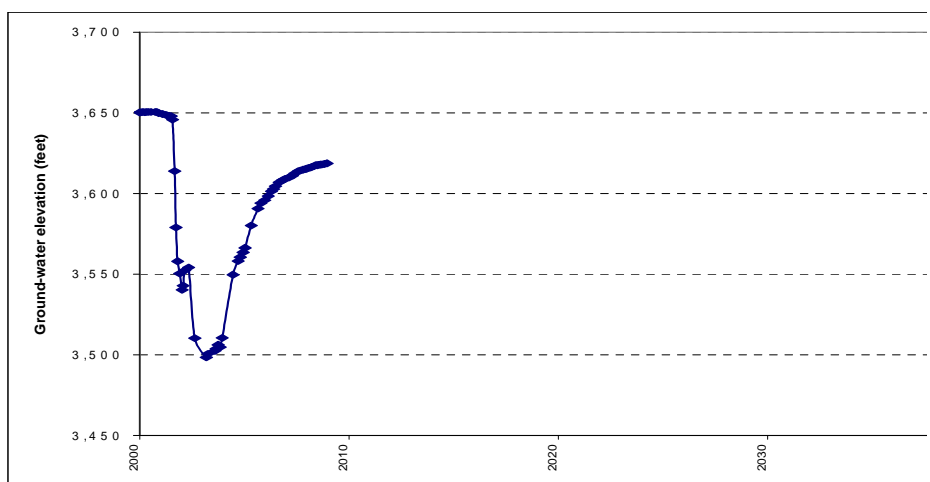
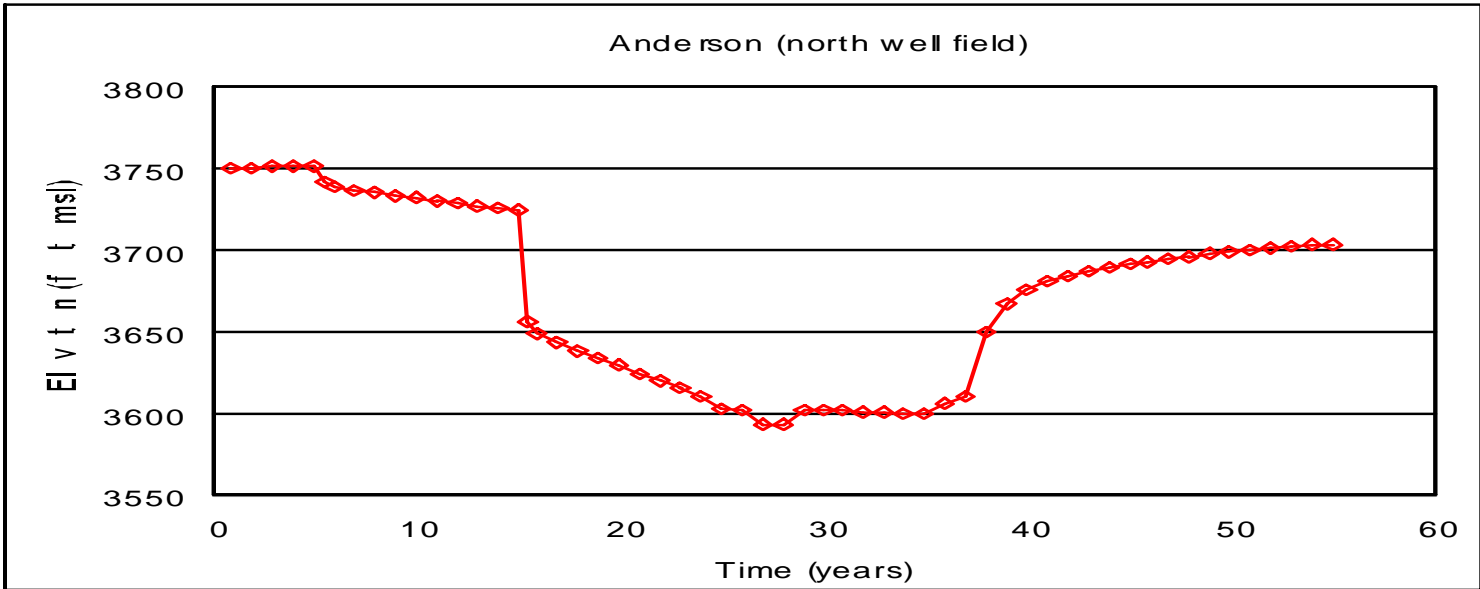


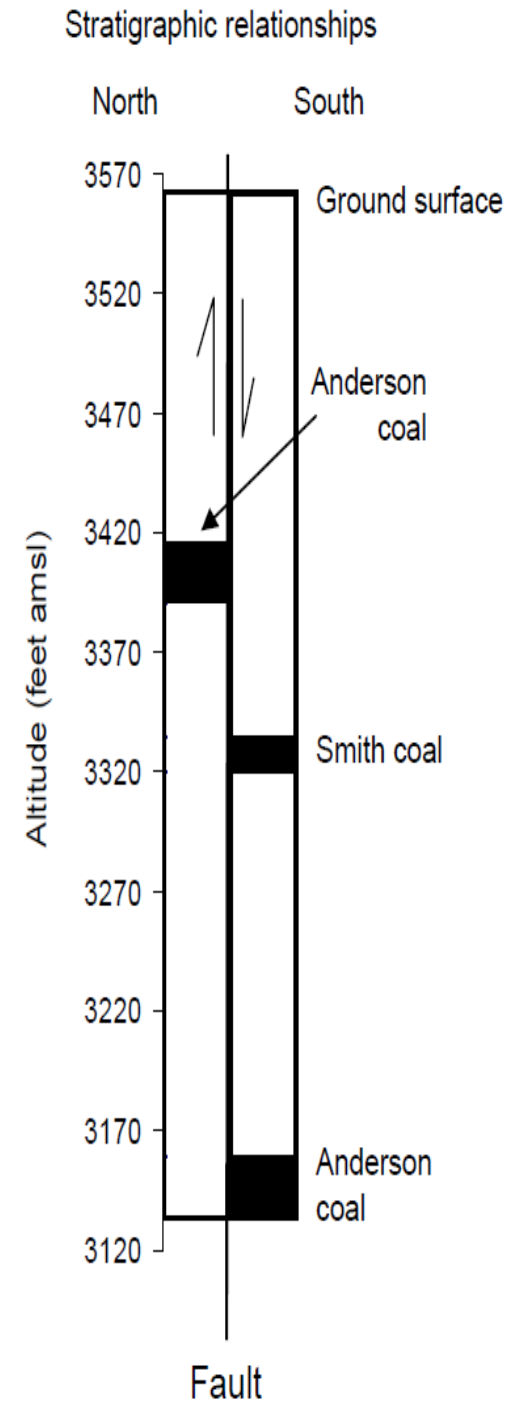
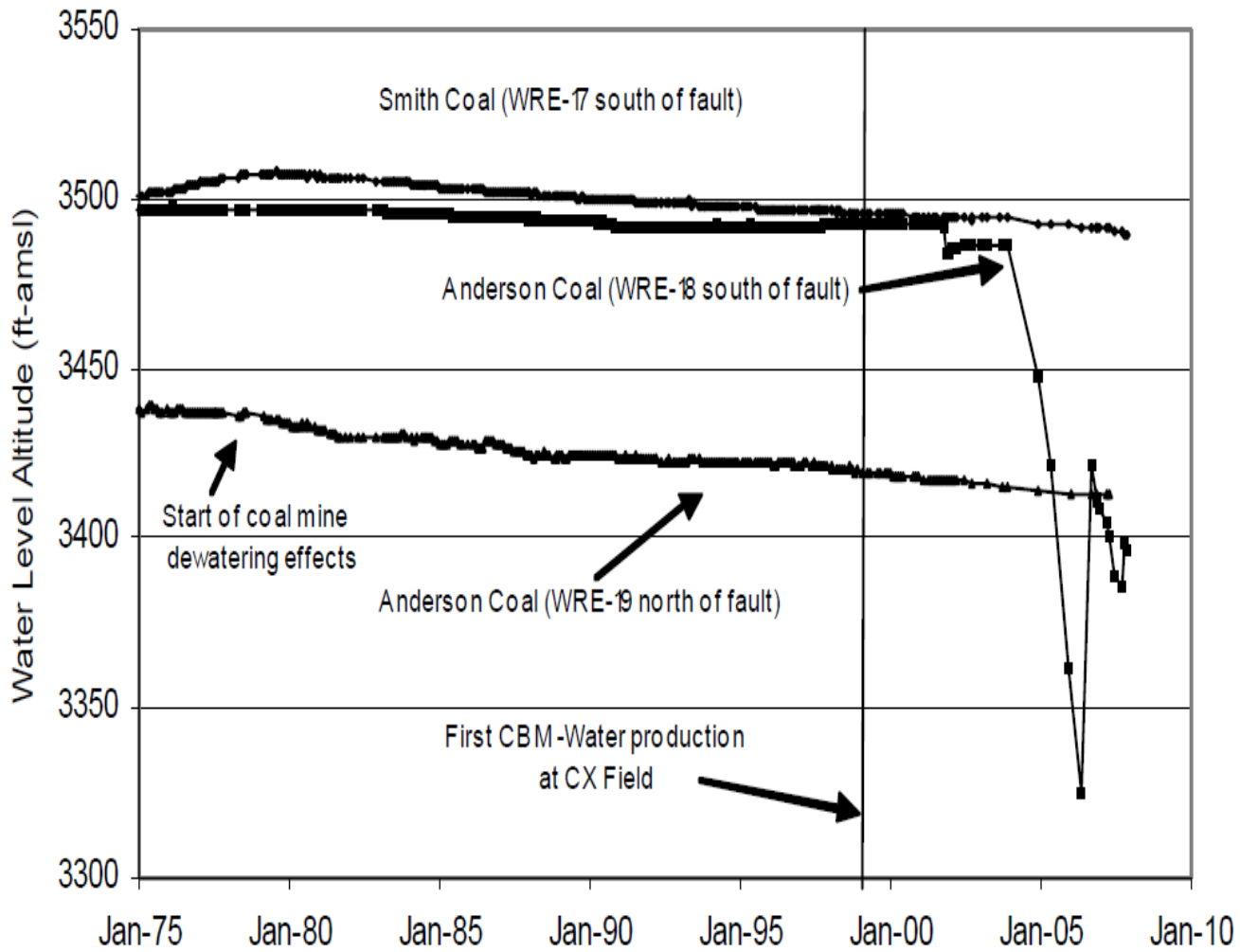
# Long Term Water Levels on Bear Creek ~5 miles South of Otter (~10 Miles From the nearest CBM development)



# Mining & CBM Impacts : Anderson – Dietz Coal Near State Line on the Western Side of the CX Field

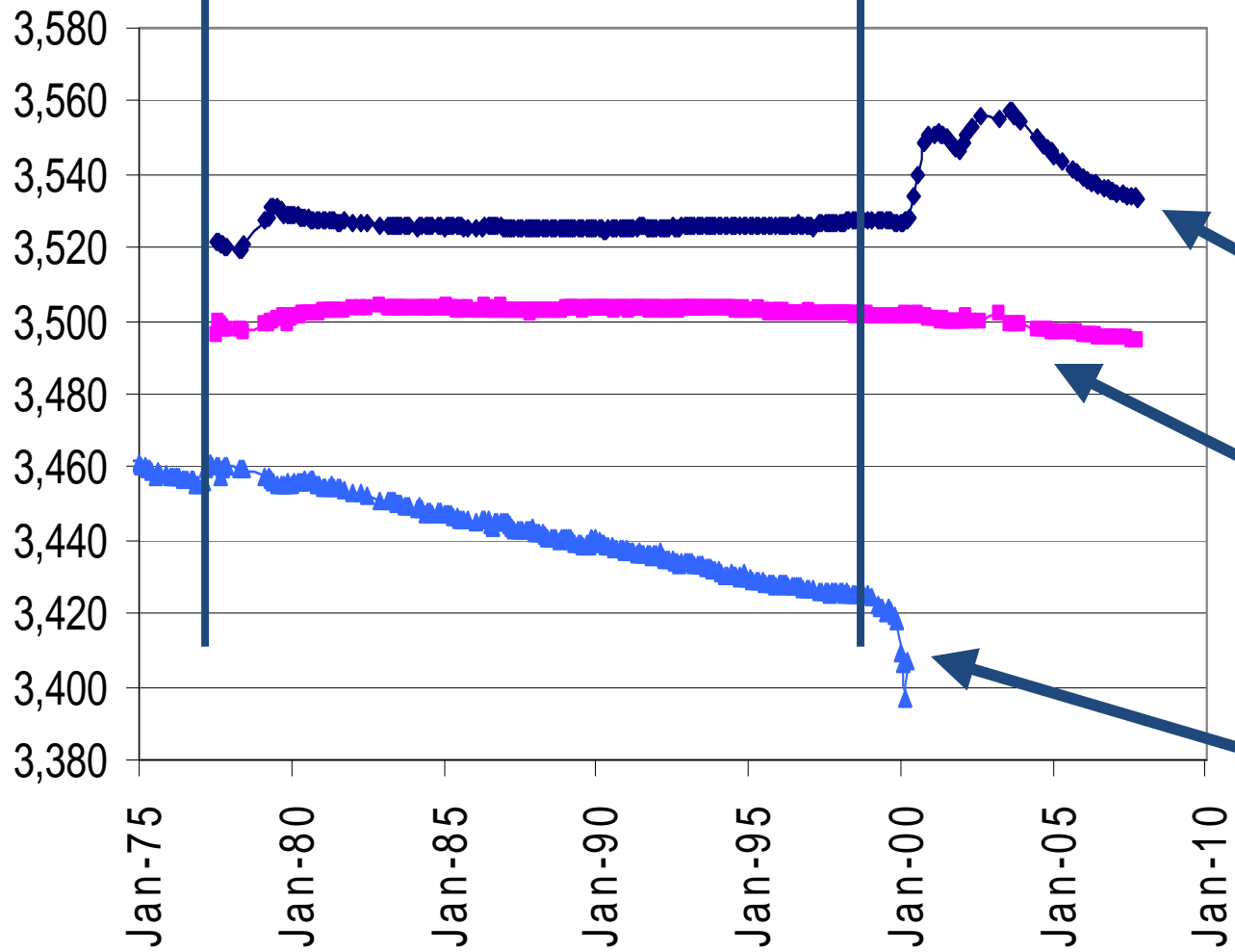




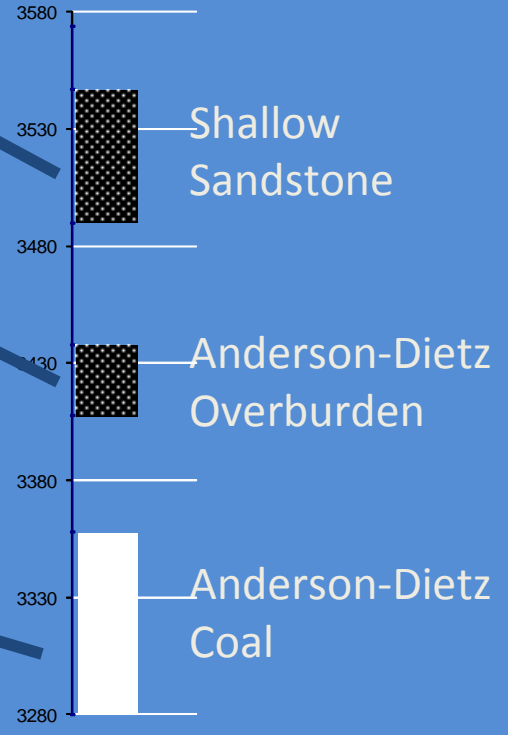


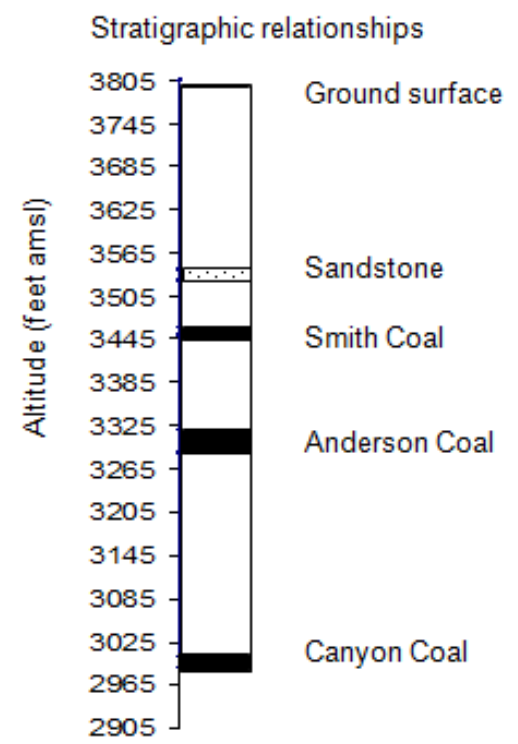
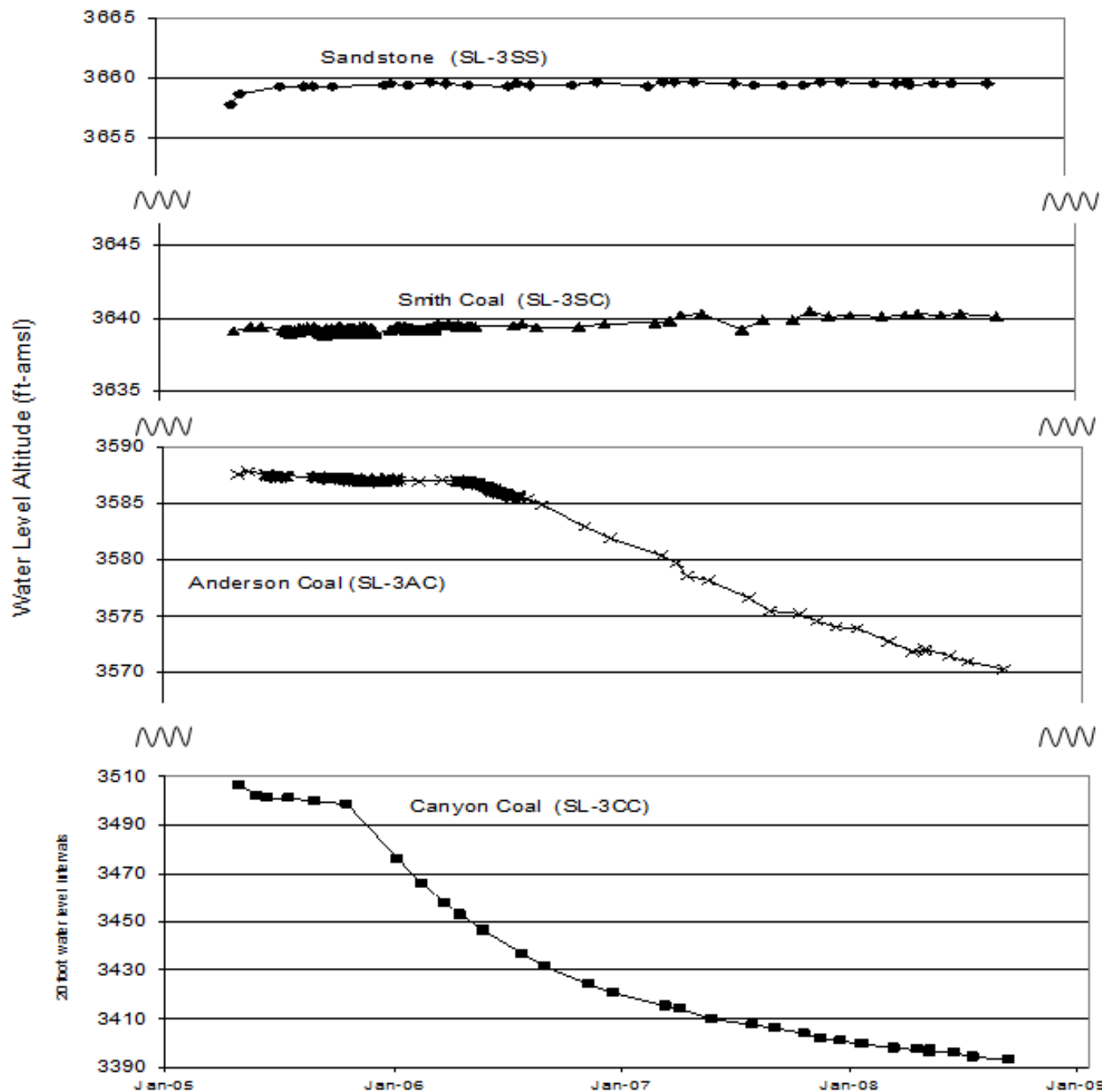


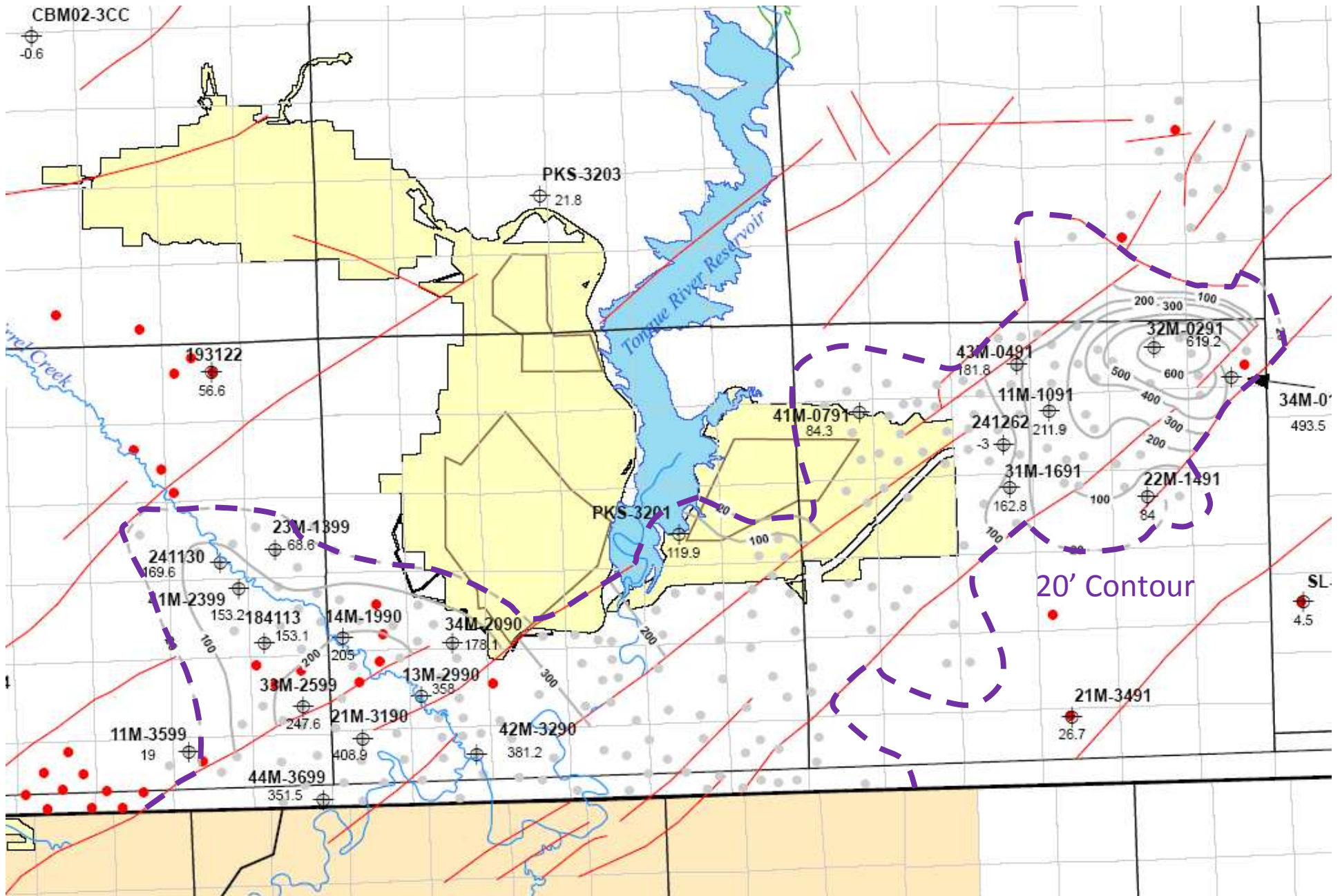
# Ground – Water Drawdown and Recharge Coal mine Mining + CBM + Pond



## Stratigraphy





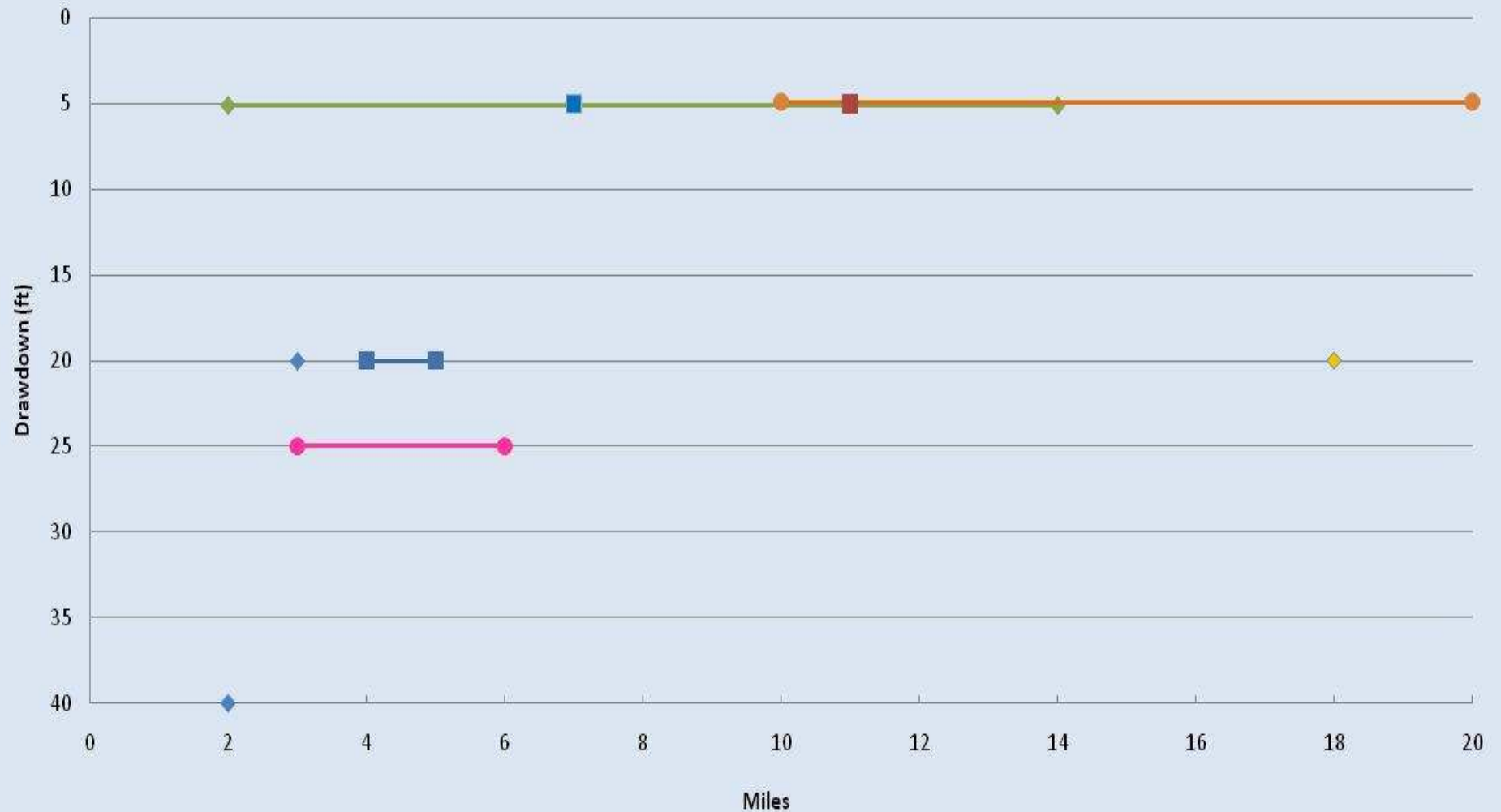


Dedicated Monitoring Wells & 48 hr Shut-in tests on CBM Wells  
 Canyon (Monarch) Coal

# Monitoring Results

- After 10 years of CBM production at the CX Field the 20' drawdown contour extends up to 1.5 miles from the field.
- Recovery has been rapid in areas where CBM wells have been shut-in, with 73-82% recovery over 5-7 years.
- Coals appear to function as confined aquifers, with little, if any, measurable drawdown in adjacent aquifers.
- Major faults function as flow boundaries.
  - Calculations show that faults with throw not more than 10' thicker than the coal may not be barriers.

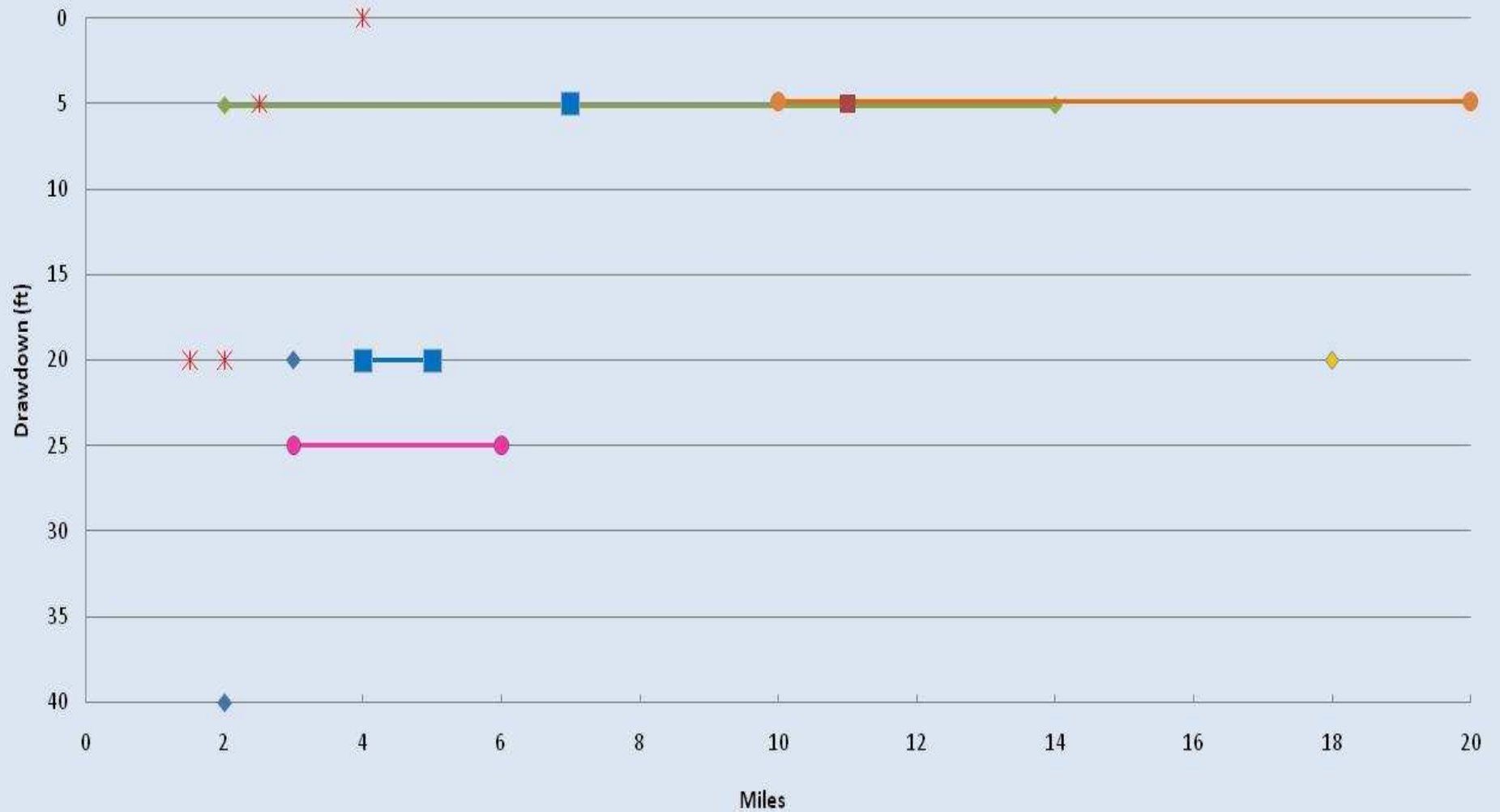
## Modeled and Observed Drawdown from CBM in the Powder River Basin



Wyodack, Coal Mine Analog, 15 yr  
Wheaton & Metesh, 2D, 5 yr  
Wheaton & Metesh, 3D, 20 yr  
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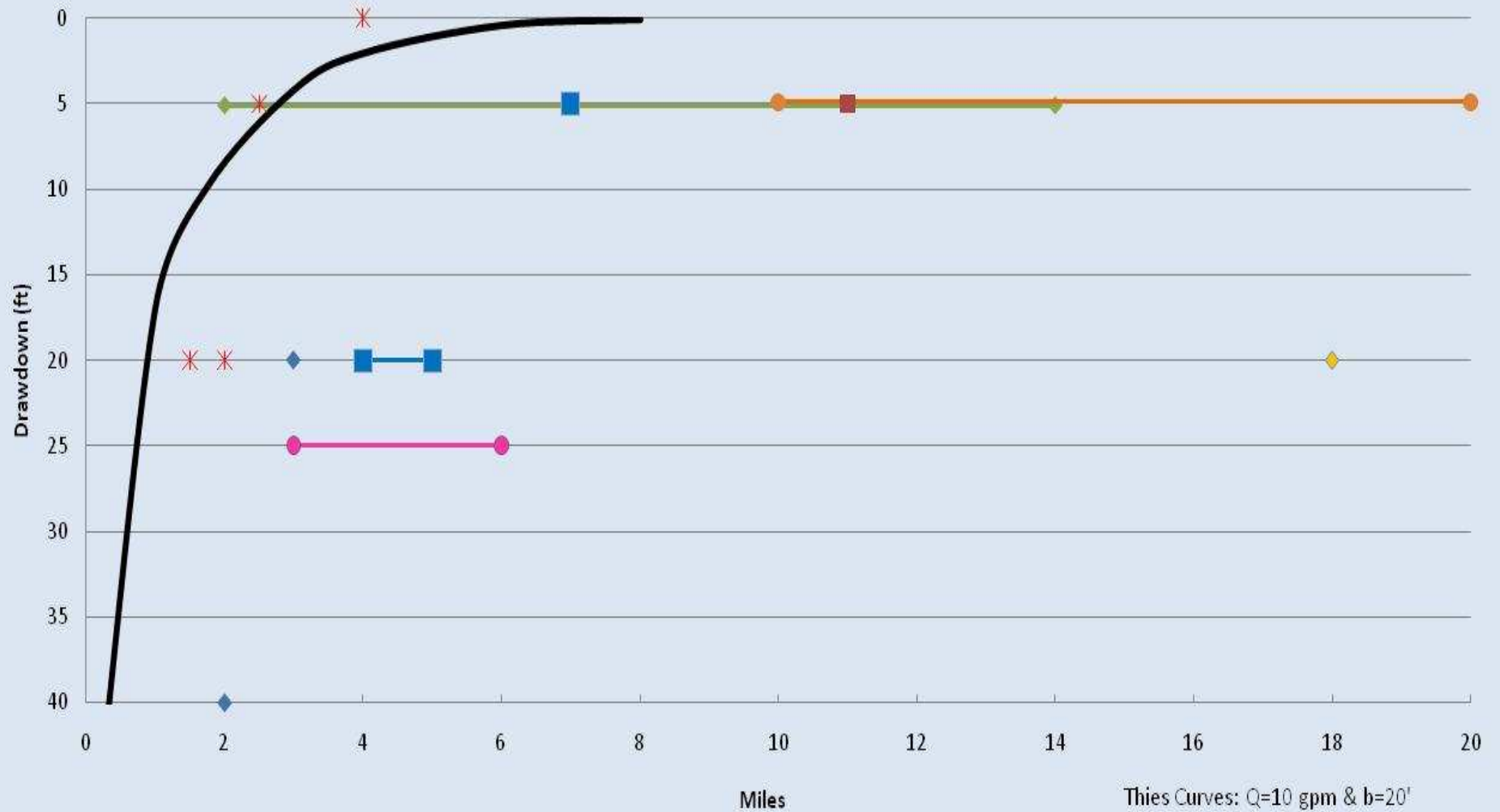
- |  |                                     |  |
|--|-------------------------------------|--|
| ◆ Wyodack, 1999, Coal Mine Analog, 15 yr | ● Wyodack, 1999, 3D, 20 years       | ■ Wheaton & Metesh, 2001, 2D, 5 yr               |
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| ◆ Meyers, 2009, 3D, 15 yrs               | * Observed, 10 years                |  |

Location (number of tests) *	Hydraulic conductivity (ft/day)			Storativity (unconfined) Mean	or	Storativity (confined) Mean
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<b>Alluvium</b>						
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\* PRB refers to tests within the entire Powder River Basin, Montana.  
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From Wheaton and Metesh, 2002

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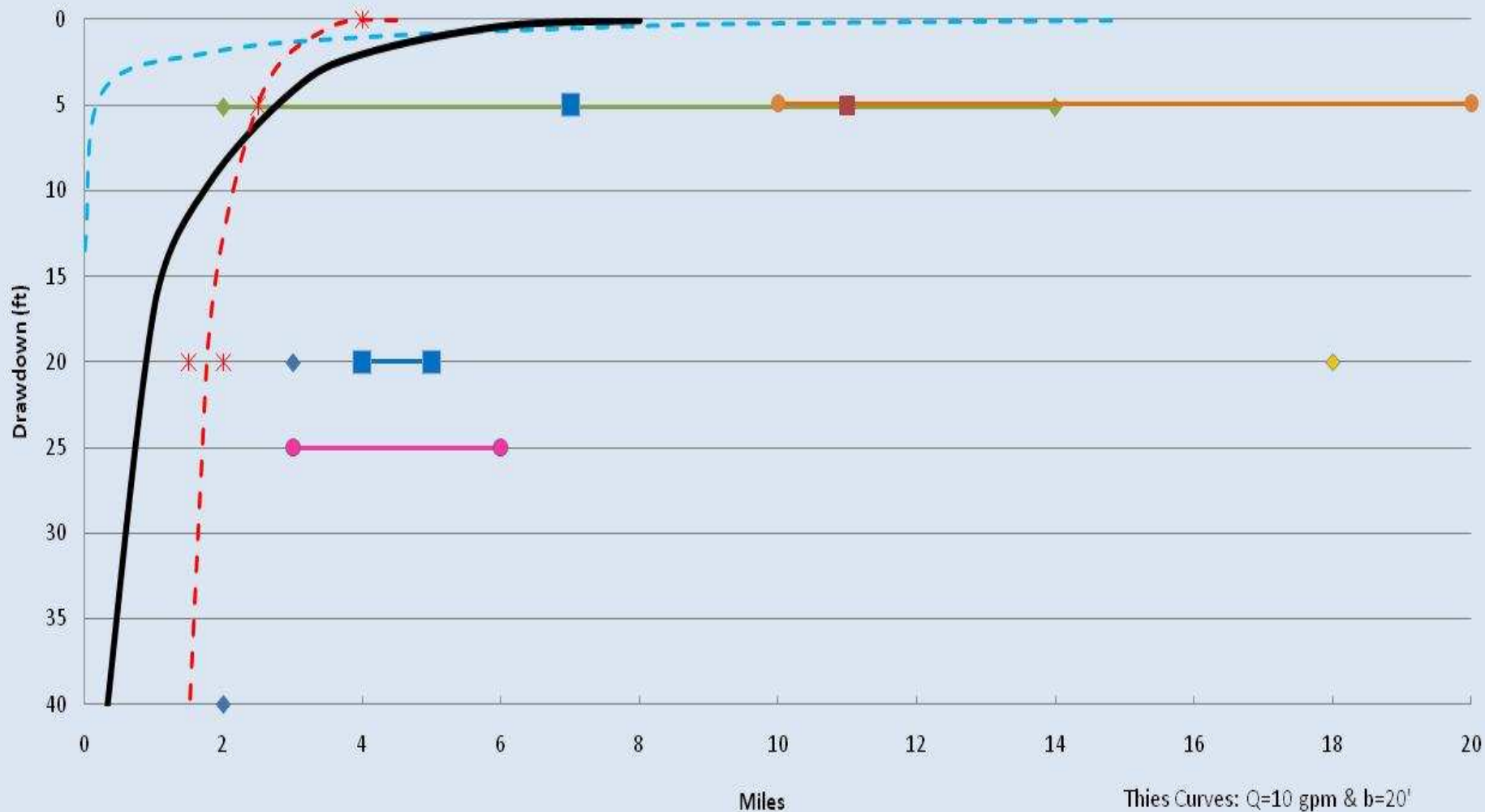
◆ Meyers, 2009, 3D, 15 yrs

\* Observed, 10 years

— Thies: GeoMean K, Mean S, 10 yrs



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— Thies: GeoMean K, Mean S, 10 yrs

○ Wyodack, 1999, 3D, 20 years

■ Wheaton & Metesh, 2002, 3D, 20 yr

\* Observed, 10 years

- - - Thies Low K, Low S, 10 yrs

■ Wheaton & Metesh, 2001, 2D, 5 yr

● Applied Hydrology & Greystone, 2002, 3D, 7 yrs

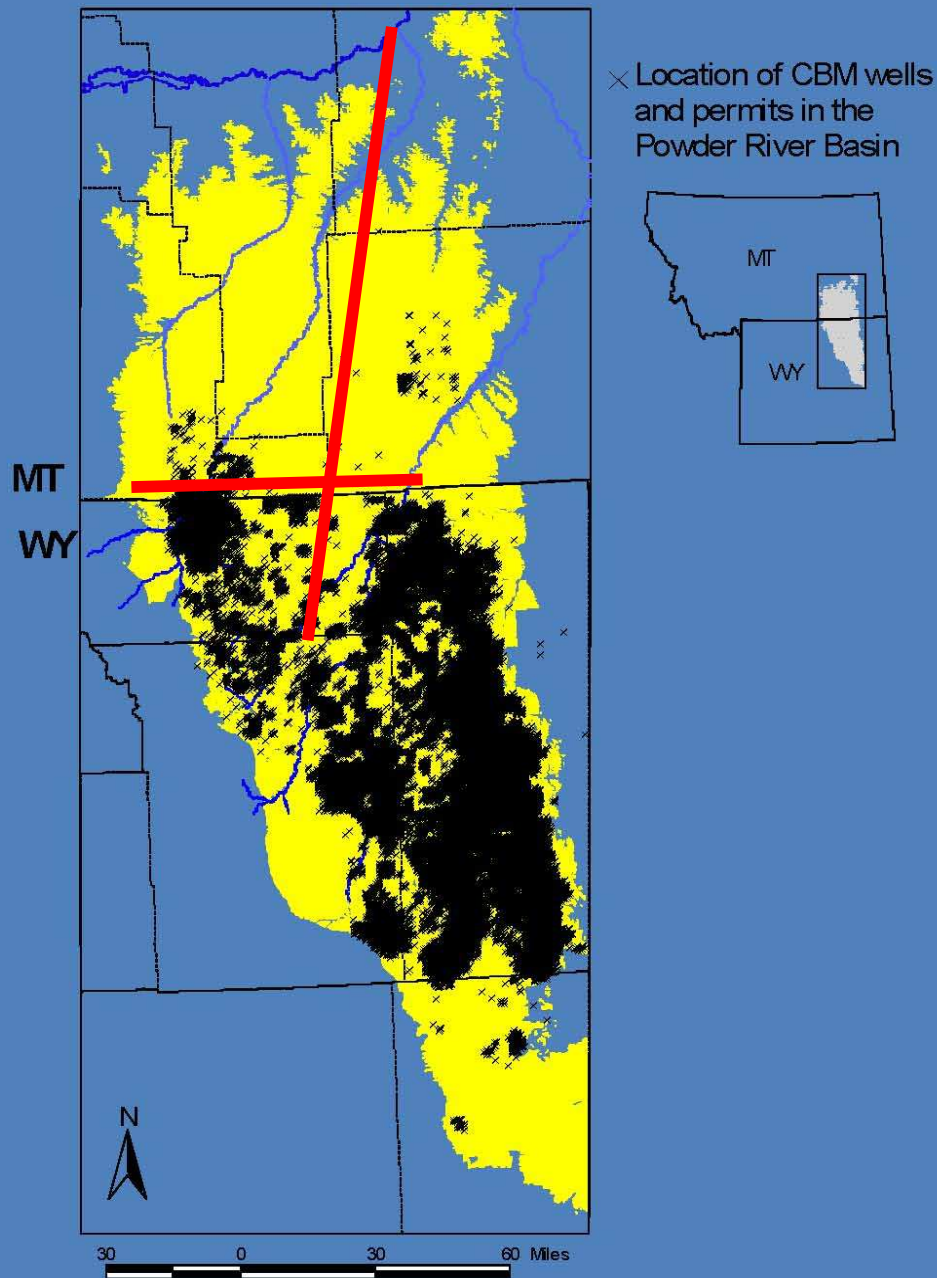
- - - Thies: High K, High S; 10 yrs

# Conclusions

- Given uncertainties with regard to well numbers, well locations, timing of well installations, and aquifer properties, it is not surprising that a wide range of impacts has been forecasted.
- Monitoring results show the actual extent of impacts.
- Lesson for the Future: When there is a high degree of uncertainty, it may be best to focus on conceptual models, and limited analytical modeling.
  - The time, effort and cost of numerical modeling is not justified if the uncertainty associated with the result is not substantially lower.



Questions?



As of 2008

Wells or permits in PRB

Montana: 1,686  
Producing: 827

Wyoming: 26,369  
Producing: 17,876

Powder River Basin, Montana  
Cross Section South to North

South

North

Wasatch  
Fm

Wyoming

Montana

Tongue River  
Member

Lebo Member

Yellowstone  
River

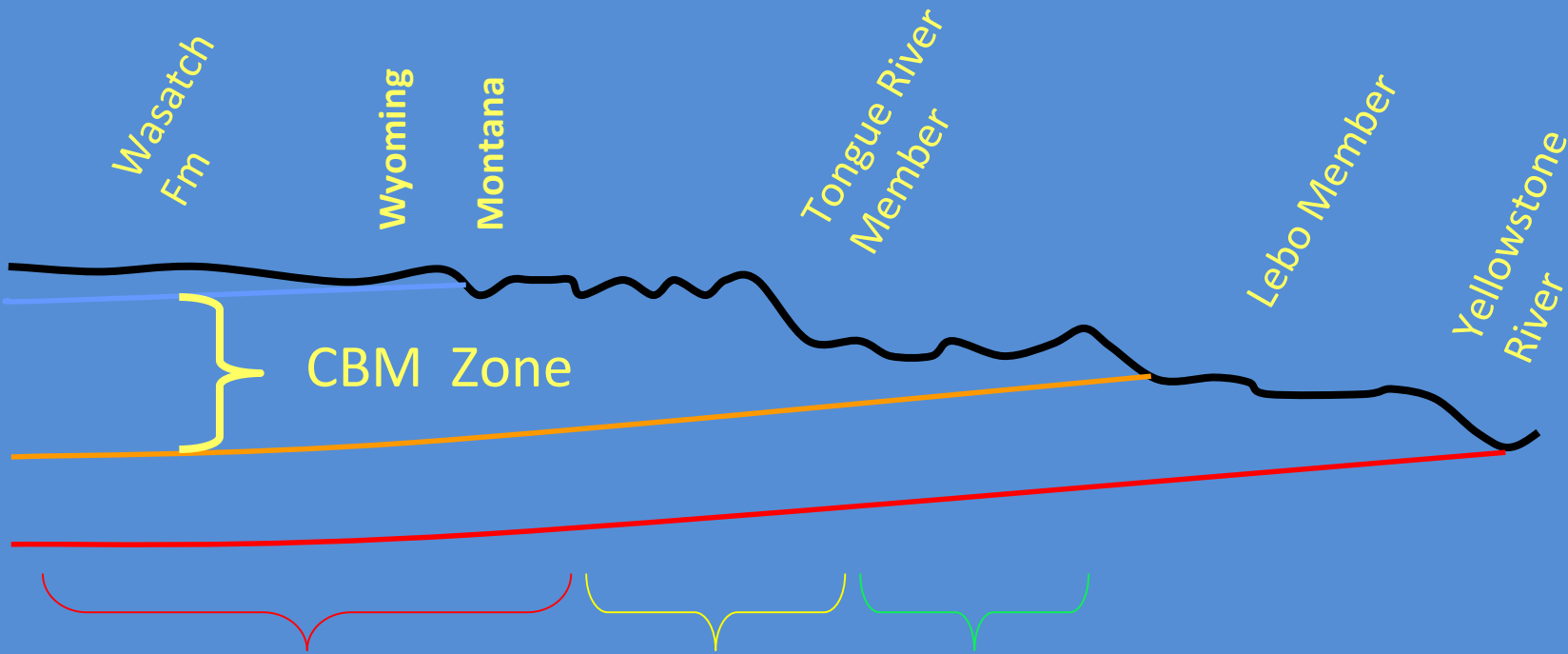
CBM Zone

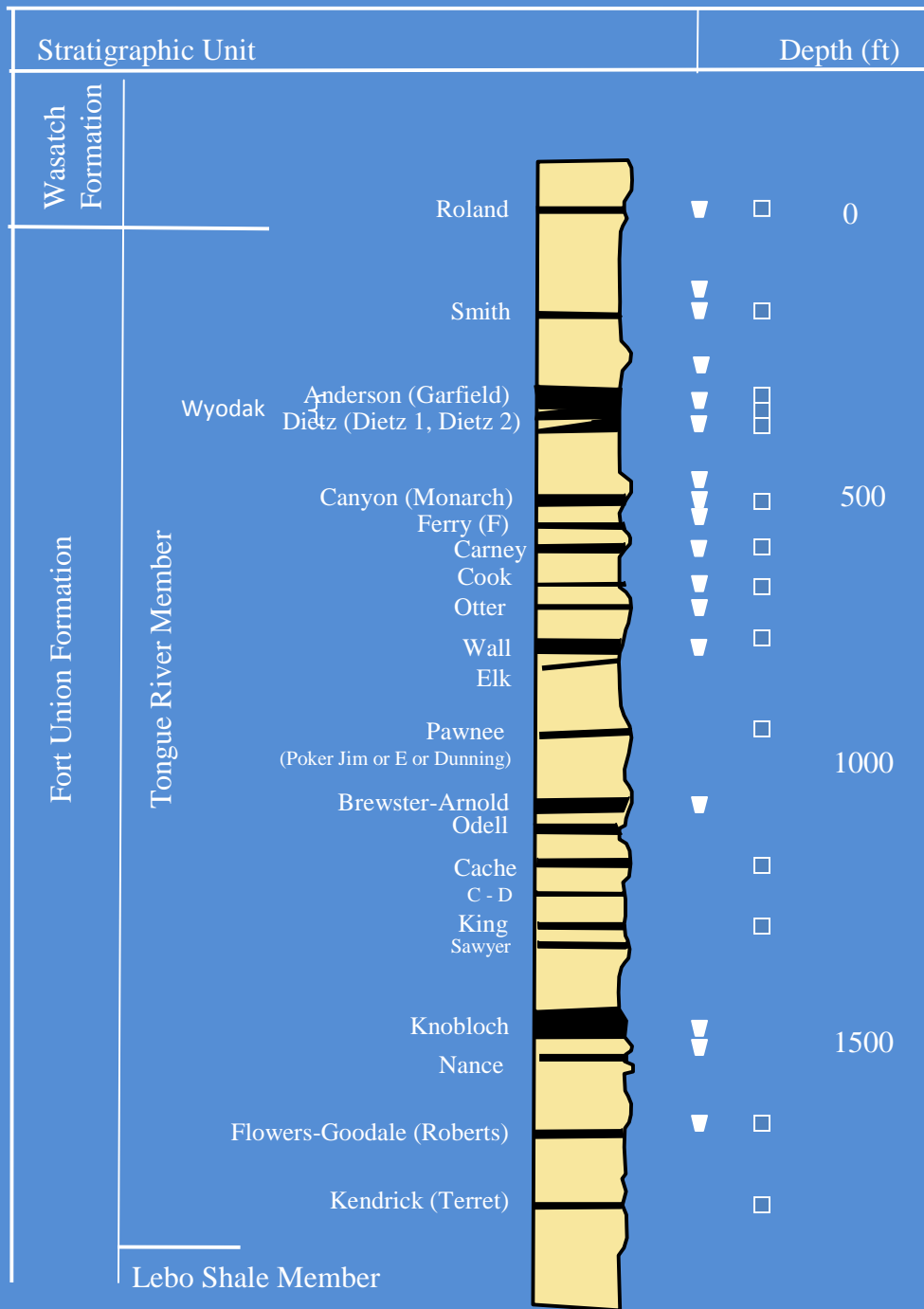
High

Moderate

Low

Potential for CBM Development

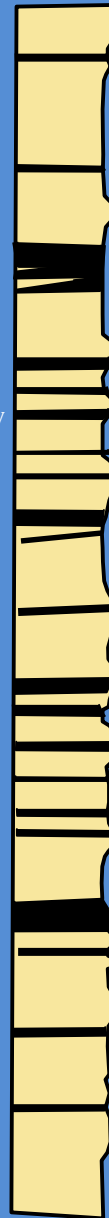




Monitored aquifers

Monitored zones: ▼

Montana/Wyoming CBM producing zones: □

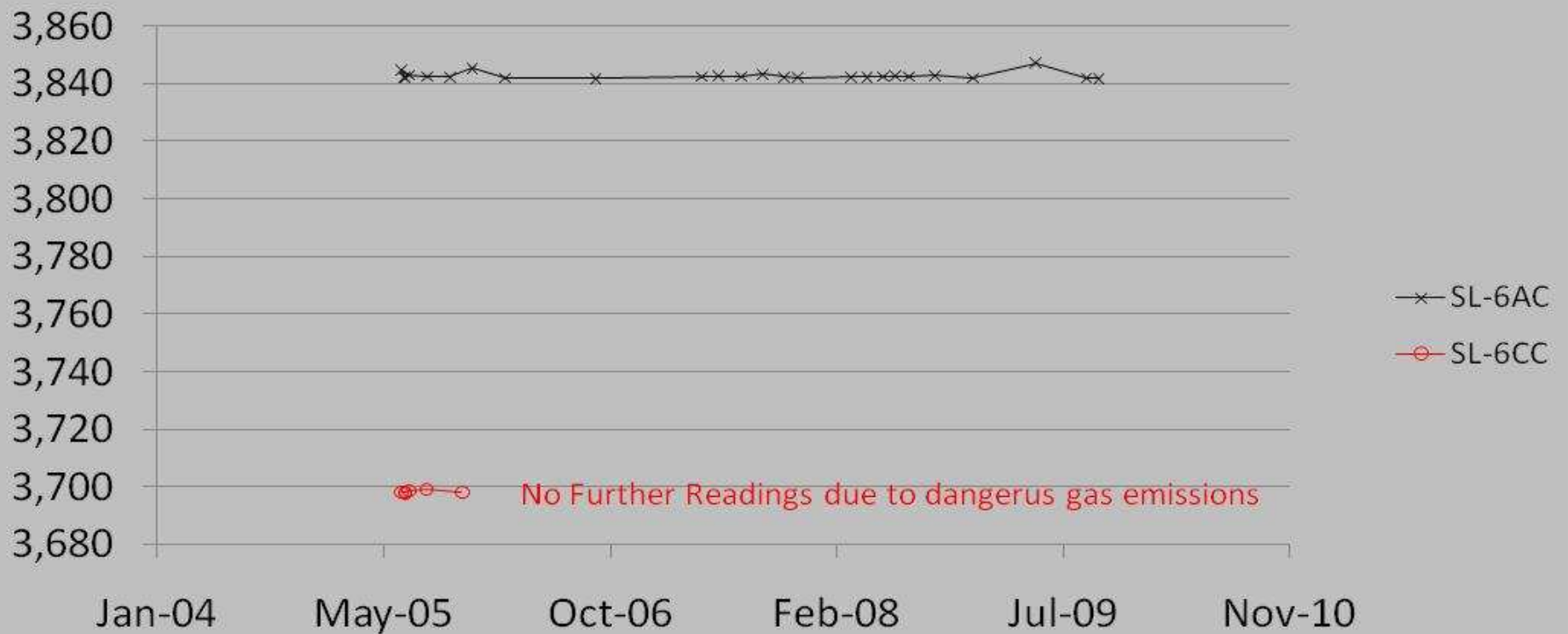


# CBM Regional Ground Water Monitoring Network

## Use of results and data:

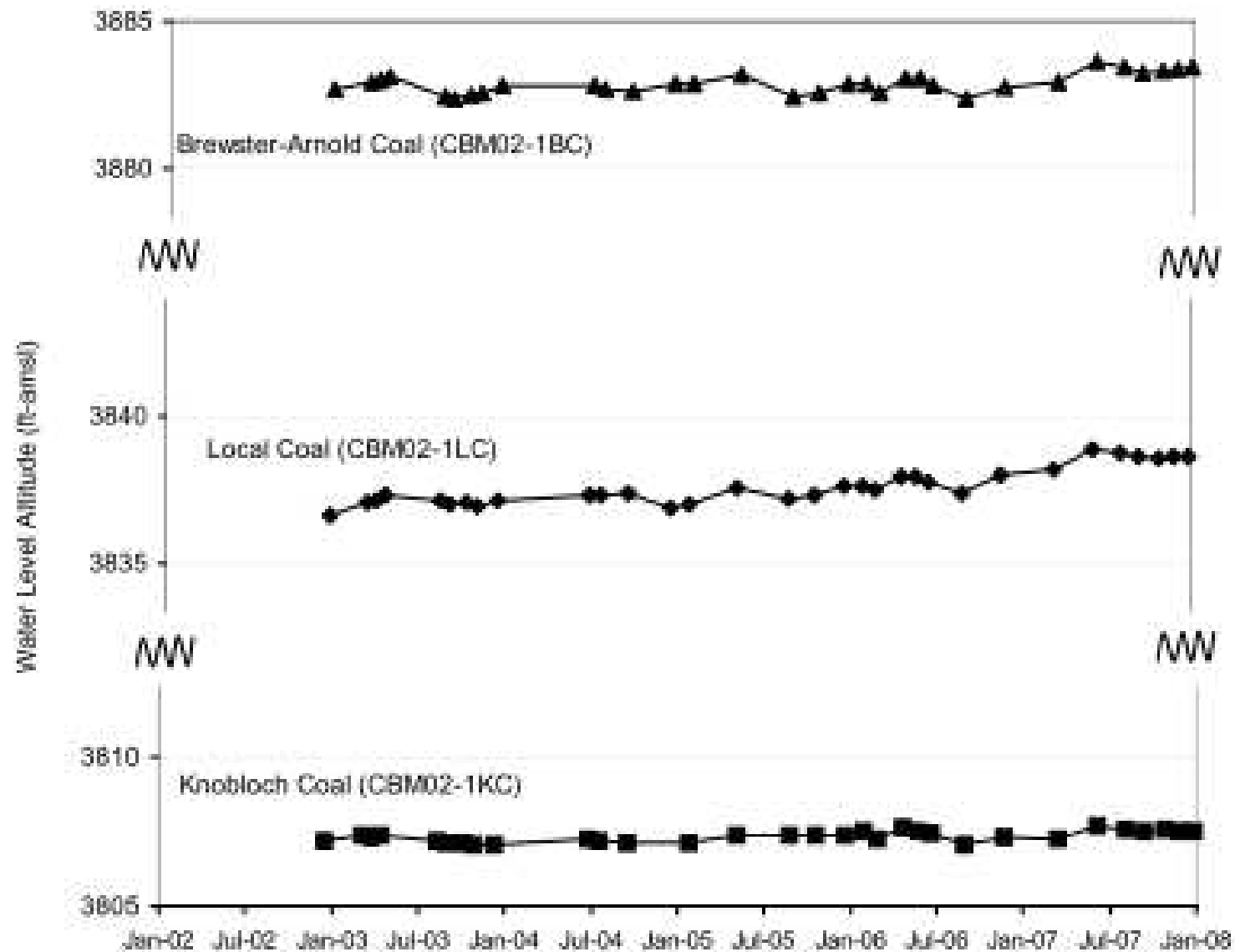
- 1) Annual update on groundwater monitoring available on-line at:
  - [www.mbmgs.mtech.edu](http://www.mbmgs.mtech.edu)
- 2) Regulatory permitting assessments
- 3) Exploration data
- 4) Public knowledge
  - <http://mbmgs.mtech.edu/>

**Water Levels at SL-6 Site**  
**On the State Line ~12 miles West of the Powder River**  
**(~4 miles from nearest CBM development)**





# Water Levels ~2 miles Southeast of Kirby (~11 Miles From the nearest CBM development)



Ground – Water Drawdown  
Coal mine

CBM + mining

Stratigraphy

