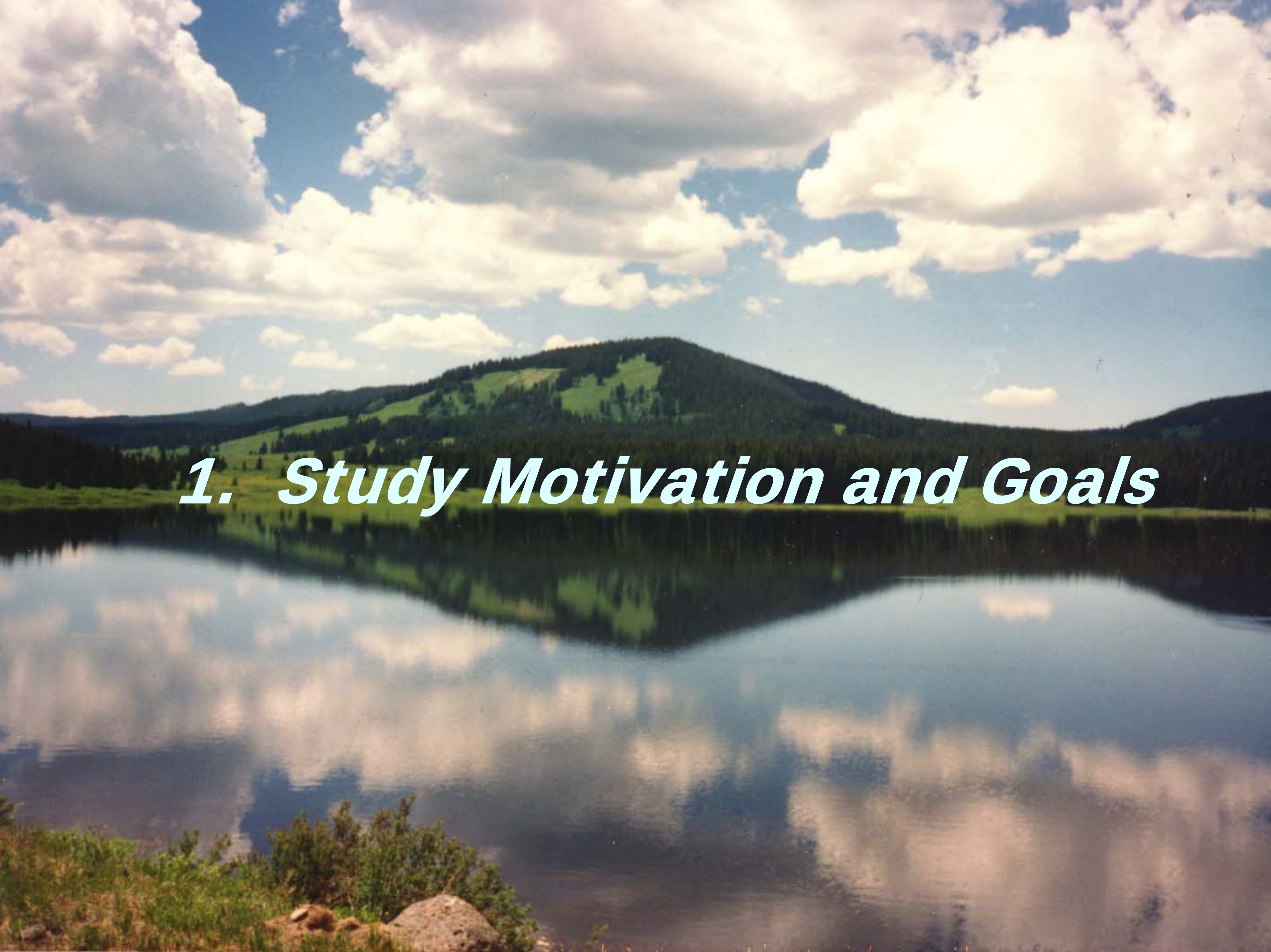
Raton Basin Coalbed Methane Stream Depletion Assessment: Plan of Study

January 24, 2007

Summary of Presentation

1. **Study motivation and goals**
2. **Background**
   a. CBM extraction industry
   b. Regulating agencies and jurisdiction
   c. Geologic setting
3. **Plan of study**
   a. Key study elements
   b. Schedule
   c. Communications

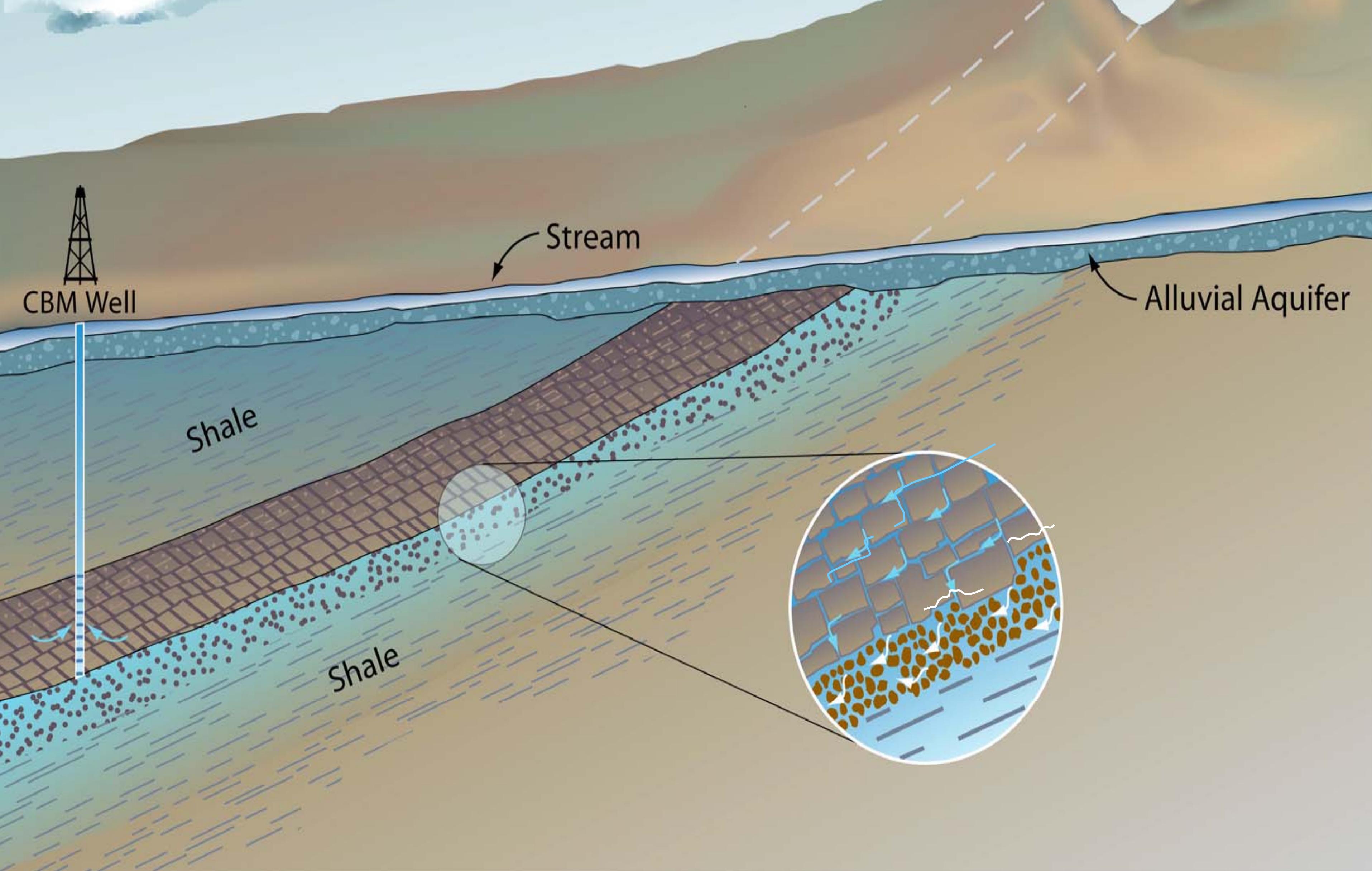
1. Study Motivation and Goals



Motivation for Stream Depletion Assessment Study

- **Local concerns**
  - Impact of coal bed methane extraction on water availability
  - Potential beneficial uses of extracted water
- **State responsibility**
  - Protection of existing water rights
  - Maintain compliance with interstate stream compacts and Water Rights Acts

Potential for connection of coal interval to surface water



Goals for Stream Depletion Assessment Study

- Determine magnitude of stream depletion, if any, from extraction of water and methane
  - Current and post-pumping
  - Regional and interstate
- Define areas from which extraction would be considered tributary vs. non-tributary, for purposes of regulating groundwater extraction under provisions of Colorado water law
- Provide framework for decision-makers regarding suitability of present level of regulation, primarily with respect to impacts on stream-related water rights

Other important issues, but not evaluated in this study

- **Environmental impacts of CBM**
  - Undesirable or hazardous methane migration
  - Mitigation or remediation
- **Local, site-specific impacts**
  - Questions regarding specific wells or springs
  - Detailed migration or depletion patterns
- **Wellfield longevity or production issues**
  - Spacing of wells
  - Operational procedures

Study Team

- **Colorado Division of Water Resources**
- **Colorado Oil and Gas Conservation Commission**
- **Colorado Geological Survey**
- **S.S. Papadopulos & Associates, Inc.**

COLORADO DIVISION OF WATER RESOURCES
DEPARTMENT OF NATURAL RESOURCES

Colorado Oil and Gas Conservation Commission

COLORADO GEOLOGICAL SURVEY

$\Sigma^2\Pi$

Water Resource and Environmental Consultants

Study Resources

- **Knowledge of participating agencies**
- **Information provided by basin property owners/ public**

- **Data provided by oil and gas operators**

- **Other public domain reports**

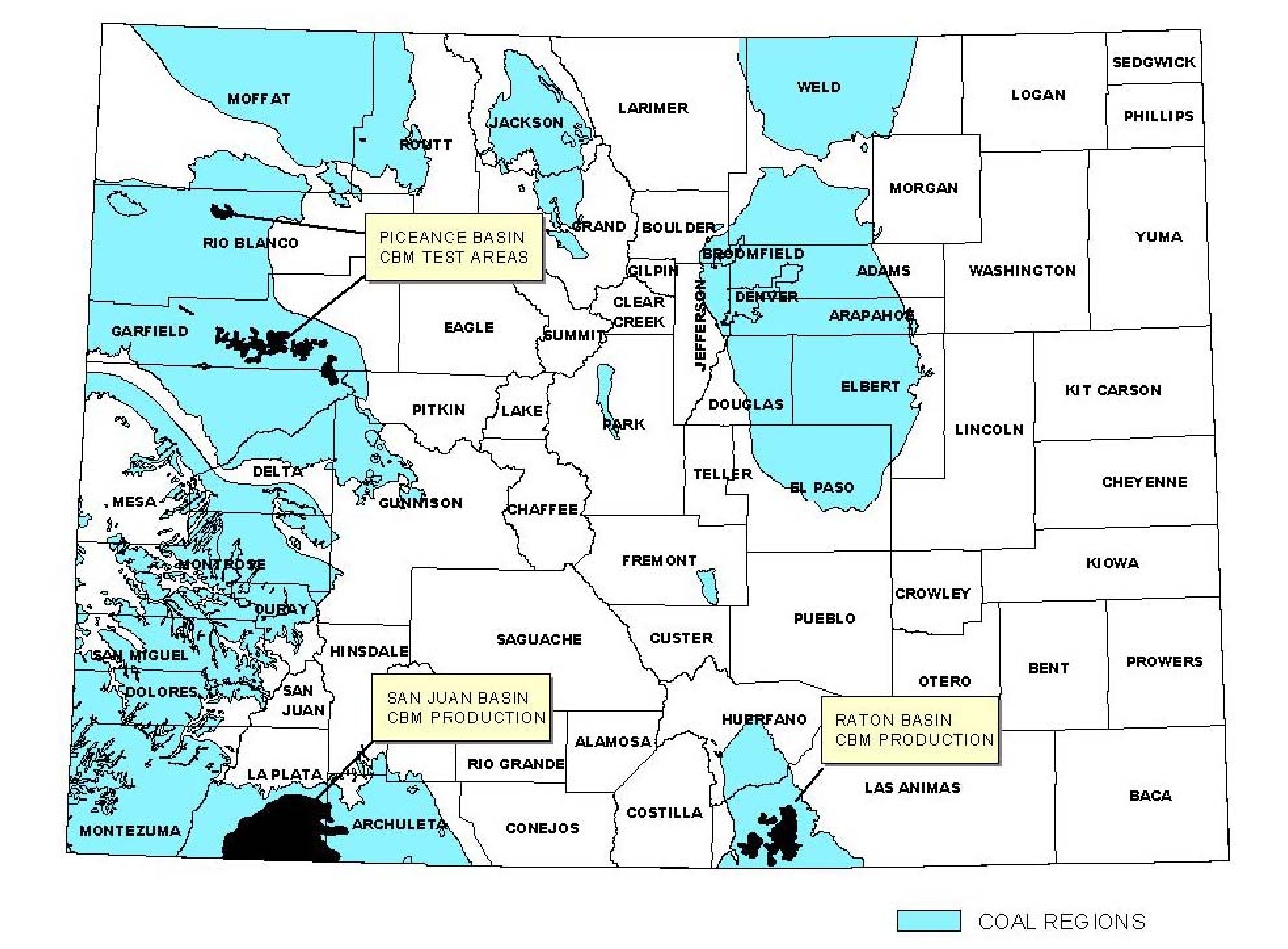
2. Background

Background:

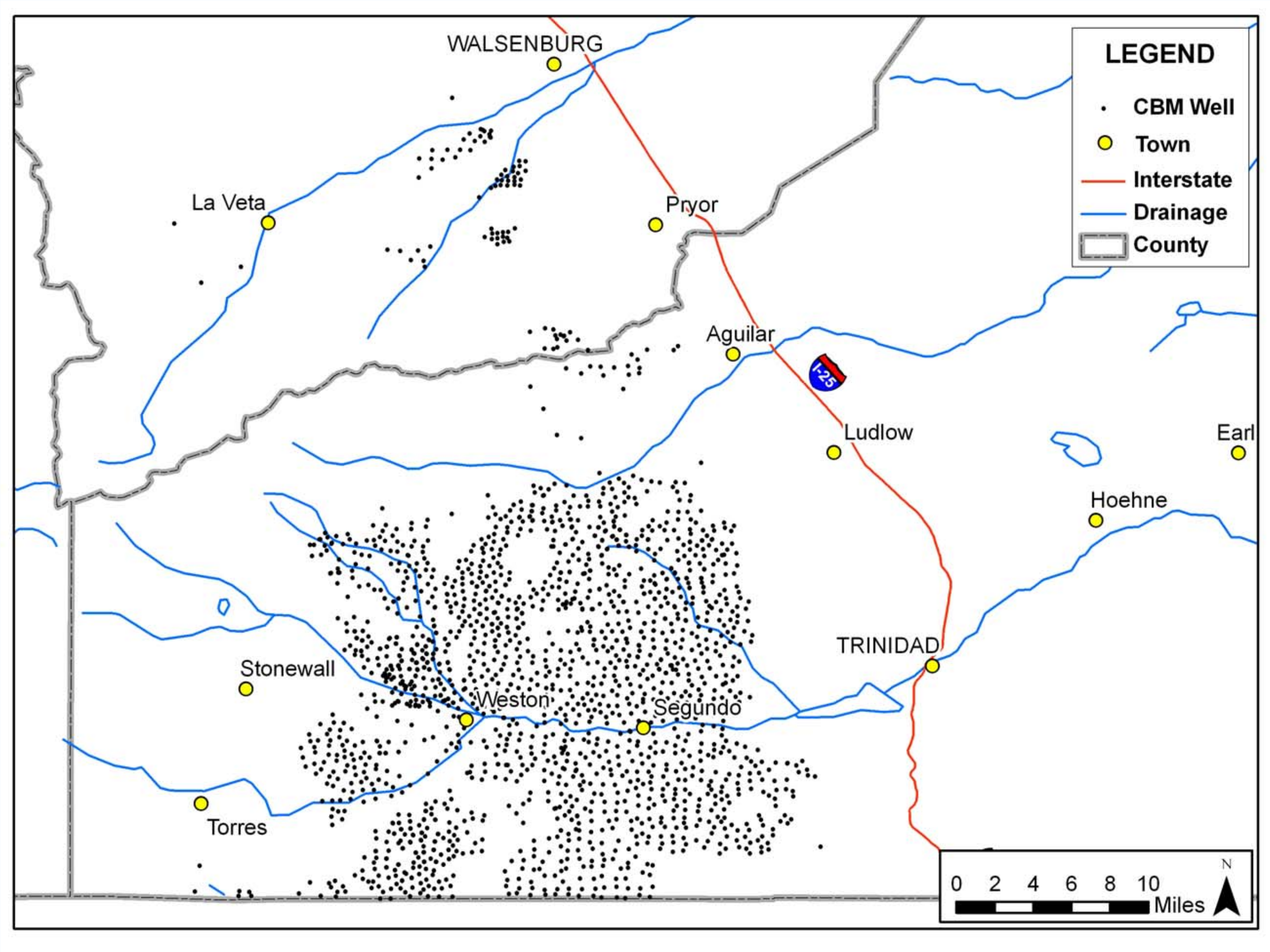
a) Coal Bed Methane Extraction Industry

3,909 Coalbed Methane (CBM) Wells in Colorado

1,836 CBM Wells in San Juan Basin
1,994 CBM Wells in Raton Basin
79 CBM Wells in Piceance Basin



CBM Wells in Raton Basin, Colorado



Historic Annual Colorado Drilling Permits

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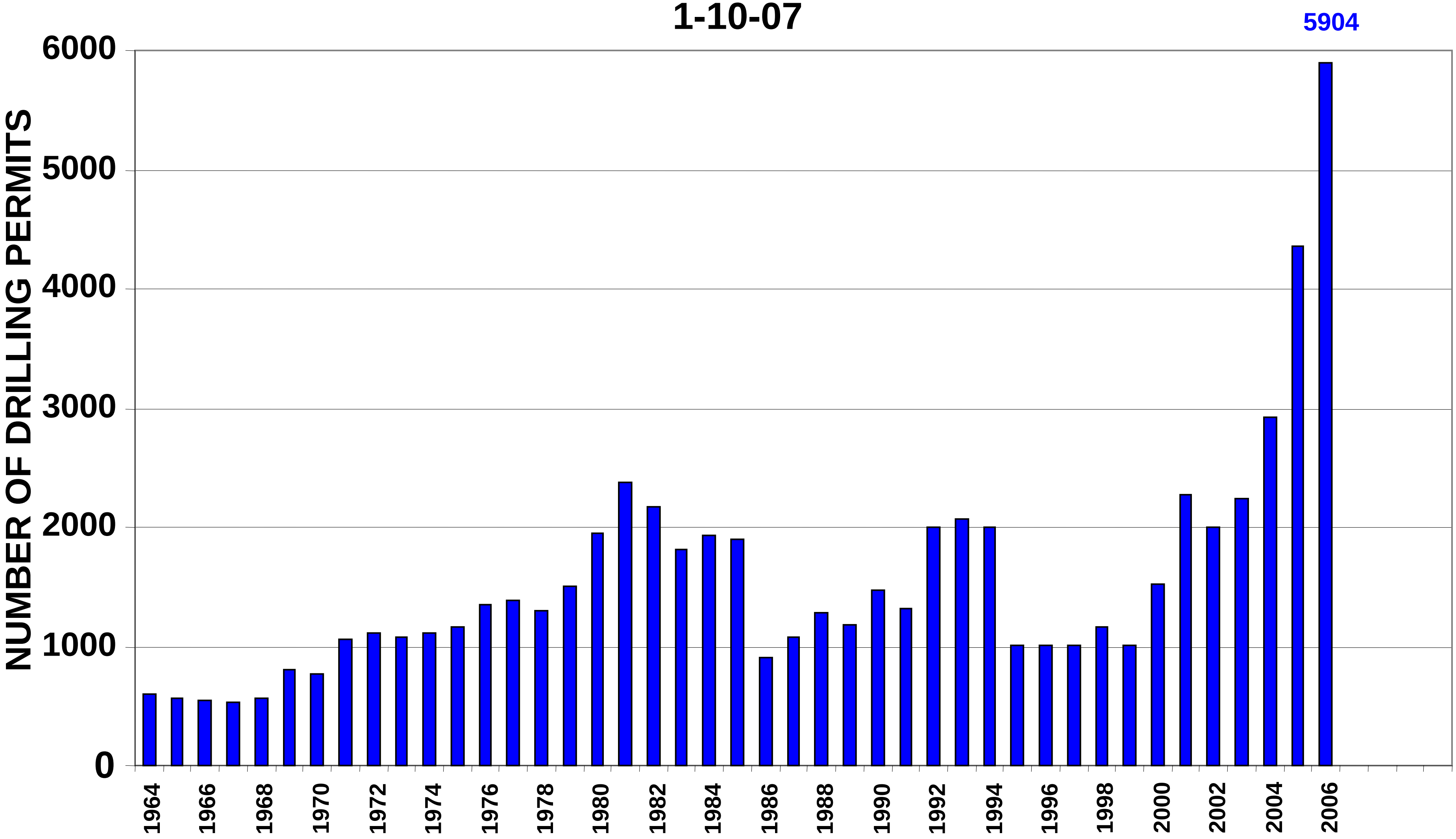
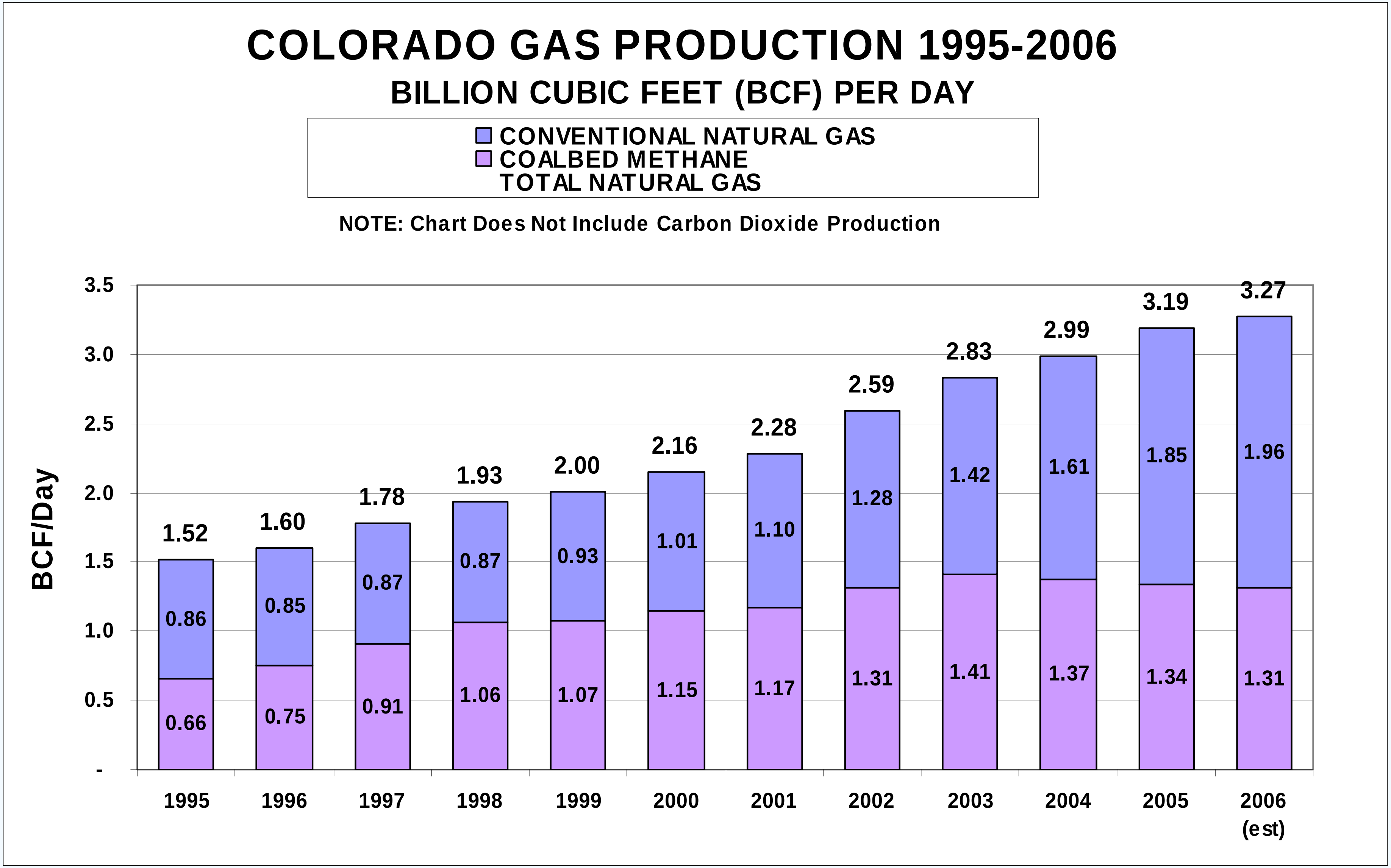
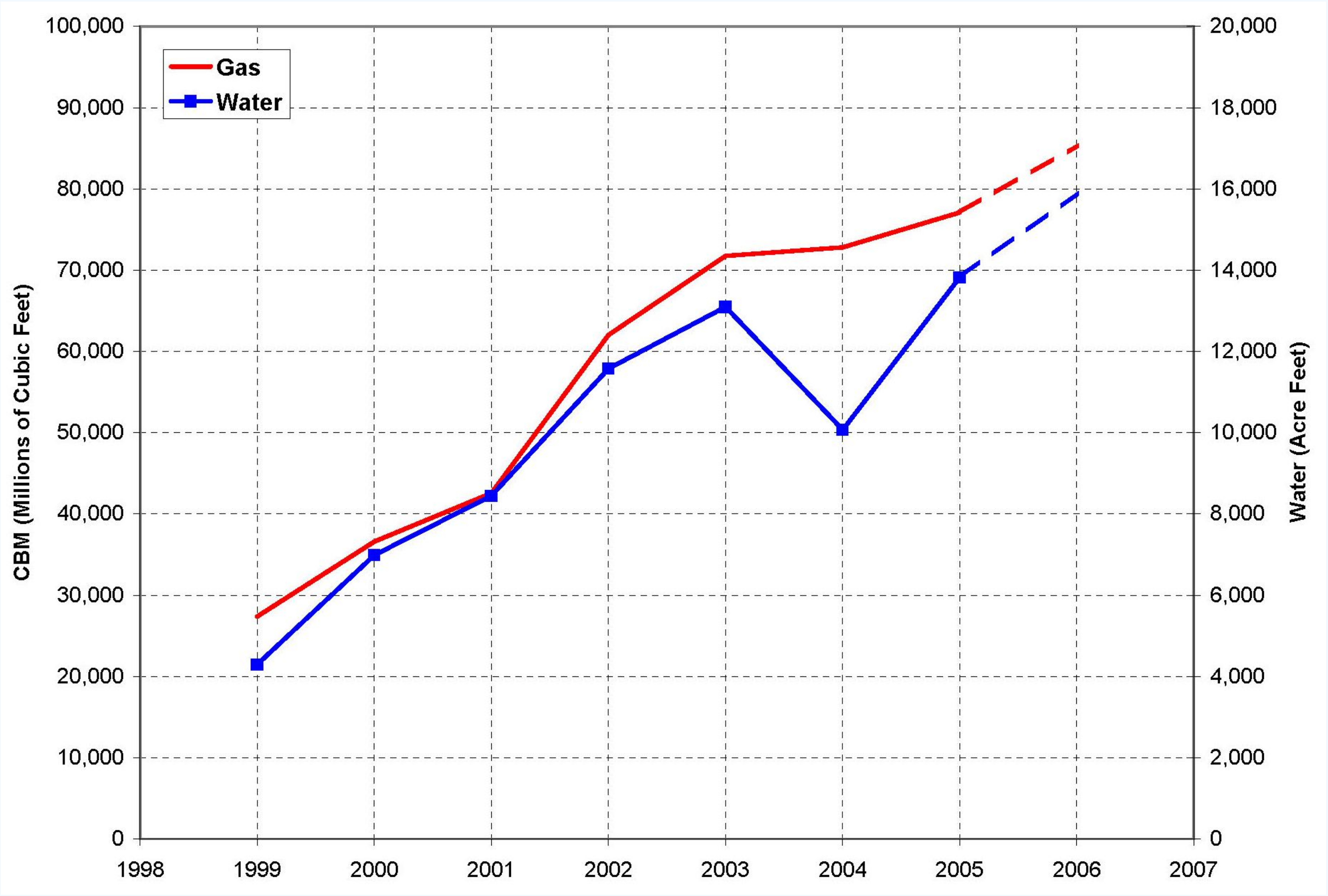


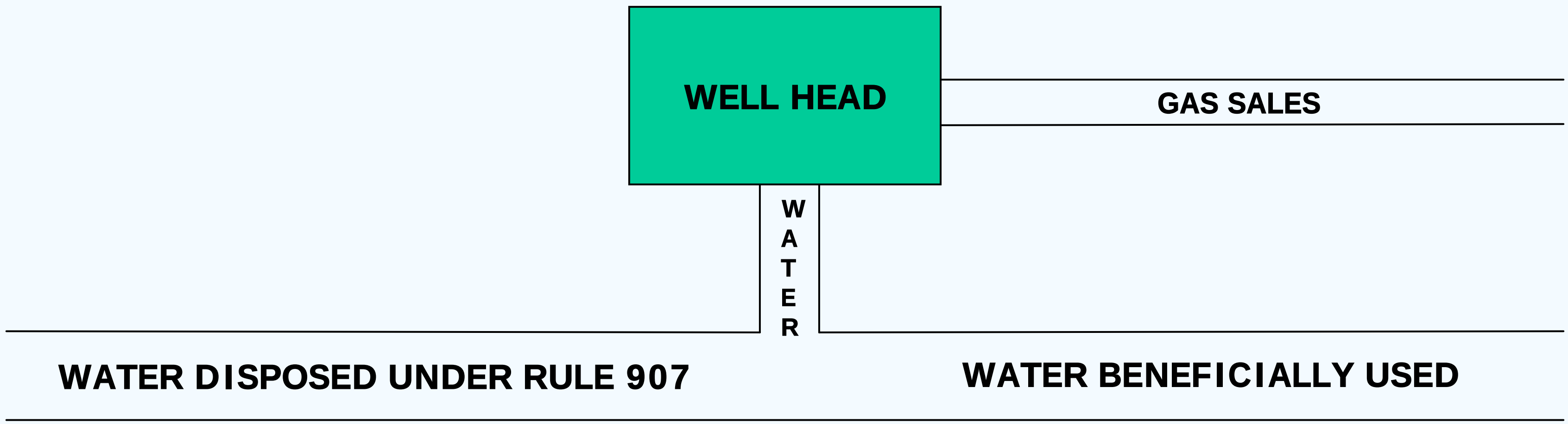

COLORADO GAS PRODUCTION 1995-2006
BILLION CUBIC FEET (BCF) PER DAY
CONVENTIONAL NATURAL GAS
COALBED METHANE
TOTAL NATURAL GAS
NOTE: Chart Does Not Include Carbon Dioxide Production
BCF/Day
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006 (est)
1.52
1.60
1.78
1.93
2.00
2.16
2.28
2.59
2.83
2.99
3.19
3.27
0.86
0.85
0.87
0.87
0.93
1.01
1.10
1.28
1.42
1.61
1.85
1.96
0.66
0.75
0.91
1.06
1.07
1.15
1.17
1.31
1.41
1.37
1.34
1.31

Annual Produced Volumes, Raton Basin, Colorado



Background:
b) Regulatory Setting and Jurisdiction

Who Regulates Produced Water?



These water disposal methods are under the jurisdiction of the **Colorado Oil and Gas Conservation Commission**.

Approval to discharge water to surface water is under the jurisdiction of the **Colorado Department of Public Health and Environment - Water Quality Control Division**.

After the water is discharged it is under the jurisdiction of the **Division of Water Resources** for issues concerning water rights.

Subject to the Water Rights Act under the jurisdiction of the **Division of Water Resources**.

Regulatory Considerations

- CBM wells are treated just like any other O&G wells in Colorado
- Water quality is often poor
- Unreliable as long-term source

Oil and Gas Commission Regulates:

- Location of wells
- How wells are constructed
- Production operations
- Management of E&P waste
- Plugging wells
- Restoration of the surface

Methods of Use and Disposal

- **COGCC Rule 907**
  - Inject into a disposal well
  - Place in lined or unlined pit
  - Dispose at a commercial facility
  - Road spreading
  - Discharge into waters of the state
  - Reuse for recovery, recycling and drilling
  - Mitigation

DWR regulates groundwater withdrawal for beneficial use:

- **Types of Beneficial Uses**
  - Irrigation
  - Municipal
  - Domestic
  - Stock watering
  - Minimum streamflows
  - Augmentation

CBM Water Rights and Ownership

- Doctrine of Prior Appropriation (First in time-first in right)
- DWR has jurisdiction over administration of water – right of use
- Comply with the “Water Rights Acts”
  - Ground Water Management Act
  - Water Right and Determination and Administration Act

CBM Water Rights and Ownership

- **Surface Water Discharge**
  - Must comply with Water Rights Act
    - Must have intent to use
    - Must be diverted in priority
    - Must be beneficially used
    - Must not waste
    - Must prevent material injury to vested water rights

CBM Water Rights and Ownership

- **Beneficial Use by Well-Tributary**
  - §37-90-137(1) & (2), CRS (2005)
    - Permit required
    - Must determine if unappropriated water is available
    - Must prevent material injury to vested water rights (may require augmentation)

CBM Water Rights and Ownership

- **Beneficial Use by Well-Nontributary**
  - §37-90-137(7), CRS (2005)
    - No permit required unless beneficially used
    - Use not based on land ownership
    - Do not need to determine if unappropriated water is available
    - Must determine by modeling if nontributary

Background

c) Geologic Setting

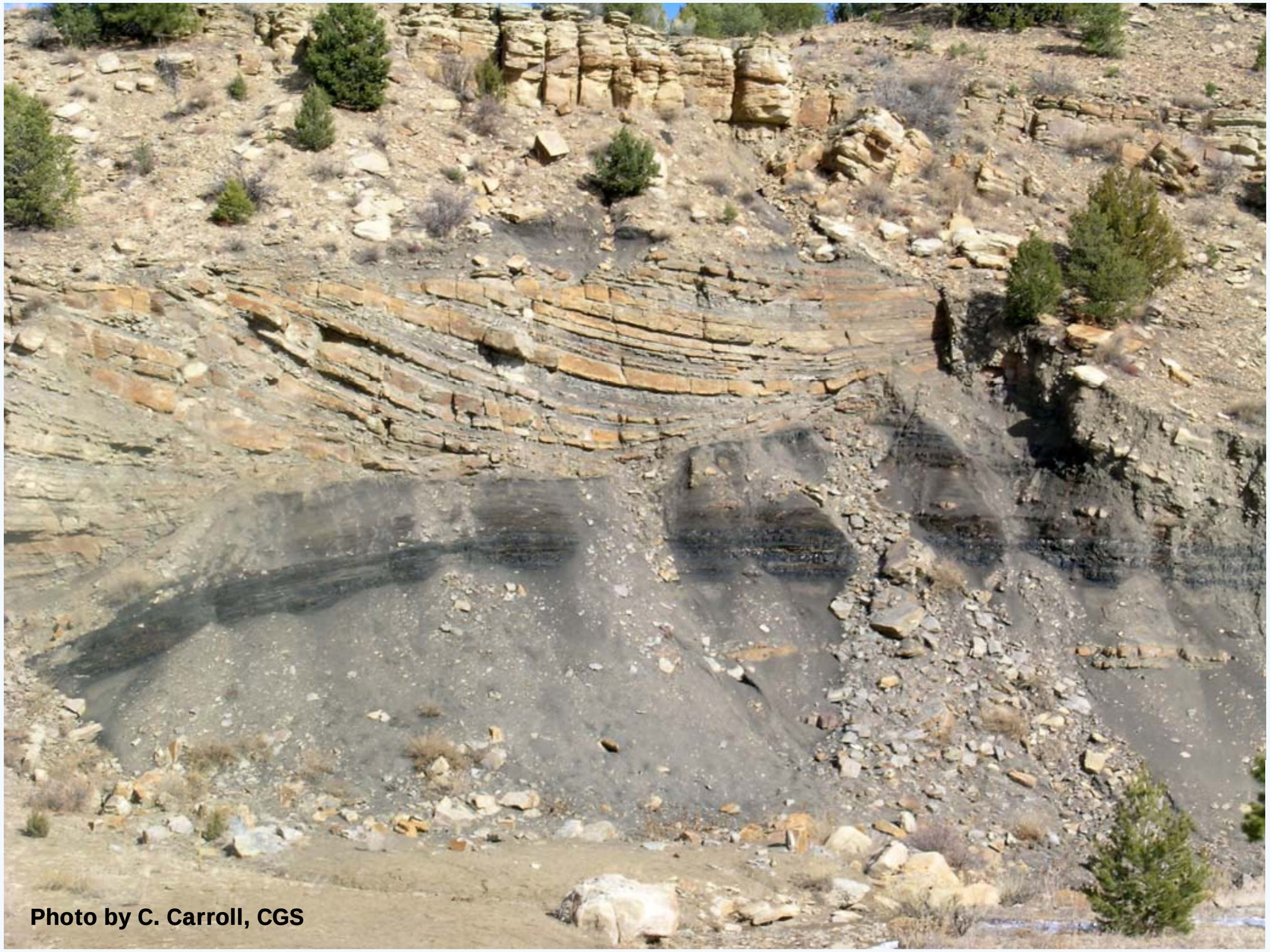


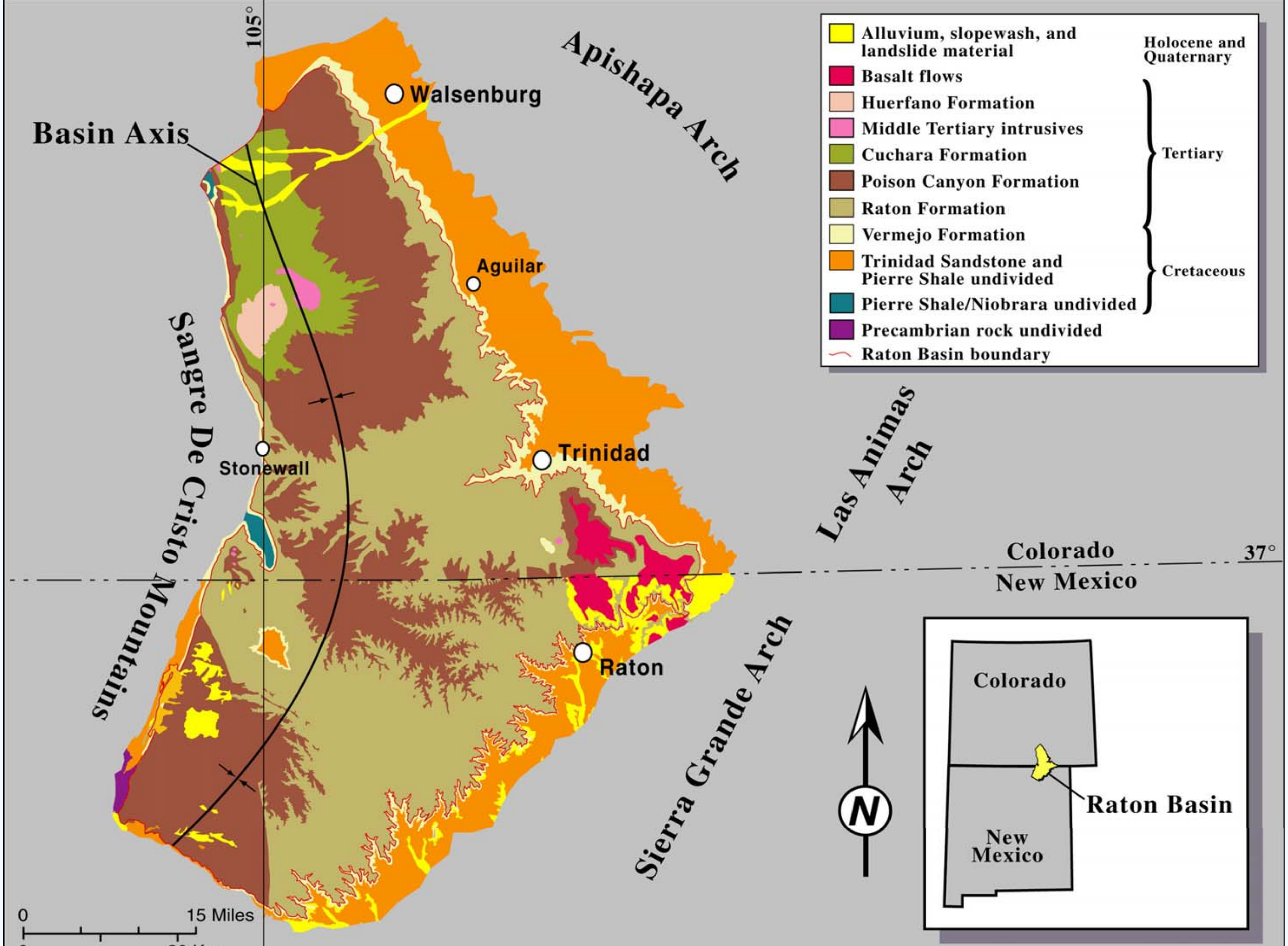
Photo by C. Carroll, CGS

Coal Miners Memorial in Trinidad

Photo by C. Carroll, CGS

Cokedale Coke Ovens

Photo from Denver Public Library Collection



Flores and Bader, 1999

ERA	PERIOD / EPOCH	FORMATION	THICKNESS (FT)	LITHOLOGY
CENOZOIC	Recent		0—30	Alluvium, basalt flows
CENOZOIC	Miocene	Devils Hole Formation	25–1,300	Light-gray conglomeratic tuff and conglomerate
CENOZOIC	Oligocene	Farisita Formation	0–1,200	Buff conglomerate and sandstone
CENOZOIC	Eocene	Huerfano Formation	0–2,000	Variegated maroon shale and red, gray, and tan claystone
CENOZOIC	Eocene	Cuchara Formation	0–5,000	Red, pink, and white sandstone, and red, gray, and tan claystone
CENOZOIC	Paleocene	Poison Canyon Formation	0–2,500	Buff arkosic conglomerate and sandstone, yellow siltstone, and shale
CENOZOIC	Paleocene	Raton Formation	0–2,075	Light-gray to buff sandstone, dark-gray siltstone, shale, and coal; conglomerate at base
MESOZOIC	Upper Cretaceous	Vermejo Formation	0–360	Dark-gray silty and coaly shale, buff to gray carbonaceous siltstone, and sandstone beds; coal
MESOZOIC	Upper Cretaceous	Trinidad Sandstone	0–255	Light-gray to buff sandstone
MESOZOIC	Upper Cretaceous	Pierre Shale	1,300–2,900	Dark-gray fissile shale and siltstone
MESOZOIC	Upper Cretaceous	Niobrara Group: Smokey Hill Marl	560–850	Yellow chalk, marine gray shale and thin white limestone; and light-gray limestone at base
MESOZOIC	Upper Cretaceous	Niobrara Group: Fort Hayes Limestone	0–55	
MESOZOIC	Upper Cretaceous	Benton Group: Codell Sandstone	0–30	Brownish sandstone, dark-gray shale, gray limestone and gray shale
MESOZOIC	Upper Cretaceous	Benton Group: Carlile Shale	165–225	
MESOZOIC	Upper Cretaceous	Benton Group: Greenhorn Limestone	30–80	
MESOZOIC	Upper Cretaceous	Benton Group: Graneros Shale	185–400	
MESOZOIC	Lower Cretaceous	Dakota Sandstone	100–200	Buff sandstone, buff conglomerate sandstone, and dark-gray shale
MESOZOIC	Lower Cretaceous	Purgatoire Formation	100–150	
MESOZOIC	Jurassic	Morrison Formation	150–400	Variegated maroon shale, gray limestone, red siltstone, gypsum, and gray sandstone
MESOZOIC	Jurassic	Ralston Creek Formation	30–100	
MESOZOIC	Jurassic	Entrada Sandstone	40–100	
MESOZOIC	Triassic	Dockum Group	0–1,200	Red sandstone, calcareous shales, and thin limestones
PALEOZOIC UNDIVIDED			5,000–10,000	Variegated shales, arkose, conglomerates, and thin marine limestone

Hemborg, 1998


Ron Blakey, Northern Arizona University
(http://jan.ucc.nau.edu/~rcb7/)


Ron Blakey, Northern Arizona University
(http://jan.ucc.nau.edu/~rcb7/)



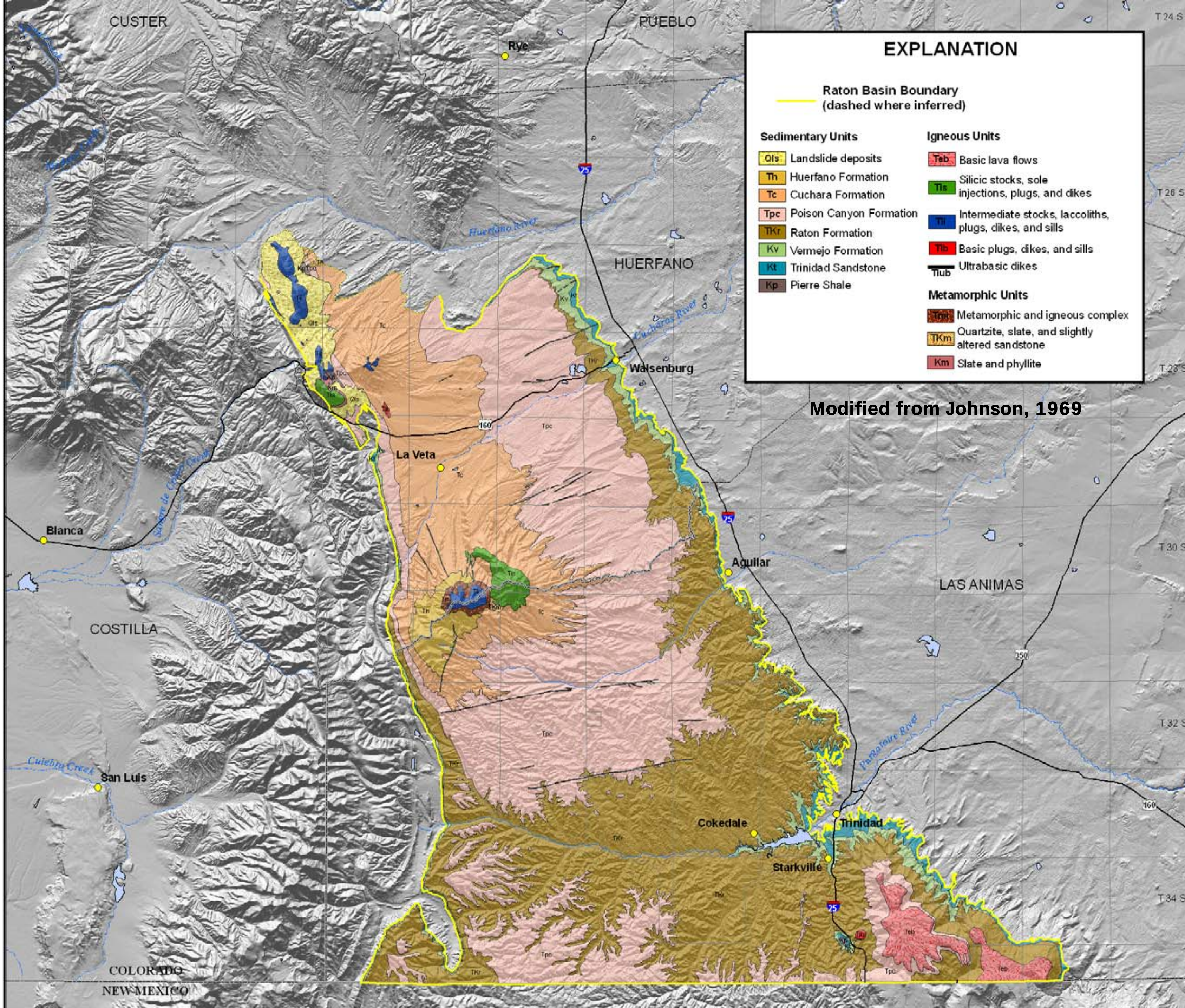
Donna Braginetz, DMNS

Geology of the Coal-bearing Units

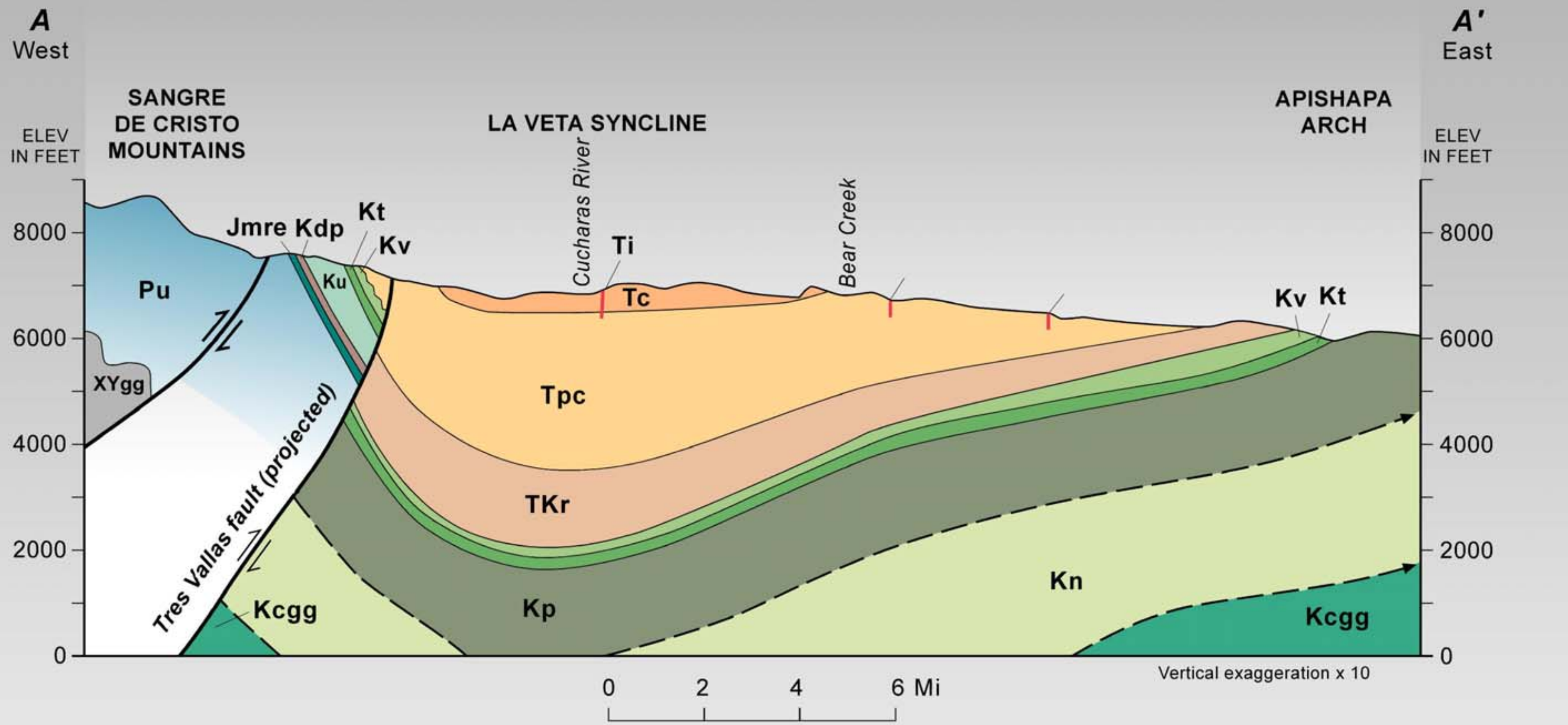
AGE		FORMATION NAME	GENERAL DESCRIPTION	LITHOLOGY	APPROX. THICKNESS IN FEET
TERTIARY	PALEOCENE	POISON CANYON FORMATION	SANDSTONE–Coarse to conglomeratic beds 13–50 feet thick. Interbeds of soft, yellow-weathering clayey sandstone. Thickens to the west at expense of underlying Raton Formation		0–2,500
TERTIARY / MESOZOIC	PALEOCENE / UPPER CRETACEOUS	RATON FORMATION	Formation intertongues with Poison Canyon Formation to the west UPPER COAL ZONE–Very fine grained sandstone, siltstone, and mudstone with carbonaceous shale and thick coal beds BARREN SERIES–Mostly very fine to fine grained sandstone with minor mudstone, siltstone, with carbonaceous shale and thin coal beds LOWER COAL ZONE–Same as upper coal zone; coal beds mostly thin and discontinuous. Conglomeratic sandstone at base; locally absent		0–1,700 *180–600* ←K/T Boundary *100–250*
MESOZOIC	UPPER CRETACEOUS	VERMEJO FORMATION	SANDSTONE–Fine to medium grained with mudstone, carbonaceous shale, and extensive, thick coal beds. Local sills		0–380
MESOZOIC	UPPER CRETACEOUS	TRINIDAD SANDSTONE	SANDSTONE--Fine to medium grained; contains casts of *Ophiomorpha*		0–300
MESOZOIC	UPPER CRETACEOUS	PIERRE SHALE	SHALE--Silty in upper 300 ft. Grades up to fine grained sandstone. Contains limestone concretions		1,300-2,300

Adapted from Flores and Bader (1999), Tyler and others (1991), and Tremain (1980).


Photo by C. Carroll, CGS



Modified from Johnson, 1969

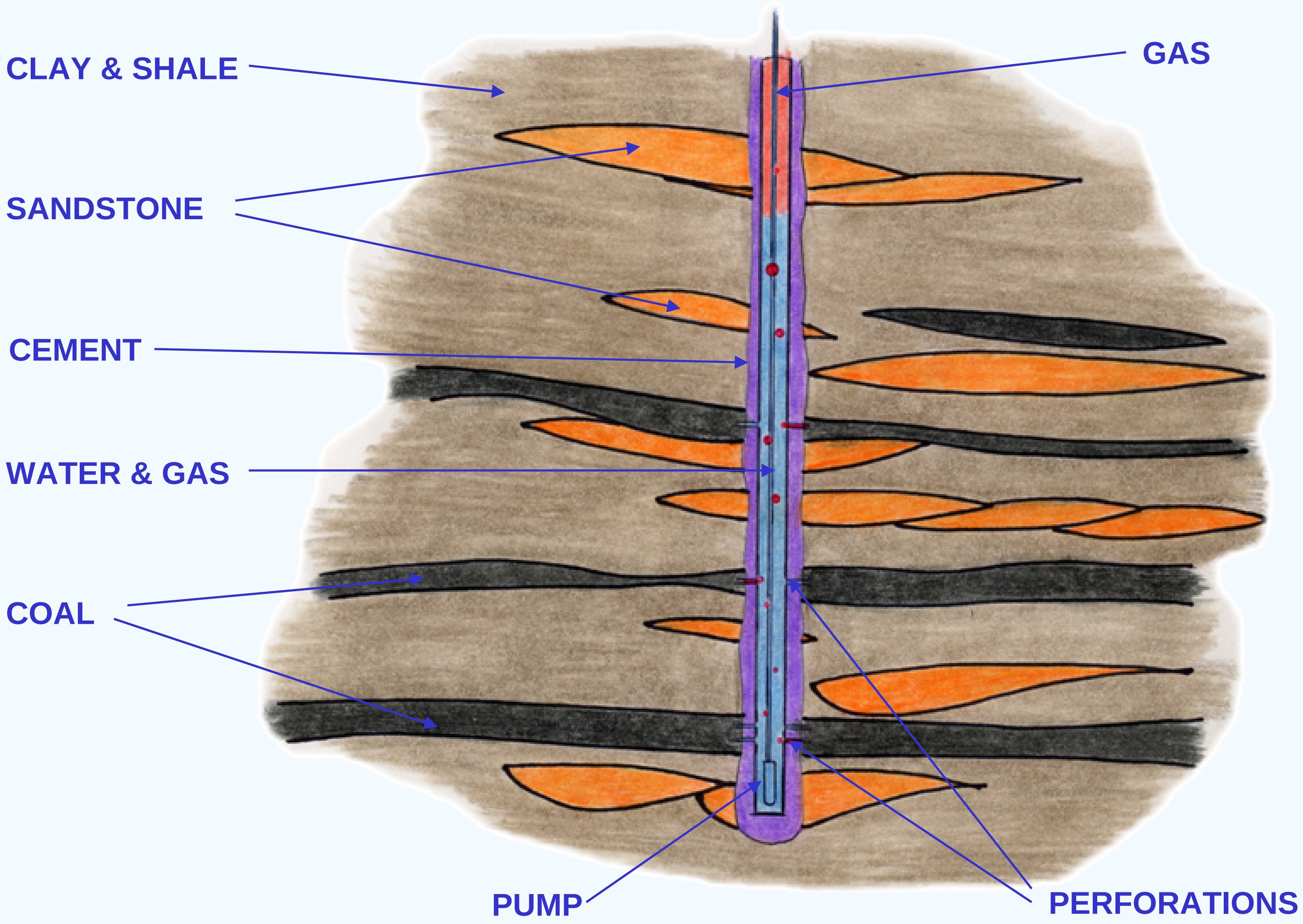


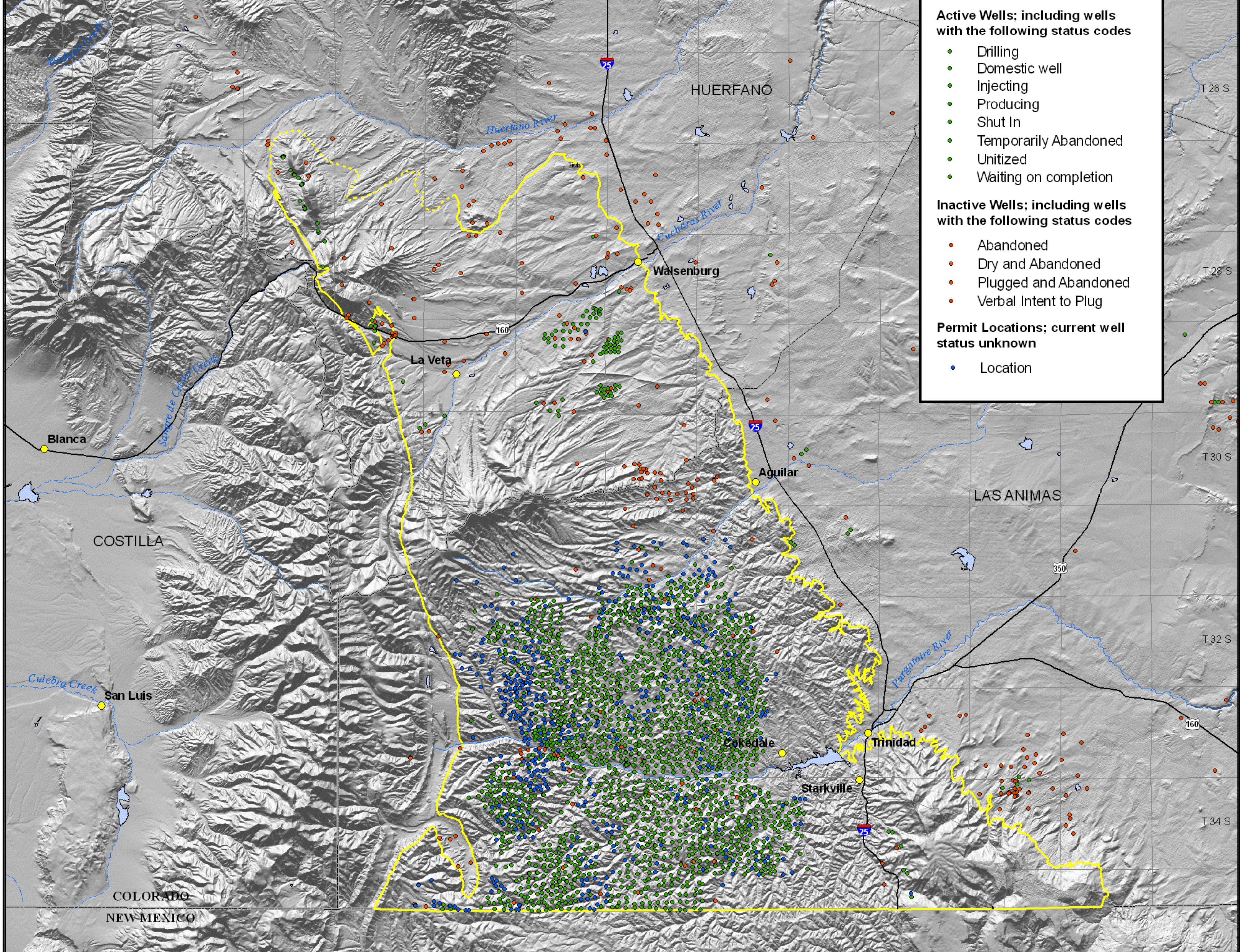
EXPLANATION

Ti	Igneous intrusives
Tc	Cuchara Formation
Tpc	Poison Canyon Formation
TKr	Raton Formation
Kv	Vermejo Formation
Kt	Trinidad Sandstone
Kp	Pierre Shale
Kn	Niobrara Formation
Kcgg	Carlile Shale, Greenhorn Limestone, and Graneros Shale, undifferentiated
Ku	Pierre, Niobrara, Carlile, and Greenhorn formations, undifferentiated
Kdp	Dakota Sandstone and Purgatoire formations
Jmre	Morrison Formation, Ralson Creek Formation, and Entrada Sandstone
Pu	Paleozoic undivided
XYgg	Proterozoic granite and gneisses

Modified from Stevens and others, 1992

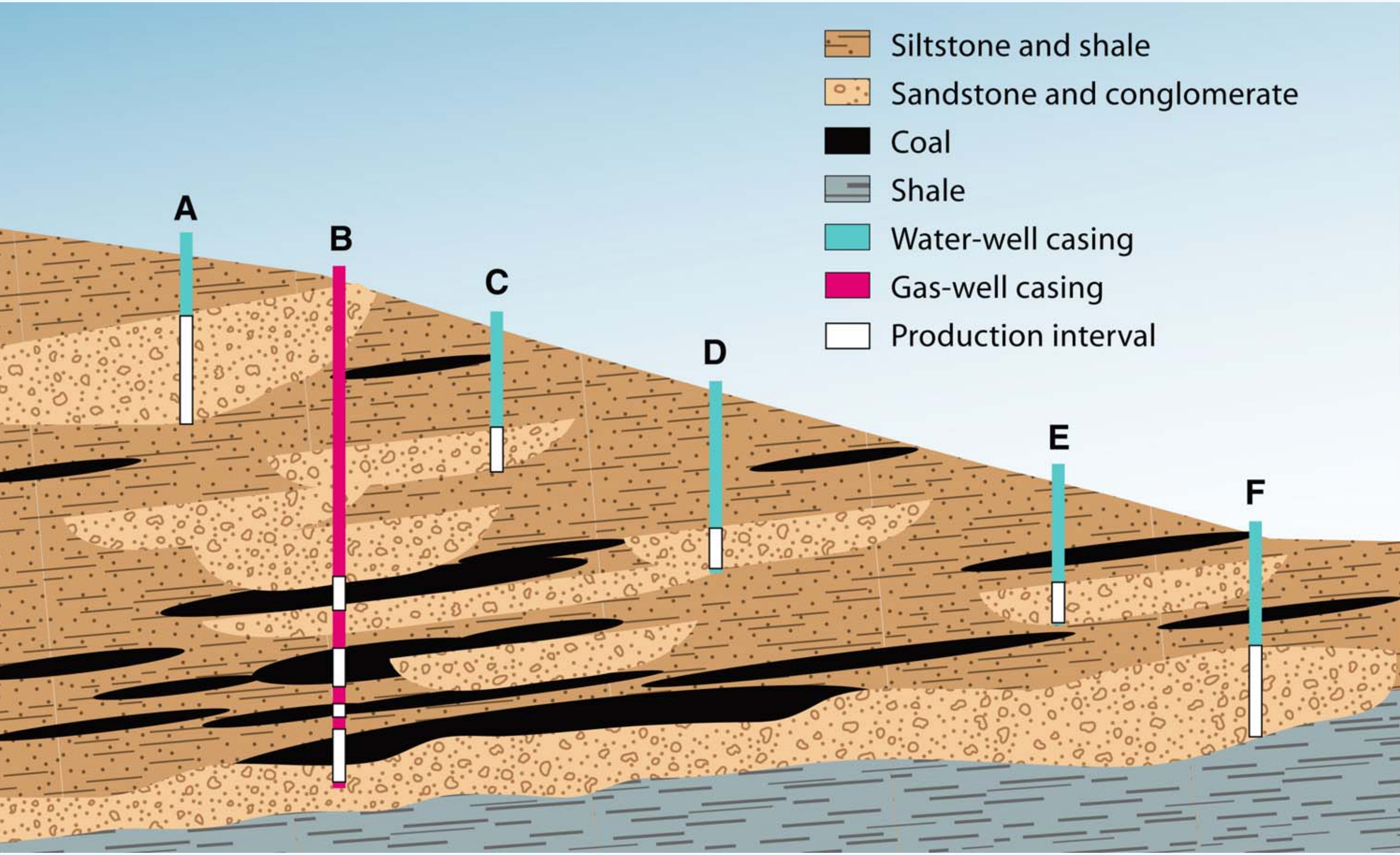
Typical CBM Well Completion





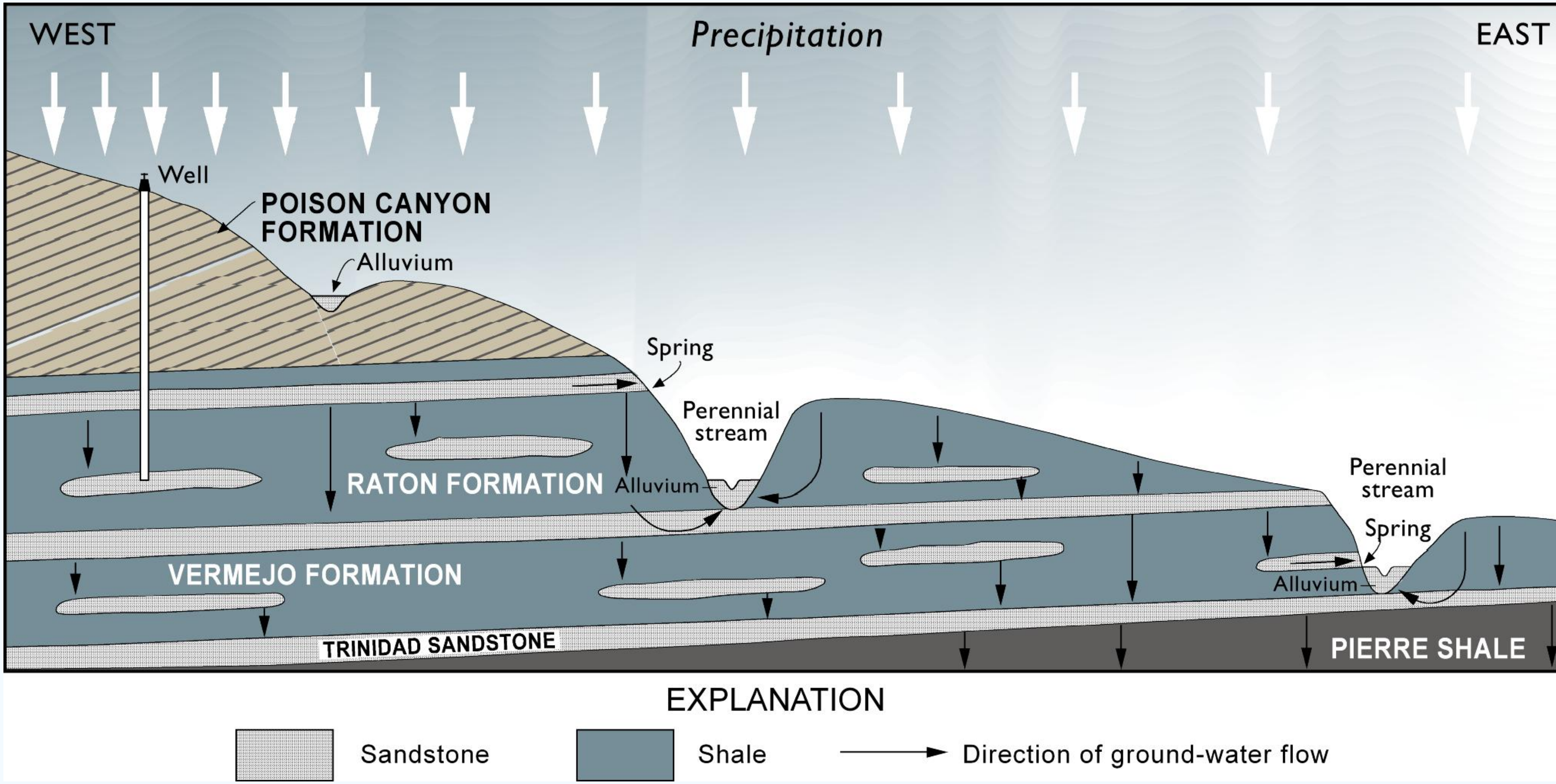
Active Wells; including wells with the following status codes
Drilling
Domestic well
Injecting
Producing
Shut In
Temporarily Abandoned
Unitized
Waiting on completion
Inactive Wells; including wells with the following status codes
Abandoned
Dry and Abandoned
Plugged and Abandoned
Verbal Intent to Plug
Permit Locations; current well status unknown
Location
HUERFANO
LAS ANIMAS
COSTILLA
Huerfano River
Cucharas River
Purgatoire River
Culebra Creek
Sangre de Cristo Creek
Walsenburg
La Veta
Blanca
Aguilar
San Luis
Cokedale
Trinidad
Starkville
COLORADO
NEW MEXICO
T 26 S
T 28 S
T 30 S
T 32 S
T 34 S
25
160
350

Relationship of CBM Production to Water Wells



Modified from Watts, 2006

Schematic of Ground Water Flow



Modified from Geldon, 1989


3. Plan of Study

Scope of Work
Stream Depletion Assessment Study

- Review available data and studies
- Describe regulatory framework
- Describe hydrogeologic setting
- Characterize extraction activity
- *Assess impact of extraction on regional water conditions, particularly, impact to streams*
- Provide analysis and assessment in report
- Provide framework for decision-makers regarding suitability of present level of regulation, primarily with respect to streamflow impacts

Simplified Stream Depletion Modeling Analysis

- Lead agencies have specified an analytical approach, if plausible, based on Glover method
- Key elements for method
  - Identification of key flow path in hydraulic communication with stream
  - Characterization of flow geometry and barriers
  - Quantification of controlling aquifer properties
  - Quantities of fluid withdrawal, water equivalents

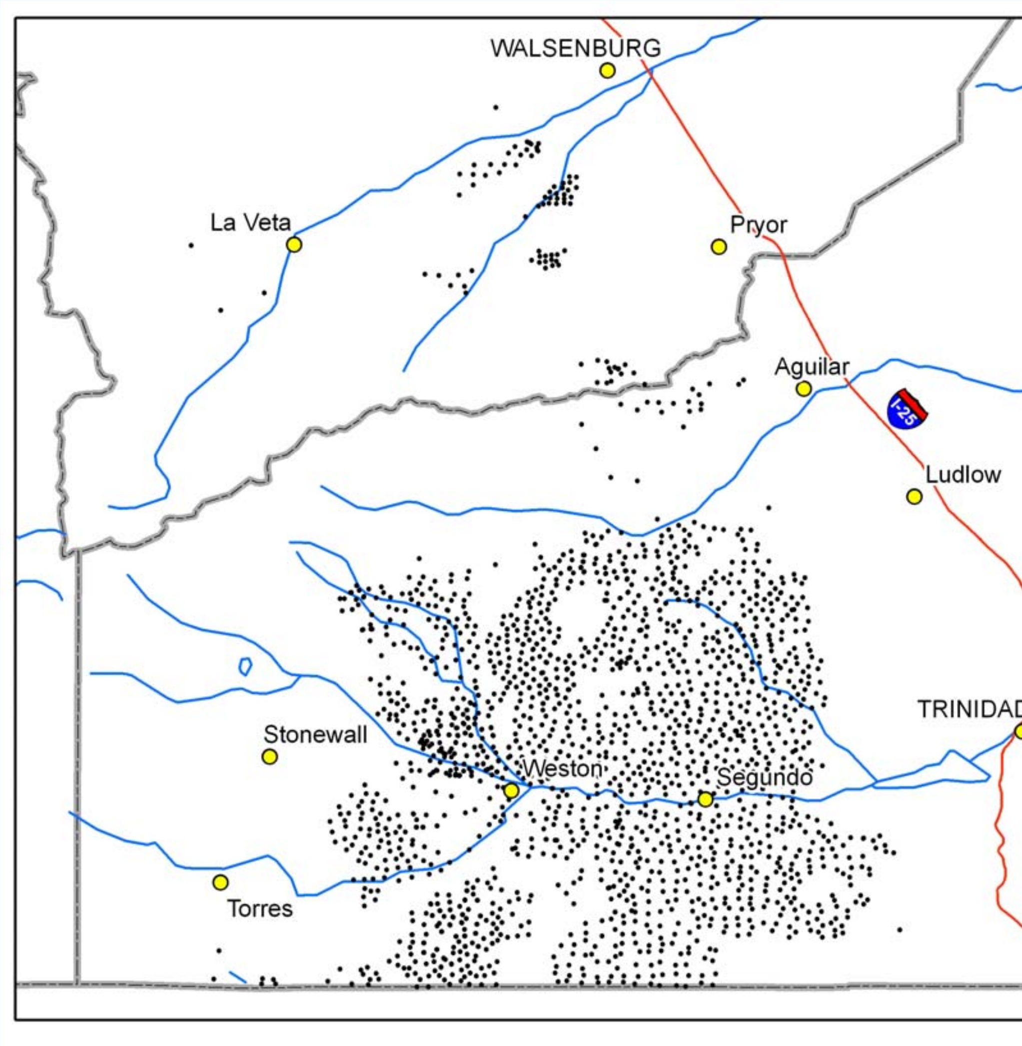
Related Analyses

- Suitability of Glover method for regulatory purposes (regional emphasis, not site-specific)
- Other methods, correlations, or indicators that might serve to identify tributary vs. non-tributary zones
- Issues unanswered – areas for further study

Conceptual Model Development, Step 1

Identify potentially impacted surface water features:

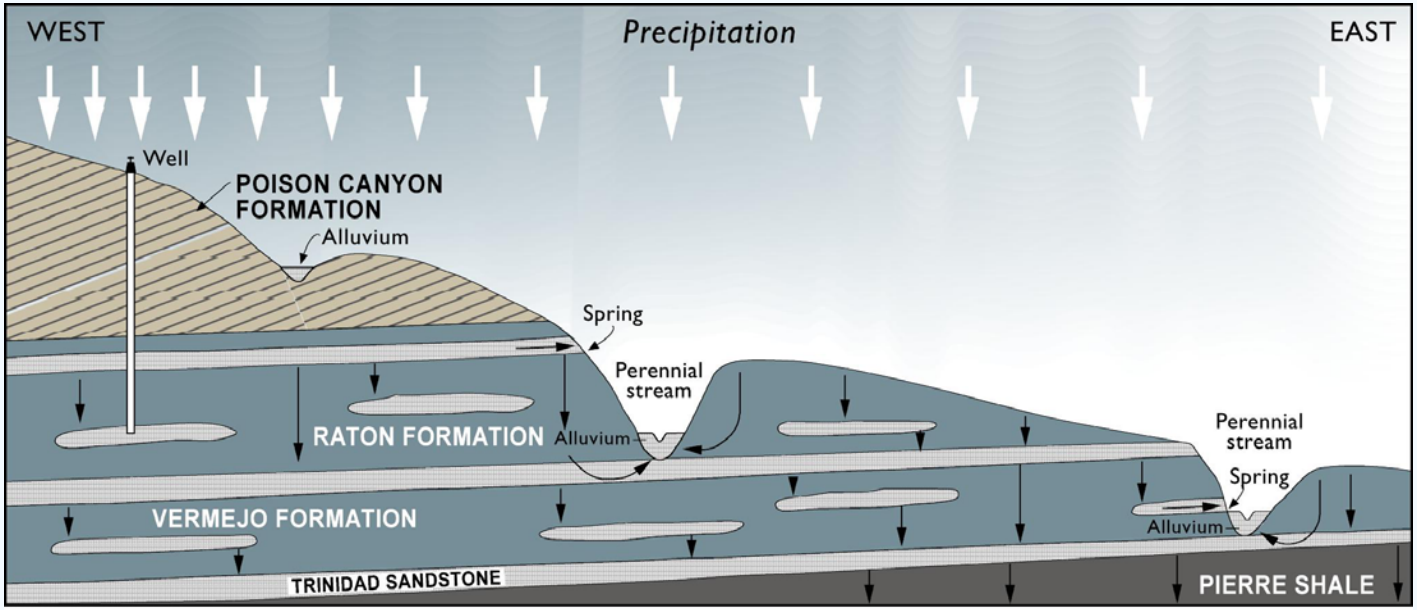
- River valley alluvium of major streams?
- Locally incised streams?
- Springs, seeps?
- Outcrops traversed by streams?



Conceptual Model Development, Step 2

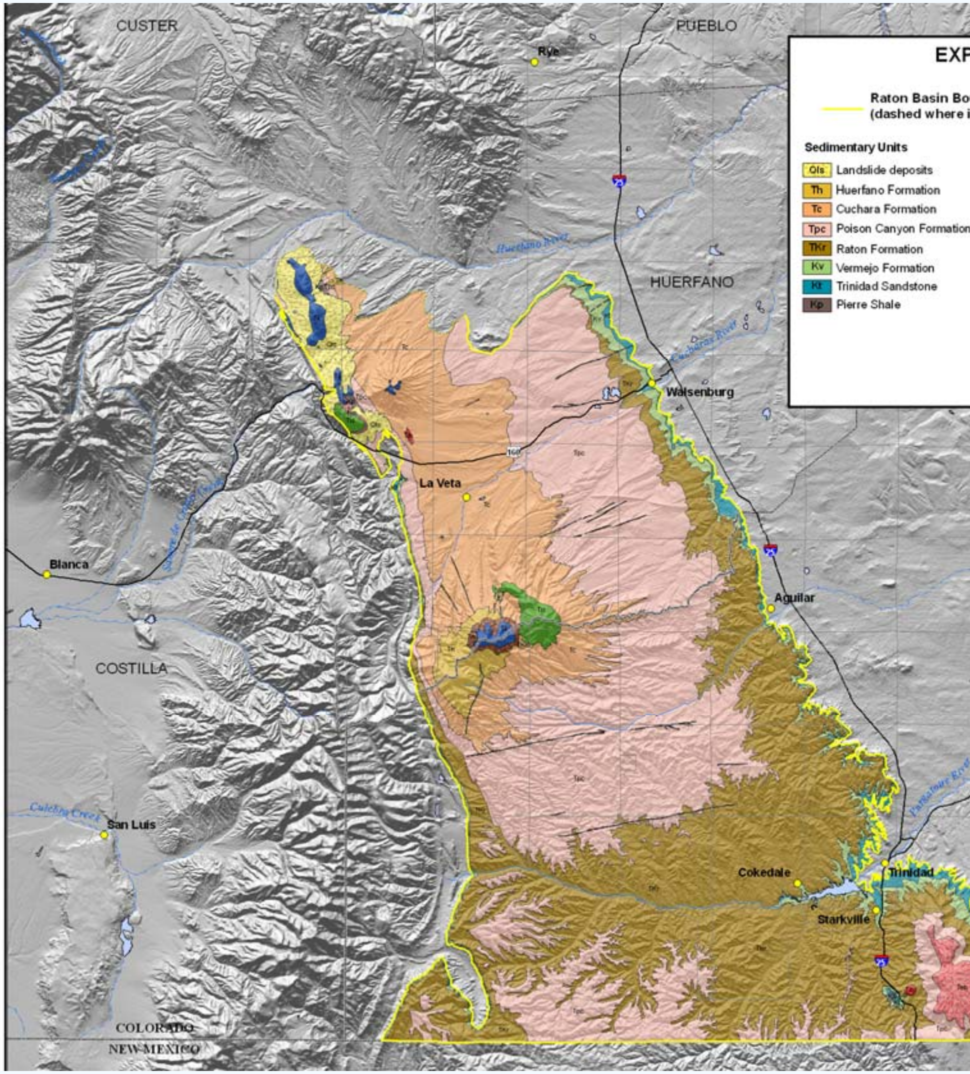
Identify type of hydraulic connection between CBM water production intervals and potentially impacted surface water features:

- Horizontal, vertical, or both?
- Internal or external formation boundaries?
- Significant spatial variation?



Preliminary Observations

- The timing and magnitude of stream depletion from CBM water production will be dependent on “effective average” horizontal and vertical hydraulic conductivity, and formation storage characteristics
- Spatial differences between northern and southern parts of basin:
  - Presence of overlying Poison Canyon-Cuchara Formations lacking in southern part of basin
  - More extensive dikes, intrusive bodies in northern part of basin
  - Hydraulic separation between CBM production intervals and streams dependent on thickness of shales encountered in overlying beds



Simplified Modeling Approach

- Can Glover Method be applied ?
  - What are reasonable values for “effective average” horizontal and vertical hydraulic conductivity?
  - At what distance from stream do vertical properties become less important to the propagation of pumping impacts?
  - Where are the present and potential CBM water-producing wells located in the context of these considerations?
  - Is it realistic to configure a series of Glover analyses to address the different conditions for different sets of wells?

- Is an alternate, ***but simple***, modeling approach better suited to address the stream depletion question posed?

Work in Progress

- Compilation and review of data
  - Well tests
  - Shut-in pressures
  - Formation properties
  - Shallow aquifer conditions
- Evaluation of horizontal and vertical hydraulic conductivity; storage properties
- Evaluation of formation geometry with reference to surface streams

Report
Stream Depletion Assessment Study

- Summary of available data and studies
- Regulatory framework
- Hydrogeologic setting
- Extraction activity and projections
- Stream depletion assessment
- Conclusions / Recommendations

Schedule

- Project kick-off, December 2006
- Public Meeting, Trinidad, January 24
- Compile, assess data, through April
- Report to lead agencies, June
- Report posted on website, TBD
- Final public presentation, TBD

Communications

- Public Meeting, Trinidad, January 24, 2007
- Concerns, observations or information from any interested party is of value to the study team and will be reviewed – best to submit within next 2 weeks, boulder@sspa.com
- Study report will be available through links on DWR and COGCC websites
- Post-study comments will be received by DWR and COGCC
- Post-study meeting will be scheduled

Your interest is appreciated, contact us at:
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