Monitoring and Protecting Groundwater During Oil & Gas Development

Overview of Colorado Aquifer Systems

November 26, 2012

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Colorado Aquifer Systems

- Topics
  - Locations and occurrence of:
    - Aquifer systems
    - Oil & gas basins
  - Potential contamination events
    - What types of events are we monitoring for?
  - Travel times
  - Considerations with respect to rulemaking

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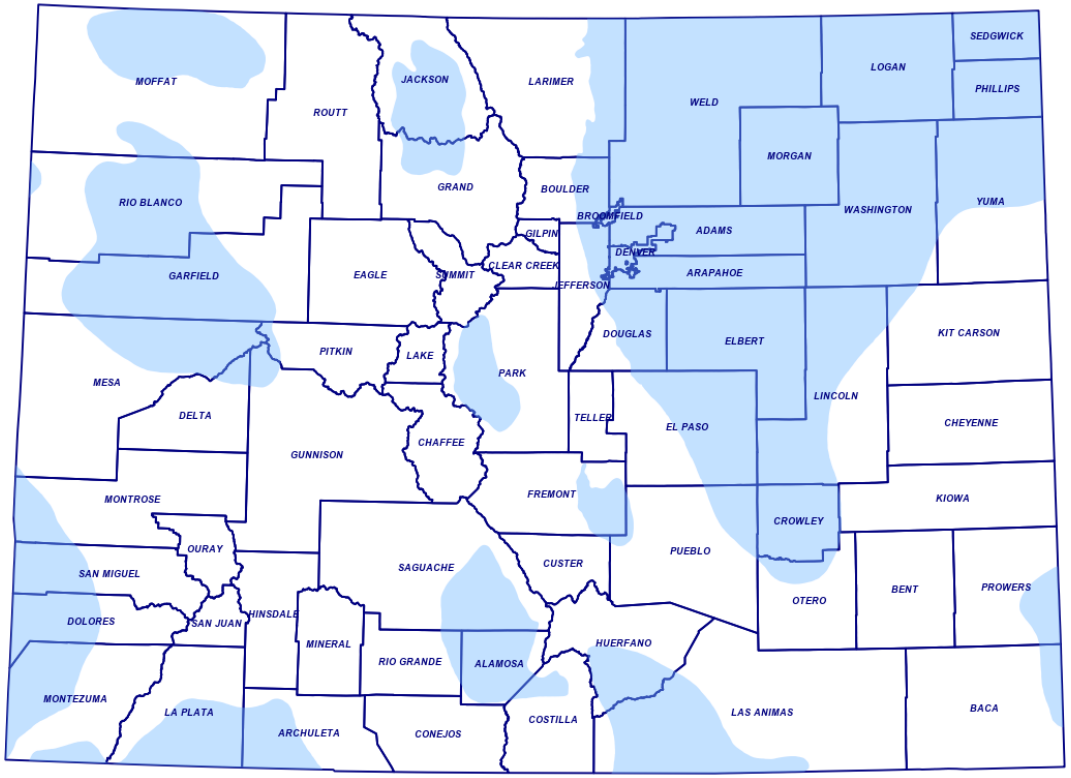
Colorado Oil & Gas Basins



Source: COGCC GIS database

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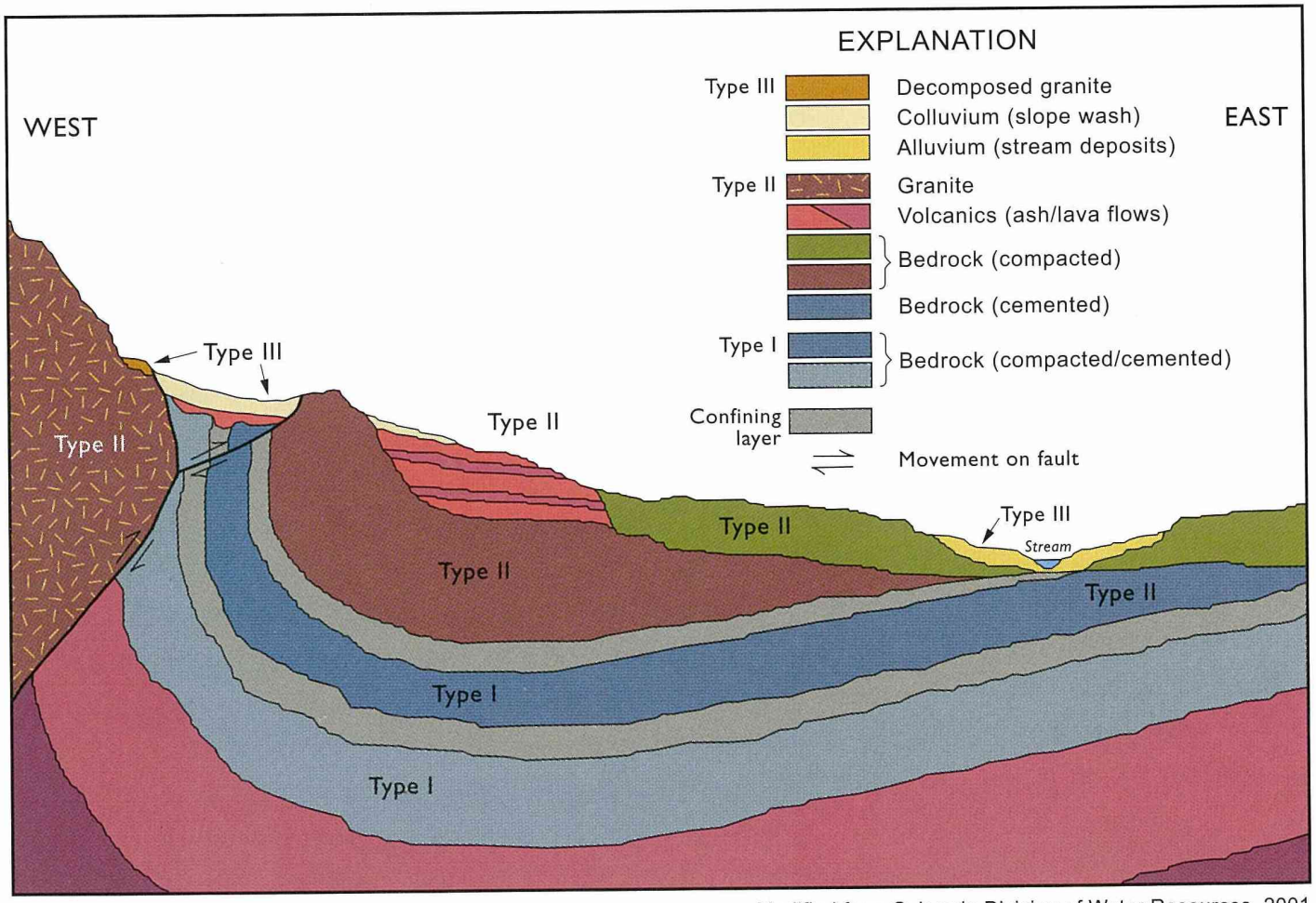
Colorado Aquifer Systems

- Interaction of aquifers and oil and gas drilling activities
  - Focus is on sedimentary aquifer systems
  - Sedimentary bedrock and alluvial aquifers typically overlay O&G formations
  - Other aquifer types exist, but typically do not interact with O&G formations

Schematic Geologic Cross-Section



Modified from Colorado Division of Water Resources, 2001

Figure 3-3. Schematic cross section of various types of aquifers.

Source: Ground Water Atlas of Colorado

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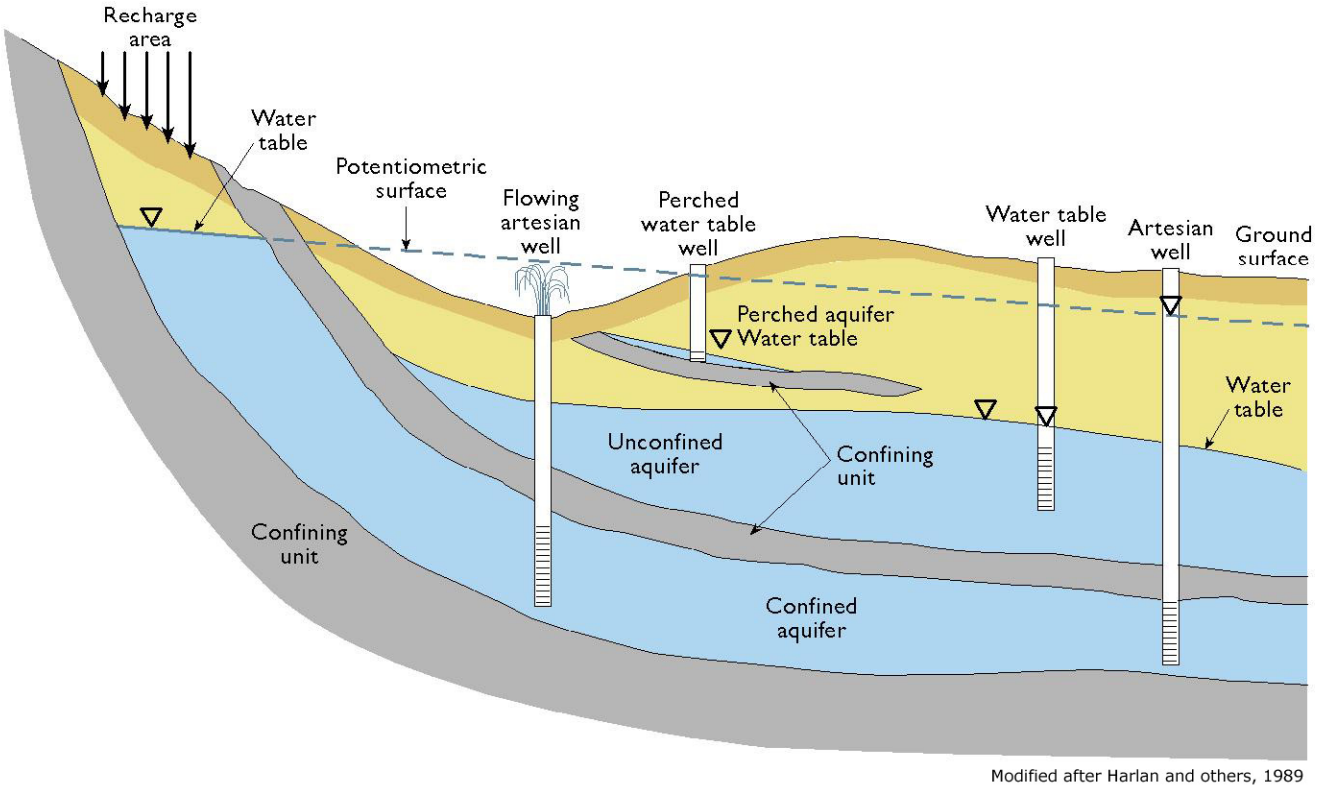
Schematic Cross-Section of Aquifer Types in Colorado



Source: Ground Water Atlas of Colorado

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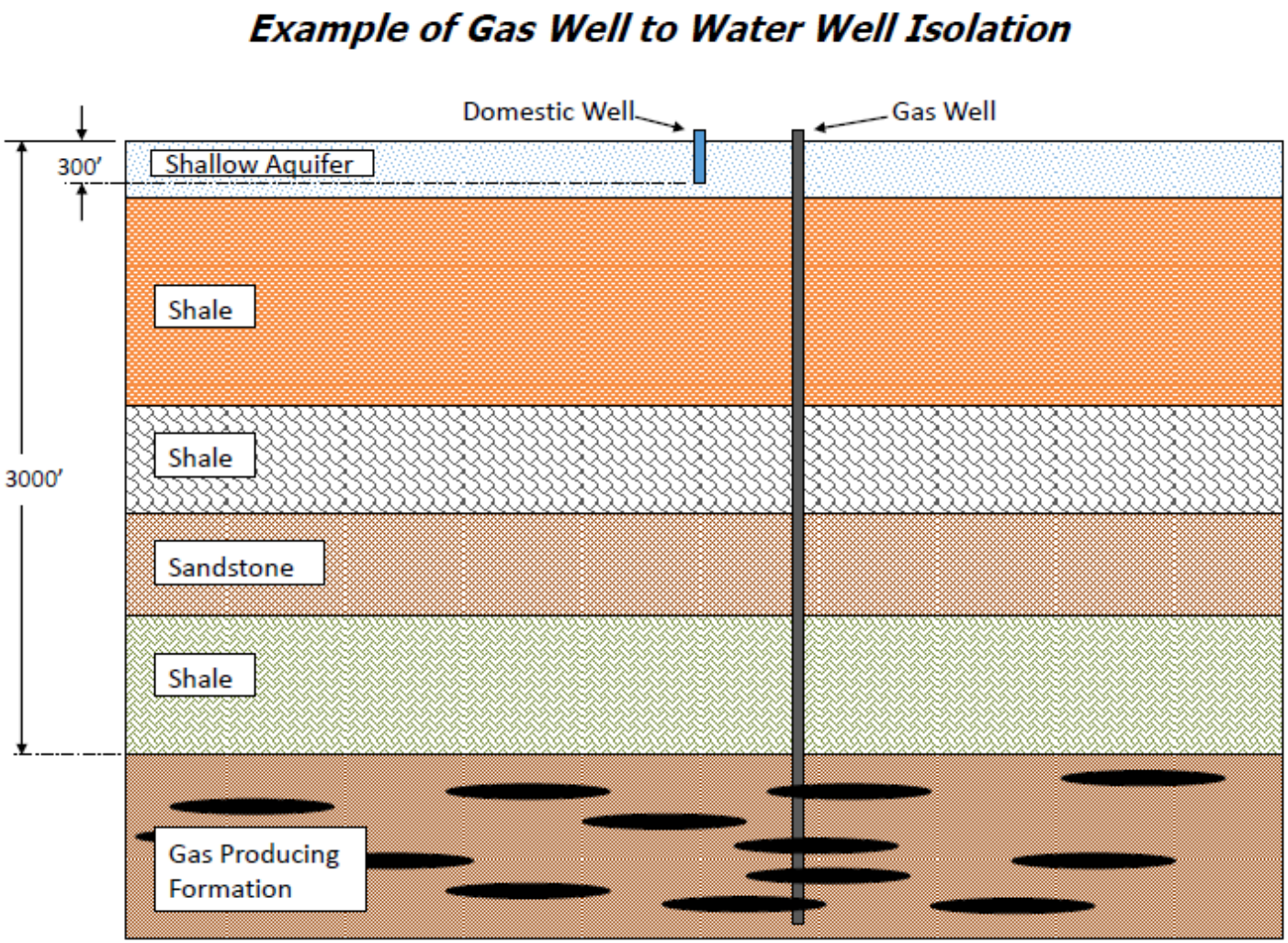
Simple model, sometimes but not always true



Source: Rein, Kevin, presentation titled Water Resources and Oil & Gas Development in Colorado, March 15, 2012.

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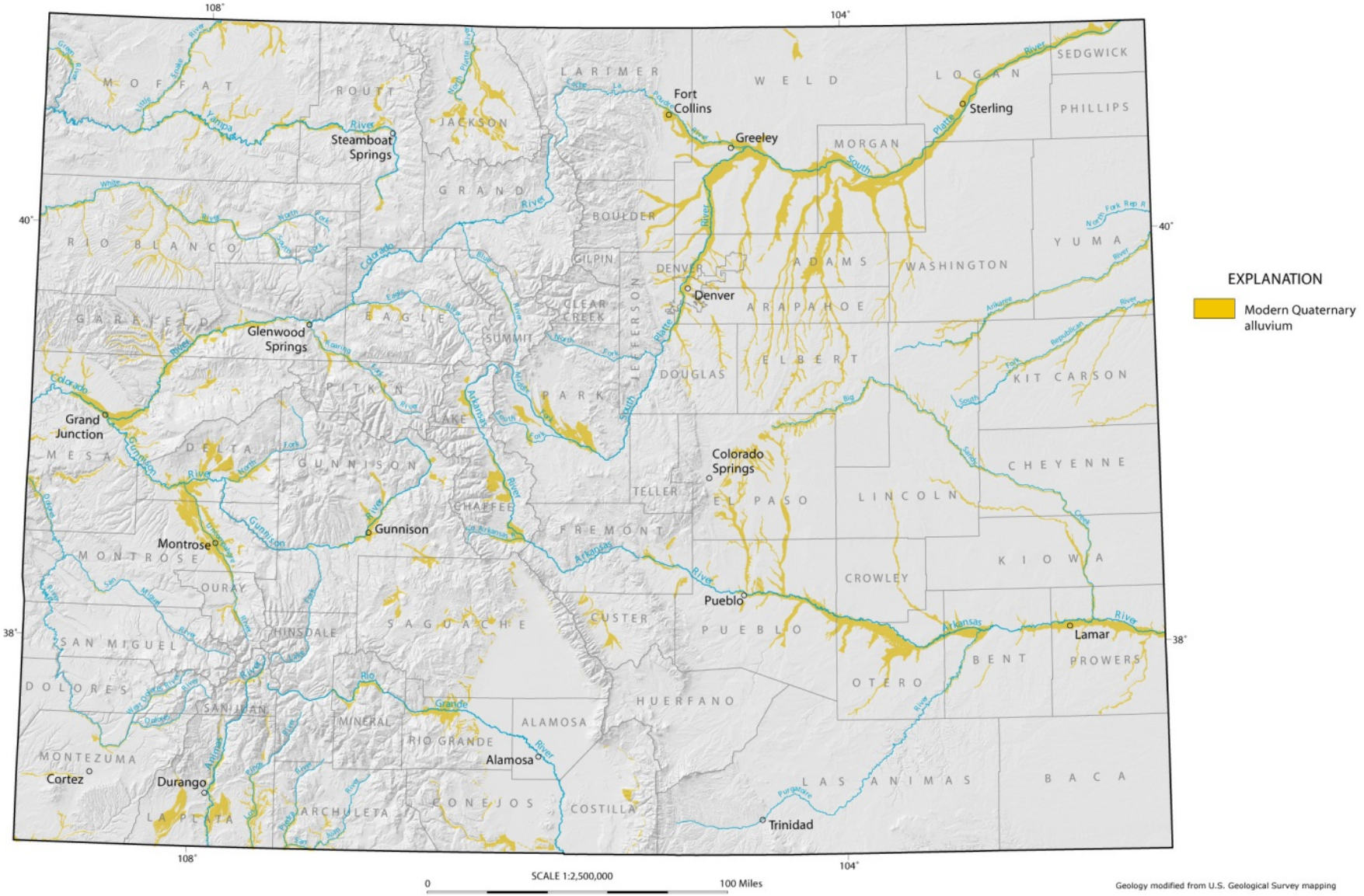

Alluvial Deposits in Colorado

Source: Ground Water Atlas of Colorado

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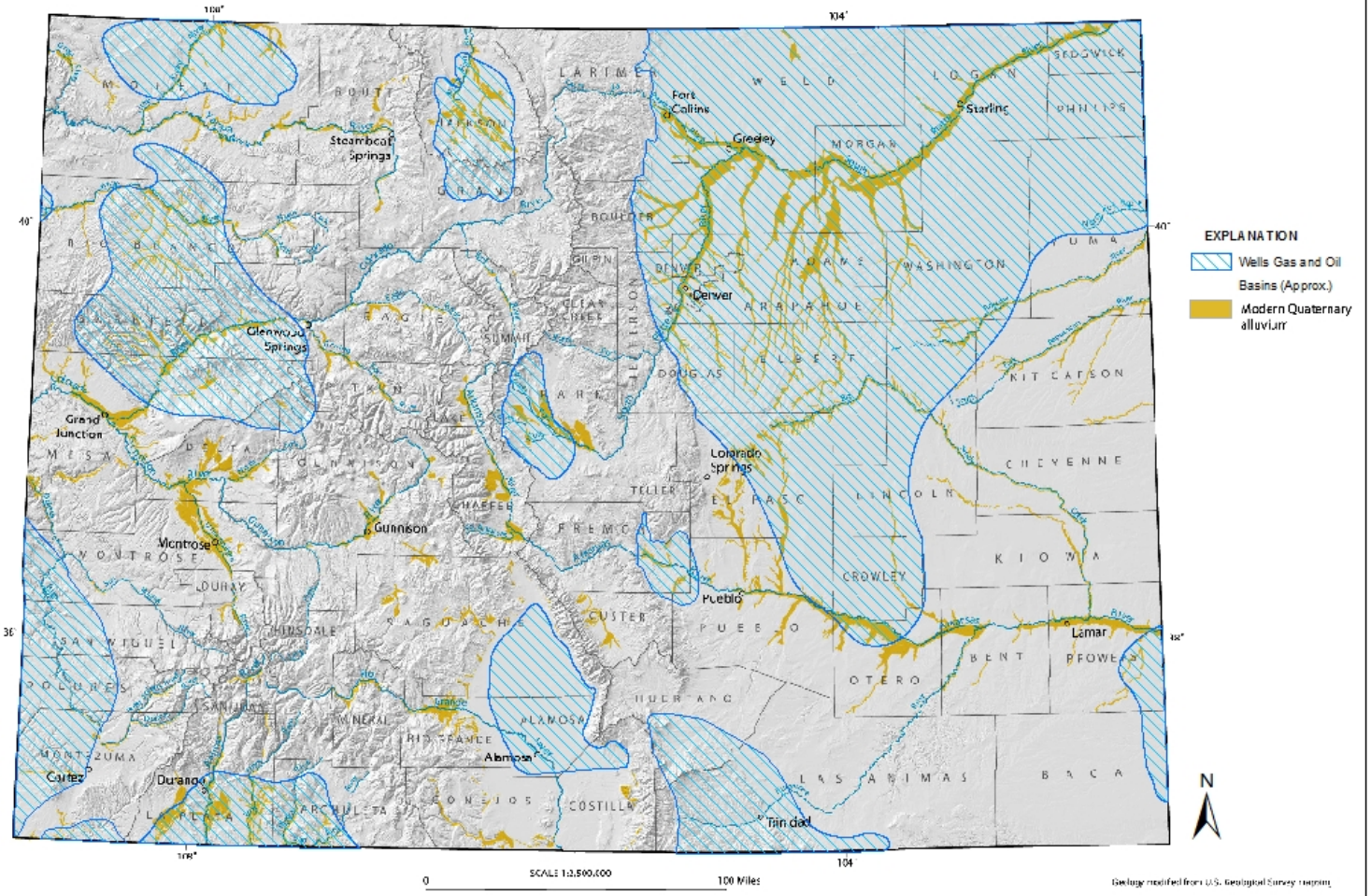

Overlay of Alluvial Deposits and Oil & Gas Basins

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Northeastern CO, Alluvial Deposits and Oil and Gas Basins

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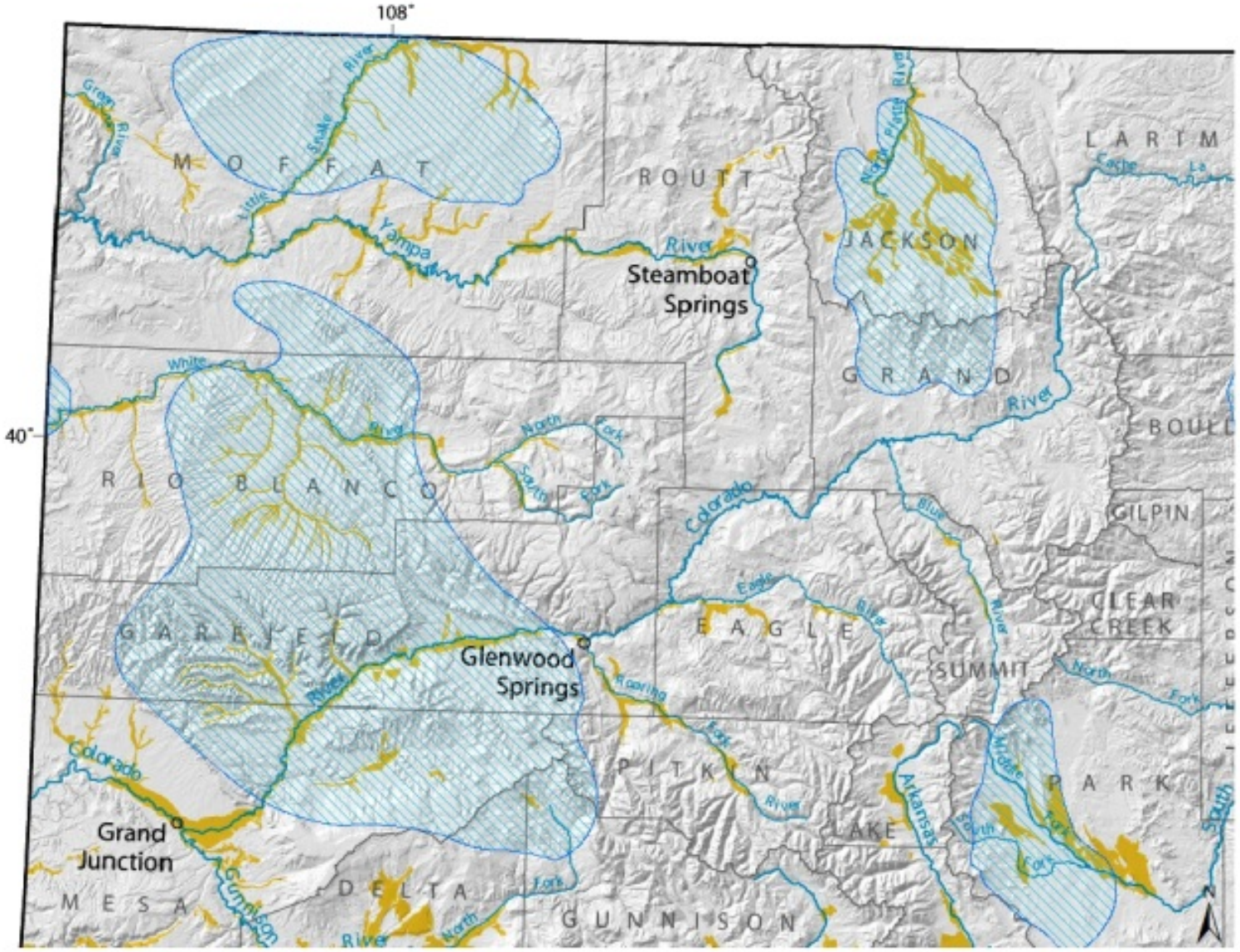

Northwestern CO, Alluvial Deposits and Oil and Gas Basins

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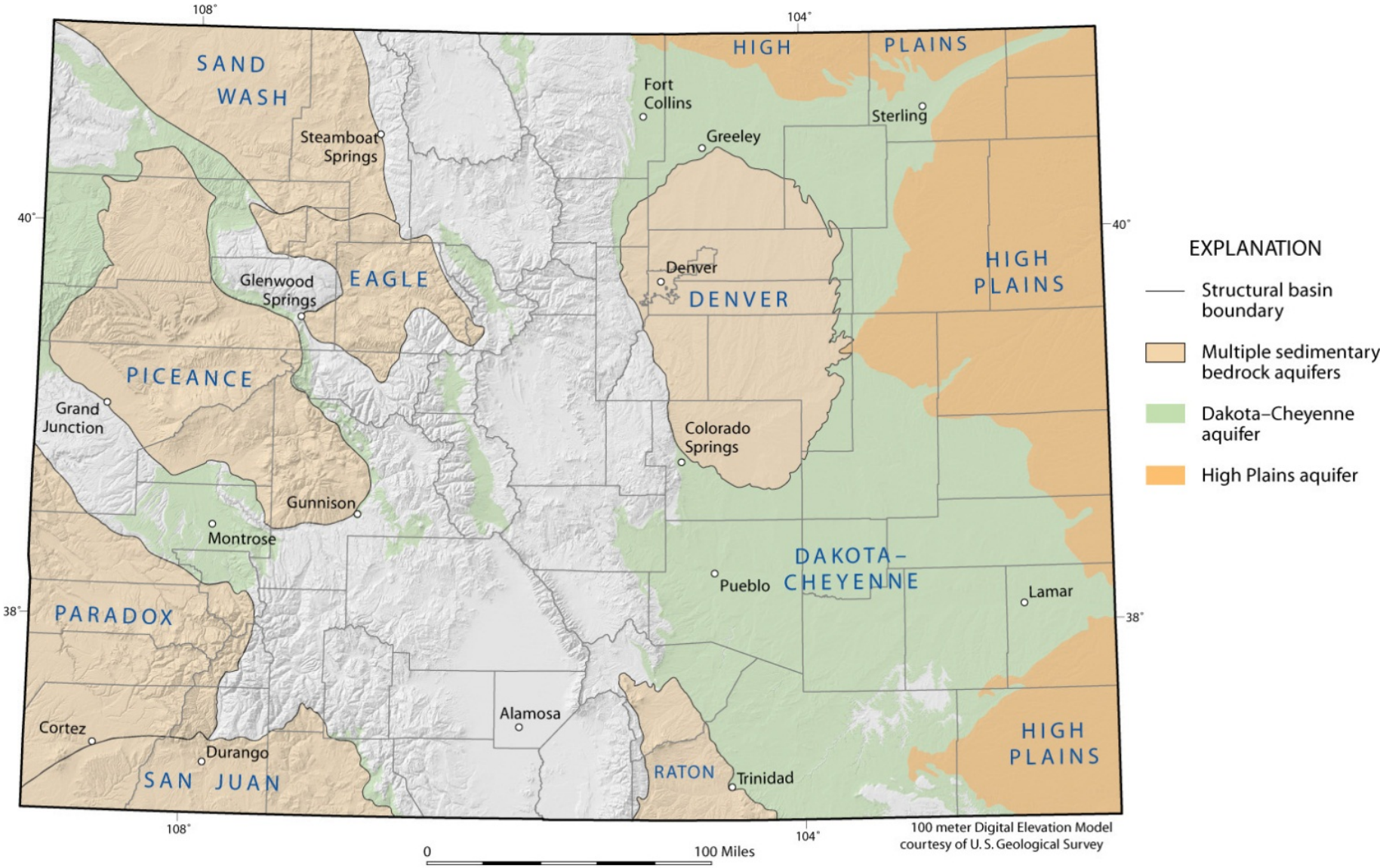

Sedimentary Bedrock Aquifer Systems in Colorado

Source: Ground Water Atlas of Colorado

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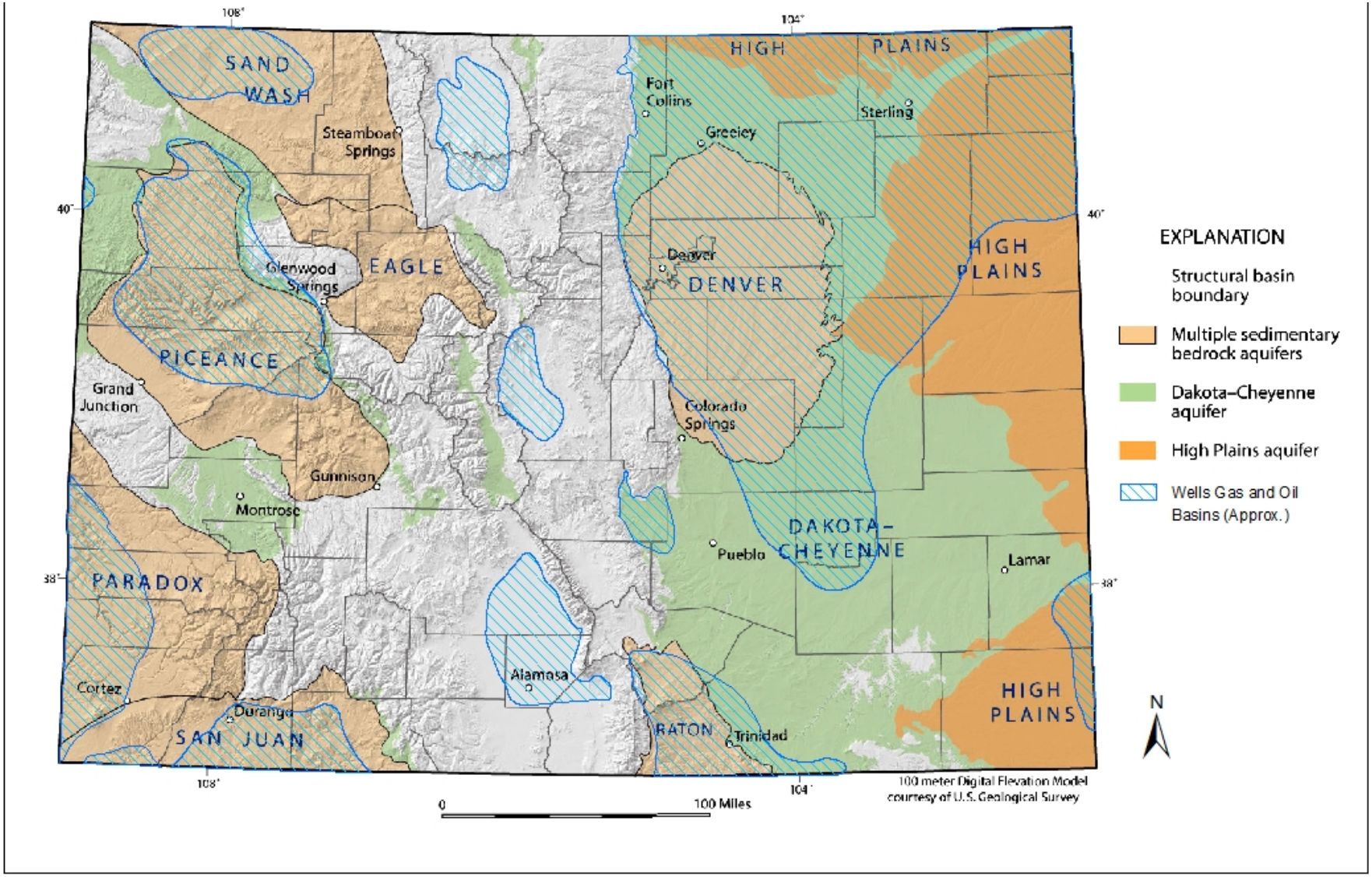

Overlay of Bedrock Aquifers and Oil and Gas Basins

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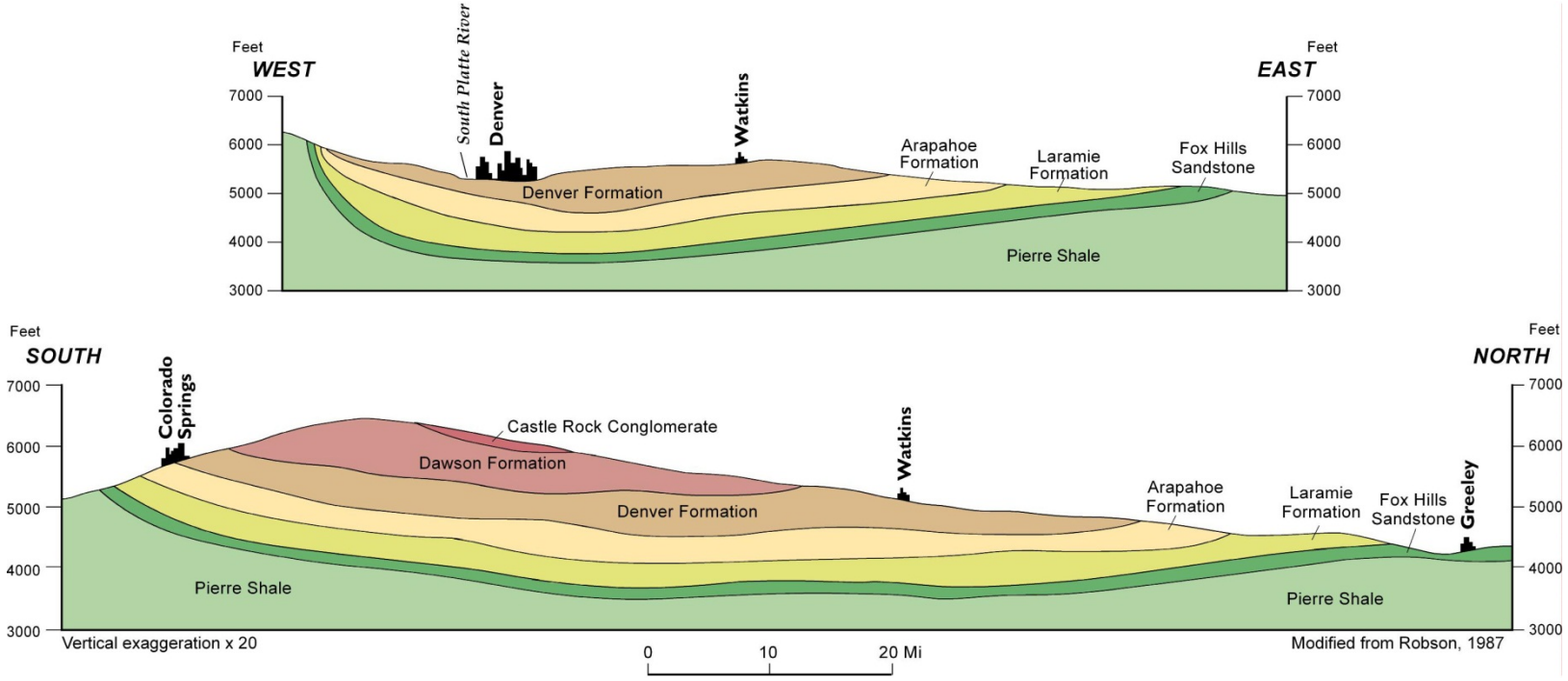
Denver Basin Example



Schematic geologic cross section of Denver Basin – Oil & Gas zones located in and below Pierre Shale

Source: Ground Water Atlas of Colorado

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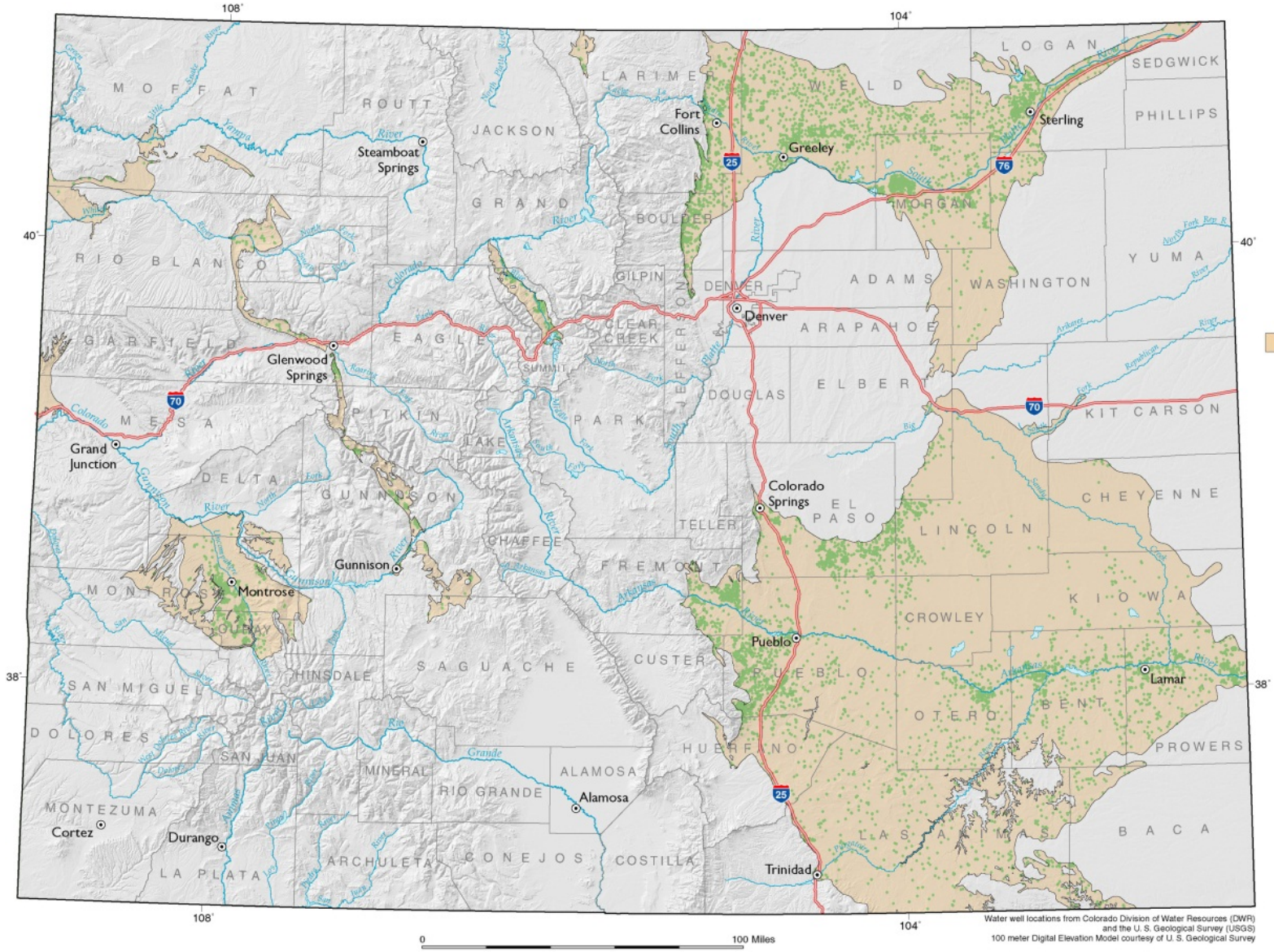

Dakota-Cheyenne Aquifer

Source: Ground Water Atlas of Colorado

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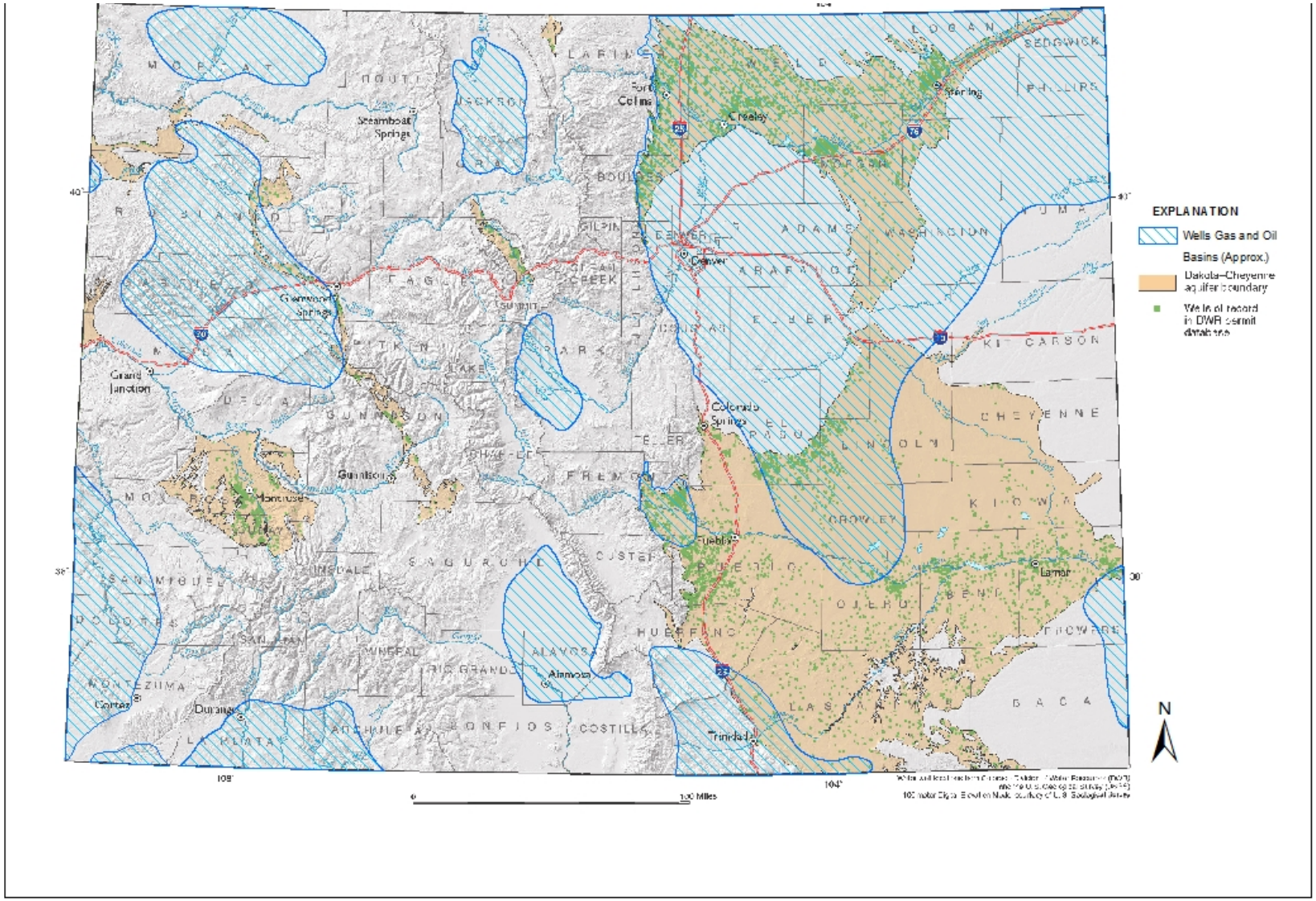

Overlay of Dakota-Cheyenne Aquifer and Oil and Gas Basins

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Era	System	Series	Stratigraphic Unit	Unit Thickness (feet)	Physical Characteristics	Hydrogeologic Unit	Saturated Thickness (feet)	Hydrologic Characteristics
Mesozoic	Cretaceous	Upper Cretaceous	Pierre Shale	0–4,000+	Black to dark-gray shale	Confining layer		Not known to yield water to wells
			Niobrara Formation	200+	Upper unit is yellowish chalk, lower unit is chalky limestone and marl	Fort Hayes Limestone	50–60	Yields water to stock wells and springs north of Arkansas River
			Carlile Shale	200+	Upper unit is sandy shale; middle unit is black, fissile shale; lower unit is chalky shale	Codell Sandstone	20+	Yields water to a few stock wells
			Greenhorn Formation	65	Upper unit is chalky shale and thin limestone; lower unit is hard, crystalline limestone	Confining layer		Yields no water to wells
			Graneros Shale	85–100	Gray to black shale	Confining layer		Yields no water to wells
		Lower Cretaceous	Dakota Sandstone	150–235	Fine-grained, thin-bedded to massive sandstone	Dakota-Cheyenne aquifer: Dakota Sandstone	150+	Yields sufficient for domestic and stock use; in some areas yields enough for municipal and industrial use
			Purgatoire Formation	60–350	Upper unit is gray to black clayey shale; lower unit is massive, fine-grained sandstone	Dakota-Cheyenne aquifer: Cheyenne Sandstone Member	30–200	Yields sufficient for industrial, municipal, and irrigation use
	Jurassic		Morrison Formation	20–240	Varicolored marl	Confining layer		Minimal yield to wells from sandstone lenses

Modified from Romero, 1994

Hydrogeologic Units in Eastern CO.
All of these units are also developed for Oil & Gas
In some locations

Source: Ground Water Atlas of Colorado

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Example Well Depths

- Wattenberg area (DJ O&G Basin, Denver Basin aquifer system)
  - Alluvial water supply wells: 80 ft
  - LFH water supply wells: 890 ft
  - O&G wells (Niobrara): 8000 ft
  - Dakota Formation (not aquifer at this location): 8400 ft

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Considerations re. Well Depths

- Locations other than eastern Colorado
  - Water supply wells vary in depth
  - O&G wells have variable depths
  - Water supply wells may be constructed in formations not typically considered to be aquifers
  - Geology and relationship between aquifers and O&G formations may be complex

Contamination Occurrences - During O&G Drilling and Fracking

- Cement seals in boreholes prevent interaction
  - Cement plugs may fail if not properly installed
- Fractures may create conduits between aquifers and O&G wells (fracked wells)
- Surface spills
- Unforeseen events
  - There are many unknowns
  - Impossible to fully understand subsurface fluid movement

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Fluid flow mechanisms

- Fluids will not migrate from oil and gas formations to aquifers unless a conduit has been created
  - New fracture
  - Well borehole
- Surface spills can contaminate aquifers
  - Spills
  - Leaky surface pits
  - Contaminants can migrate through surface streams, through aquifers, or by overland flow

Aquifer Travel Times

- Variable based on site-specific conditions
- Alluvial aquifers
  - 0.05 to 10 feet per day (18 to 3,650 ft per year)
- Bedrock aquifers
  - 0.05 to 0.5 feet per day (18 to 182 ft per year)
- Groundwater moves very slowly
  - Monitoring may need to continue for long periods to identify contaminants
- Well pumping can impact travel times

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Considerations Regarding Sampling points

- Need to define what the Rules are seeking to protect
  - Existing wells?
  - All aquifers?
  - Surface water?
- Use of existing wells only will protect just that, existing wells only
- Springs provide opportunity for groundwater discharge sample
- New wells provide opportunity to sample aquifers in which no local wells are constructed at strategic aquifer locations

Water Quality Samplings Parameters

- Parameters to be analyzed need to cover fluids introduced in borehole
- Hydrocarbon profile will help to identify O&G that may migrate from a new well
- Sampling of gas from wells is recommended if any evidence of gas in wells is present

Considerations for Rulemaking

- Contamination may occur to:
  - Shallow alluvial aquifers
  - Deeper bedrock aquifers
  - Surface water
- A single monitoring approach may not be appropriate for all situations
- Monitoring of existing wells may not be protective of all aquifer systems
- It will be cost prohibitive to construct new monitoring wells in some situations

Considerations for Rulemaking – cont.

- Contaminants may move very slowly
- Monitoring for extended time periods may be required in order to detect contaminants
- Horizontal location of O&G wells and orientation of fractures should be considered when developing monitoring strategy
- Draft rules require two samples. This may not adequately cover existing aquifers and stream systems if more than two aquifer systems and / or surface water is present.

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Considerations for Rulemaking – cont.

- Monitoring program is protective for property / well owners as well as O&G operators
- Statewide consistent approach helps to streamline process and establish expectations
- Need flexibility to adjust requirements based on site-specific conditions
  - Single approach will not match all situations

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Questions / Discussion

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