Promising Hydrogeologic Settings in Colorado

A geologist's Perspective

Subsurface Water Storage Symposium 2024

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COLORADO SCHOOL OF MINES

CGS Background

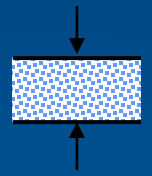
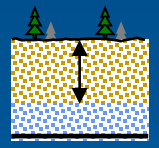
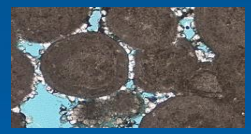
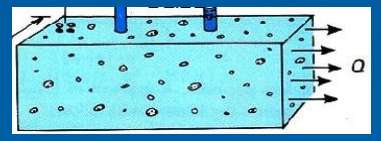
- 2003-Ground Water Atlas of Colorado, SP -53, Topper and others
- 2004-Artificial Recharge of Ground Water in Colorado, EG-13, Topper and others
- 2008-Upper Black Squirrel Creek Basin Aquifer Recharge and Storage Evaluation, OF-08-04, Topper
- 2011-Lost Creek Basin Aquifer Recharge and Storage Study, OF-11-05, Watterson and Topper
- 2020-ASCE Standard Guidelines for Managed Aquifer Recharge, (ASCE 69-19)
- 2020-Colorado Groundwater Atlas (online), ON-010, Barkmann and others
- Aquifer Mapping (ongoing): 2021 Colorado Statewide Alluvial Aquifer, Lindsey and others, ON-010-02D: Dakota Aquifer (in publication)

2004 Statewide Assessment

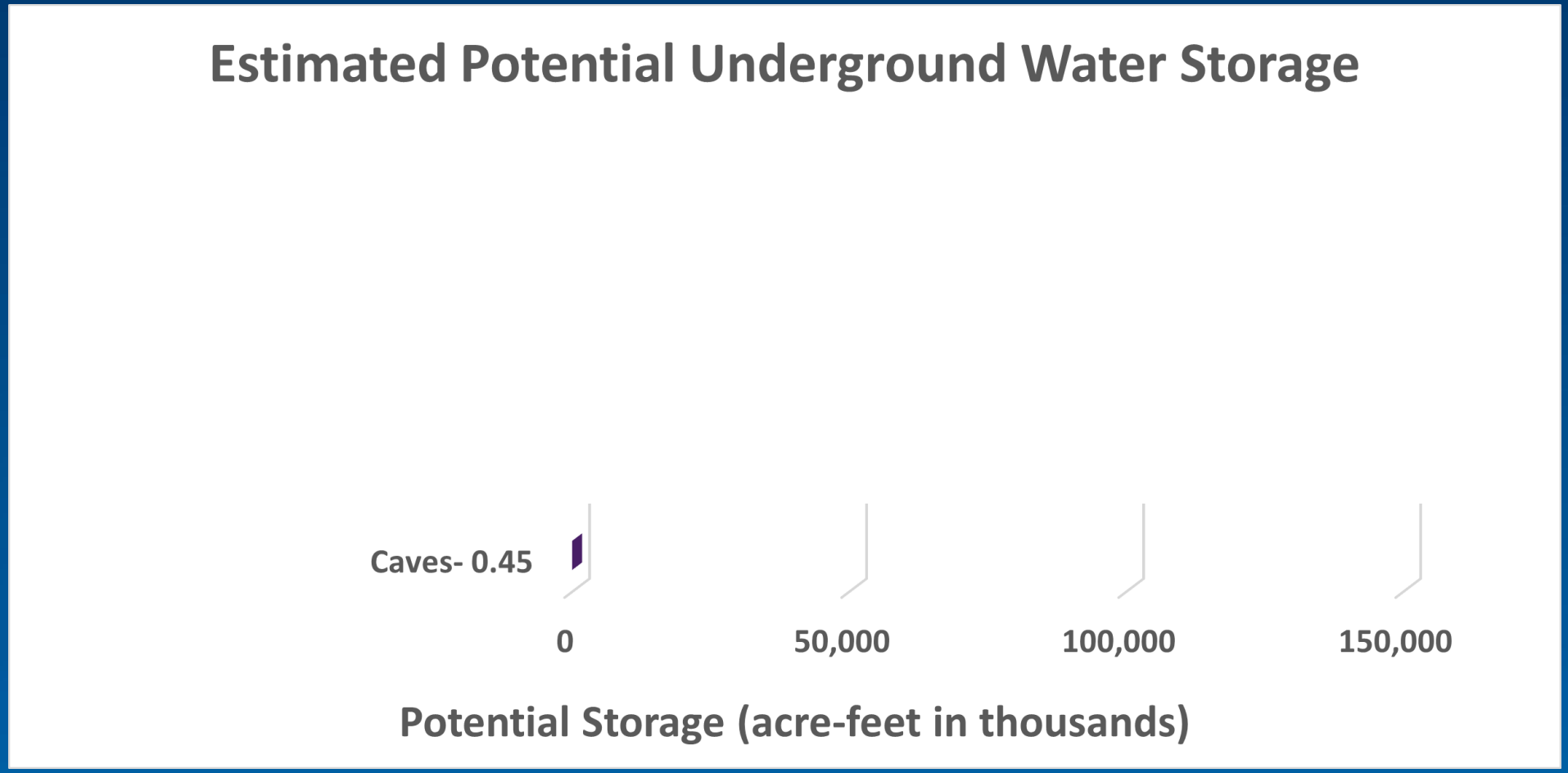
- **Unconsolidated aquifers *(alluvium)***
- **Consolidated bedrock *(sedimentary formations)***
- **Unconventional**
  - ***Caves***
  - ***Coal mines***
  - ***Metal mines***

Aquifer Storage Potential

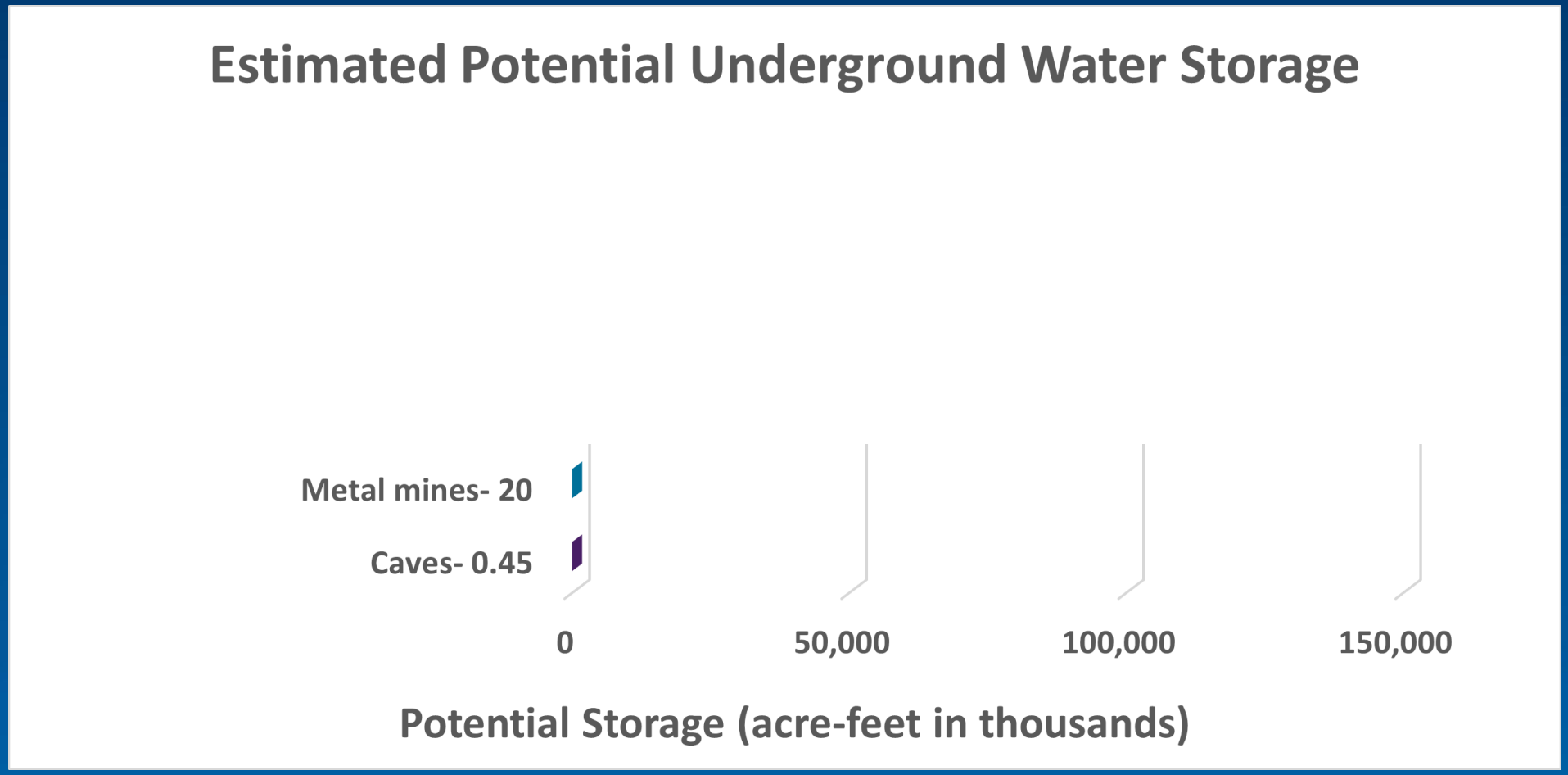
Based on Aquifer Properties:

- ***Areal extent***
- ***Depth***
- ***Saturated thickness*** 
- ***Head freeboard*** 
- ***Storage coefficient*** 
- ***Hydraulic conductivity*** 

Aquifer Storage Potential



Aquifer Storage Potential



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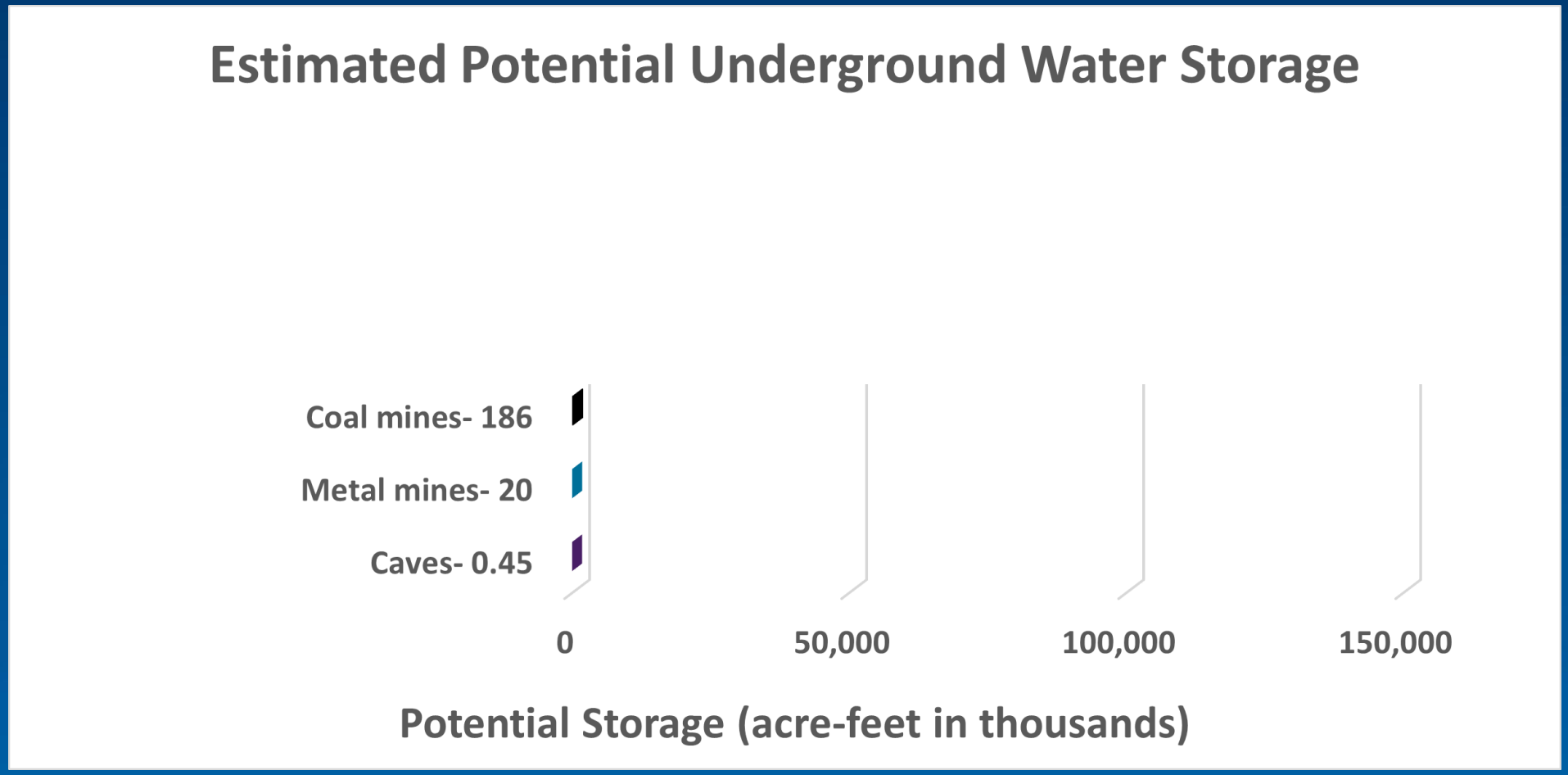
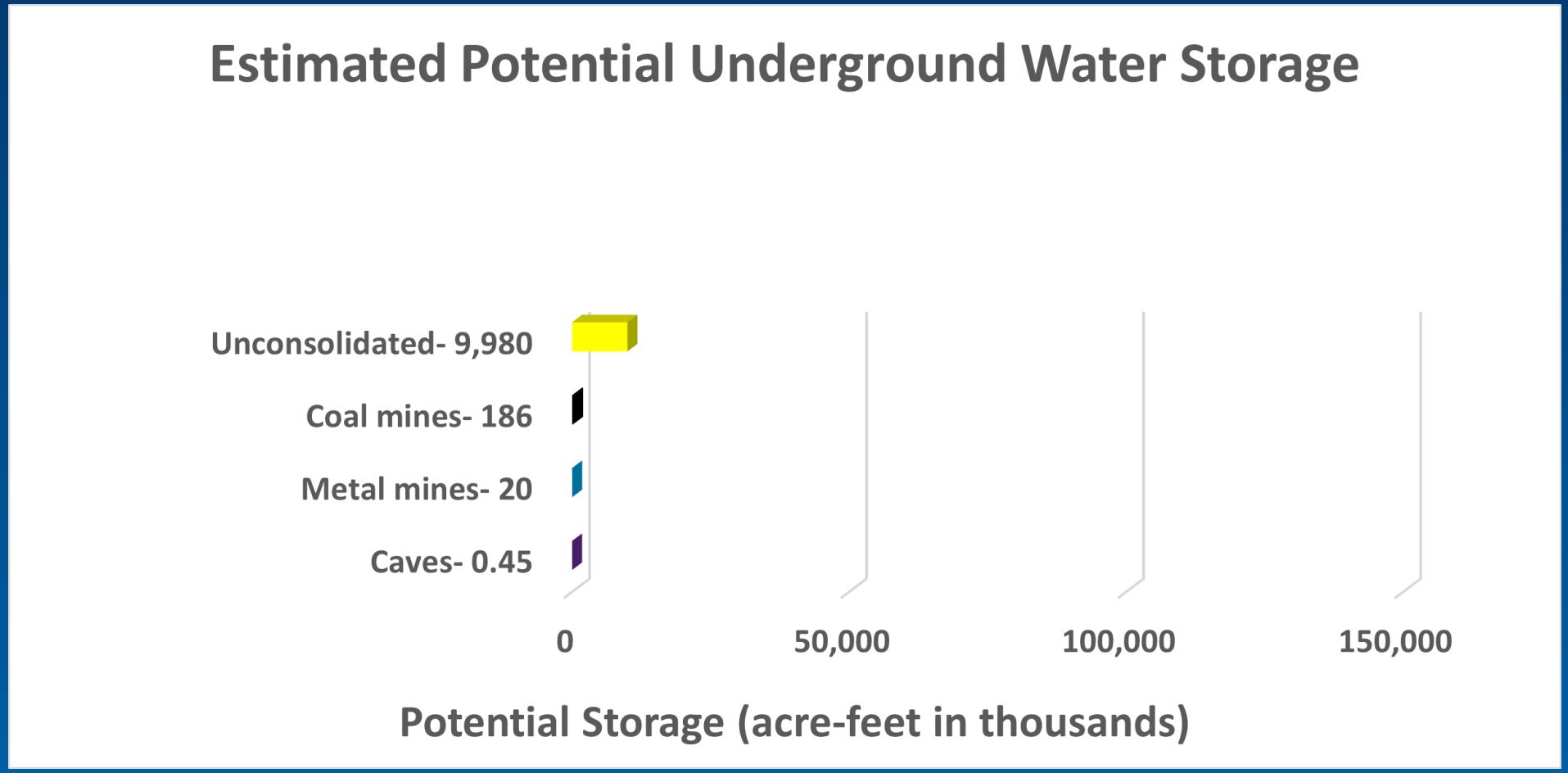


Aquifer Storage Potential



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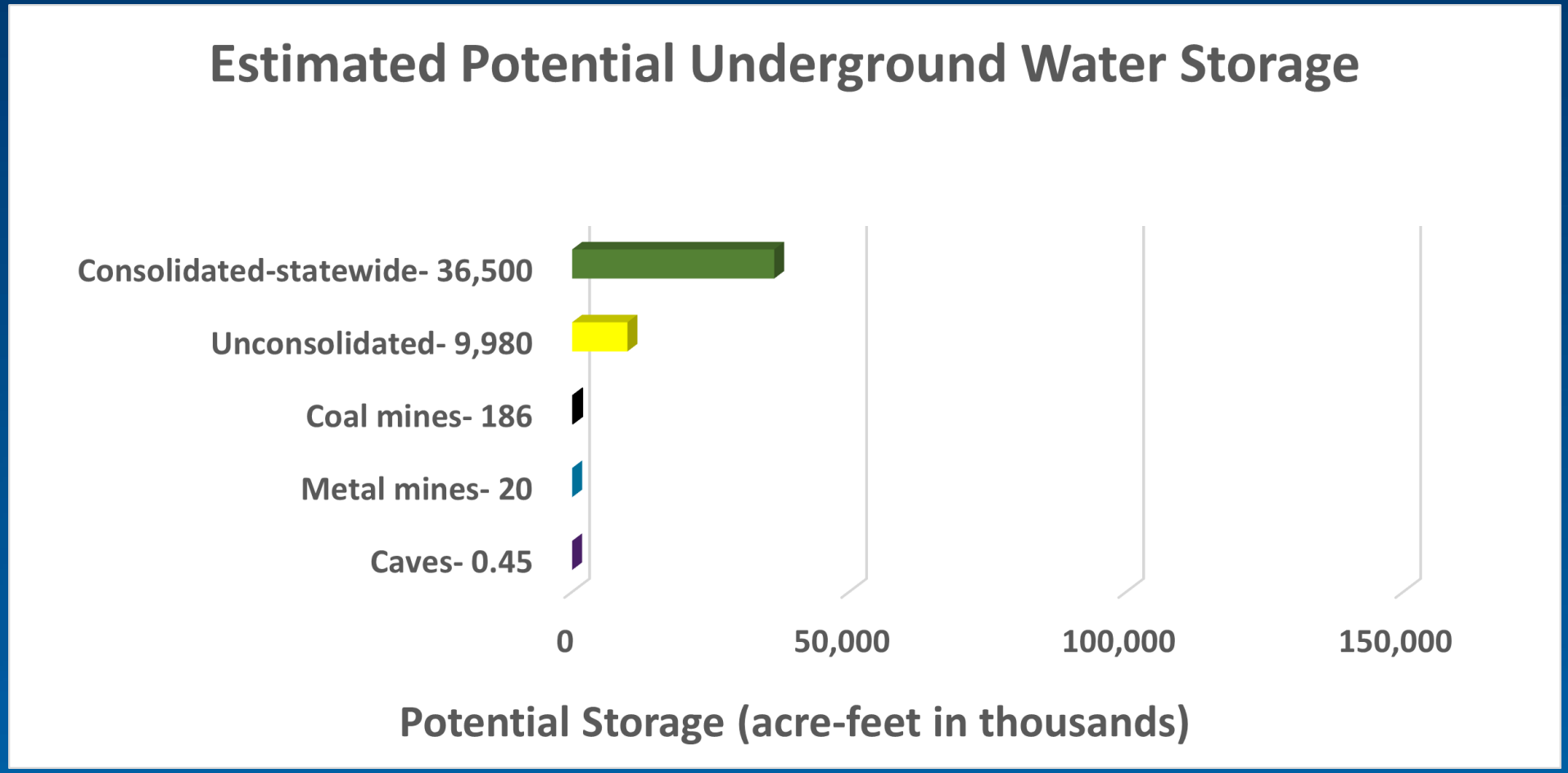

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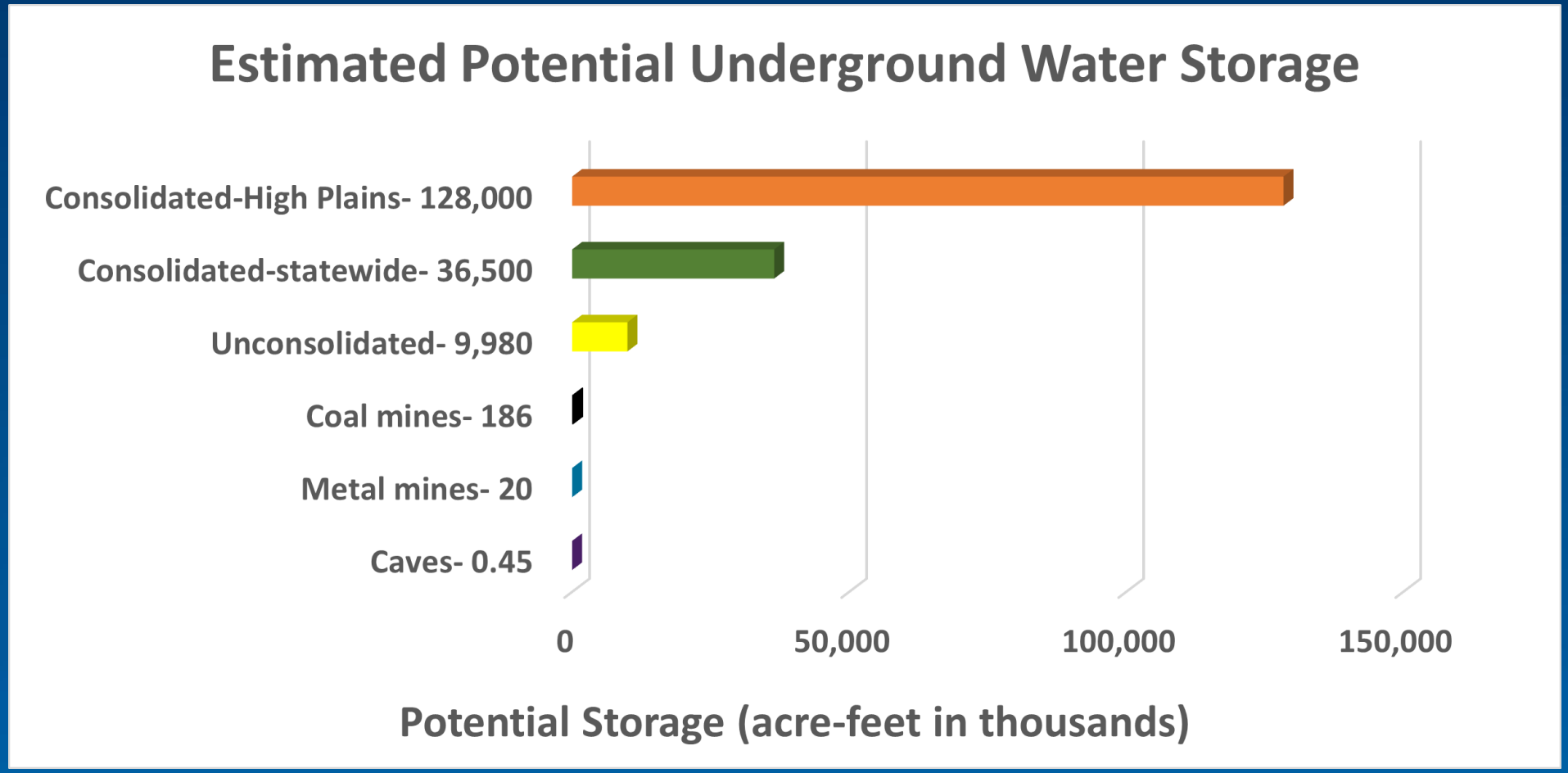
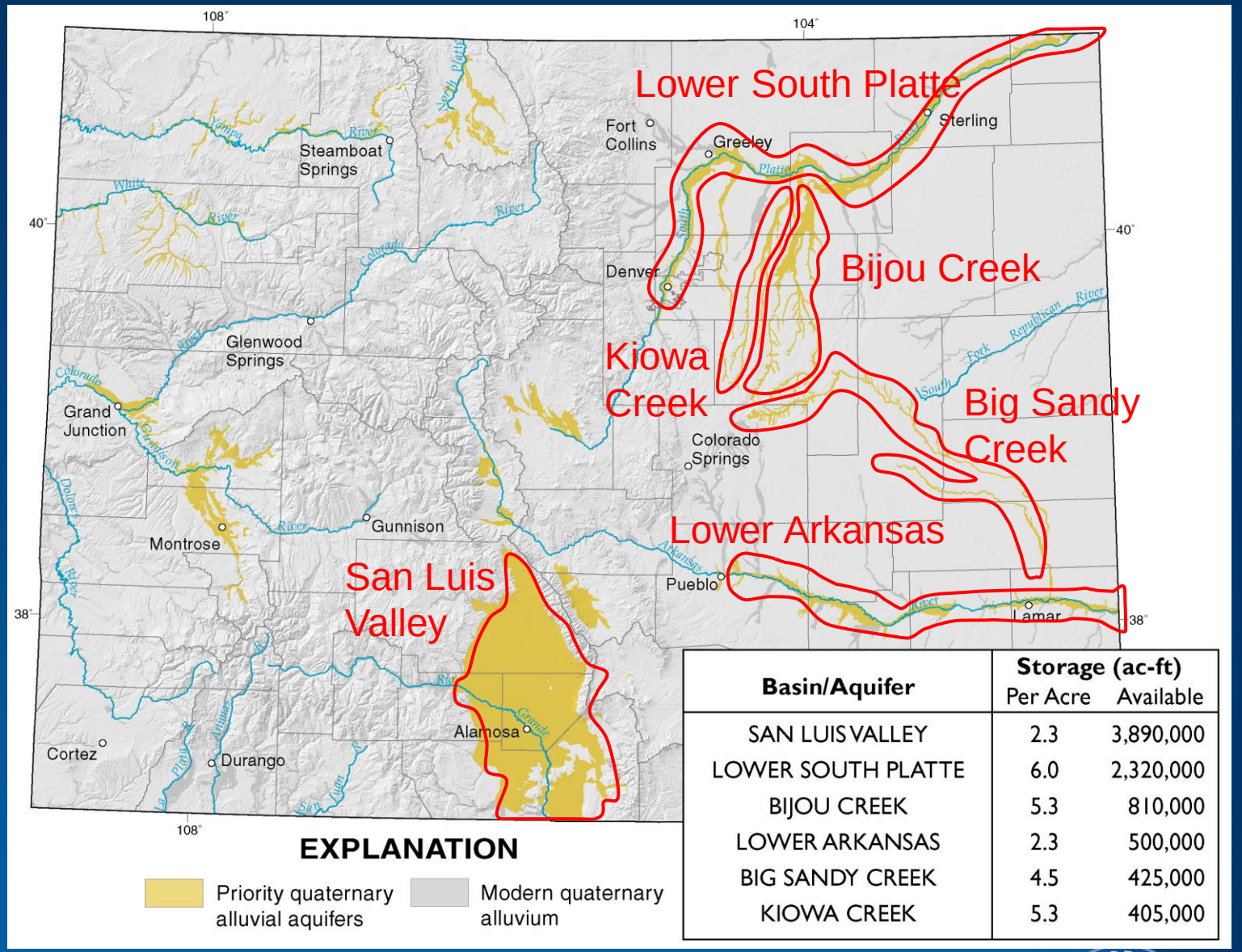


Unconsolidated Aquifers-Alluvium Top Candidates



Basin/Aquifer	Storage (ac-ft) Per Acre	Available
SAN LUIS VALLEY	2.3	3,890,000
LOWER SOUTH PLATTE	6.0	2,320,000
BIJOU CREEK	5.3	810,000
LOWER ARKANSAS	2.3	500,000
BIG SANDY CREEK	4.5	425,000
KIOWA CREEK	5.3	405,000

Unconsolidated Aquifers-Alluvium

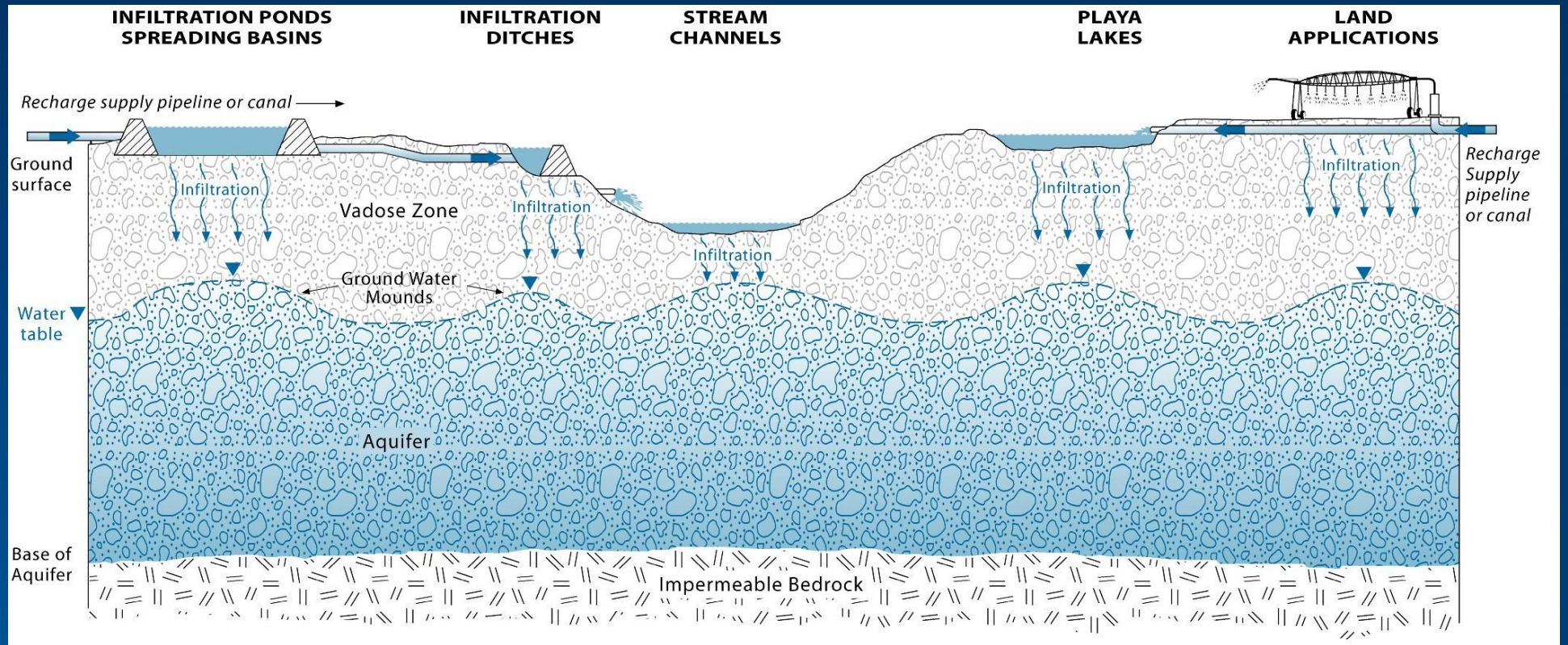
Pro's:

- ***Located along all state's major rivers***
- ***Close to source and need***
- ***Large storage coefficient & high yield***
- ***Shallow, amenable to multiple recharge techniques***

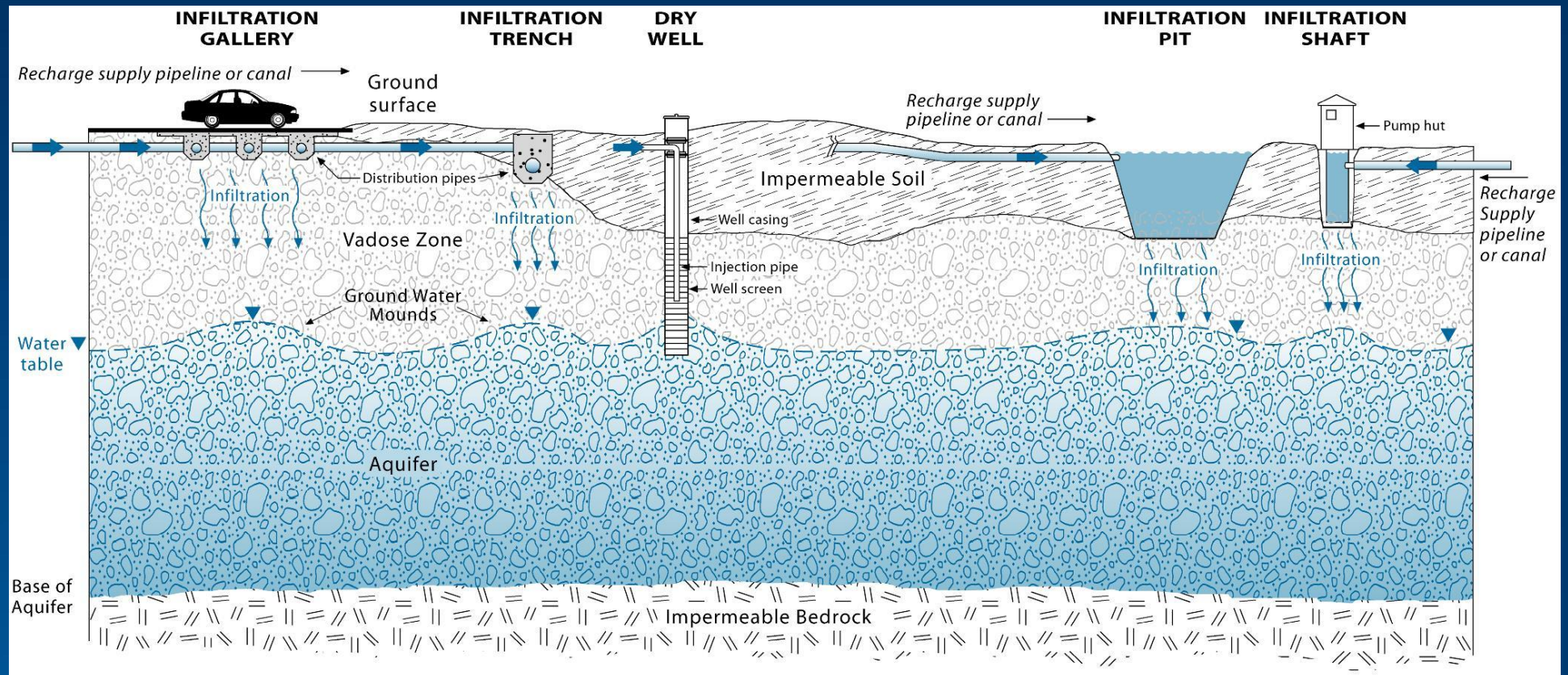
Con's:

- ***Limited areal extent***
- ***Shorter retention times***
- ***Tributary to surface water***

"Simple" Recharge System Options



- Surface ownership
- Shallow water table
- Compatible land-use
- Favorable subsurface hydrogeology

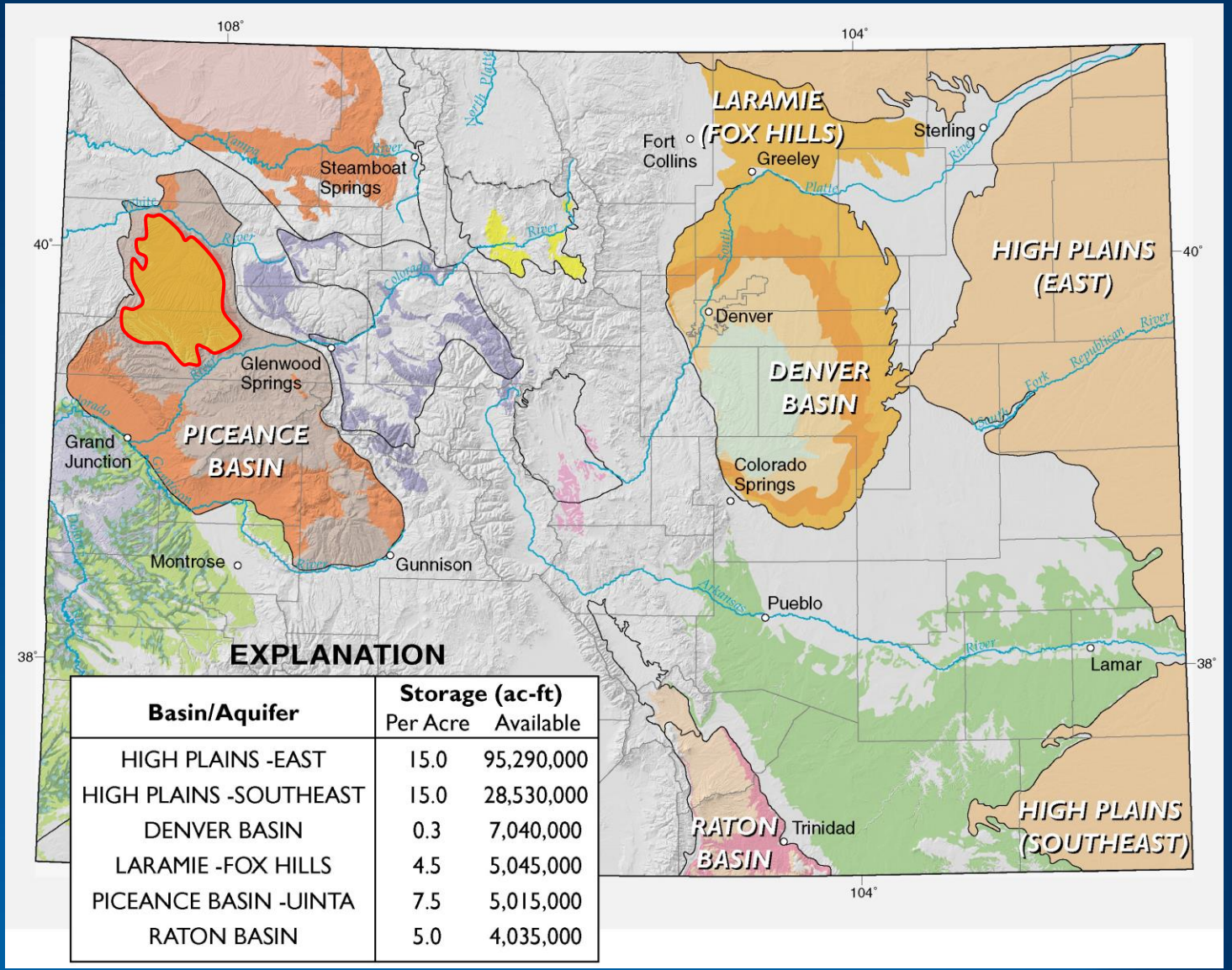


- Smaller parcel ownership • Conflicting land-use
- Relatively shallow water table • Unfavorable near-surface hydrogeology

Consolidated Aquifers

Sandstone bedrock

Top Candidates



Basin/Aquifer	Storage (ac-ft) Per Acre	Available
HIGH PLAINS -EAST	15.0	95,290,000
HIGH PLAINS -SOUTHEAST	15.0	28,530,000
DENVER BASIN	0.3	7,040,000
LARAMIE -FOX HILLS	4.5	5,045,000
PICEANCE BASIN -UINTA	7.5	5,015,000
RATON BASIN	5.0	4,035,000

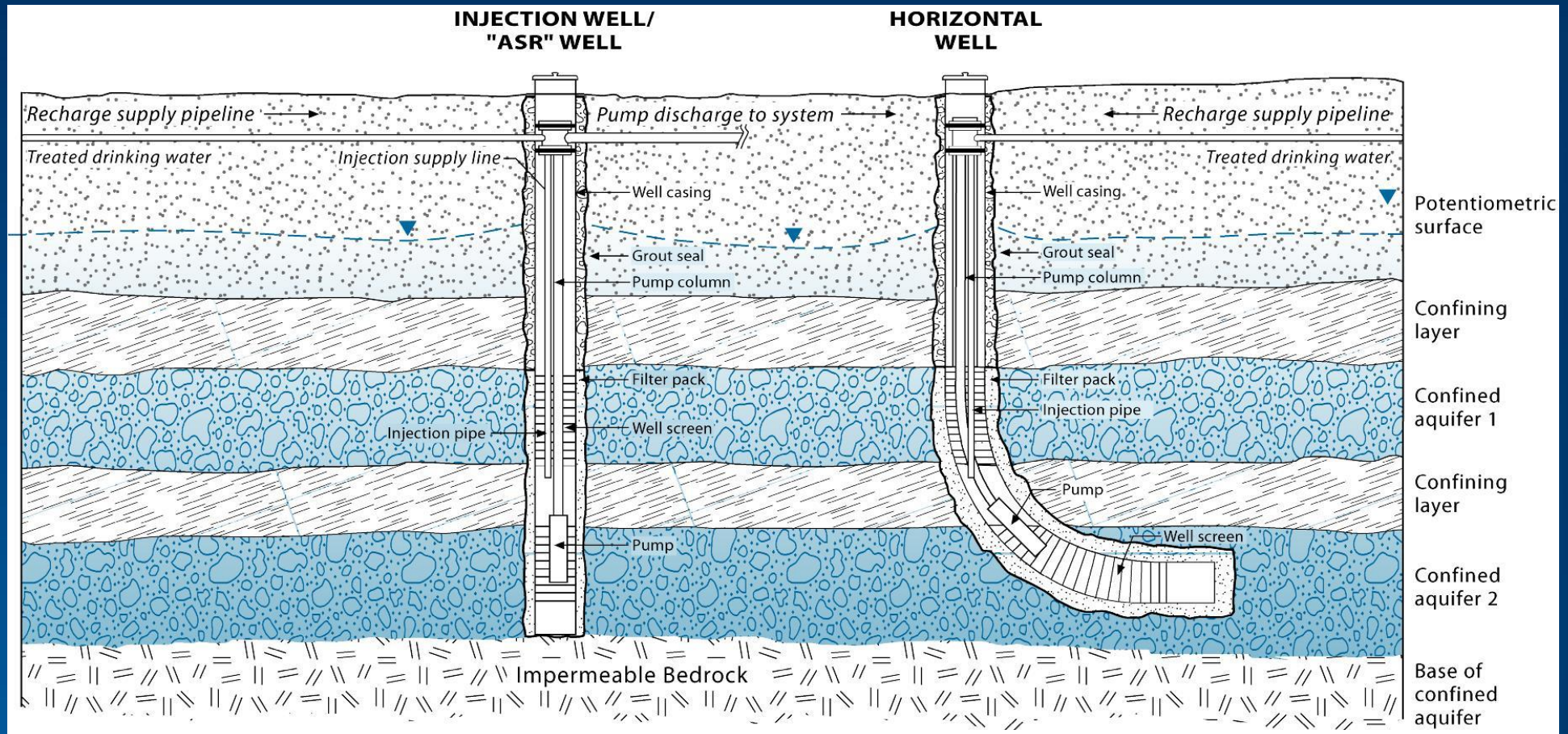
Consolidated Aquifers–Sandstone bedrock

Pro's:

- ***Located throughout the state***
- ***Large areal extent and available head freeboard***
- ***Can be non-tributary***
- ***Good for long-term storage***

Con's:

- ***Deep - often confined***
- ***Small storage coefficient and lower yield***
- ***Recharge technique application limited***
- ***May require significant infrastructure***



- Water is typically “injected” by gravity feed and controlled by down-hole valves
- Applicable to deep confined or unconfined bedrock aquifers

The Geologist's Perspective–

The devil is in the details

What Can Get in the Way-

(of successful underground water storage)

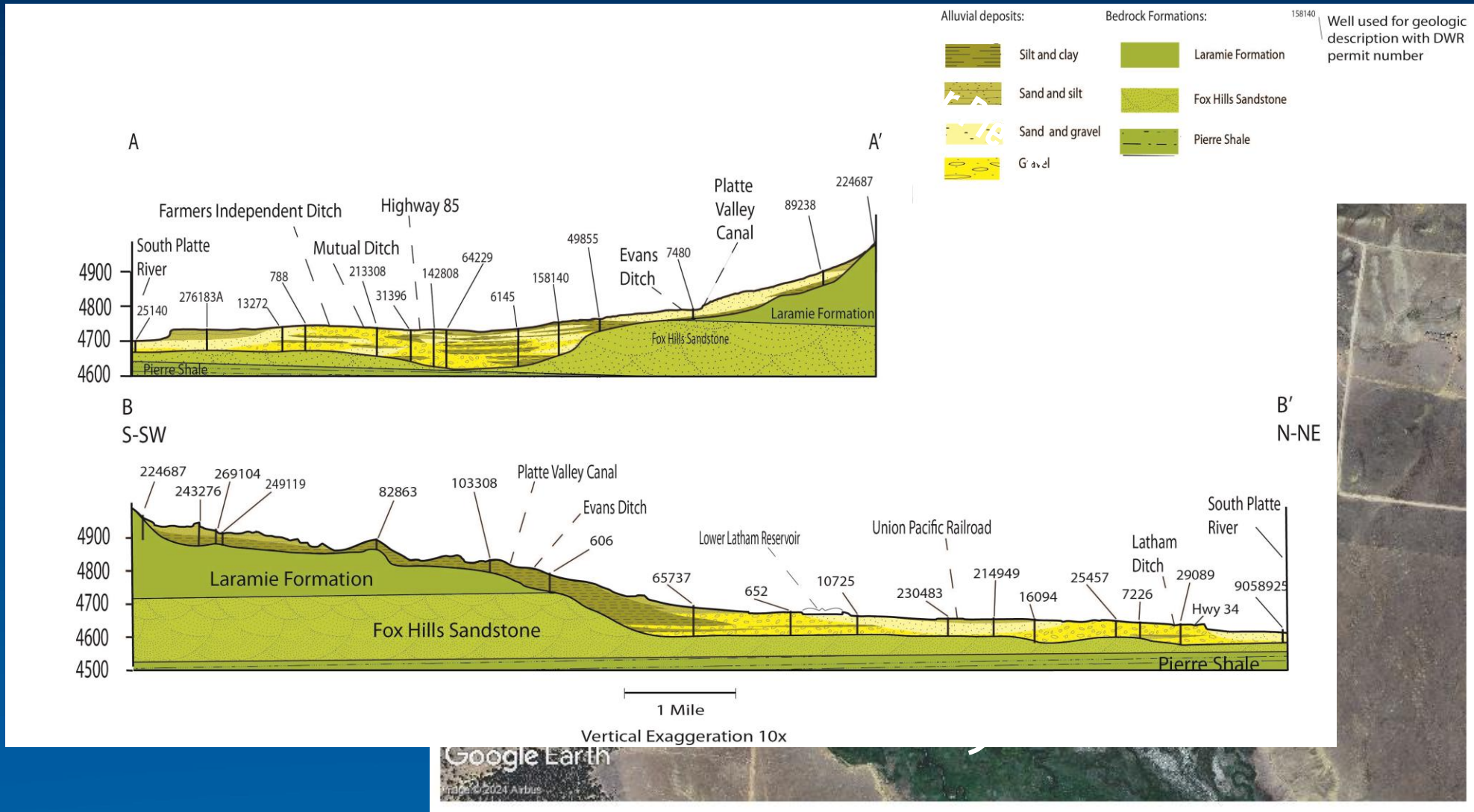
Alluvium is not always ideal (uniform and homogenous)

Unconsolidated Aquifer – Heterogeneity

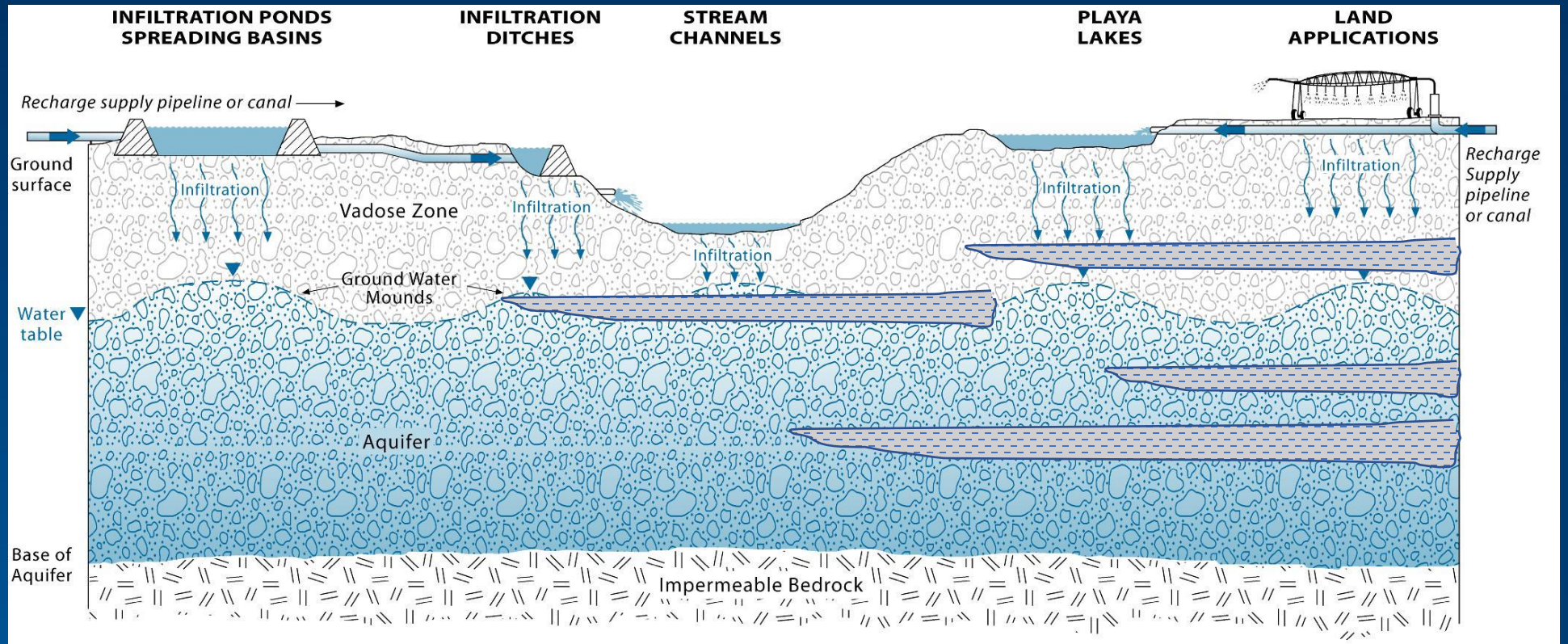
Clay layers

- *Overbank deposits*
- *Shale dominant tributaries can lead to "mud fans"*

What are "mud fans"?



Potential Impact

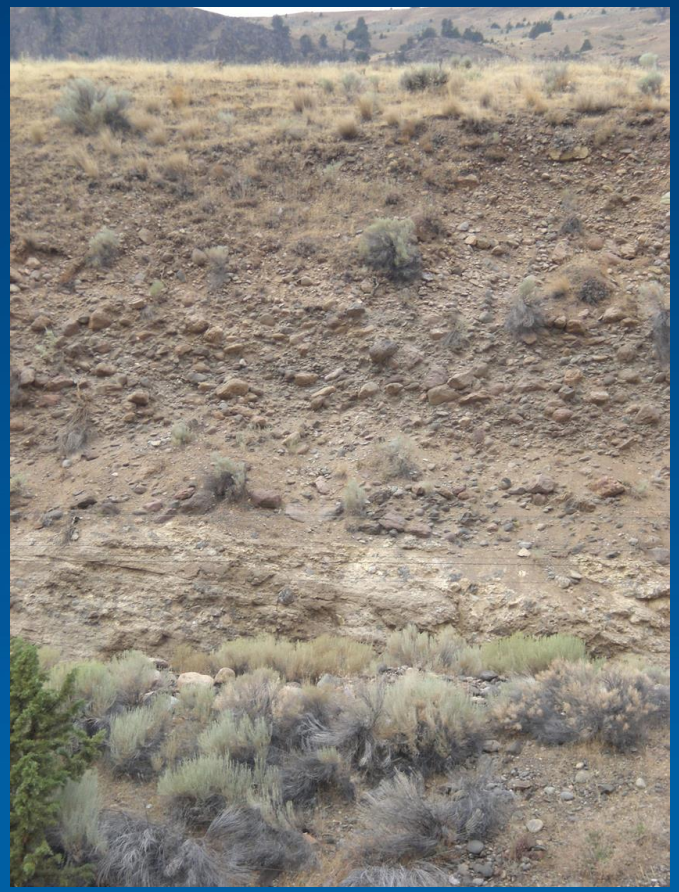


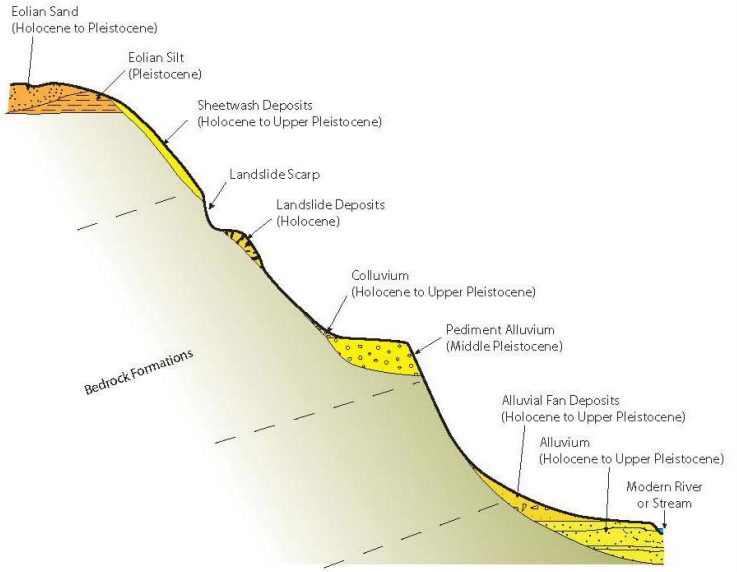
Clay-dominant layers, some discontinuous, some widespread, impact water flow characteristics.

Unconsolidated Aquifer – Geochronology
Understanding terrace sequences

- *"Strath" terraces*

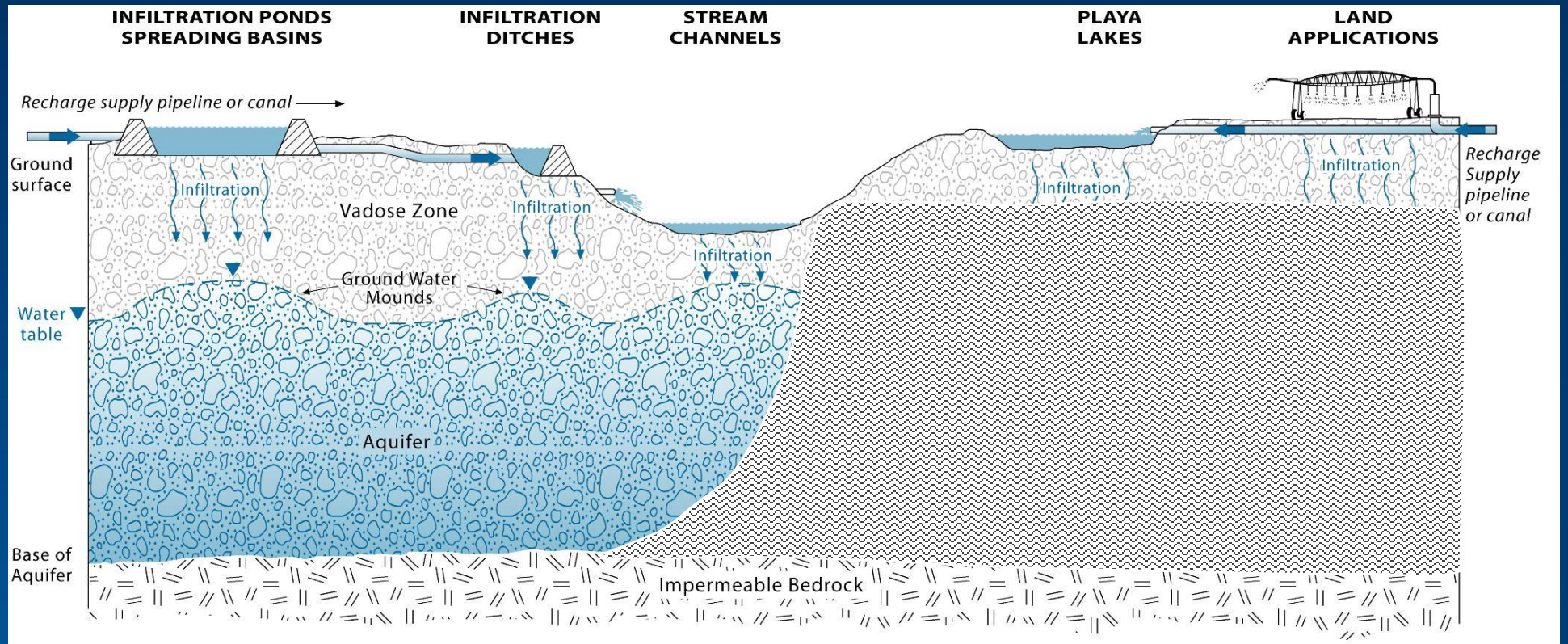
Older terraces are typically higher in the landscape, disconnected from stream system





Period	Epoch	Age	Beginning (million years)
Quaternary	Holocene		0.012
	Pleistocene	Upper	0.13
		Middle	0.78
		lower	2.6

Potential Impact



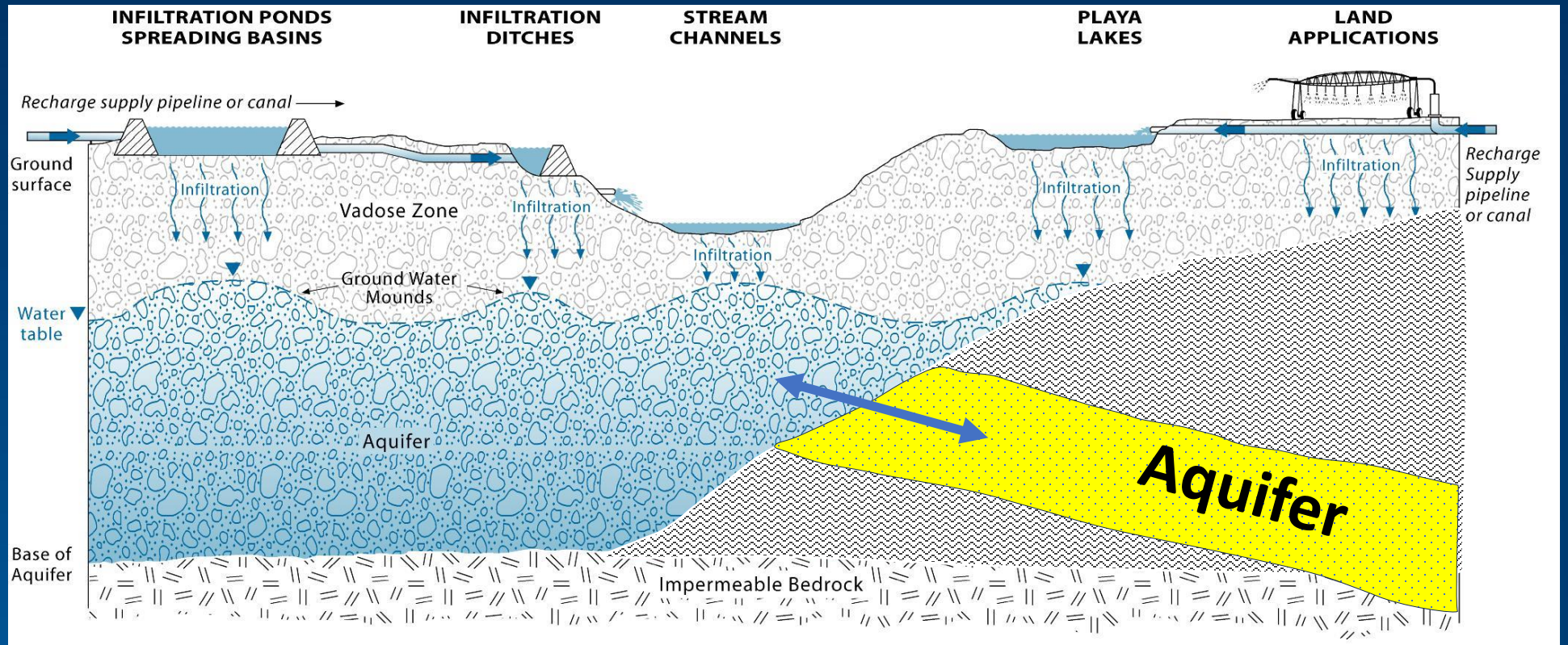
Mapped alluvium may not be hydraulically connected with the active stream system

Unconsolidated Aquifer – Local Bedrock

Local Tributary Watersheds and Subcrop Patterns

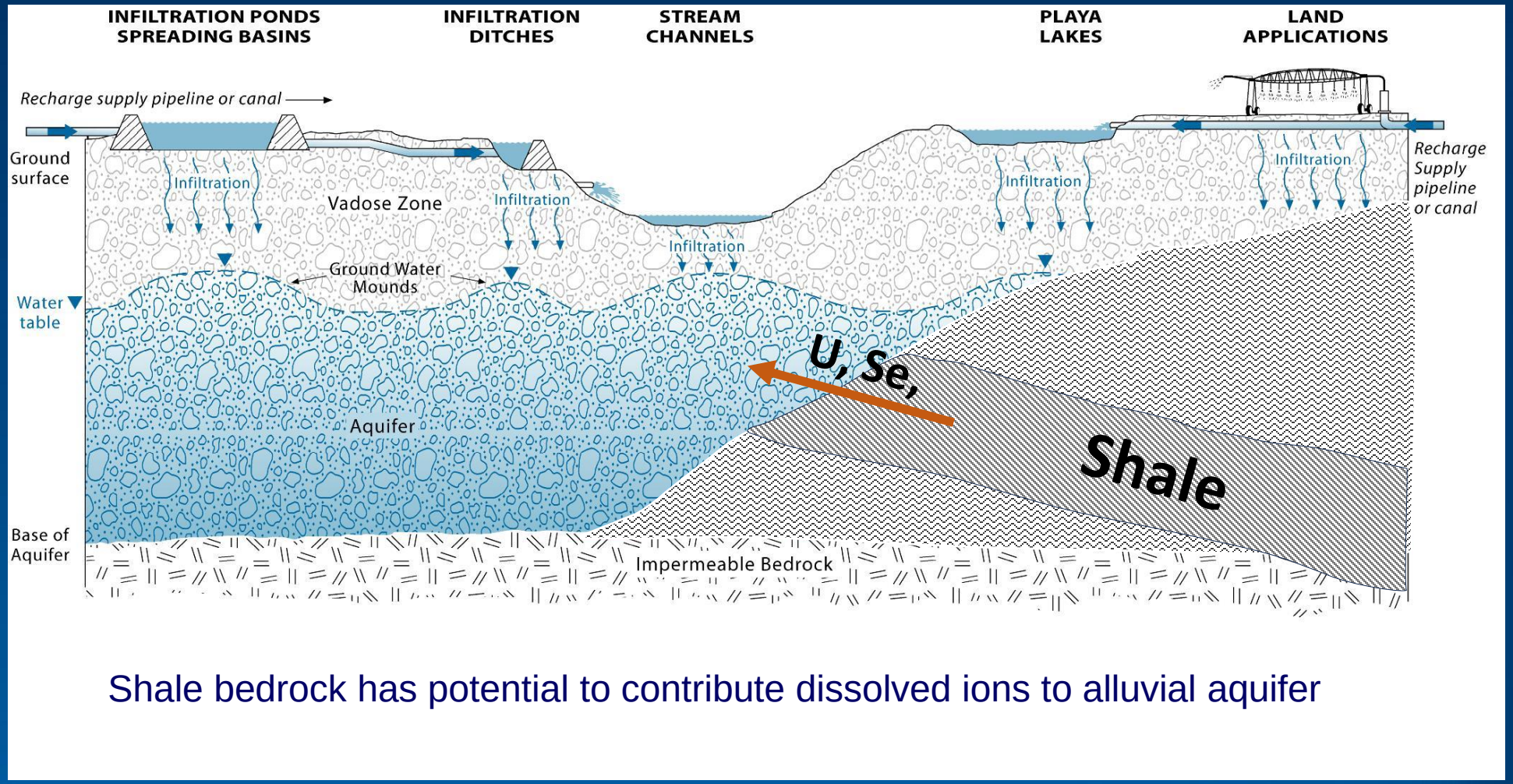
- *Bedrock aquifers*
- *Shale formations and water quality (uranium, selenium)*
- *Evaporite deposits (salt, gypsum)*

Potential Impact



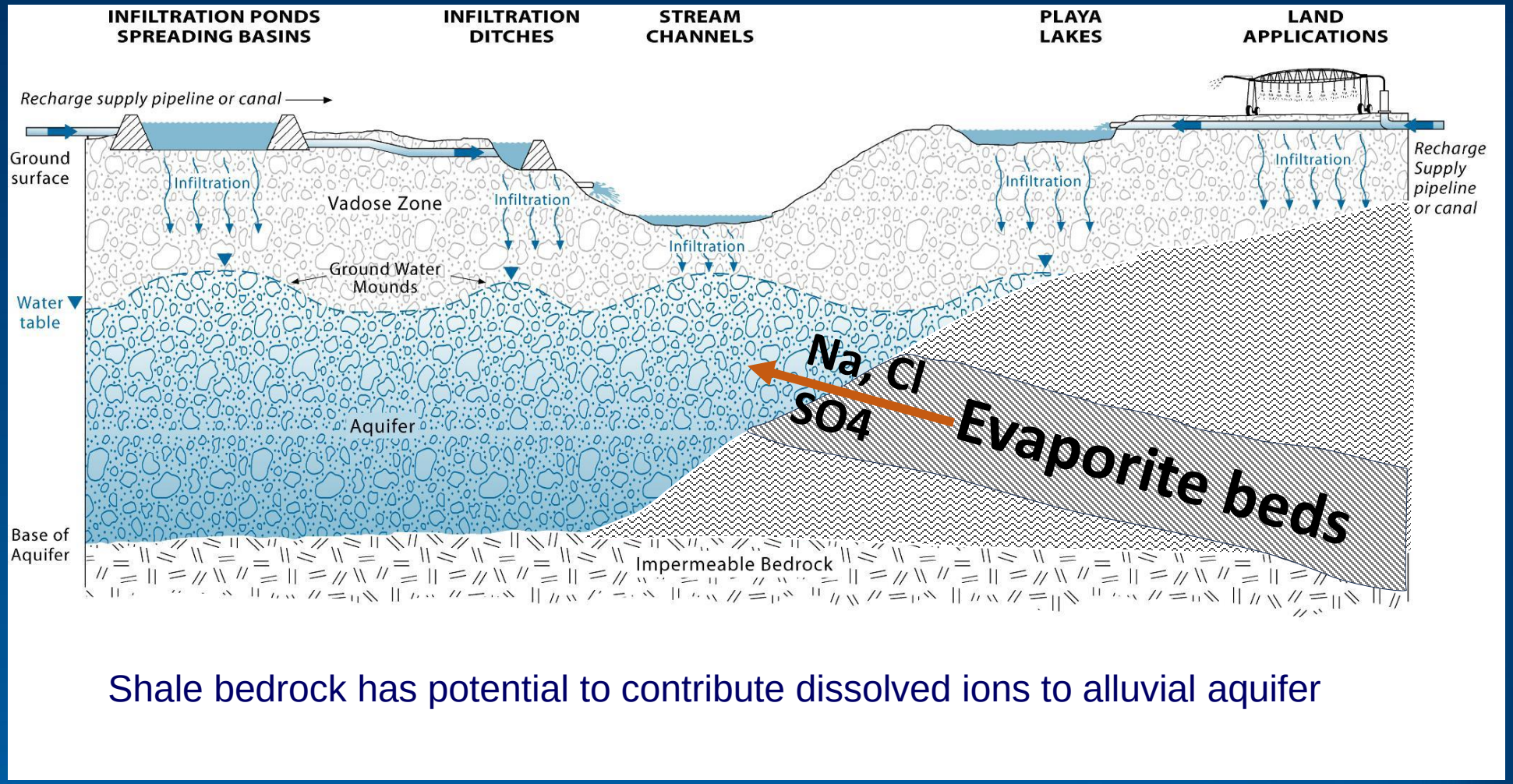
Potential flow into or out of a connected bedrock aquifer

Potential Impact



Shale bedrock has potential to contribute dissolved ions to alluvial aquifer

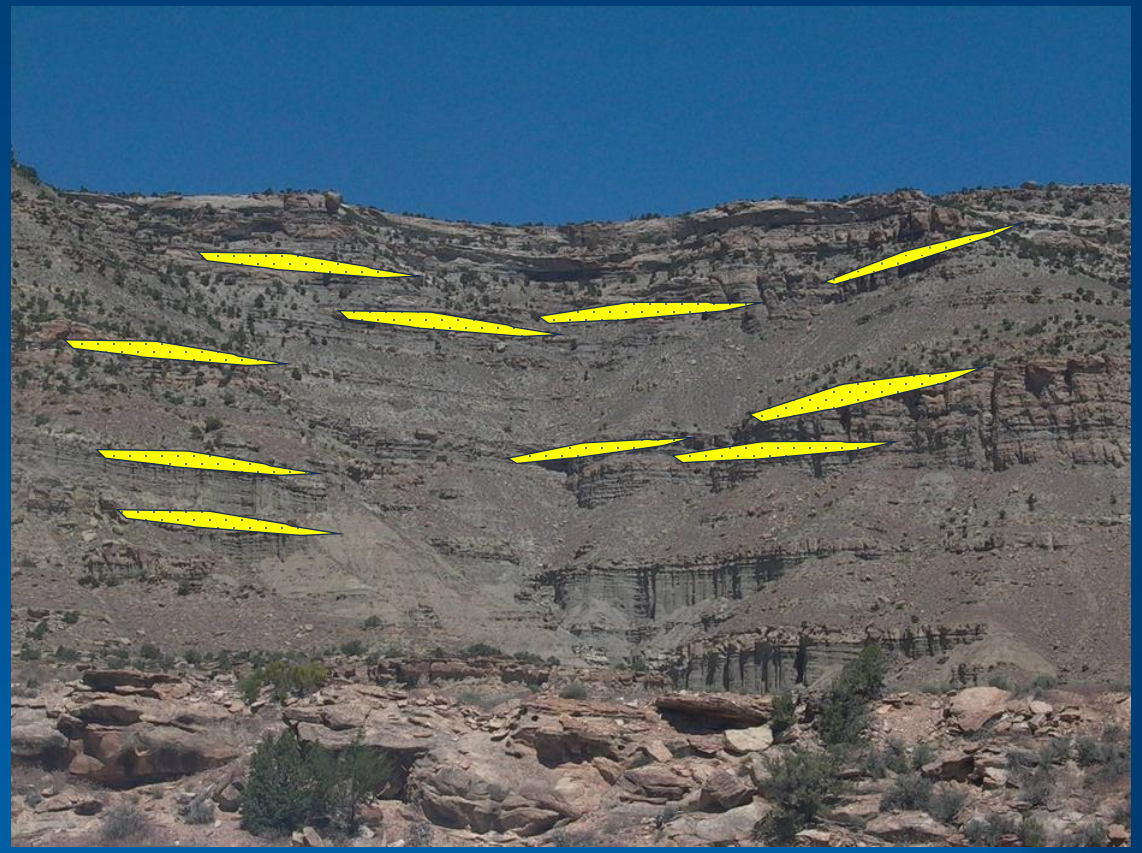
Potential Impact



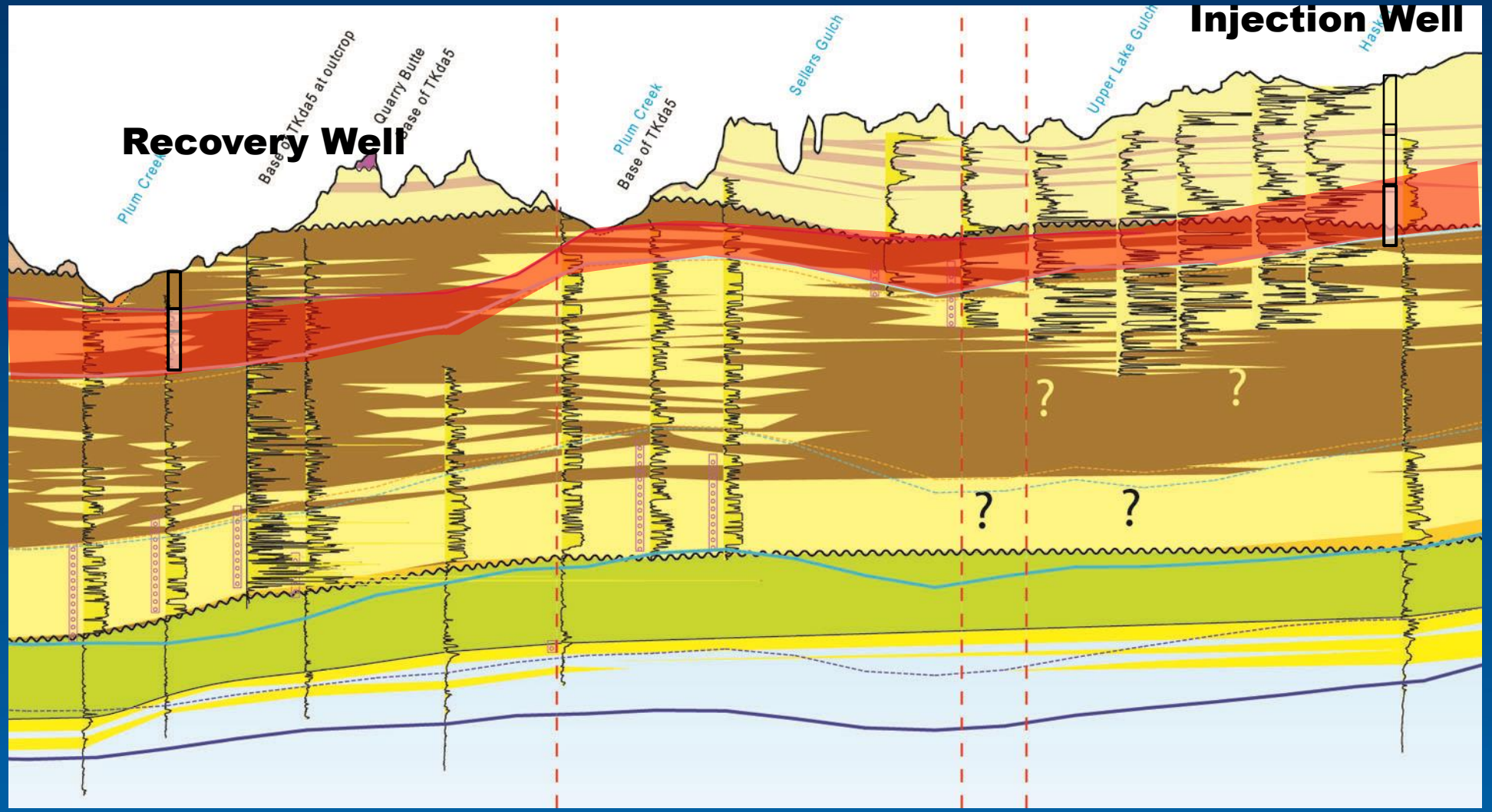
Shale bedrock has potential to contribute dissolved ions to alluvial aquifer

Consolidated Aquifer – Stratigraphic Heterogeneity

VS



What is the “real” 3D architecture of a target aquifer



(CGS Denver Basin Cross Sections [OF-11-03])

What Can Be Done?

To avoid these traps

Careful, detailed hydrogeologic characterization

- *Surface mapping and sampling*
- *Borehole and waterwell data compilation*
- *Geophysics (with borehole calibration)*

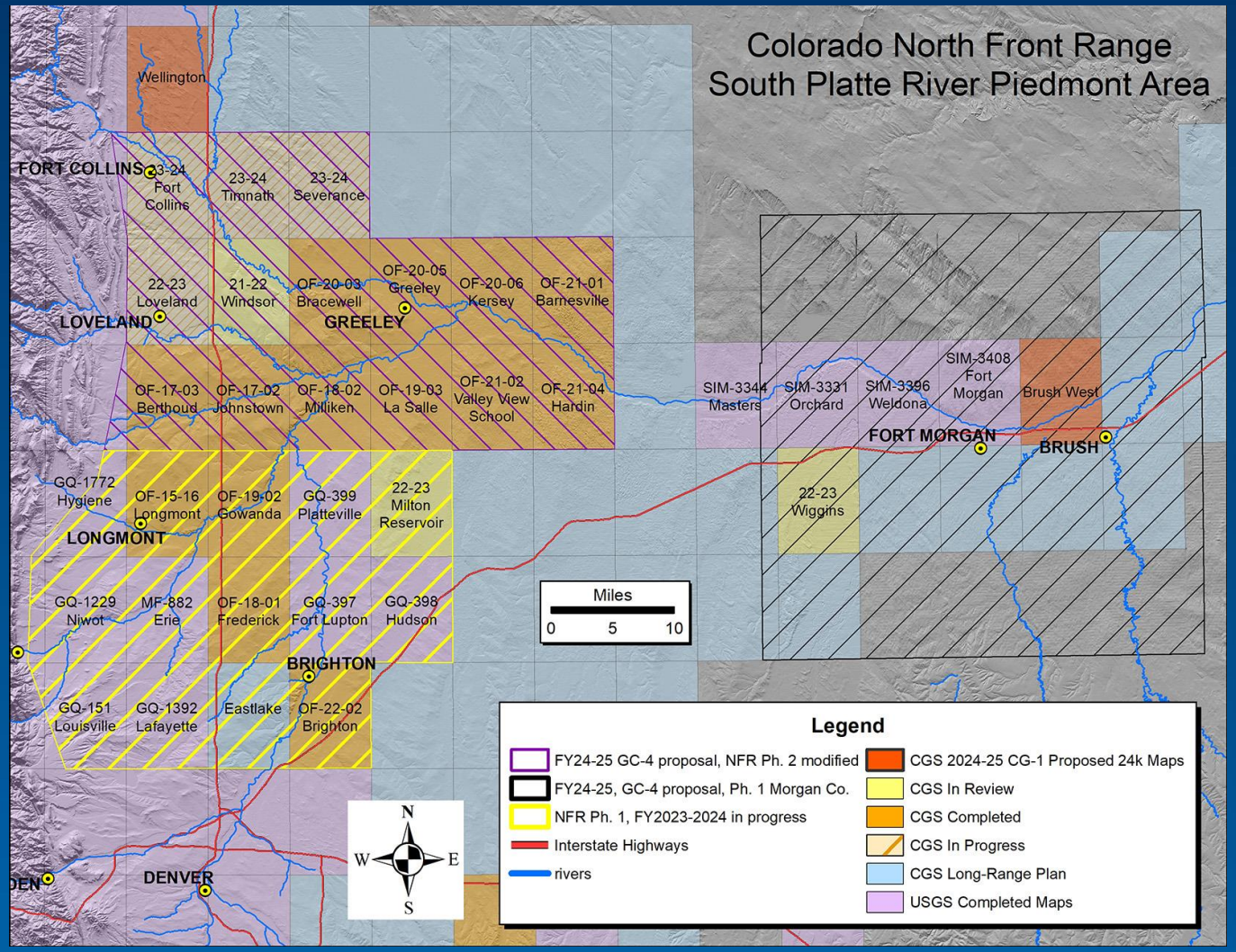
Colorado Geological Survey Activities

Geologic mapping program

- *1:24K quadrangle mapping through STATEMAP*
- *1:100K block-compilations*
- *1:100K county compilations*
- *Utilize current technologies (LiDAR), recent borehole data, geotechnical, data hours of field work*

South Platte River Area

- *3-phase compilation*
- *Detailed surface geology*
- *Geochronology*



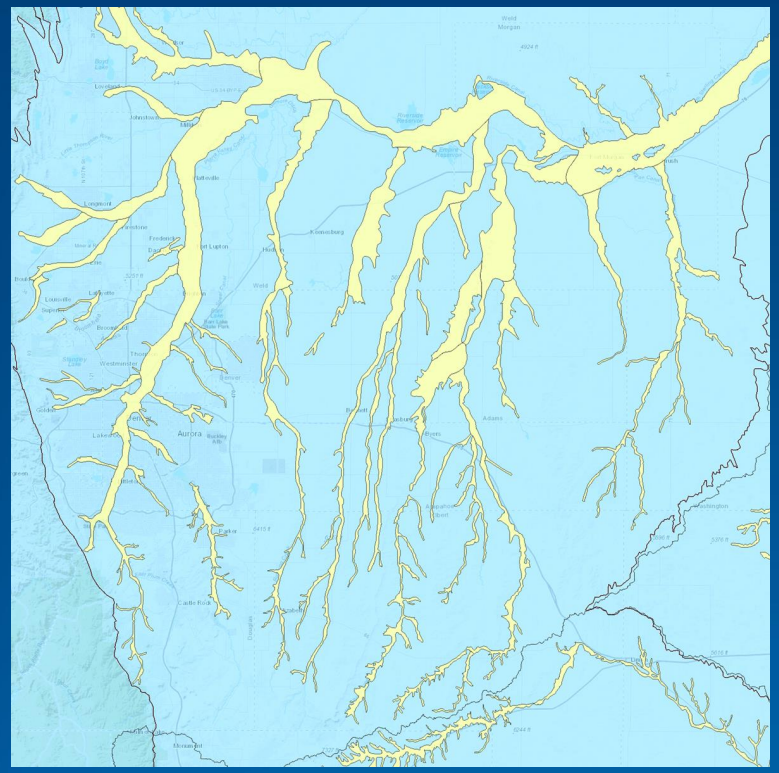
Colorado Geological Survey Activities

Aquifer mapping

- *County Geology and Ground Water Resource series*
- *(Douglas, Park, Elbert, Chaffee, Mesa, La Plata, El Paso [in works])*
- *Specific aquifer mapping*
- *(Statewide Alluvium, Dakota Group aquifer in Division 2 and South Park [in publication])*

Colorado Geological Survey Activities

Statewide Alluvium



Colorado Statewide Alluvial Aquifer ON-010-02D, Lindsey and others, 2021

- *1:100K scale*
- *Consistent methoddology and criteria*
- *Emphasis on only alluvial deposits in connection with surface water*

https://coloradogeologicalsurvey.org/publications/colorado-alluvial-aquifer-map/

Thank You!

https://coloradogeologicalsurvey.org/

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