Hydrogeology of Wyoming

WYOMING STATE GEOLOGICAL SURVEY (WSGS)

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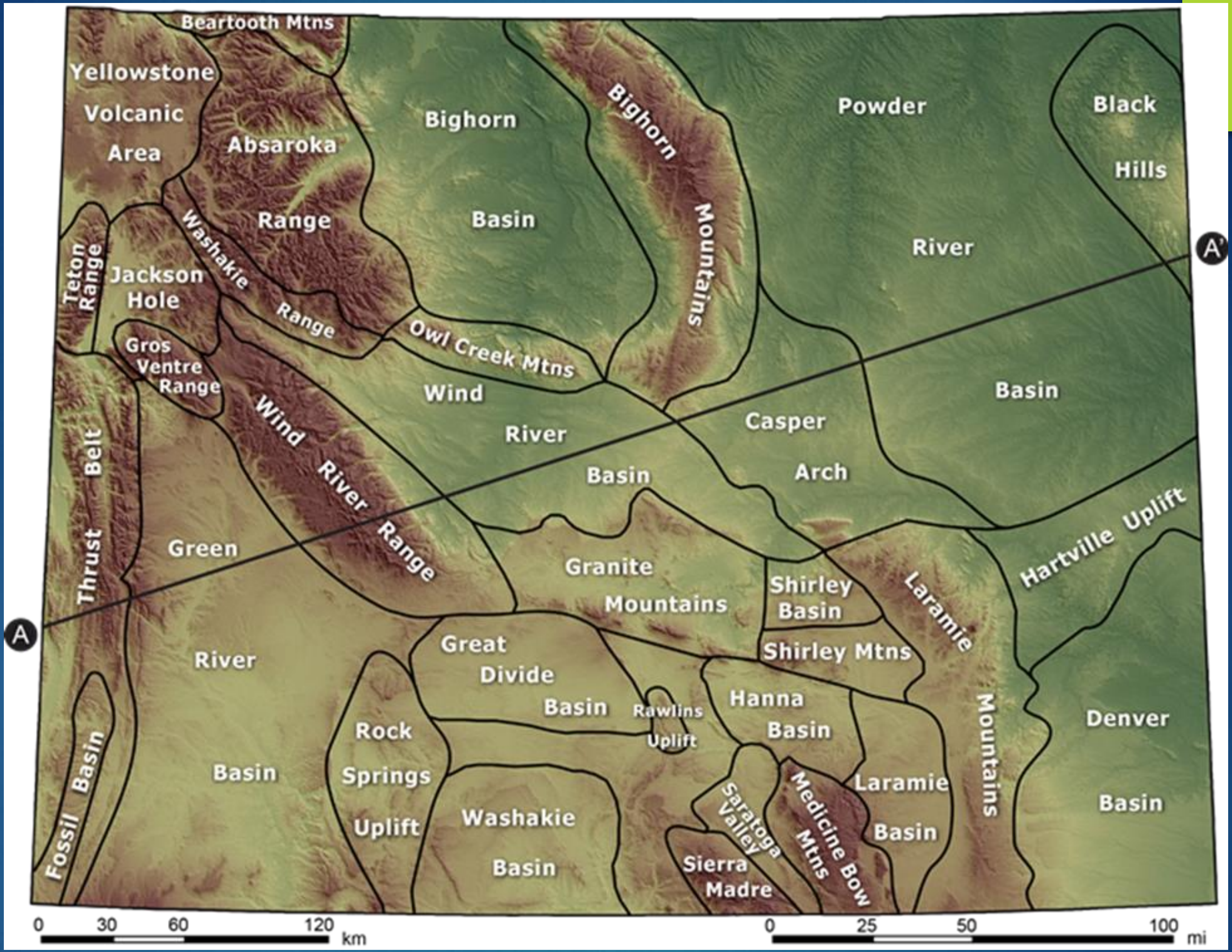
Items to discuss

- Major aquifers - physical and geologic properties.
- Groundwater use and availability.
- Groundwater quality and contamination.
- Surface water/groundwater interactions.
- Groundwater management issues.

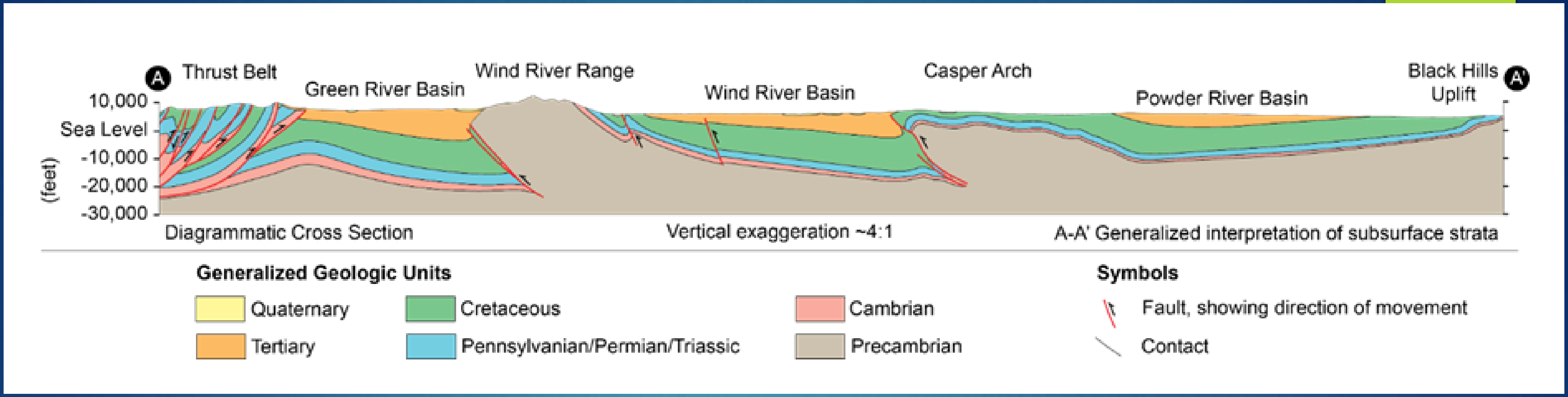
The WSGS has written six technical memoranda that evaluate Wyoming's groundwater resources within the state's seven major river basins. The series consists of over 2500 pages and 49 plates in six volumes.

- These reports represent cooperative efforts by the Wyoming Water Development Office (WWDO), Wyoming State Geological Survey (WSGS), United States Geological Survey (USGS) Wyoming-Montana Water Science Center and the University of Wyoming Water Resources Data System (WRDS).

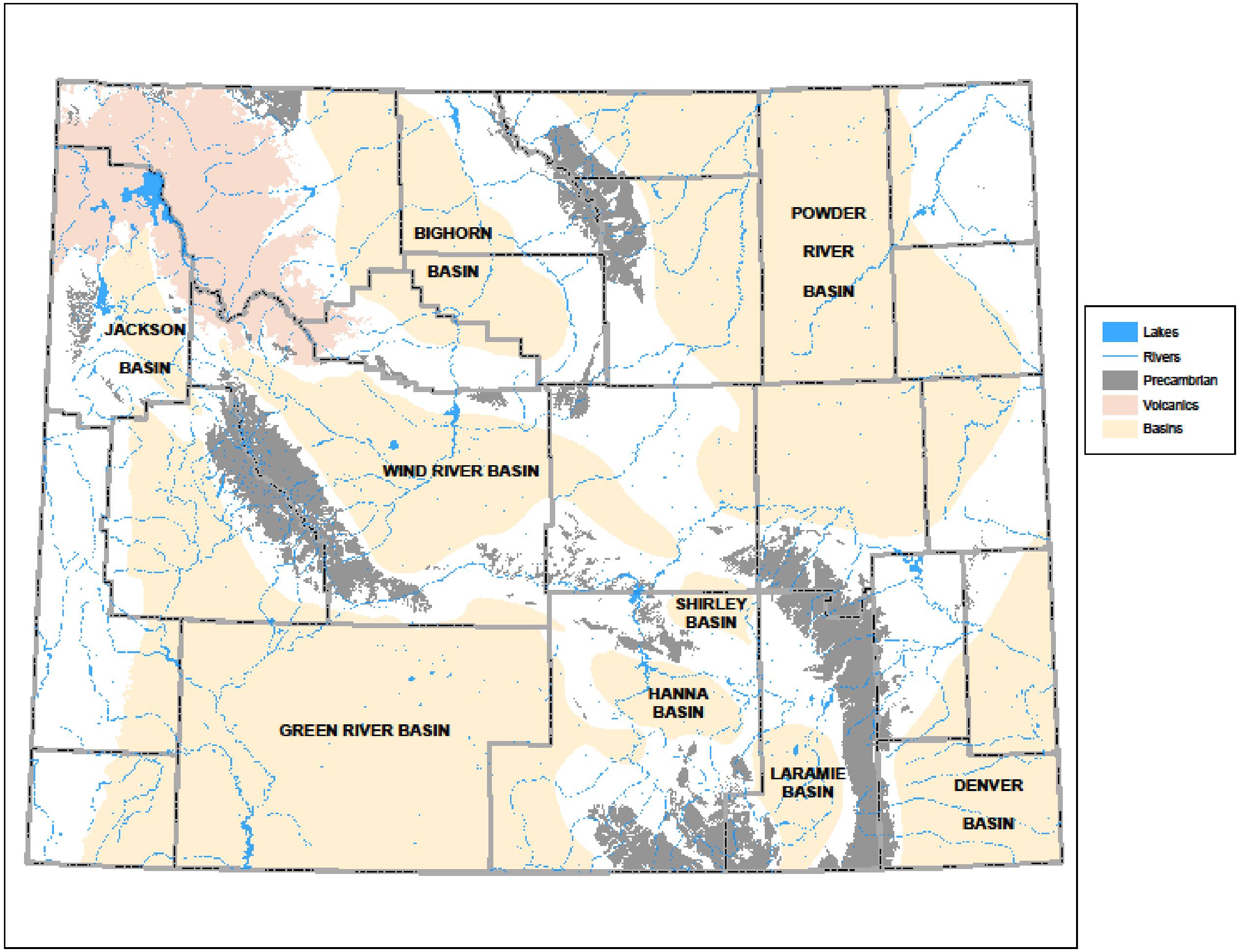
*Additional contributors: **Wyoming State Engineer's Office, Department of Environmental Quality, Oil and Gas Conservation Commission; United States Environmental Protection Agency; Bureau of Land Management** and the **U.S. Forest Service.***



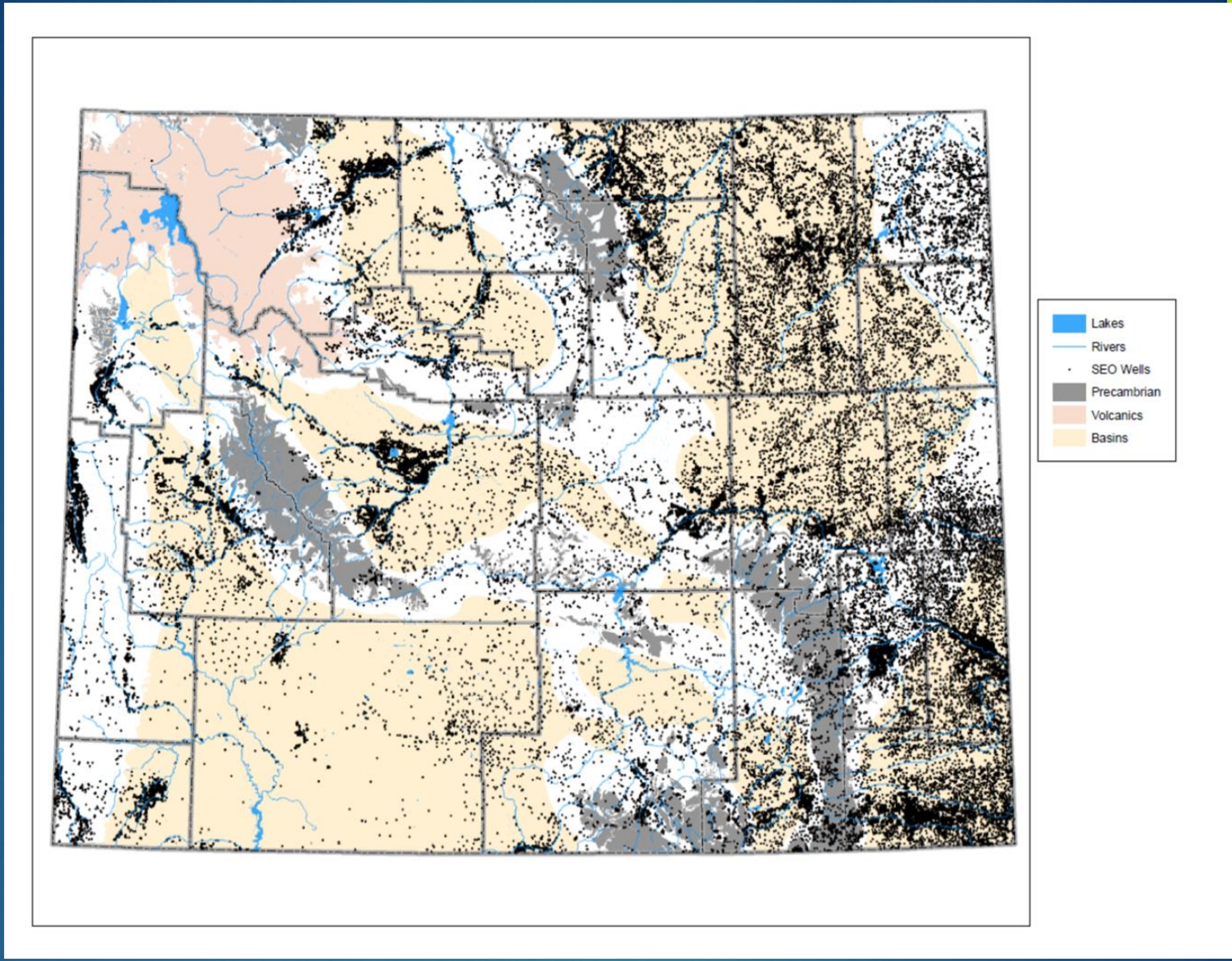
Wyoming's geological structure is dominated by alternating Laramide uplifts and basins. The Thrust Belt in the far west is an exception.



- The cross section A-A’, above, shows the typical system of alternating Precambrian-cored uplifts, intervening sediment-filled basins, and associated faults that largely determine the occurrence, availability and quality of groundwater.



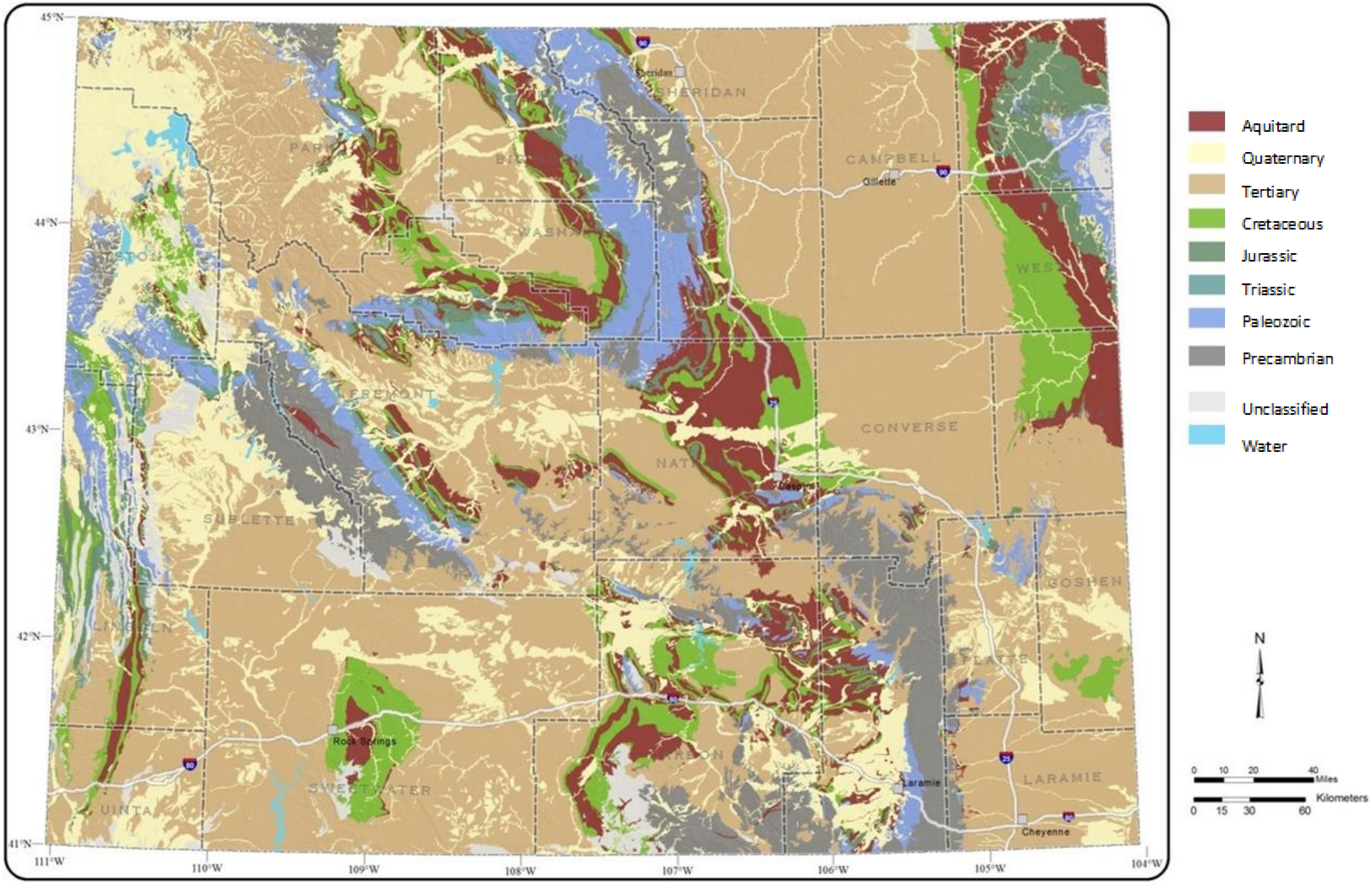
- A large percentage of groundwater rights are located in the structural basins where most of Wyoming's residents live.



- Most wells are completed in Tertiary basin aquifers and Quaternary alluvial deposits. Shallow Mesozoic and Paleozoic aquifers produce water along the basin margins.

Wyoming State Geological Survey

Erin Campbell
Director and State Geologist



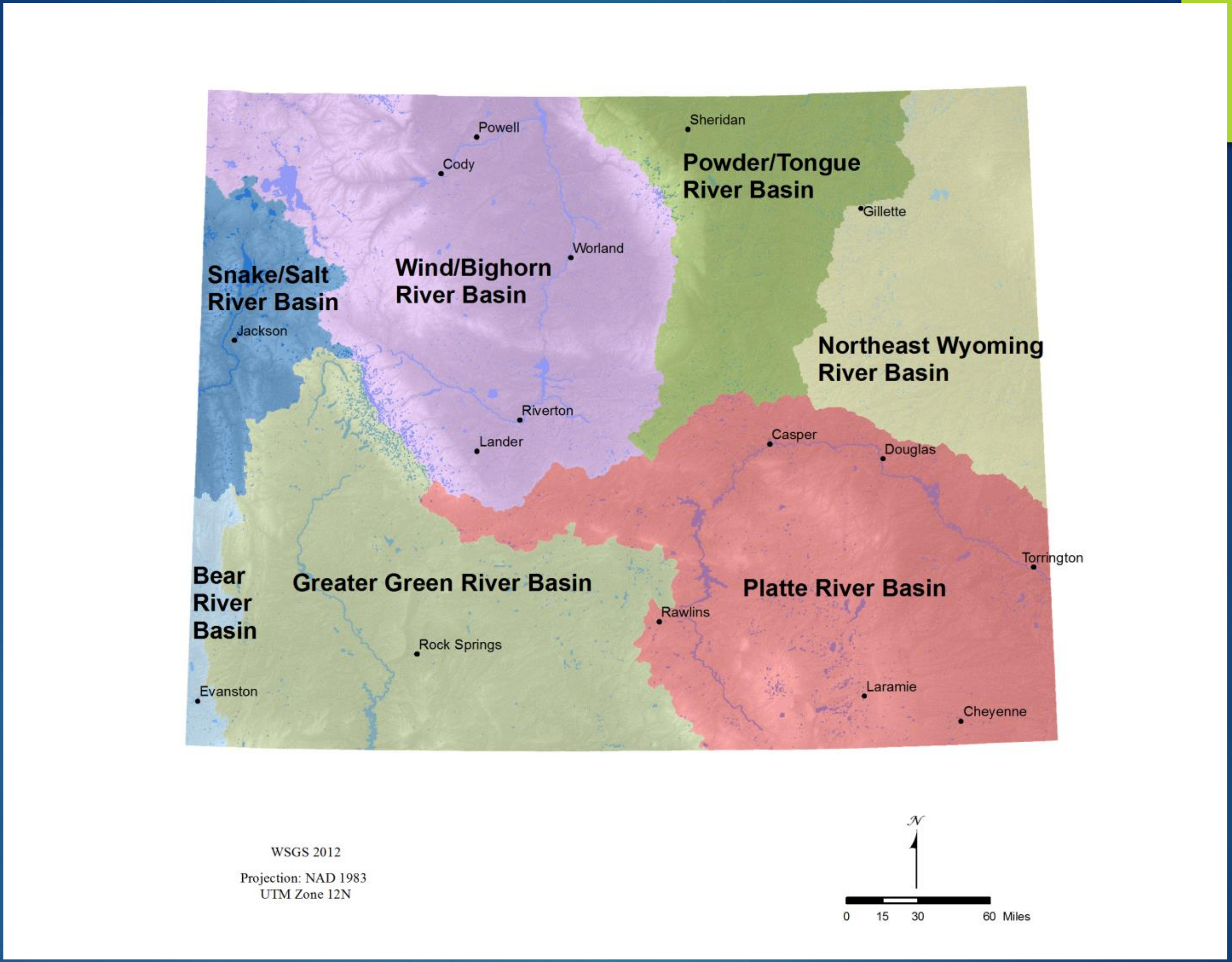
Wyoming Aquifers

Wyoming's major aquifers

- Quaternary: Alluvial deposits.
- Tertiary (sandstone): Ft. Union, Ogallala, Arikaree, Teewinot/ Salt Lake, Bridger/Battle Springs/Fowkes and Wasatch/Wind River.
- Mesozoic (sandstone): Lance, Fox Hills, Mesaverde, Cloverly/Dakota and Nugget.
- Paleozoic (limestone): Madison and Tensleep.

Confining units are predominately Cretaceous shales.

Precambrian rocks produce water from shallow fracture-associated wells but are confining units at depth.



Wyoming's aquifers are grouped by river basin.

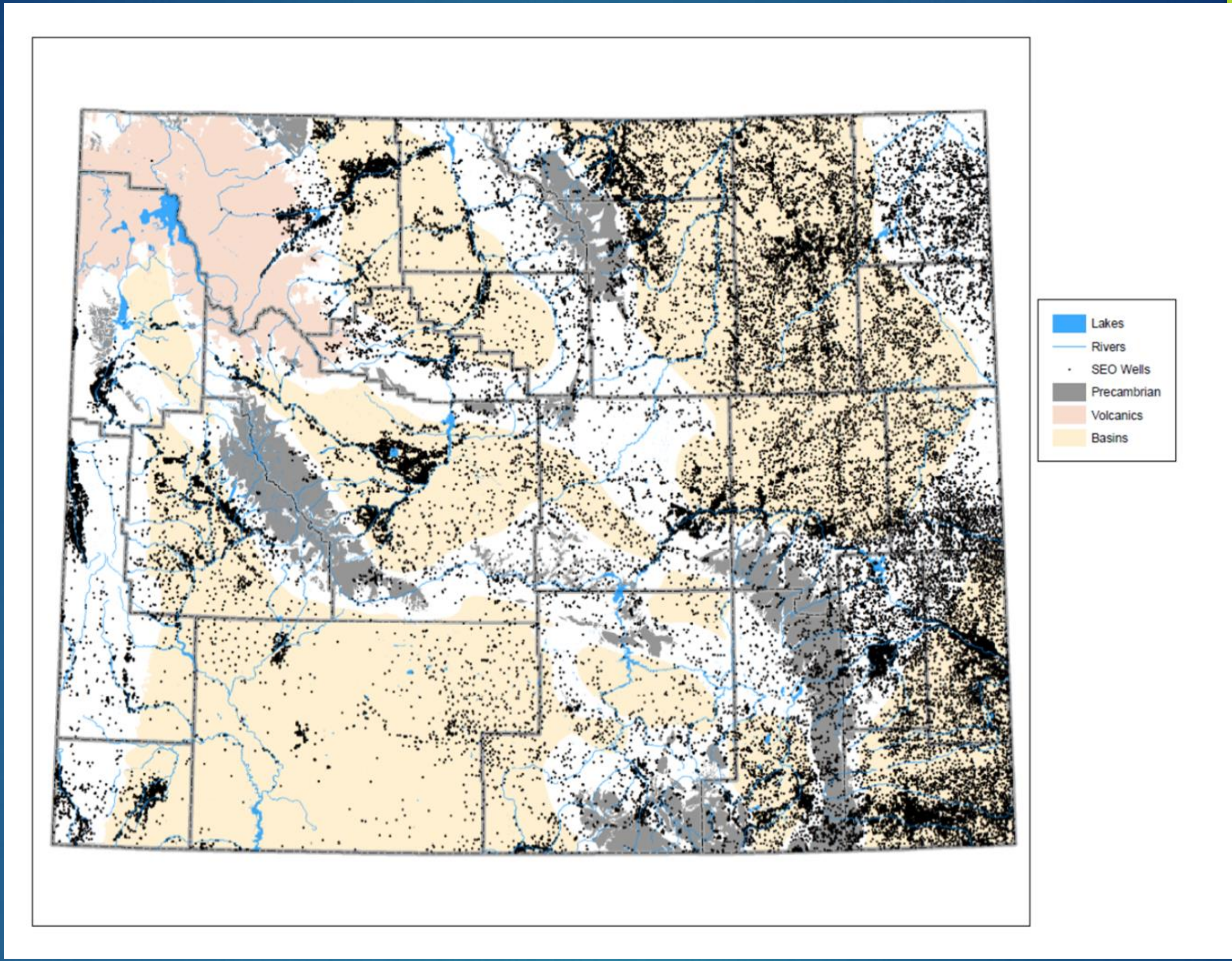
Geologic unit	Dominant lithology	River basins						
		Bear	Greater Green	North-east	Platte	Powder/ Tongue	Snake/ Salt	Wind/ Bighorn
Alluvium	Sand, gravel, silt, clay	X	X	X	X	X	X	X
Ogallala	SS, siltstone, gravel				X			
Teewinot and Salt Lake	Tuff, LS, claystone						X	
Arikaree, North Park, Splitrock	SS (tuffaceous)			X	X			
Bridger, Battle Springs, Fowkes	SS, conglomerate	X	X					
Wasatch, Wind River	Siltstone, SS, shale	X	X	X	X	X		X
Fort Union - various members	SS, siltstone, coal		X	X		X		
Lance	SS, siltstone			X		X		
Fox Hills	SS, shale			X		X		
Mesaverde and related rocks	SS, shale, coal	X	X					
Cloverly/Dakota	SS, siltstone	X	X	X		X		
Nugget	SS	X	X				X	
Casper, Tensleep, Minnelusa, Hartville	LS, SS, shale	X	X	X	X	X	X	X
Madison	LS, dolomite	X	X	X	X	X	X	X

Alluvial deposits, in yellow, and Paleozoic aquifers, in blue, are utilized in all seven river basins. The occurrence of Tertiary aquifers, in orange, and Mesozoic aquifers, in green, varies by basin.

Geologic unit	Lithology	Maximum thickness (ft)	Maximum yields (gpm)	TDS (mg/L)
Alluvium	Sand, gravel, silt, clay	200	>1,000	106-4,880*
Ogallala	SS, siltstone, gravel	300		
Teewinot and Salt Lake	Tuff, LS, claystone	>5,000	>1,000	160-260**
Arikaree, North Park, Splitrock	SS (tuffaceous)	500	1,000	198-1,150*
Bridger, Battle Springs, Fowkes	SS, conglomerate	3,000		213-4,380***
Wasatch, Wind River	Siltstone, SS, shale	2,500		160-8,620*
Fort Union - various members	SS, siltstone, coal	3,000	200	113-5,480*
Lance	SS, siltstone	3000	250	244-3,060*
Fox Hills	SS, shale	500	1,000	28-3,520*
Mesaverde and related rocks	SS, shale, coal	>5,000		370-4,430*
Cloverly/Dakota	SS, siltstone	300	250	1080-2,970*
Nugget	SS	500		30-388**
Casper, Tensleep, Minnelusa, Hartville	LS, SS, shale	2,500	>1,000	192-5,320*
Madison	LS, dolomite	2,500	>1,000	65-3,490*

TDS data from USGS appendices in WSGS groundwater reports for the*NERB, **Green River and ***Snake Salt river basins.

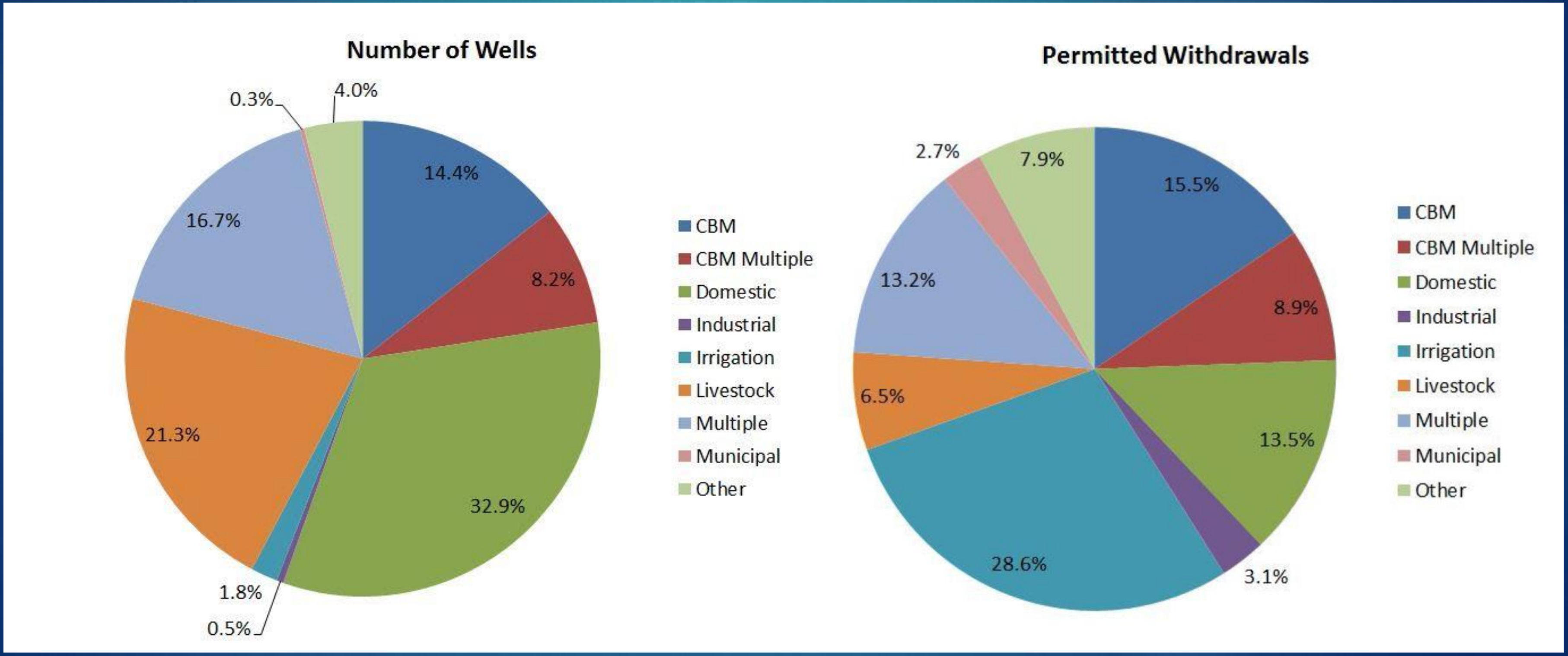
Typical physical and chemical characteristics for the major aquifers. Alluvial aquifers supply most of the state's irrigation wells. Paleozoic aquifers are the preferred target for municipal wells.



Most basin wells supply water to livestock and rural households.

Groundwater uses

- About 8 percent of all freshwater used in Wyoming comes from groundwater sources (~100,000 permitted groundwater rights).

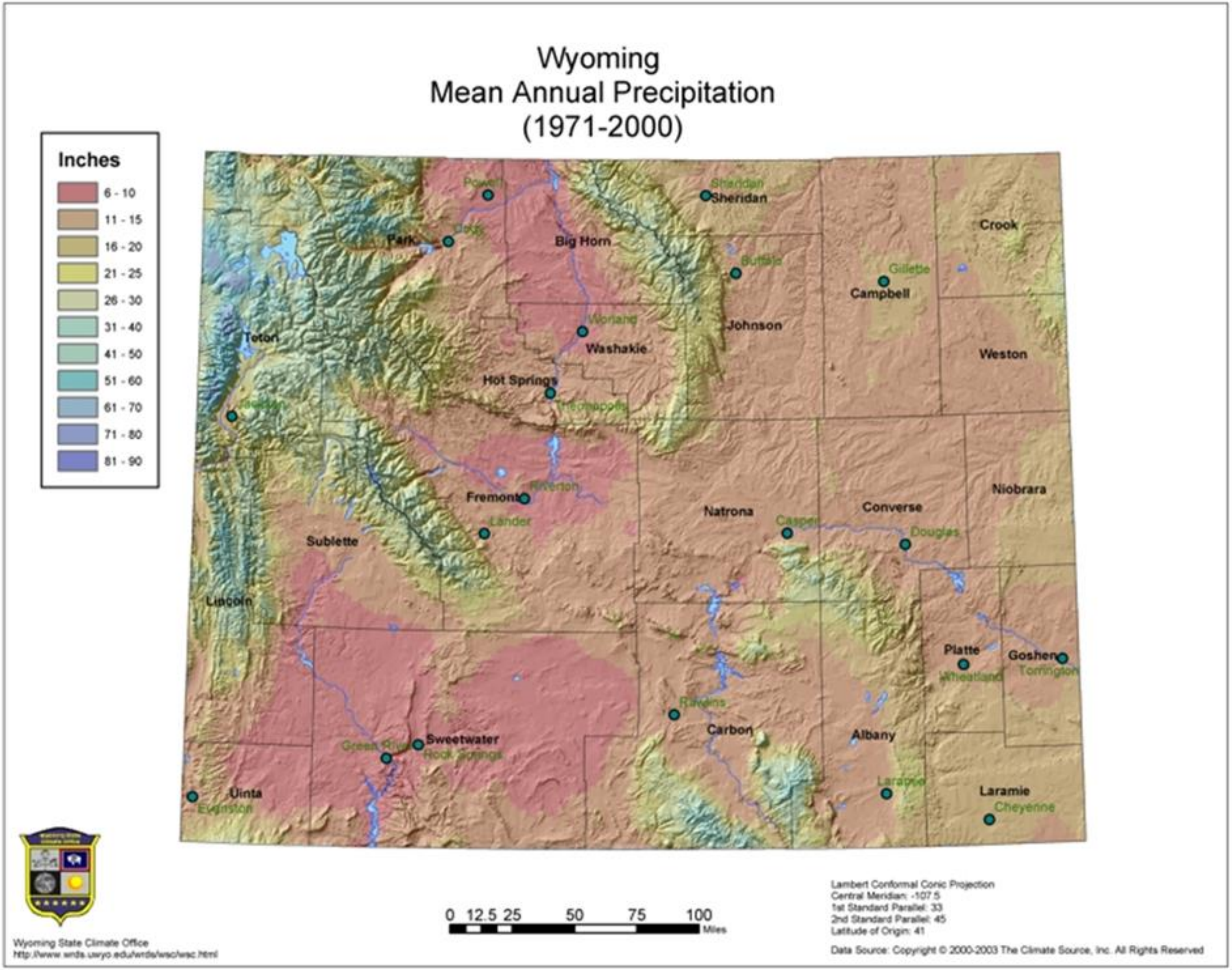


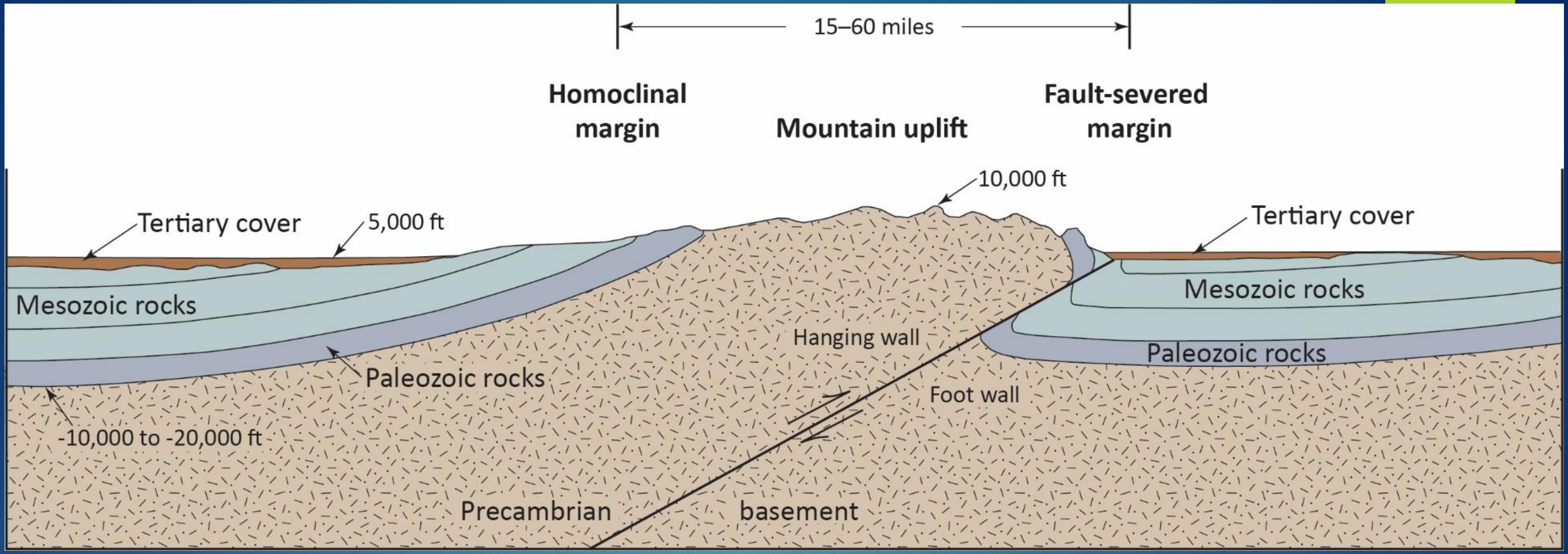
Groundwater withdrawals (freshwater) by water use category, 2015, in thousand acre-feet per year (Dieter and others, 2018).

Use Category	Volume (1000s AF/yr)	Percent Total
Public supply	61.1	8.4%
Domestic	10.0	1.4%
Irrigation	602.0	82.4%
Livestock	6.9	0.9%
Aquaculture	5.5	0.8%
Industrial	6.5	0.9%
Mining	37.1	5.1%
Thermoelectric power	1.5	0.2%
Total	730.7	

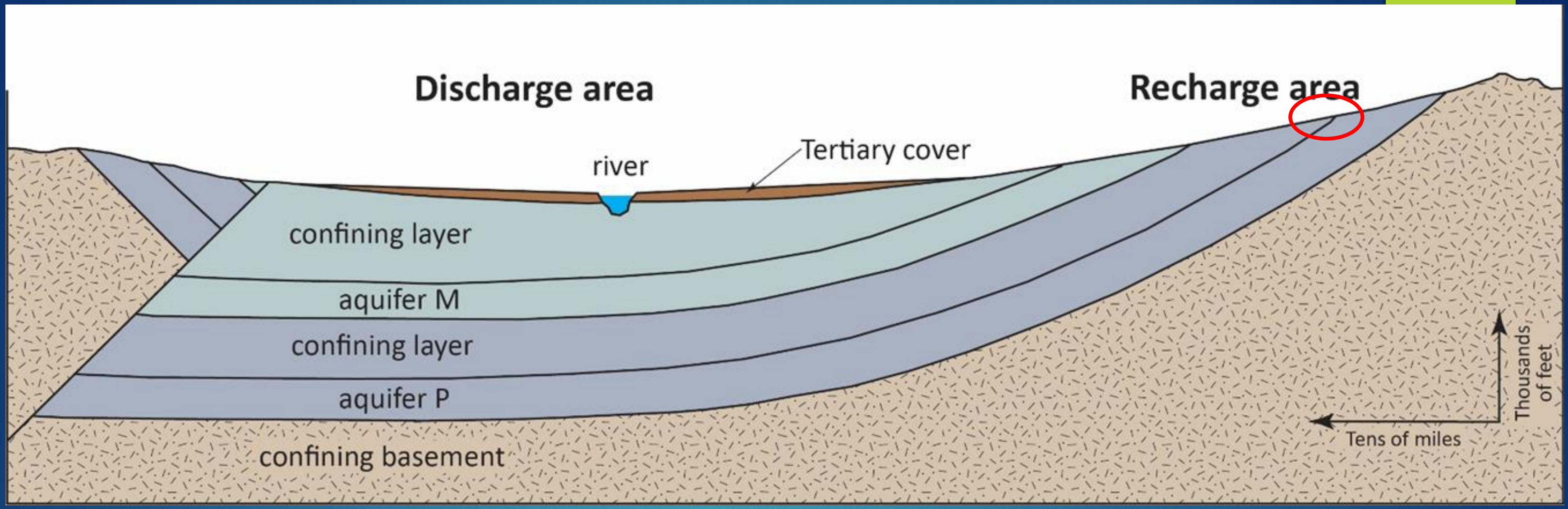
Controls on groundwater availability

- Precipitation - Climate types range from semi-arid continental (grasslands) to humid –alpine in the bordering mountain ranges.
  - For example, average annual precipitation in the City of Laramie is 11” while the crest of the Laramie Range located 7 miles away at 1,000 ft higher elevation receives 23”.
- The permeability architecture of the mountain ranges and adjacent structural basins.

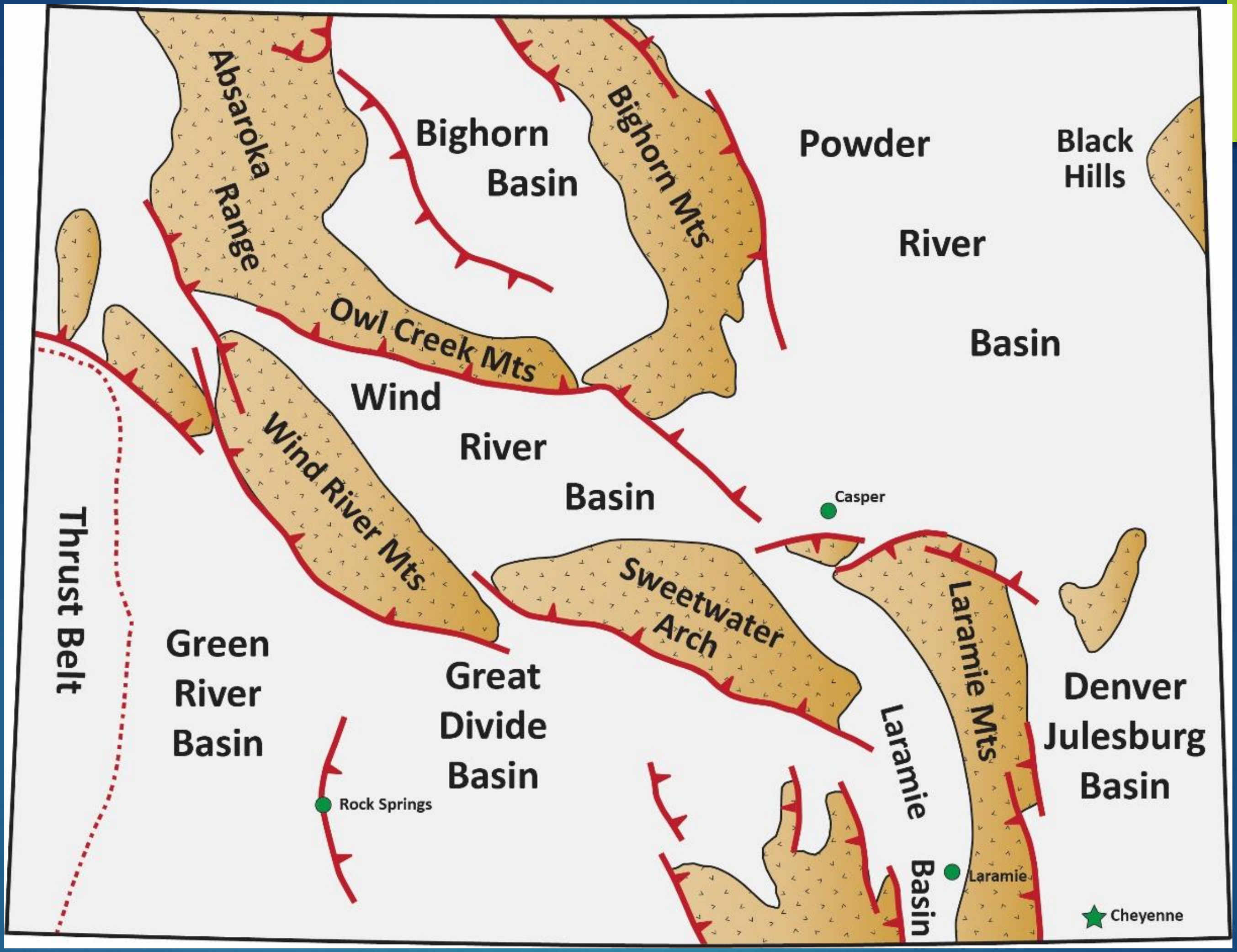

Wyoming
Mean Annual Precipitation
(1971-2000)
Inches
6 - 10
11 - 15
16 - 20
21 - 25
26 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
Park
Powell
Cody
Big Horn
Sheridan
Sheridan
Buffalo
Johnson
Campbell
Gillette
Crook
Weston
Teton
Worland
Washakie
Hot Springs
Thermopolis
Fremont
Riverton
Lander
Natrona
Casper
Converse
Douglas
Niobrara
Sublette
Lincoln
Platte
Wheatland
Goshen
Torrington
Rawlins
Carbon
Albany
Sweetwater
Rock Springs
Green River
Uinta
Evanston
Laramie
Laramie
Cheyenne
0 12.5 25 50 75 100
Miles
Lambert Conformal Conic Projection
Central Meridian: -107.5
1st Standard Parallel: 33
2nd Standard Parallel: 45
Latitude of Origin: 41
Data Source: Copyright © 2000-2003 The Climate Source, Inc. All Rights Reserved
Wyoming State Climate Office
http://www.wrds.uwyo.edu/wrds/wsc/wsc.html



Permeability architecture is another control on groundwater availability (Huntoon, 1993). This cartoon section extends from one structural basin (left) through the adjacent mountain range and into the structural basin on the right. The displacement along the fault severed margin precludes groundwater flow into the basin and the Paleozoic rocks are buried at great depths.



Permeability architecture of a Laramide structural basin. Groundwater availability is limited to Tertiary and shallow Mesozoic aquifers along the fault severed margin and in the basin interior. Municipalities located there usually depend on surface water supplies or alluvial wells. In contrast, communities located on the homoclinal margin near recharge areas (red oval) can obtain large quantities of good quality groundwater from Paleozoic aquifers.



Wyoming foreland uplifts and basins. About half of basin margins are bound by thrust faults that isolate artesian basin aquifers from upland recharge areas.

Groundwater contamination

- Contamination issues
  - Contamination of the Wind River aquifer near Pavillion, Wyoming with methane and organic compounds historically used for hydraulic fracturing natural gas wells.
  - Trichloroethylene (TCE) contamination plume from missile silos 18 miles west of Cheyenne.
  - Per- and polyfluoroalkyl substances (PFAS) contamination at the Jackson airport.
  - Naturally occurring radium and arsenic contamination at Lance Creek.

Surface water/groundwater interactions

- Future development of groundwater in the North Platte River drainage is significantly constrained by both the USSC 2001 Modified North Platte Decree and the Platte River Recovery Implementation Program (PRRIP).
- The Upper Niobrara River Compact (1962) sets the foundation for future apportionment of ground water in the basin.

Groundwater management

- Three groundwater management districts have been established in the southeast portion of the state. Applications for new wells exceeding 25 gallons per minute must pass through public notice and recommendation from a 5-member elected advisory board prior to approval.
- Sheridan and Buffalo, which depend on mountain sourced surface water are looking at developing alternate (groundwater) sources to supply their communities in the event of forest fires.
- The Wyoming Water Development Office continues to encourage the development and extension of regional water systems.

Resources

- Wyoming State Geological Survey – Reports, data, and the Wyoming groundwater atlas

  http://www.wsgs.wyo.gov/water/river-basin-plans

- Wyoming Water Development Office - Reports
  http://waterplan.state.wy.us/

- Water Resources Data System - Reports and data
  http://library.wrds.uwyo.edu/rbplans.html

In many cases, WSGS can provide available GIS data files.

Websites with hydrogeologic data

- State:
  - State Engineer's Office (SEO) - https://sites.google.com/a/wyo.gov/seo/
  - Wyoming Oil and Gas Conservation Commission: http://wogcc.state.wy.us/
  - Wyoming Department of Environmental Quality: http://deq.wyoming.gov/wqd/
- Federal:
  - U.S. Geological Survey (USGS)
    - Water Resources - https://www2.usgs.gov/water/
    - Publications - https://pubs.er.usgs.gov/
    - WY-MT Water Science Center - http://wy-mt.water.usgs.gov/

References cited

- Huntoon, P.W. 1993, The influence of Laramide foreland structures on modern groundwater circulation in Wyoming artesian basins, *in* Snoke, A.W., Steidtmann, J.R., and Roberts, S.M., eds., Geology of Wyoming: Geological Survey of Wyoming Memoir 5, p. 756-789. http://www.wsgs.wyo.gov/products/wsgs-1993-m-05.pdf

- Dieter, C.A., Maupin, M.A., Caldwell, R.R., Harris, M.A., Ivahnenko, T.I., Lovelace, J.K., Barber, N.L., and Linsey, K.S., 2018, Estimated use of water in the United States in 2015: U.S. Geological Survey Circular 1441, 65 p., https://doi.org/10.3133/cir1441.

Thanks, questions?

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