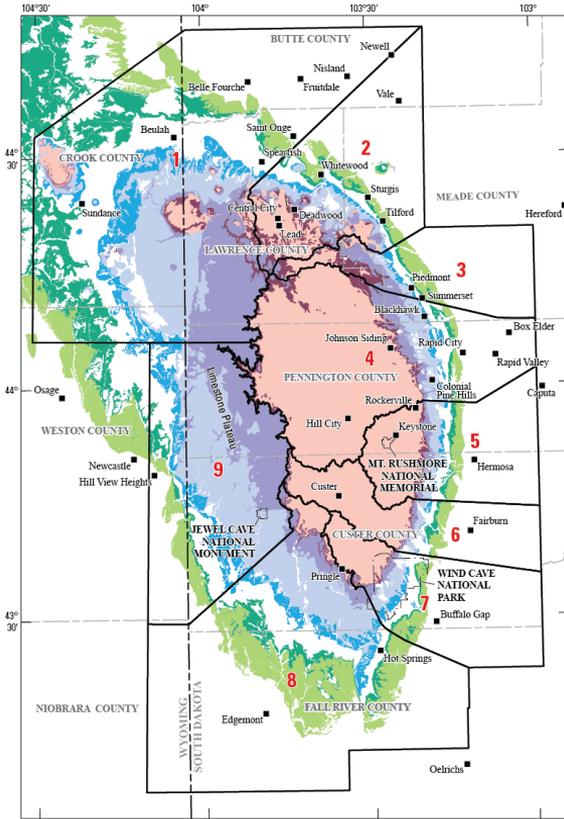


Hydrologic Budgets Revisited: Paleo Droughts and Their Impact on Modern Groundwater Availability in the Black Hills

West Dakota Regional Water System Meeting– January 9, 2026

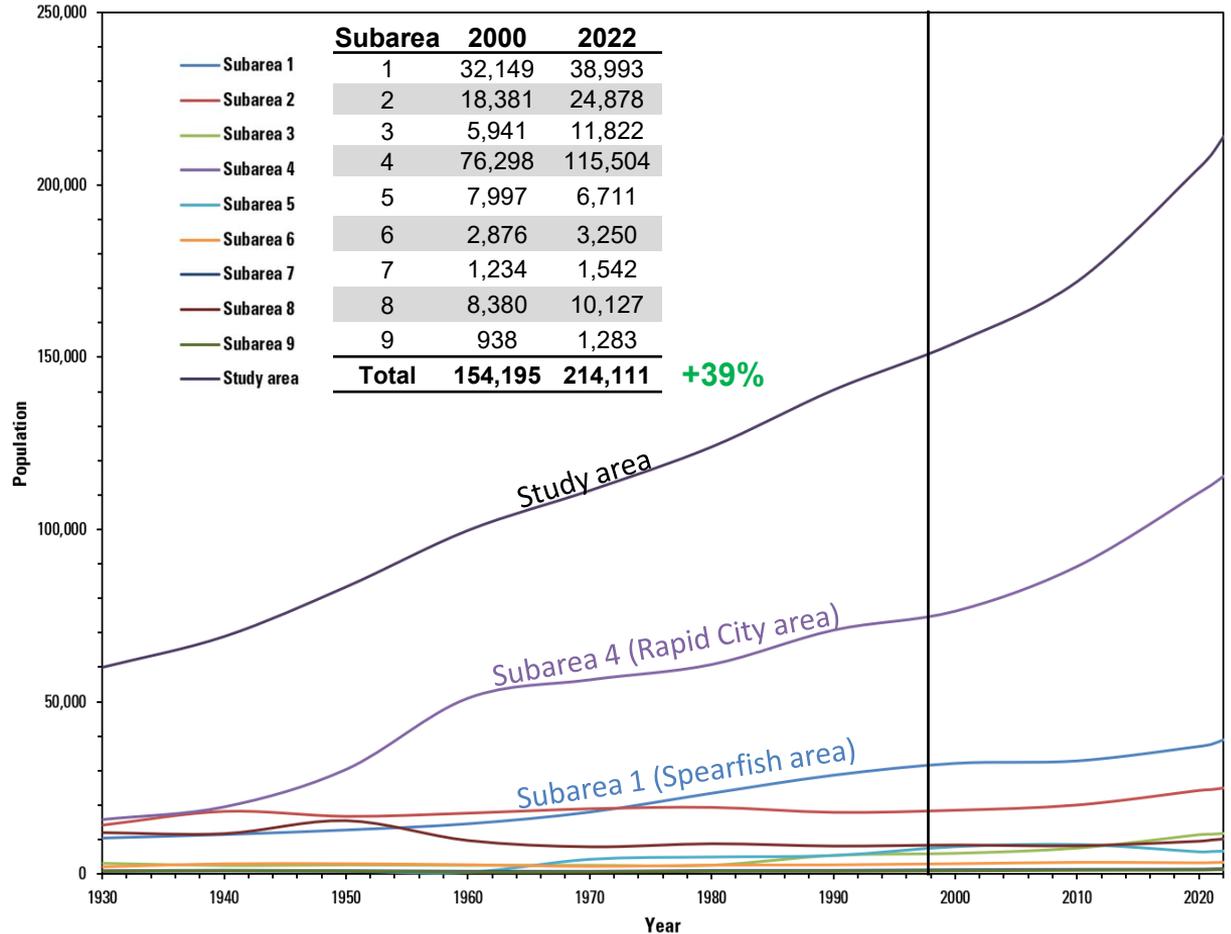
**Colton Medler
Todd Anderson
Bill Eldridge
Galen Hoogestraat
Hydrologists
Dakota Water Science Center
Rapid City, South Dakota**

Population:



BHHS 1931-1998

Updates 1999-2022

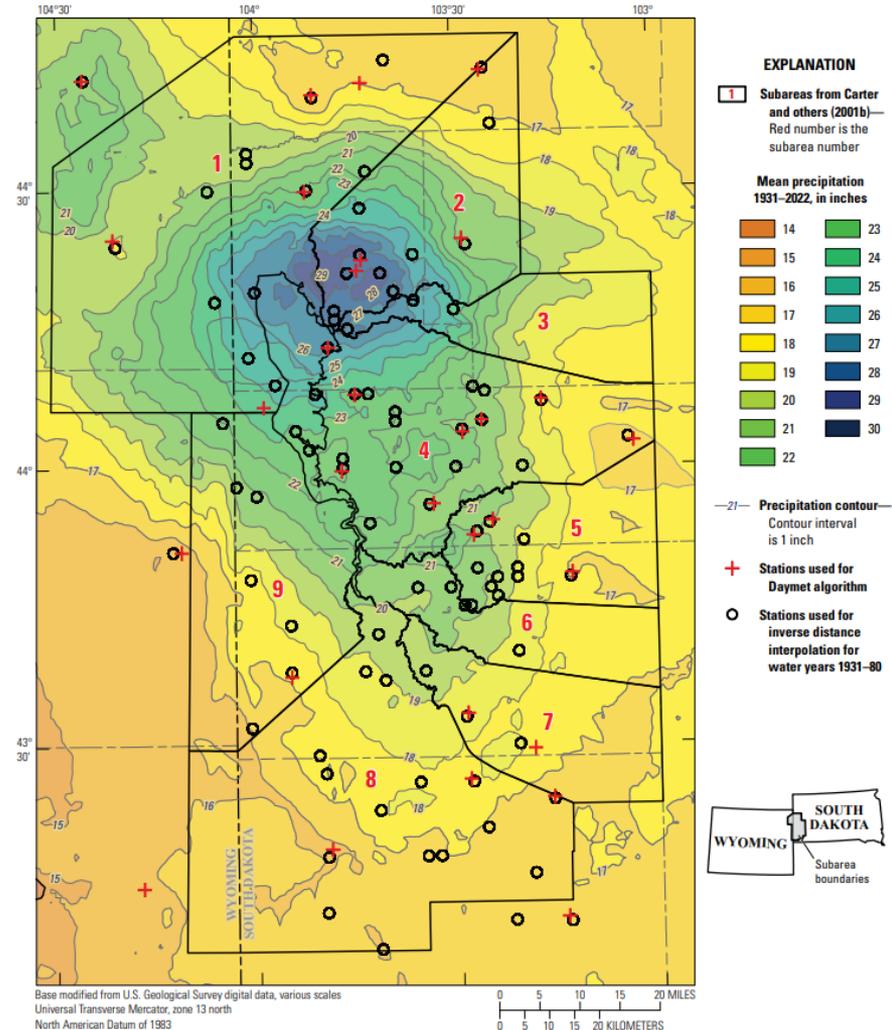
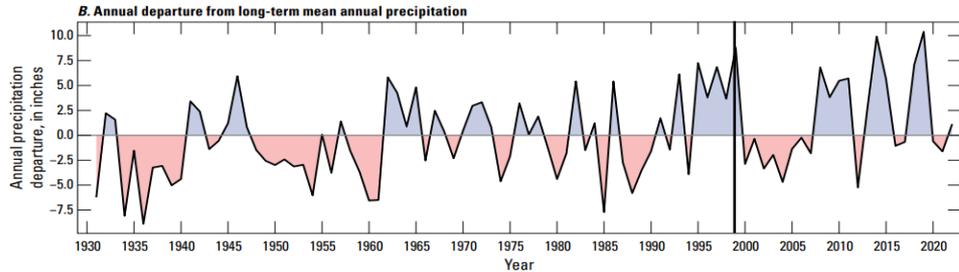


Precipitation:

- Average 1931–98: 18.8 inches
- Average 1931–2022: 19.4 inches
- Wetter conditions than normal for 1999–2022

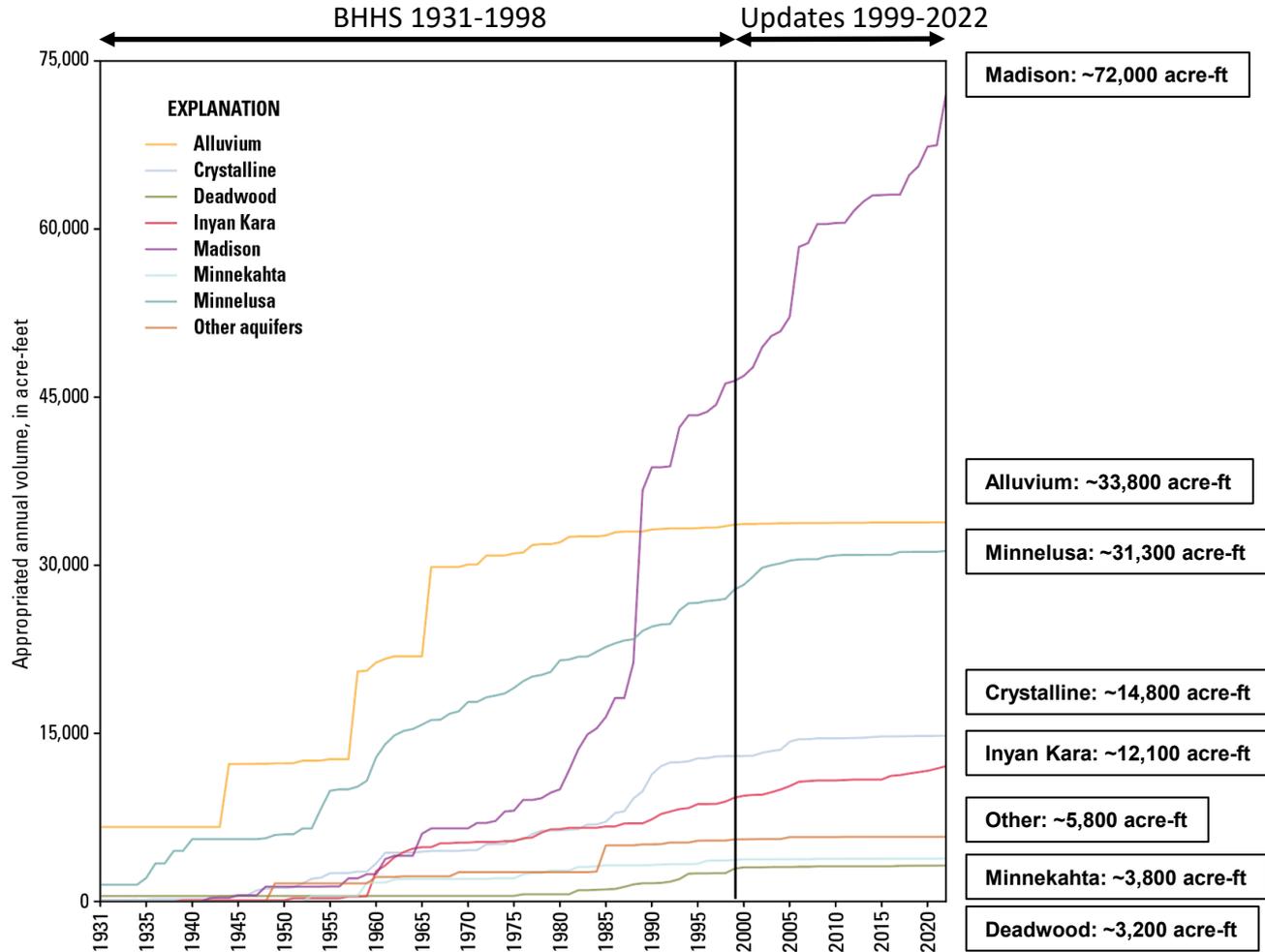
BHHS 1931-1998

Updates 1999-2022

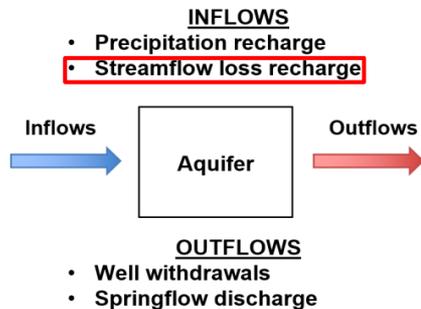


Permitting: Appropriations by aquifer 1931-2022

- Appropriations allocated from water rights by the state of South Dakota
- NOT current use
- Total appropriations: 176,800 acre-ft



Inflow: Streamflow recharge



- Stream loses all or part of its flow to aquifers
- Example: Boxelder Creek “whirlpool”
- Many streams in the Black Hills lose water to the Madison and Minnelusa aquifers
- Average yearly total: 73,800 acre-ft (about 1.3 Pactola Reservoirs)
- **9 percent greater than previous study (67,500 acre-feet)**

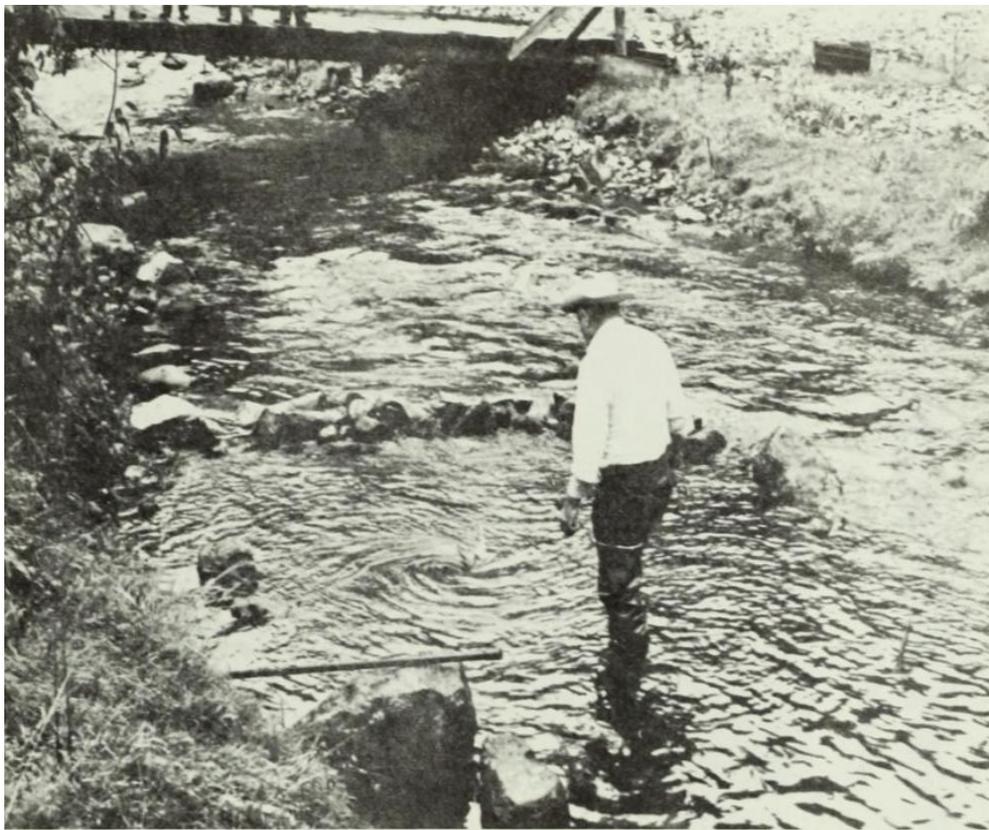
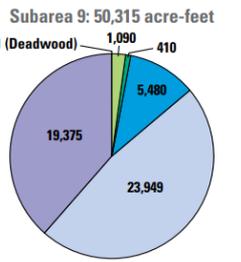
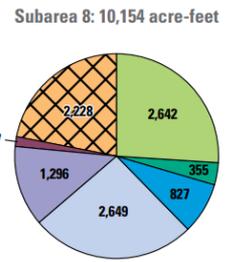
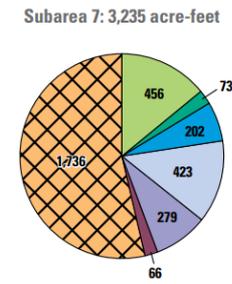
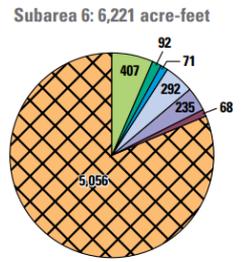
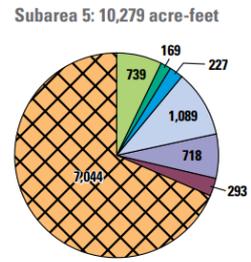
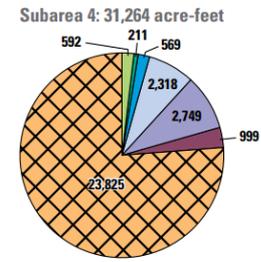
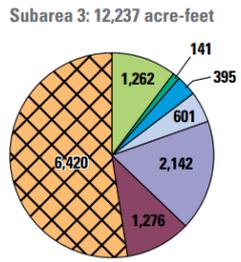
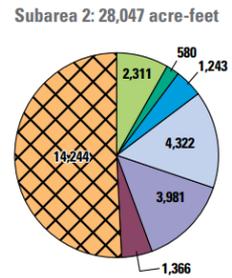
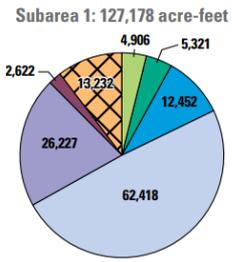
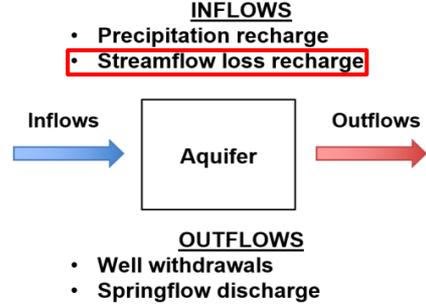
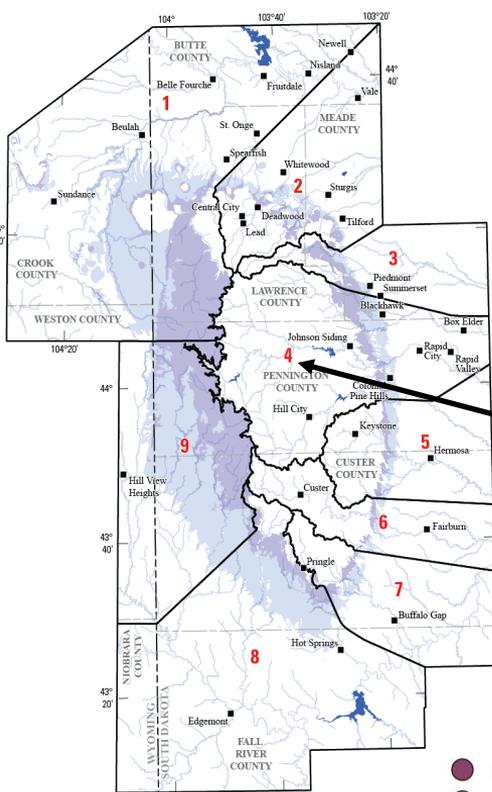


Photo from Rahn and Gries (1973)

Inflow: Streamflow recharge by subarea



EXPLANATION

Mean annual precipitation recharge, in acre-feet

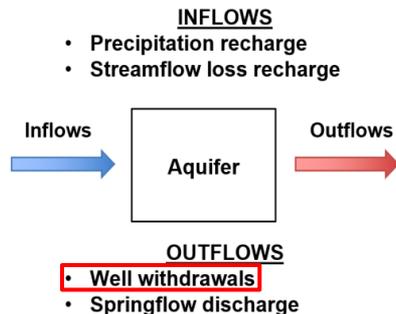
● Deadwood	● Minnelusa	● Sundance
● Madison	● Minnekahta	● Inyan Kara

Mean annual streamflow recharge, in acre-feet

Rapid Creek
Boxelder Creek
Spring Creek



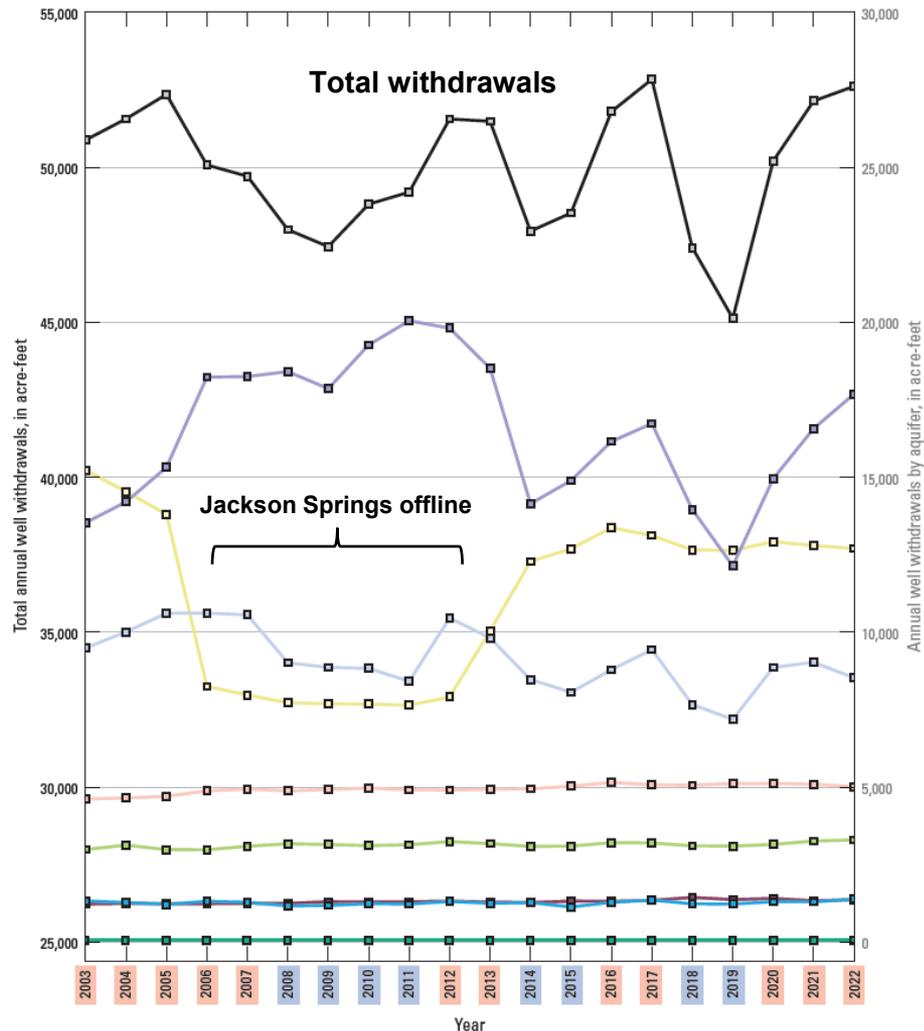
Outflow: Modern groundwater use estimates for 2003–22



- **Average: ~50,000 acre-ft (2003–22)**
- **Minimum: ~46,000 acre-ft (2019)**
- **Maximum: ~53,000 acre-ft (2017 & 2022)**
- **33% greater than previous study (~37,600 acre-ft)**

EXPLANATION

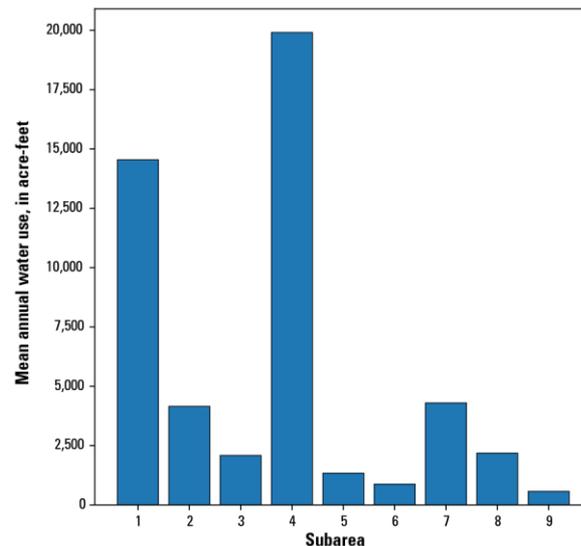
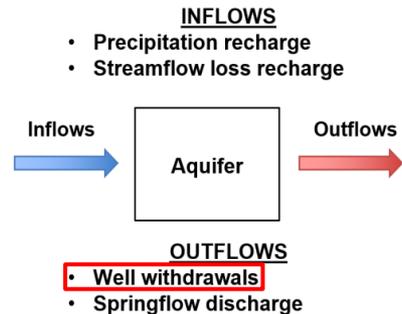
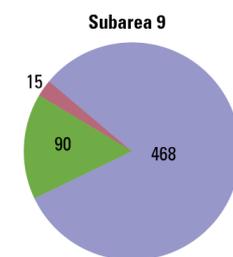
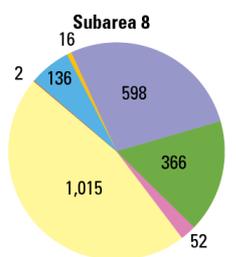
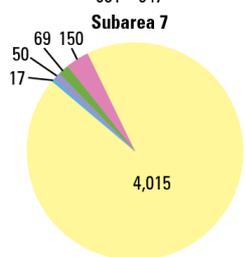
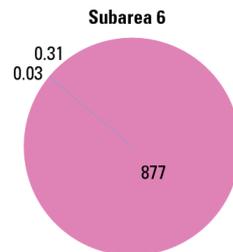
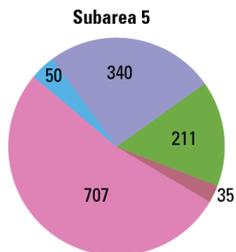
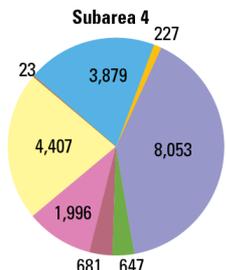
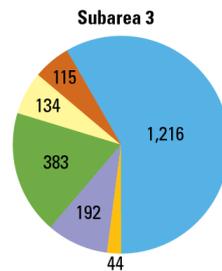
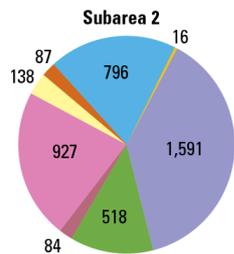
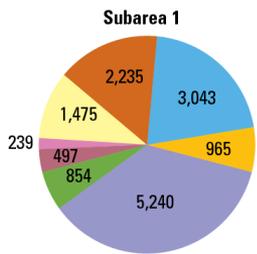
Precipitation below annual normal	Total withdrawals	Madison aquifer	Inyan Kara aquifer
Precipitation exceeding annual normal	Crystalline aquifer	Minnelusa aquifer	Sundance aquifer
	Deadwood aquifer	Minnekahta aquifer	Alluvial aquifers



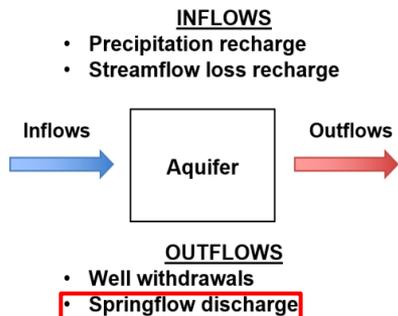
Outflow: Estimated average yearly water use by subarea and aquifer 2003–22

EXPLANATION

- Alluvium
- Crystalline
- Deadwood
- Inyan Kara
- Madison
- Minnekahta
- Minnelusa
- Other



Outflow: Springflow from the Madison and Minnelusa aquifers



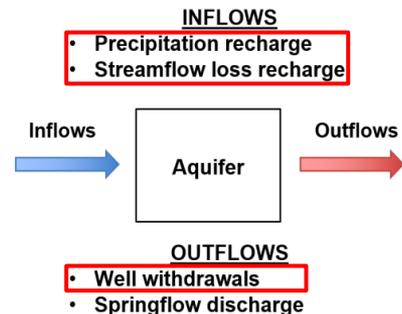
- Yearly average: 166,100 acre-ft (1931–2022)
- **+15% greater than previous study (144,100 acre-ft for 1931–98)**
- **Over 3 times greater than well withdrawals (~50,000 acre-ft)**



Example: Rhoads Fork (headwaters of Rapid Creek). Photo taken by USGS.

Water availability: Black Hills region

- Inflows compared to current demand (well withdrawals) and total appropriations
- Average yearly recharge: 278,900 acre-ft (1931–2022; 5 Pactolas)
- Average use: 50,000 acre-ft (2003–22; <1 Pactola)
- Total appropriations as of 2022: ~176,800 acre-ft (about 3 Pactolas)
- How does average yearly recharge compare to water use and appropriations in each subarea?



Satellite Imagery from Google Earth

Water availability: Madison and Minnelusa

Maximum yearly well withdrawals compared to recharge

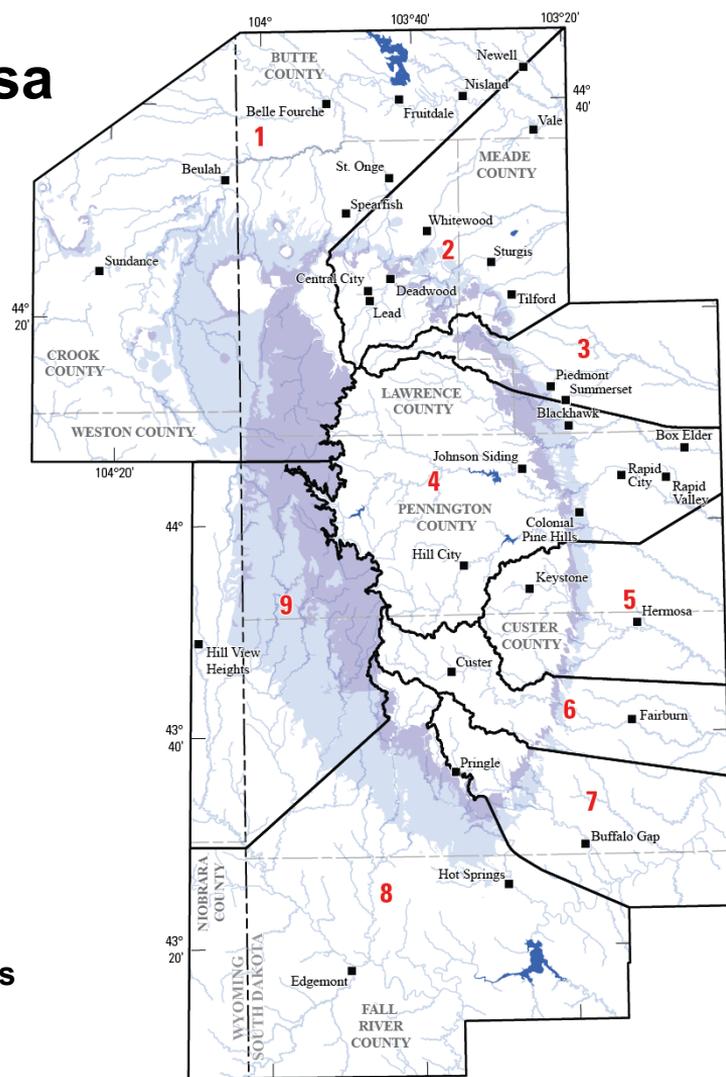
Aquifer	Subarea								
	1	2	3	4	5	6	7	8	9
Madison and Minnelusa	10%	13%	19%	56%	5%	0.1%	16%	19%	0%

(Maximum yearly well withdrawals / Average yearly recharge) * 100

Total yearly appropriations (2022) compared to recharge

Aquifer	Subarea								
	1	2	3	4	5	6	7	8	9
Madison and Minnelusa	34%	41%	62%	112%	17%	11%	32%	98%	6%

(Total yearly appropriations as of 2022 / Average yearly recharge) * 100



NOTE: Appropriations are greater than well withdrawals



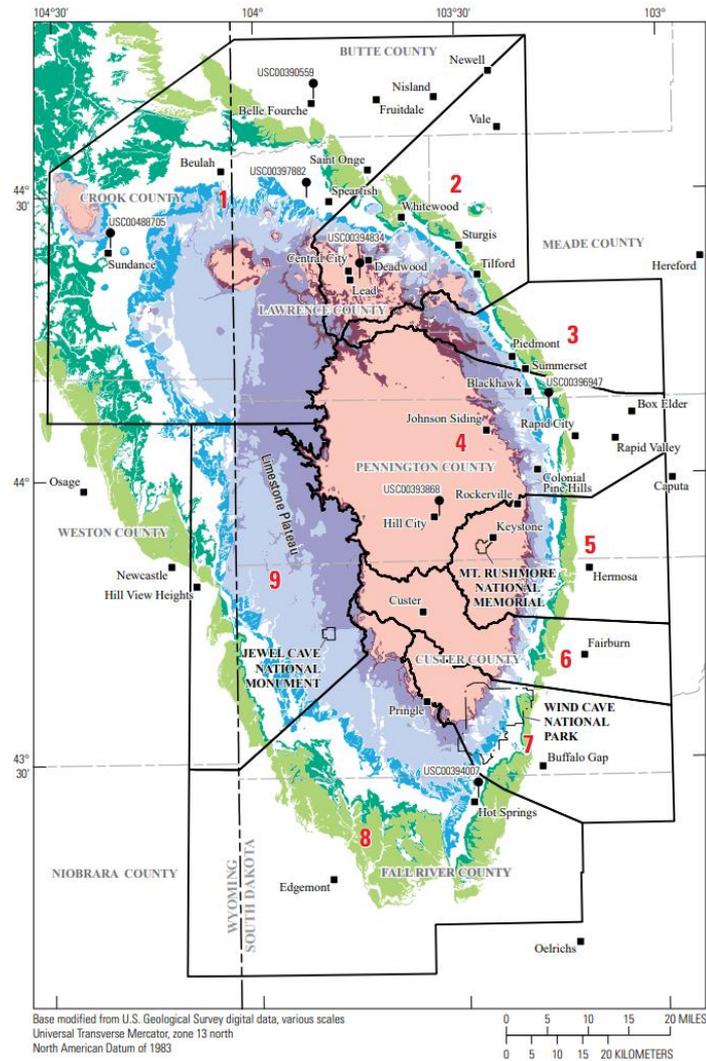
Water availability: Withdrawals

Maximum well withdrawals (2003–22) as a percent of average yearly recharge

Aquifer	Subarea								
	1	2	3	4	5	6	7	8	9
Deadwood	21%	10%	0%	77%	12%	0%	0%	0%	--*
Madison and Minnelusa	10%	13%	19%	56%	5%	0%	16%	19%	2%
Minnekahta	9%	1%	11%	41%	0%	0%	0%	4%	0%
Sundance	0%	10%	0%	0%	0%	0%	0%	0%	0%
Inyan Kara	18%	26%	35%	121%	46%	0%	15%	17%	8%

(Maximum yearly well withdrawals / Average yearly recharge) * 100

*Values reported were less than 50 acre-feet per year



Water availability: Appropriations

Total yearly appropriations (2022) as a percent of average yearly recharge

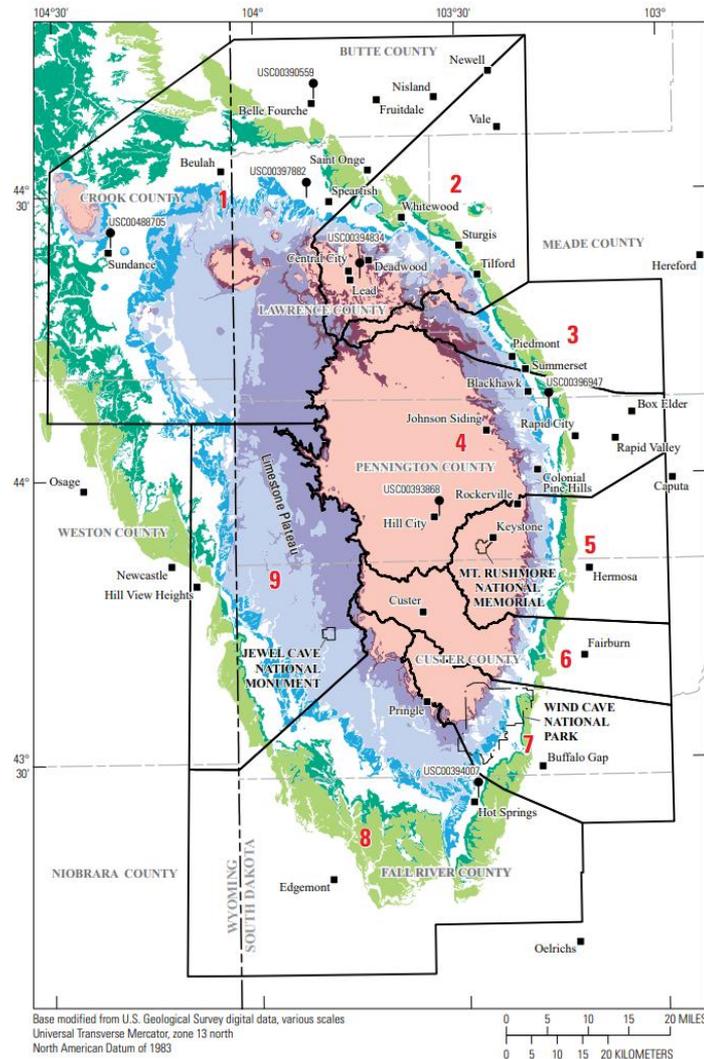
Aquifer	Subarea								
	1	2	3	4	5	6	7	8	9
Deadwood	39%	19%	0%	183%	24%	0%	0%	0%	--*
Madison and Minnelusa	34%	41%	62%	112%	17%	11%	32%	98%	6%
Minnekahta	26%	3%	22%	83%	0%	0%	0%	2%	0%
Sundance	1%	20%	0%	0%	0%	0%	0%	0%	0%
Inyan Kara	58%	81%	117%	478%	207%	0%	30%	45%	17%

(Total yearly appropriations as of 2022 / Average yearly recharge) * 100

*Values reported were less than 50 acre-feet per year



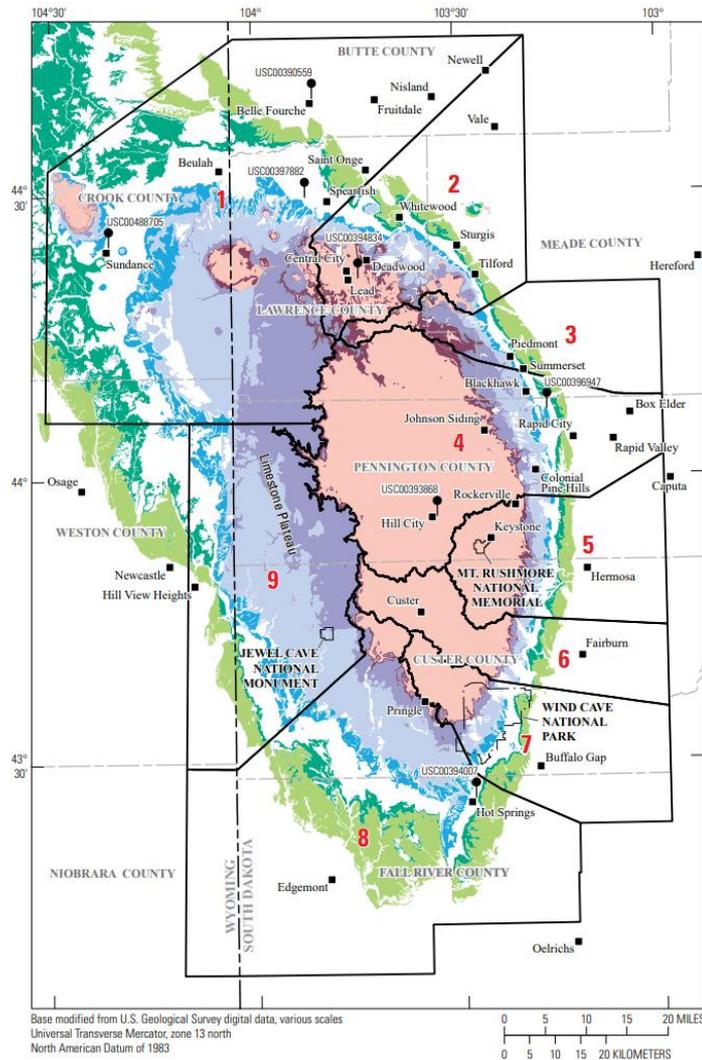
NOTE: Appropriations are not current water use



Water availability: Recoverable storage

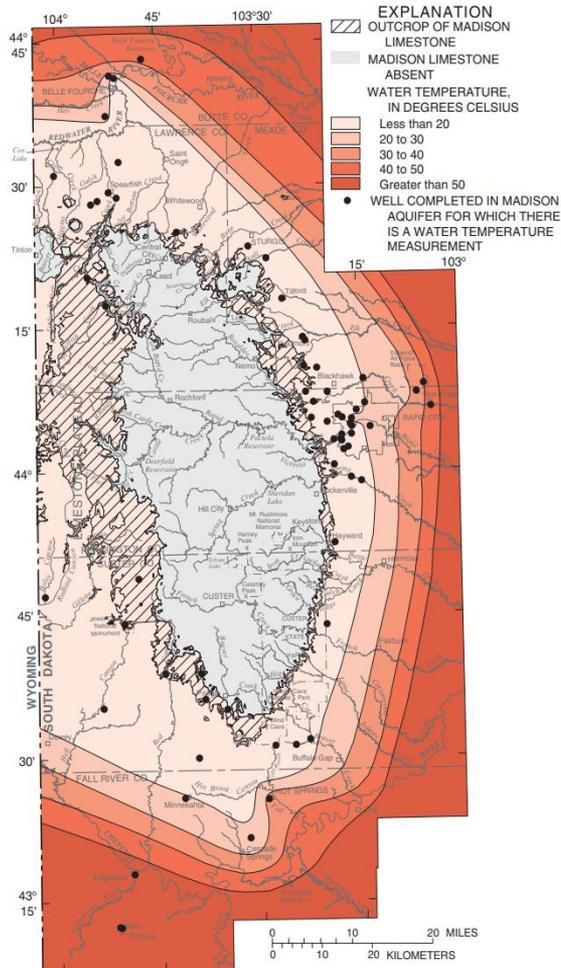
- The amount of water stored in an aquifer that can be withdrawn from wells
- Increases or decreases depending on recharge conditions

Aquifer	Previous estimate of recoverable water in storage (million acre-ft)	Updated estimate of recoverable water in storage (million acre-ft)
	South Dakota only	South Dakota and Wyoming
Precambrian	2.6	2.6
Deadwood	30.5	39.6
Madison	62.7	83.6
Minnelusa	70.9	96.9
Minnekahta	4.9	6.9
Inyan Kara	84.7	127.2
Combined storage for major aquifers	256.3	356.9

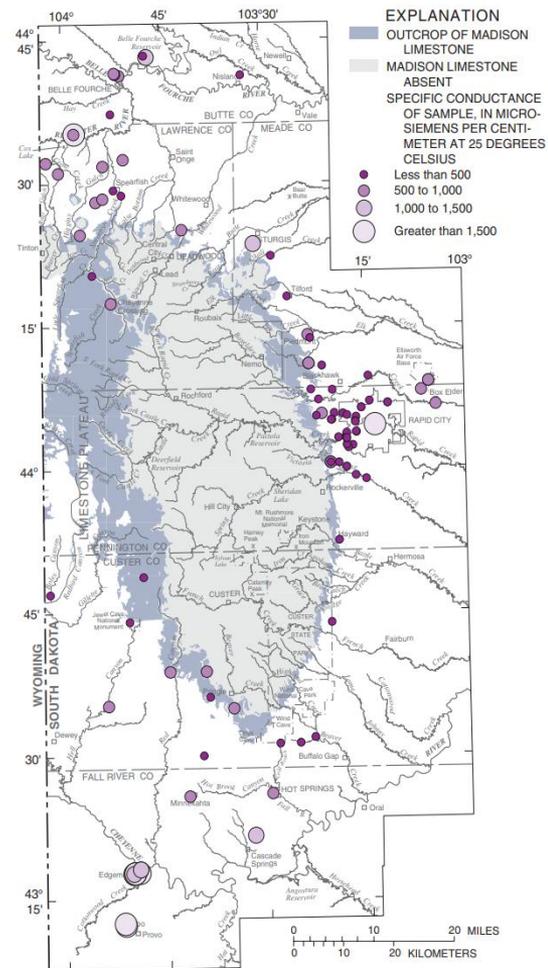


Water-quality variations

- Not all groundwater in storage is high quality
- Quality tends to decrease away from Black Hills
 - Hot ($>100^{\circ}\text{F}$)
 - Salty



Base modified from U.S. Geological Survey digital data, 1:100,000, 1977, 1979, 1981, 1983, 1985
 Rapid City, Office of City Engineer map, 1:18,000, 1996
 Universal Transverse Mercator projection, zone 13



Base modified from U.S. Geological Survey digital data, 1:100,000, 1977, 1979, 1981, 1983, 1985
 Rapid City, Office of City Engineer map, 1:18,000, 1996
 Universal Transverse Mercator projection, zone 13



Maps from Carter and others (2003)

Budget summary

- Since the last time a regional study was completed (1998)
 - **Population**: Increased from 154,200 to 214,100 (39 percent increase)
 - **Precipitation**: Greater than normal for 1999–2022
 - **Permitting**: Increased groundwater permits, especially Madison aquifer
 - **Inflows**:
 - Average yearly **precipitation** for study area was about 0.6 inches greater
 - Recharge from **streamflow** was about 9 percent greater with updated records
 - **Outflows**:
 - **Springflow** increased by 15 percent
 - **Well withdrawals** were about 33 percent higher than previous estimates
- **Well withdrawals and appropriations exceed average yearly recharge for some aquifers in some subareas**



Changes during drought conditions

- Since the last time a regional study was completed (1998)
 - Population: Increased from 154,200 to 214,100 (39 percent increase)
 - Precipitation: Greater than normal for 1999–2022
 - Permitting: Increased groundwater permits, especially Madison aquifer
 - Inflows:
 - Average yearly **precipitation** for study area was about 0.6 inches greater
 - Recharge from **streamflow** was about 9 percent greater with updated records
 - Outflows:
 - **Springflow** increased by 15 percent
 - **Well withdrawals** were about 33 percent higher than previous estimates
- Well withdrawals and appropriations exceed average yearly recharge for some aquifers in some subareas

