The Use of Age Dating and Environmental Tracers to Characterize Ground-Water Flow, Wind Cave National Park, South Dakota

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Aquatic Professionals Meeting
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Outline

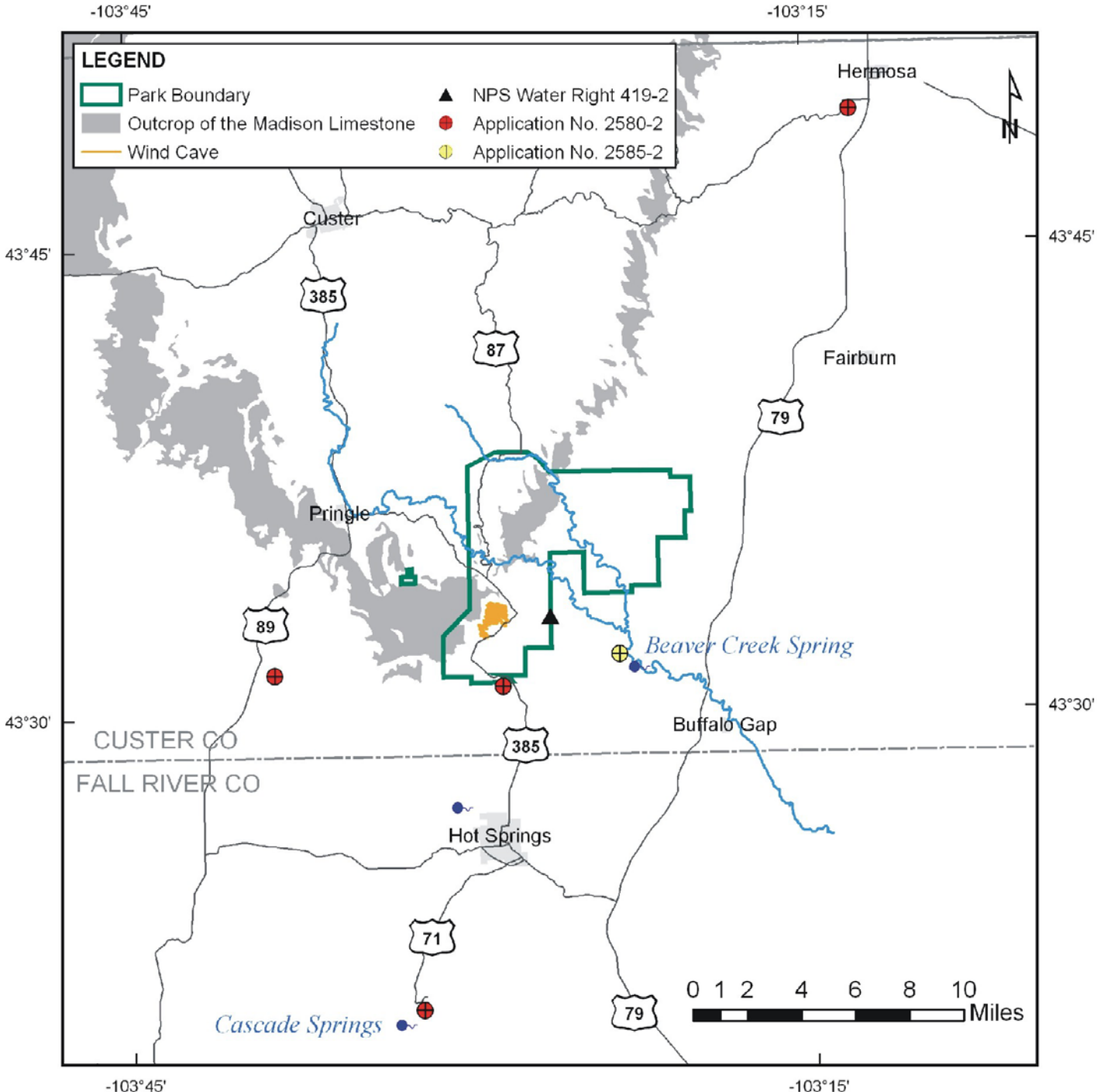
Introduction

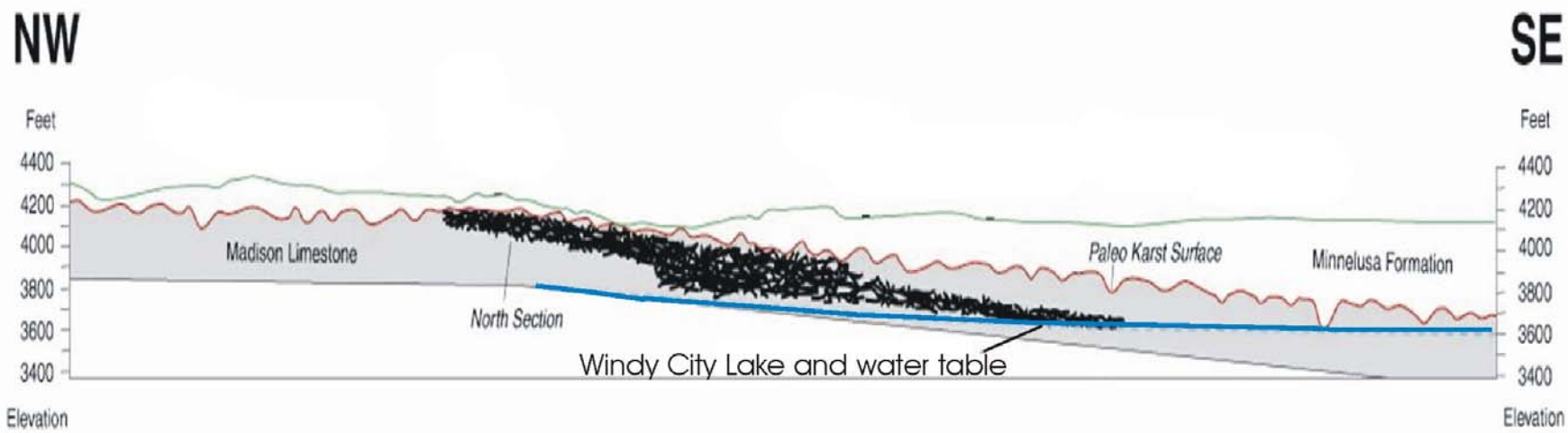
- Threat
- Hydrologic Setting
- Approach

Results

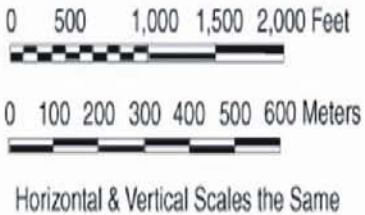
- Chemistry
- Stable Isotopes
- Age dating

Conclusions

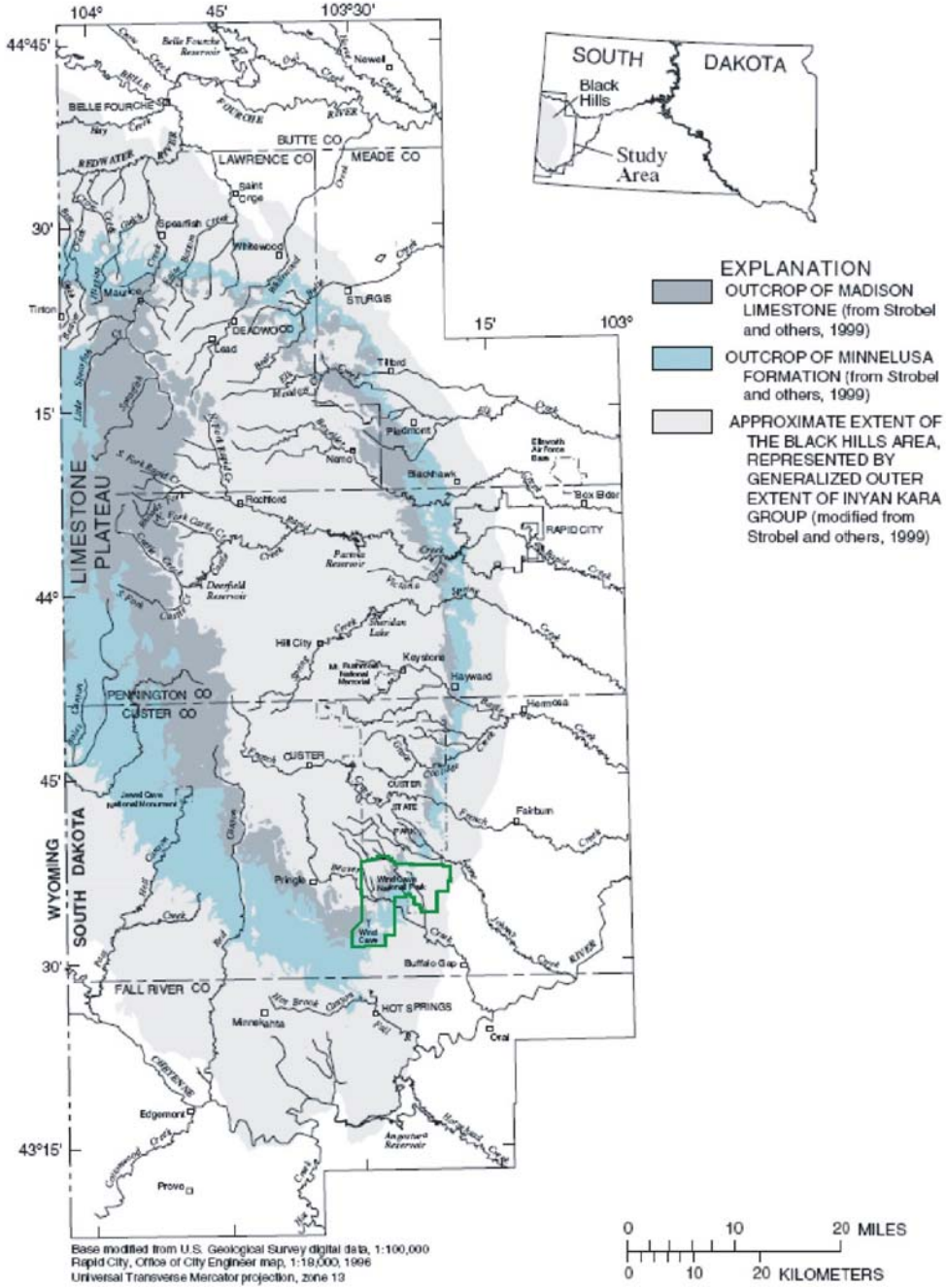

-103°45'
-103°15'
LEGEND
Park Boundary
Outcrop of the Madison Limestone
Wind Cave
NPS Water Right 419-2
Application No. 2580-2
Application No. 2585-2
Hermosa
N
Custer
43°45'
385
87
Fairburn
79
Pringle
89
Beaver Creek Spring
43°30'
Buffalo Gap
CUSTER CO
385
FALL RIVER CO
Hot Springs
71
0 1 2 4 6 8 10
Miles
Cascade Springs
79



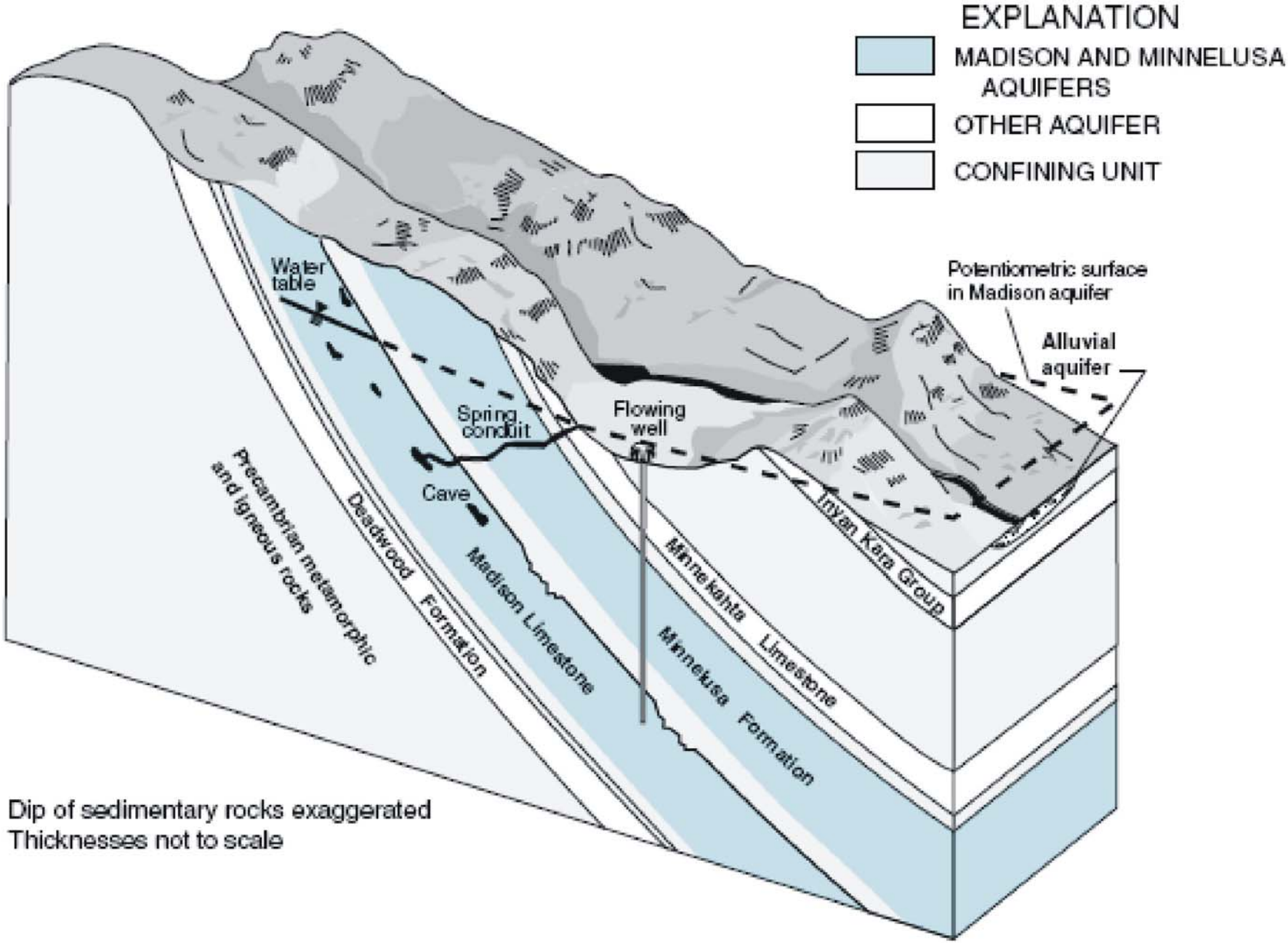
Profile of Wind Cave looking NE along the dip



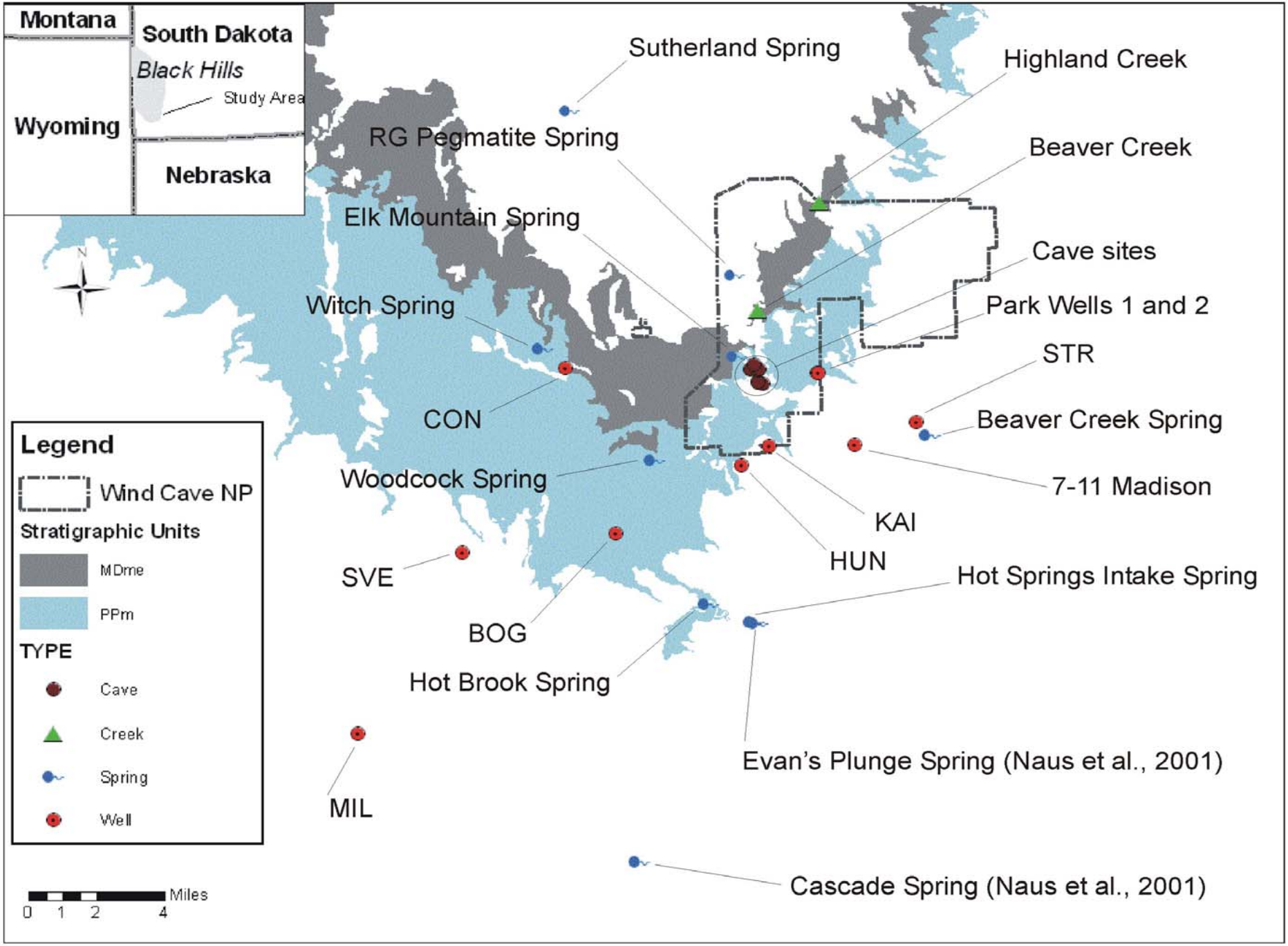
Compiled by Rodney Horrocks



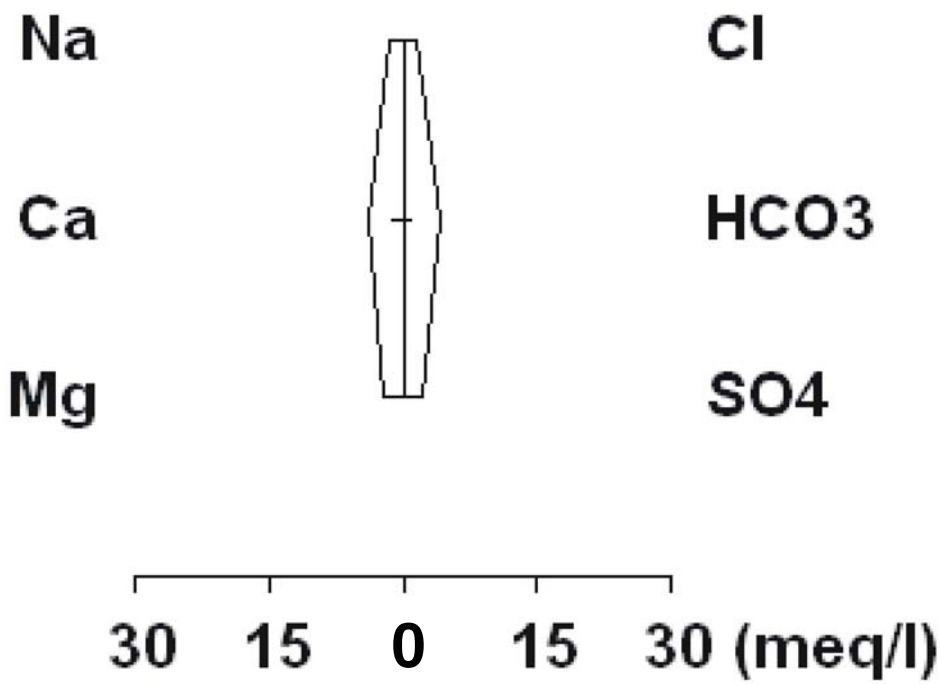
Modified from: Carter, J.M., D.G. Driscoll, and G.R. Hamade, 2000. Estimated Recharge to the Madison and Minnelusa aquifers, in the Black Hills Area, South Dakota and Wyoming, Water Years 1931-98, U.S. Geological Survey Water-Resources Investigations Report 00-4278.

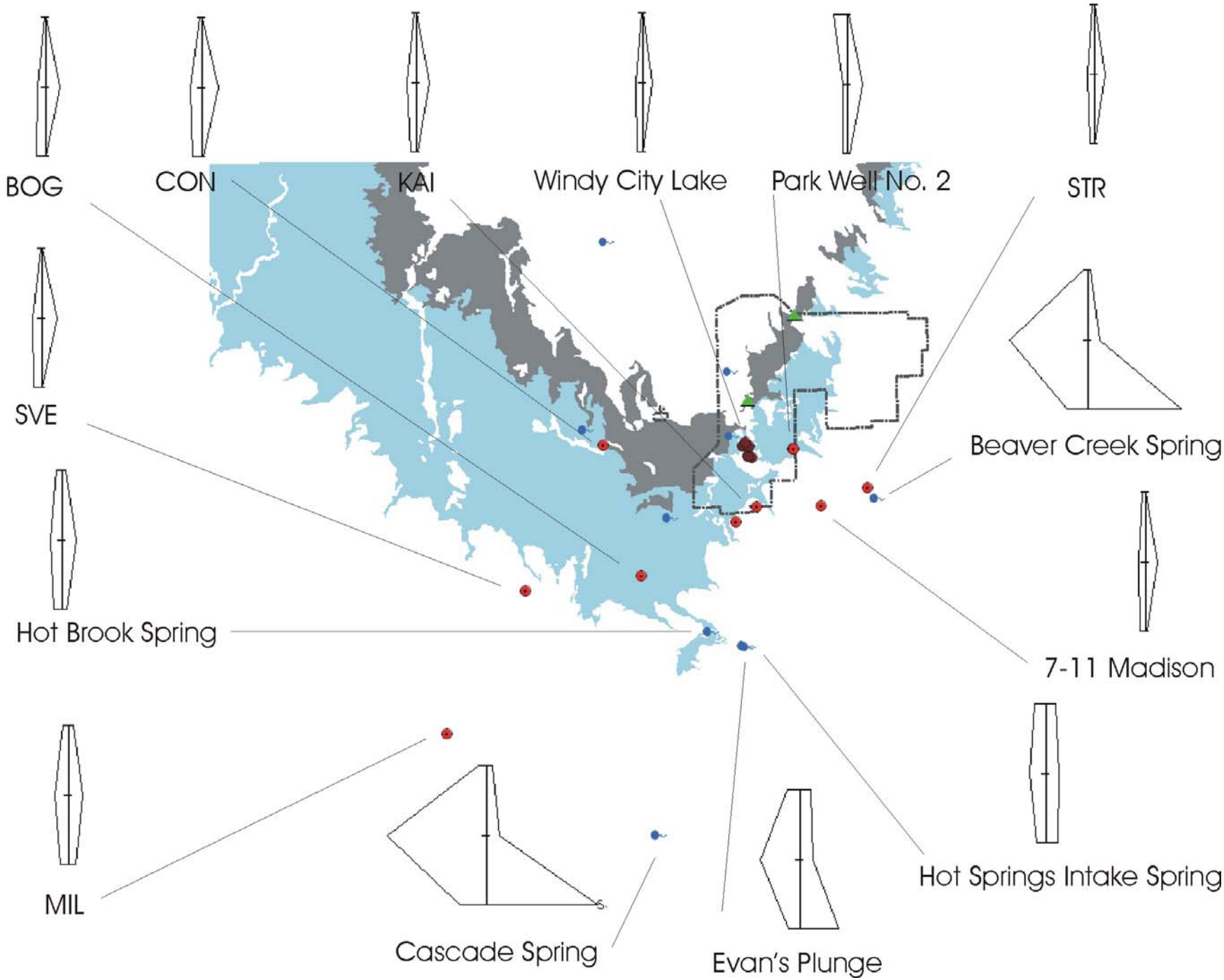


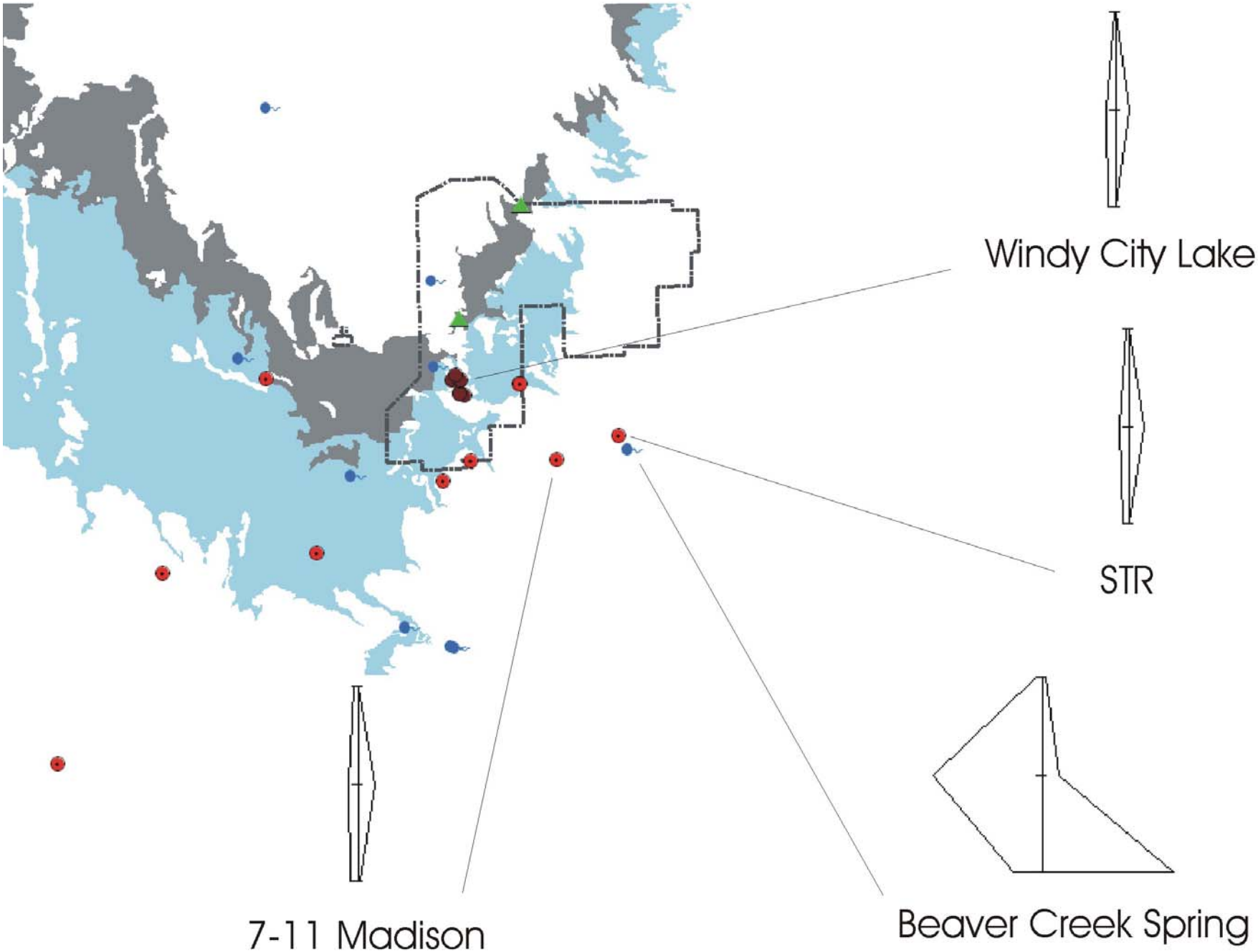
Source: Carter, J.M., D.G. Driscoll, and G.R. Hamade, 2000. Estimated Recharge to the Madison and Minnelusa aquifers, in the Black Hills Area, South Dakota and Wyoming, Water Years 1931-98, U.S. Geological Survey Water-Resources Investigations Report 00-4278.

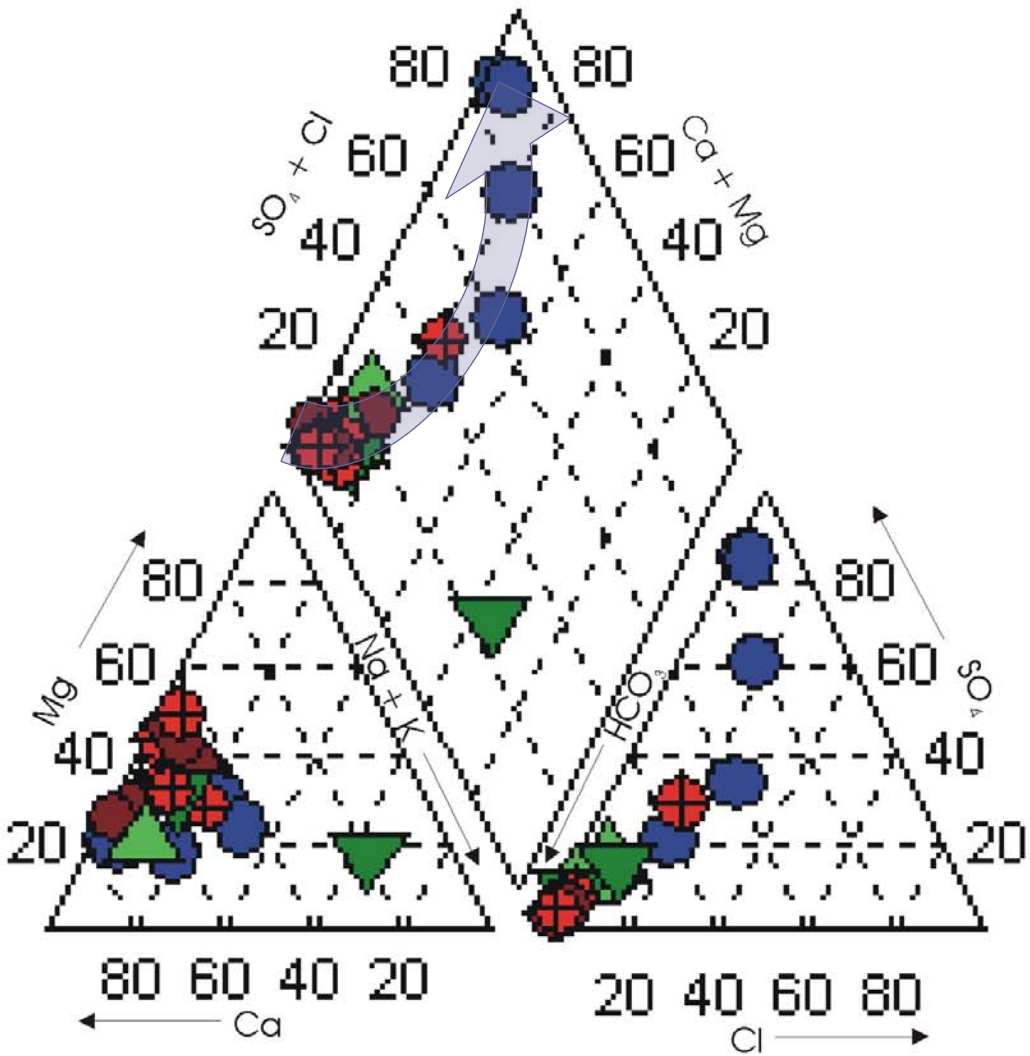

Montana
South Dakota
Black Hills
Study Area
Wyoming
Nebraska
Sutherland Spring
Highland Creek
RG Pegmatite Spring
Beaver Creek
Elk Mountain Spring
Cave sites
Park Wells 1 and 2
Witch Spring
STR
CON
Beaver Creek Spring
Woodcock Spring
7-11 Madison
KAI
HUN
SVE
Hot Springs Intake Spring
BOG
Hot Brook Spring
Evan's Plunge Spring (Naus et al., 2001)
MIL
Cascade Spring (Naus et al., 2001)
Legend
Wind Cave NP
Stratigraphic Units
MDme
PPm
TYPE
Cave
Creek
Spring
Well
Miles
0 1 2 4

Stiff Diagrams

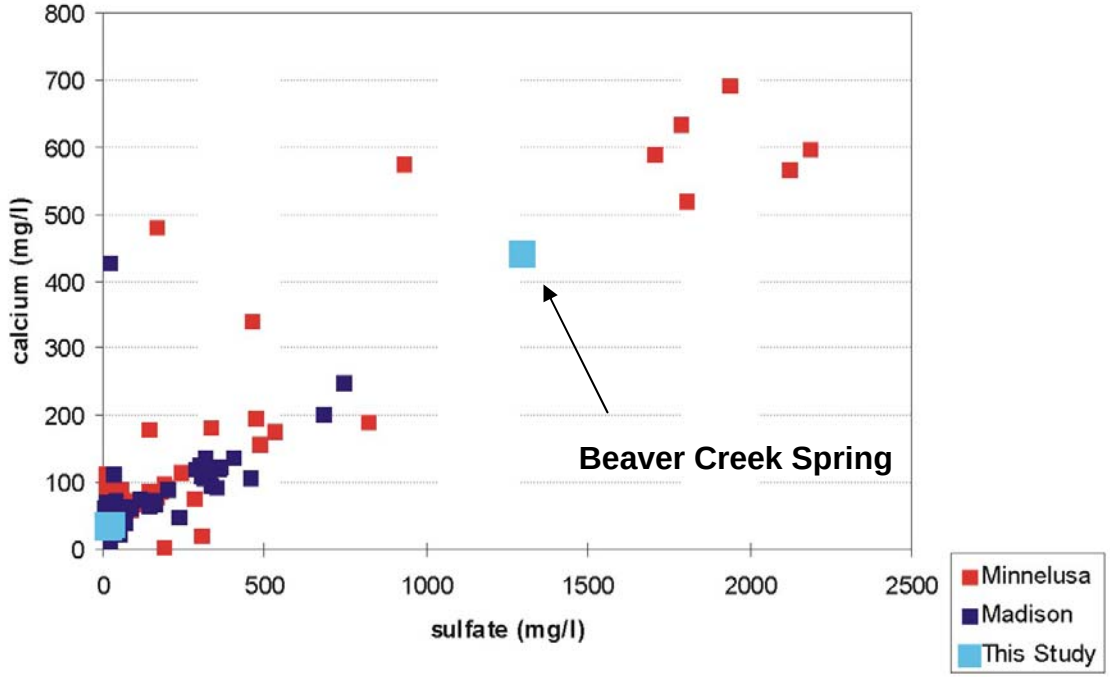


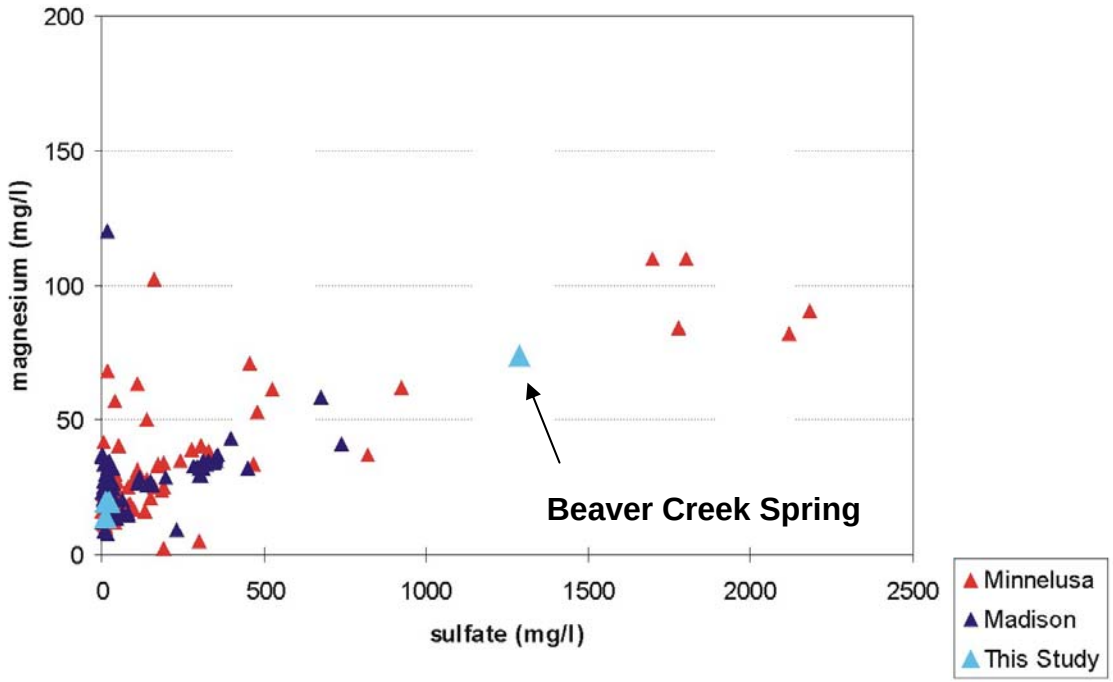

BOG
CON
KAI
Windy City Lake
Park Well No. 2
STR
SVE
Beaver Creek Spring
Hot Brook Spring
7-11 Madison
MIL
Hot Springs Intake Spring
Cascade Spring
Evan's Plunge

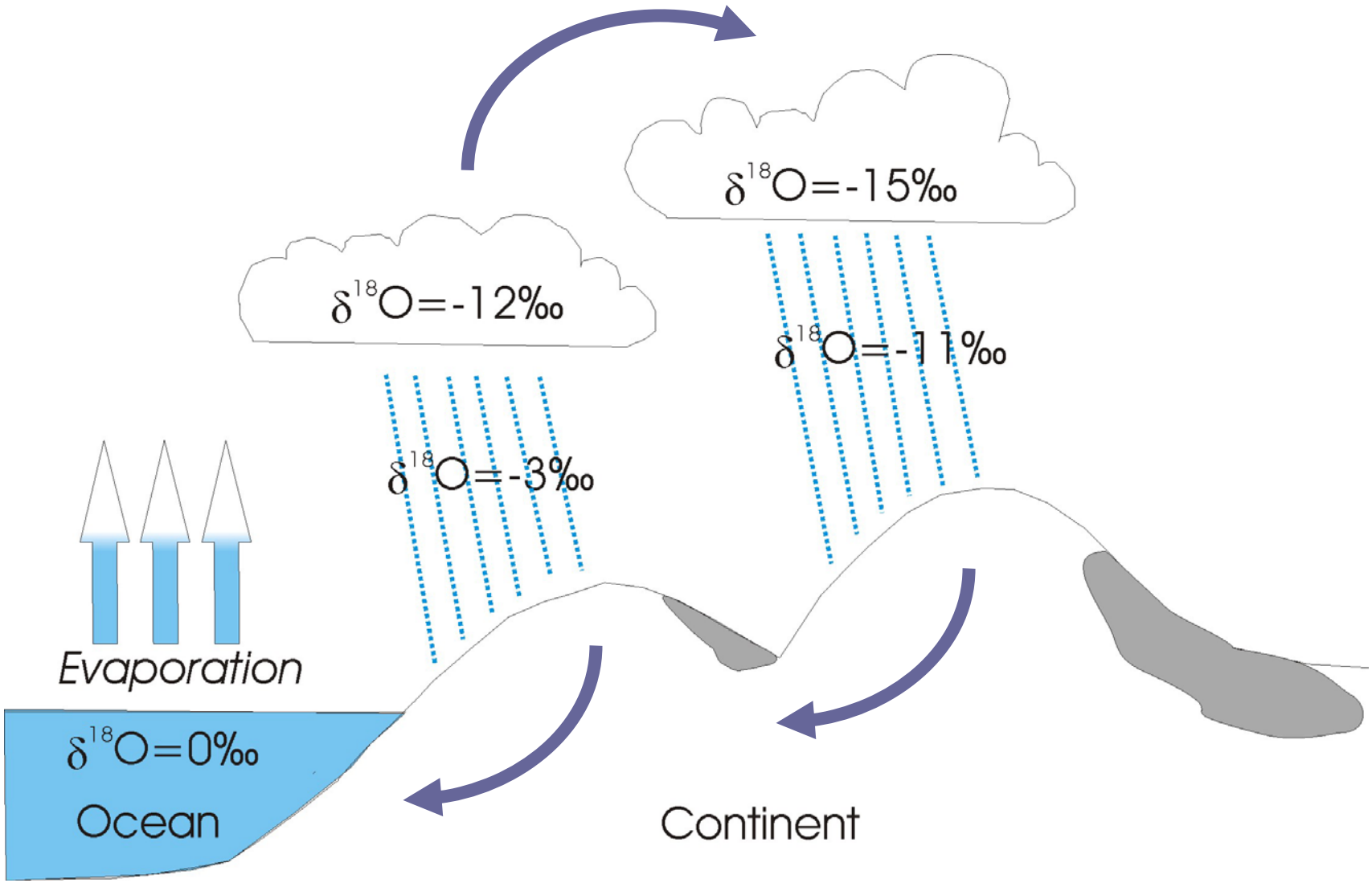

Windy City Lake
STR
7-11 Madison
Beaver Creek Spring

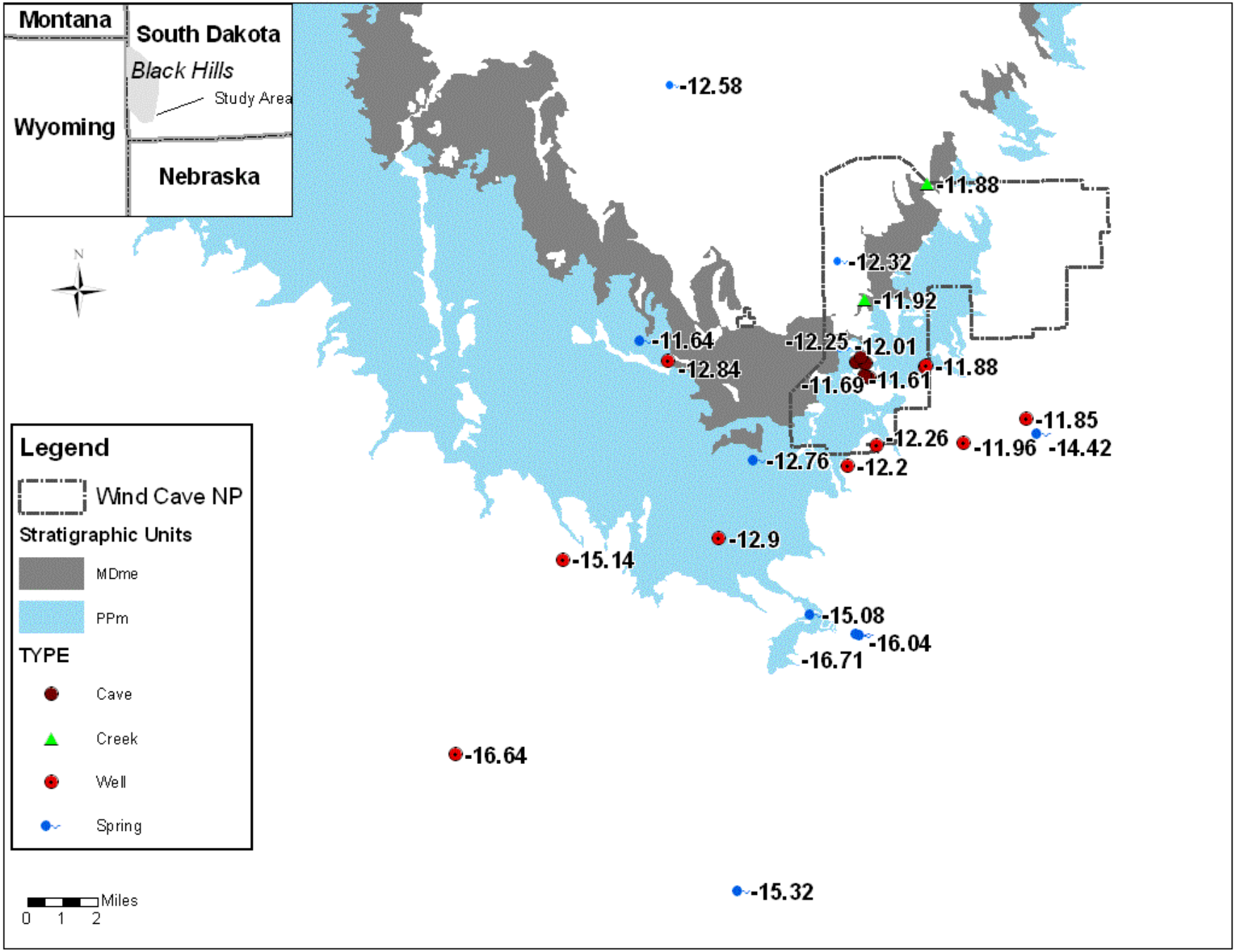


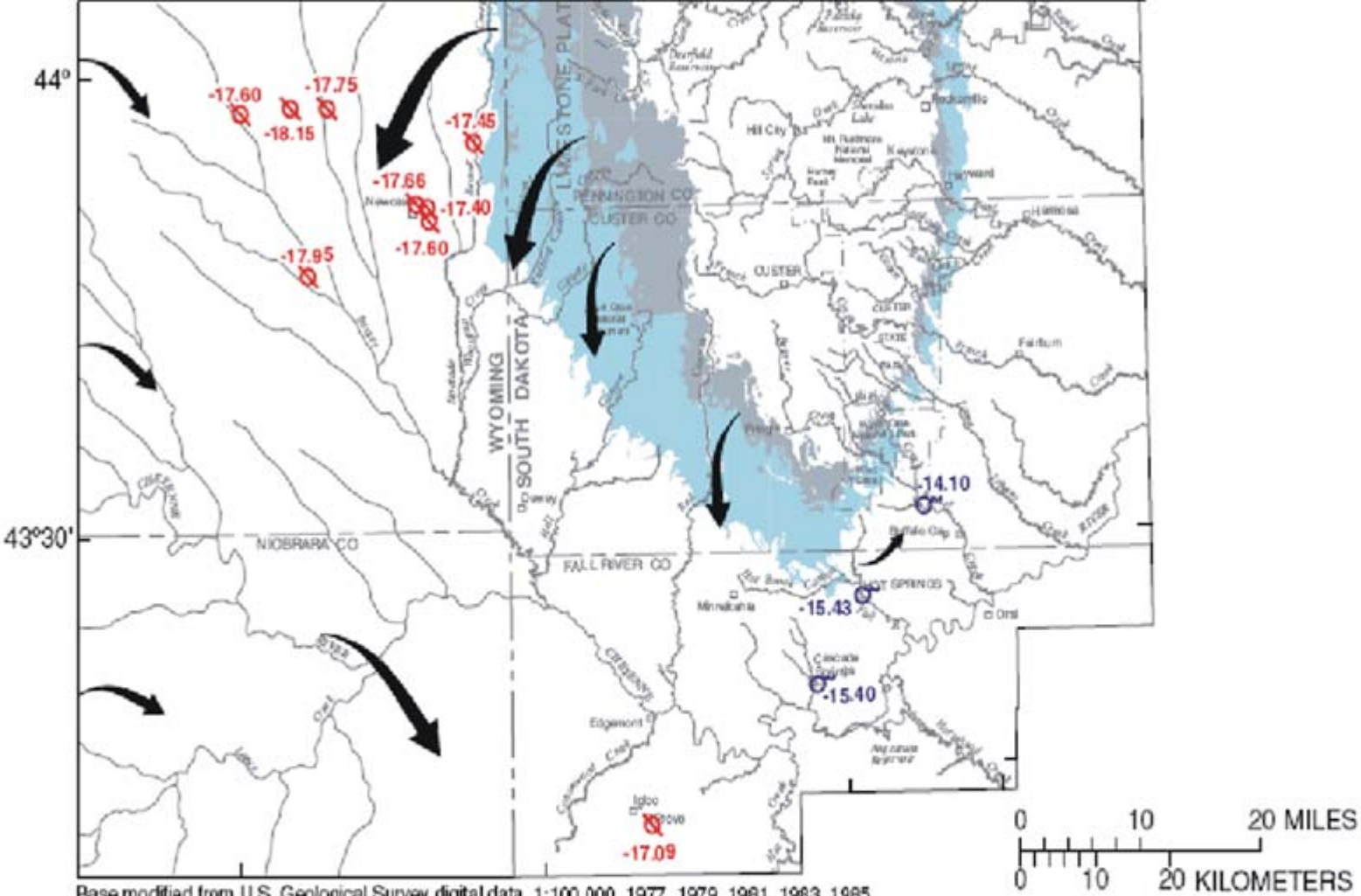
Creek
Well
Artesian spring
Cave sites
Park wells


800
700
600
500
400
300
200
100
0
calcium (mg/l)
0
500
1000
1500
2000
2500
sulfate (mg/l)
Beaver Creek Spring
Minnelusa
Madison
This Study


200
150
100
50
0
magnesium (mg/l)
0
500
1000
1500
2000
2500
sulfate (mg/l)
Beaver Creek Spring
Minnelusa
Madison
This Study


δ18O=-15‰
δ18O=-12‰
δ18O=-11‰
δ18O=-3‰
Evaporation
δ18O=0‰
Ocean
Continent


Montana
South Dakota
Black Hills
Study Area
Wyoming
Nebraska
N
-12.58
-11.88
-12.32
-11.92
-11.64
-12.25
-12.01
-12.84
-11.88
-11.69
-11.61
-11.85
-12.26
-11.96
-14.42
-12.76
-12.2
-12.9
-15.14
-15.08
-16.04
-16.71
-16.64
-15.32
Legend
Wind Cave NP
Stratigraphic Units
MDme
PPm
TYPE
Cave
Creek
Well
Spring
Miles
0 1 2



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

EXPLANATION

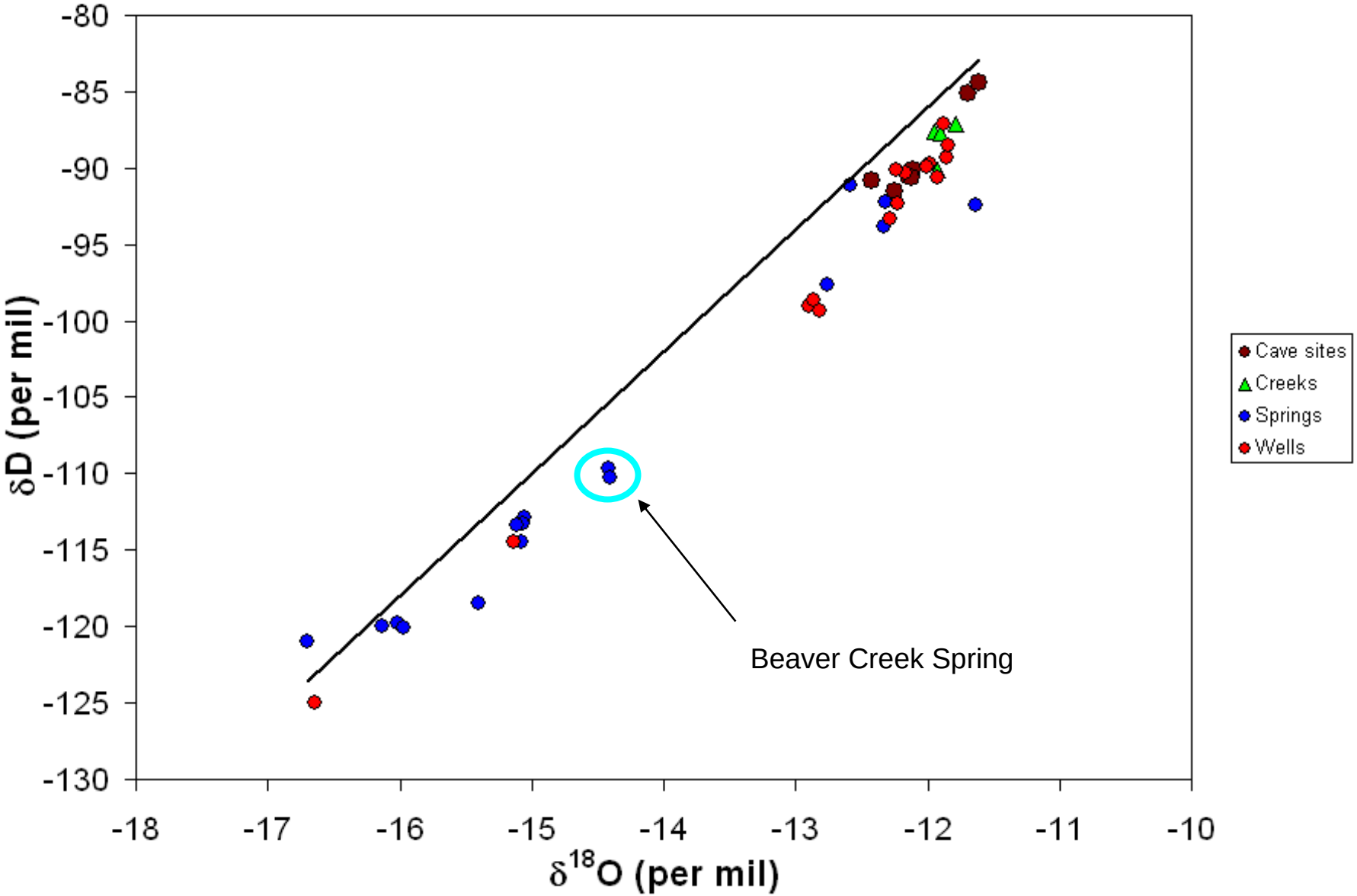
OUTCROP OF MADISON LIMESTONE (from Strobel and others, 1999; DeWitt and others, 1989)

OUTCROP OF MINNELUSA FORMATION (from Strobel and others, 1999; DeWitt and others, 1989)

GENERALIZED FLOWPATH

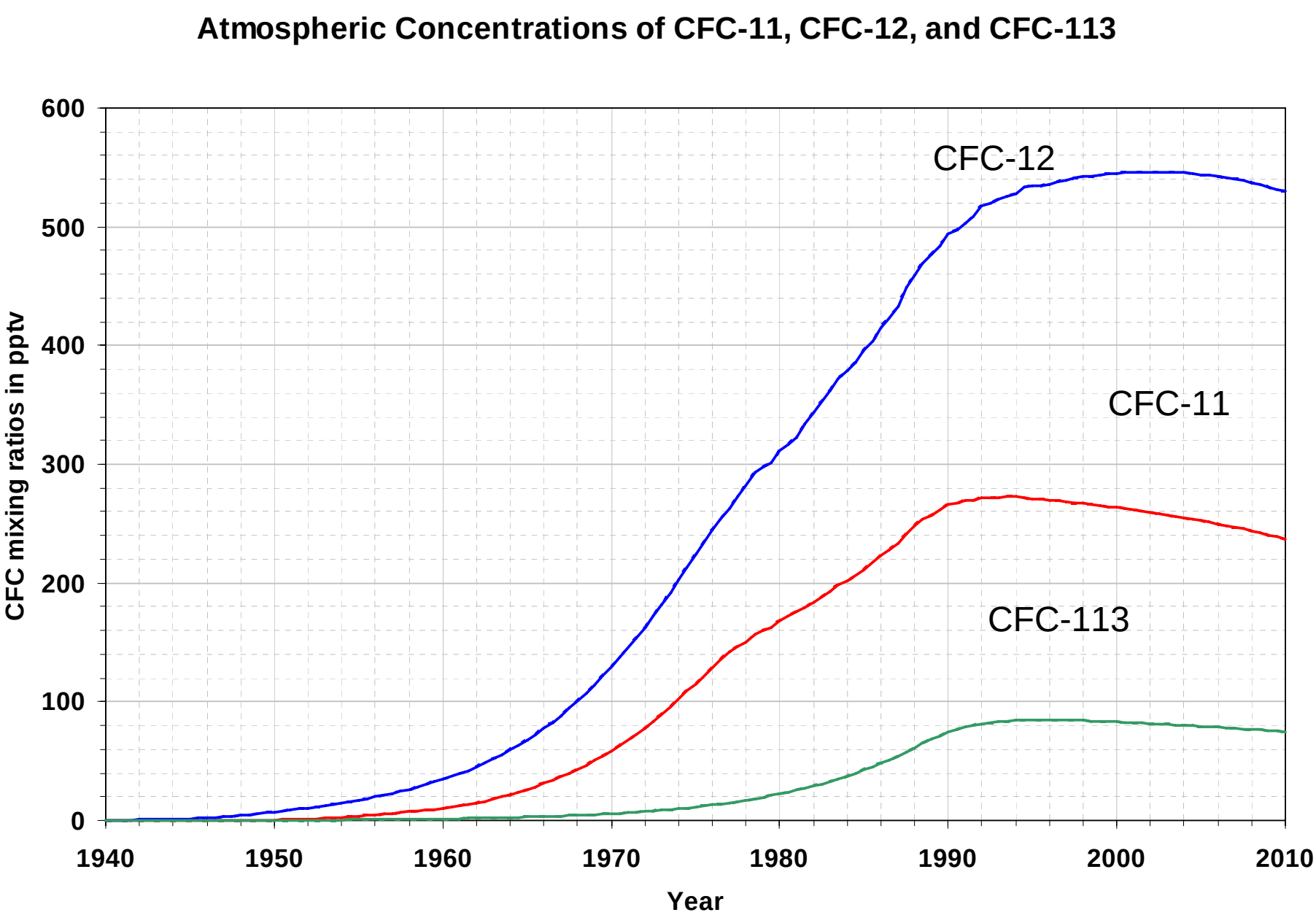
-17.09 WELL COMPLETED IN MADISON AQUIFER--Number indicates $\delta^{18}O$ value in per mil

-15.40 ARTESIAN SPRING--Number indicates $\delta^{18}O$ value in per mil


-80
-85
-90
-95
-100
-105
-110
-115
-120
-125
-130
δD (per mil)
-18
-17
-16
-15
-14
-13
-12
-11
-10
δ18O (per mil)
Beaver Creek Spring
Cave sites
Creeks
Springs
Wells

Binary Mixing Model

$$\delta_{SAMPLE} = X\,\delta_A + (1 - X)\,\delta_B$$


Atmospheric Concentrations of CFC-11, CFC-12, and CFC-113
CFC-12
CFC-11
CFC-113
CFC mixing ratios in pptv
0
100
200
300
400
500
600
1940
1950
1960
1970
1980
1990
2000
2010
Year

Site Name	Tritium	CFC Model Age	Fraction of Young Water [1]
	(pCi/L)	(years)	(%)
What the Hell Lake (cave)	15.7	20	70 - 74
HUN well	26.9	30	64 - 72
STR well	16.6	35	34 - 65
Hot Brook Springs	3.8	40	24 - 85
Beaver Creek Spring	4.5	40	18 - 65
7-11 MDSN well	0.6	60	Not Possible
BOG well	Not Available	35	35 - 84

[1]Based on binary mixing of young and old water from ratio of two CFCs

Conclusions

- The similarity in geochemistry, isotopic signature, and water levels between underground lakes and Streeter Well indicates a common source of water.
- Geochemical data and age dating techniques suggest that a large portion of water discharging at Beaver Creek Spring is recharged locally.
- Additional withdrawals at the Streeter Well site will likely cause water level declines in the Madison aquifer.

Acknowledgements

» Marc Ohms

» Andy Long

» Jason Walz

» Jeff Hughes