

The background of the slide is an abstract composition of two textured, organic shapes. On the left, a large area of deep teal and forest green has a mottled, painterly texture. On the right, a vertical strip of warm, earthy orange and tan also has a textured, slightly grainy appearance. The two colors meet at an irregular, wavy boundary line that runs roughly from the top to the bottom of the frame.

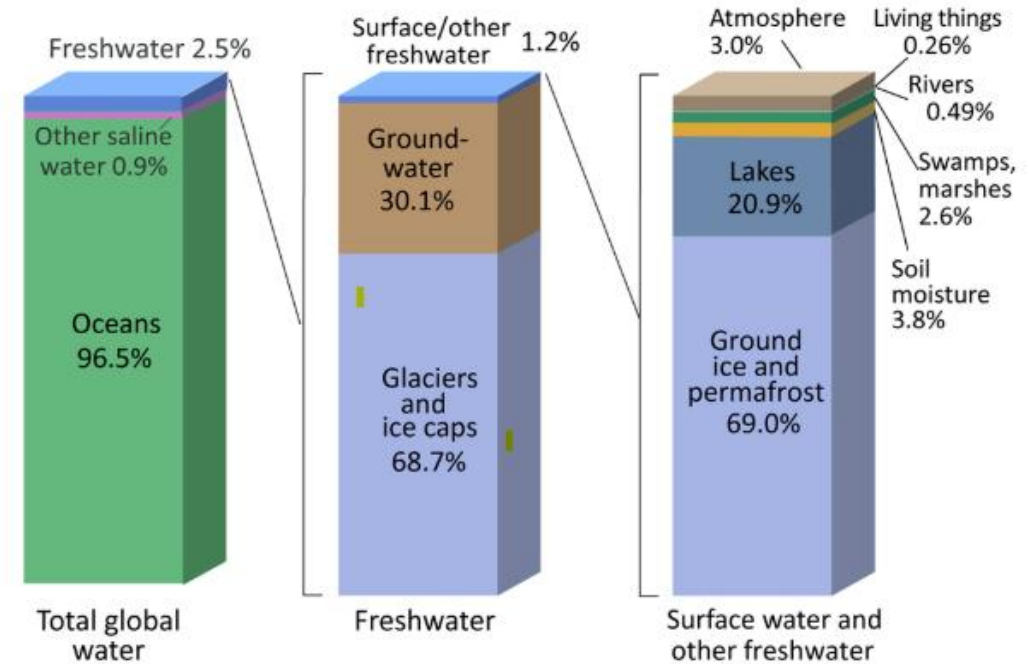
ANALYSIS OF GROUND WATER LEVELS IN THE STATE OF COLORADO

1980-2020

OVERVIEW

- Over 98 % of the Earth's useable fresh water is located in the ground
- An understanding of the Earth's ground water volumes and use is critical to planning for a sustainable economic and environmental future
- This understanding is of greatest importance in arid environments where water sources are scarce, such as the western United States

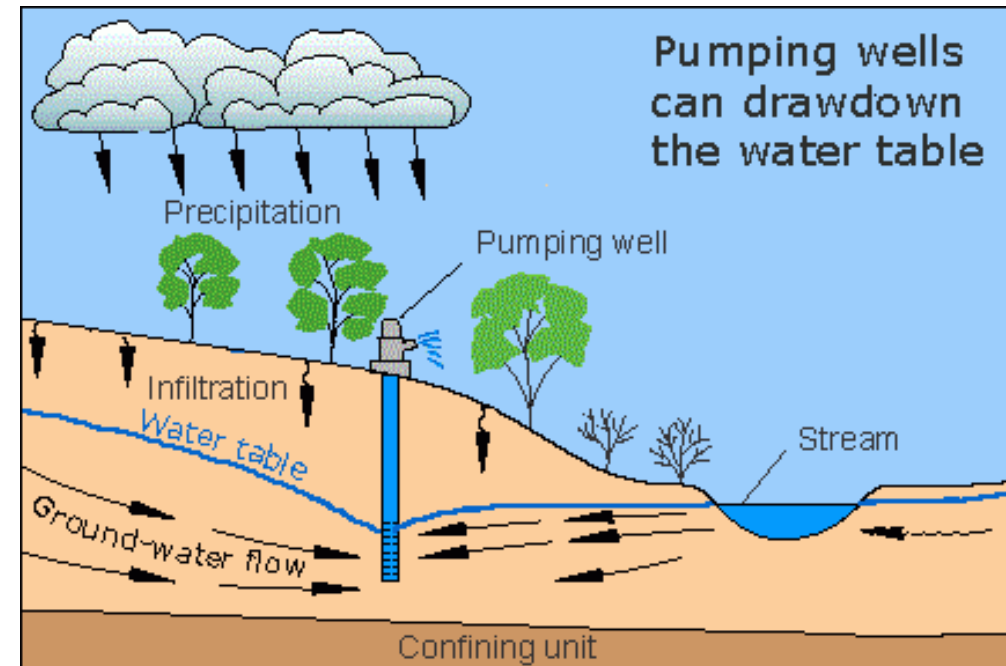
Where is Earth's Water?



Credit: U.S. Geological Survey, Water Science School. <https://www.usgs.gov/special-topic/water-science-school>
Data source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, *Water in Crisis: A Guide to the World's Fresh Water Resources*. (Numbers are rounded).

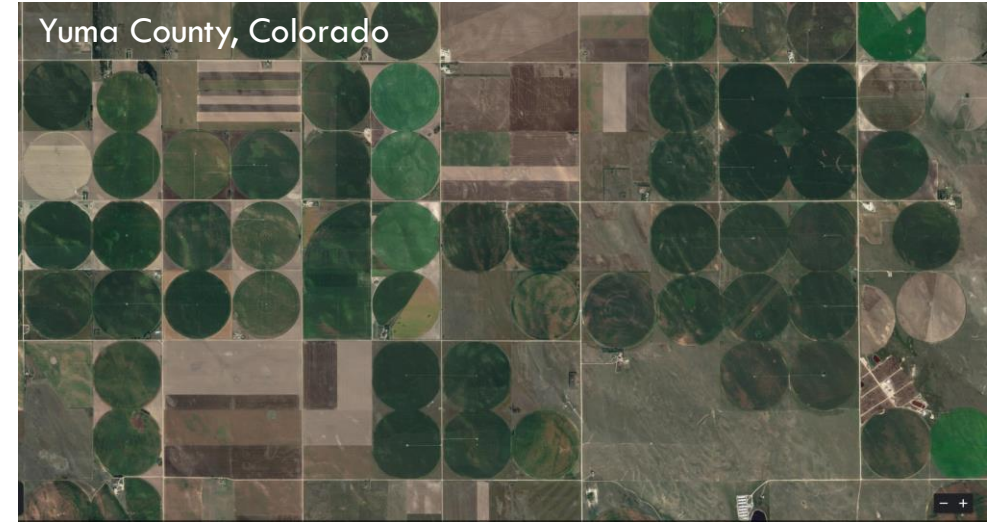
GROUND WATER MEASUREMENT OVERVIEW

- Ground water levels are measured from wells drilled into an aquifer
- Ground water levels increase or decrease based upon the balance of charge (infiltration, flow) and discharge (pumping, negative-flow)
- By measuring water levels through time, a net increase or decrease in aquifer volumes can be assessed



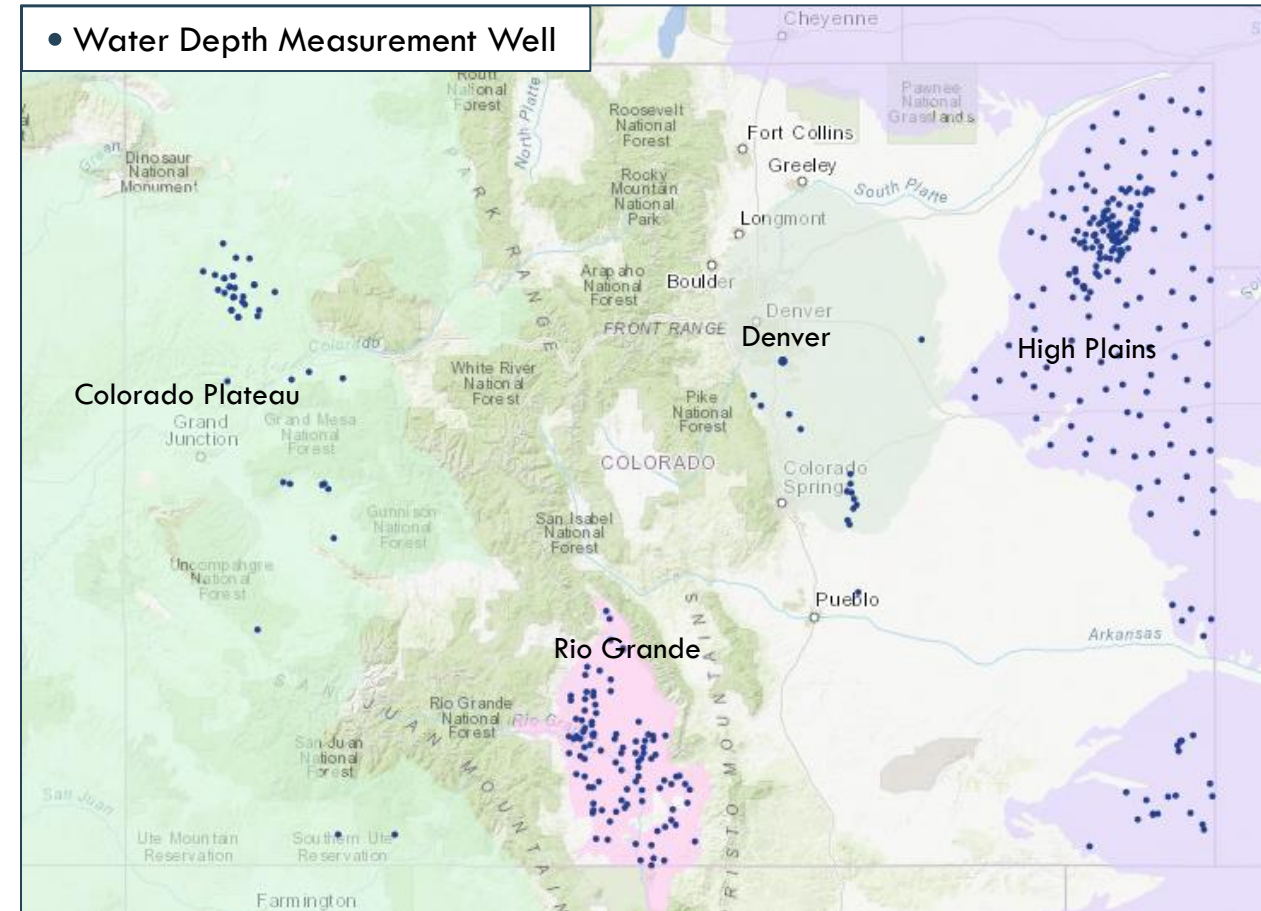
PROBLEM STATEMENT

- Have ground water levels increased or decreased in the state of Colorado from 1980-2020?
- How has ground water from 1980-2020 changed by area and aquifer formation?

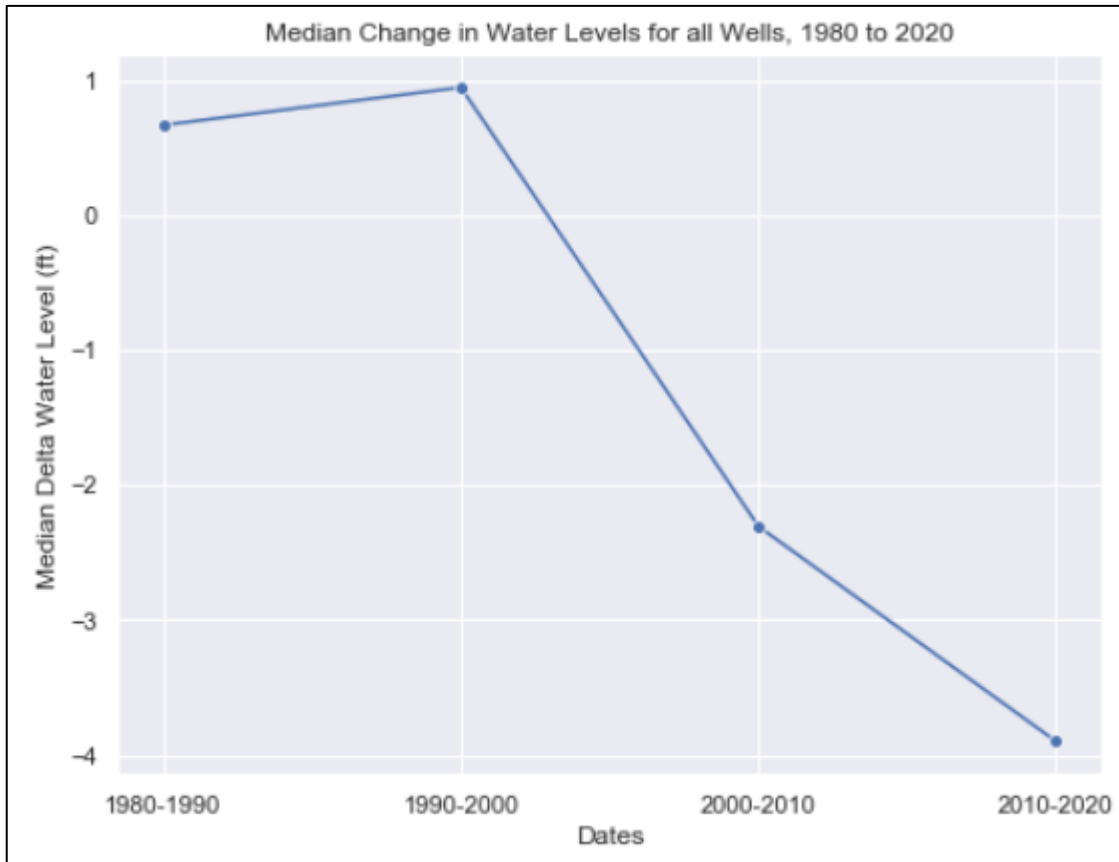


DATA ANALYZED

- Ground water level data for Colorado was derived from the National Ground Water Monitoring Network
- Data coverage is not great. Many areas of the state have poor data coverage or none at all.
- The data is composed of two csv files: [Data here](#)
 1. Site information for 299 wells (Site number identifier, location, depth, aquifer, aquifer type)
 2. Water level measurements ($n > 63,000$)
 - site number identifier, measurement date, water level
- Wells without data prior to 01/01/1990 were omitted
 - Resulted in 221 wells and 19,220 well level measurements for analysis



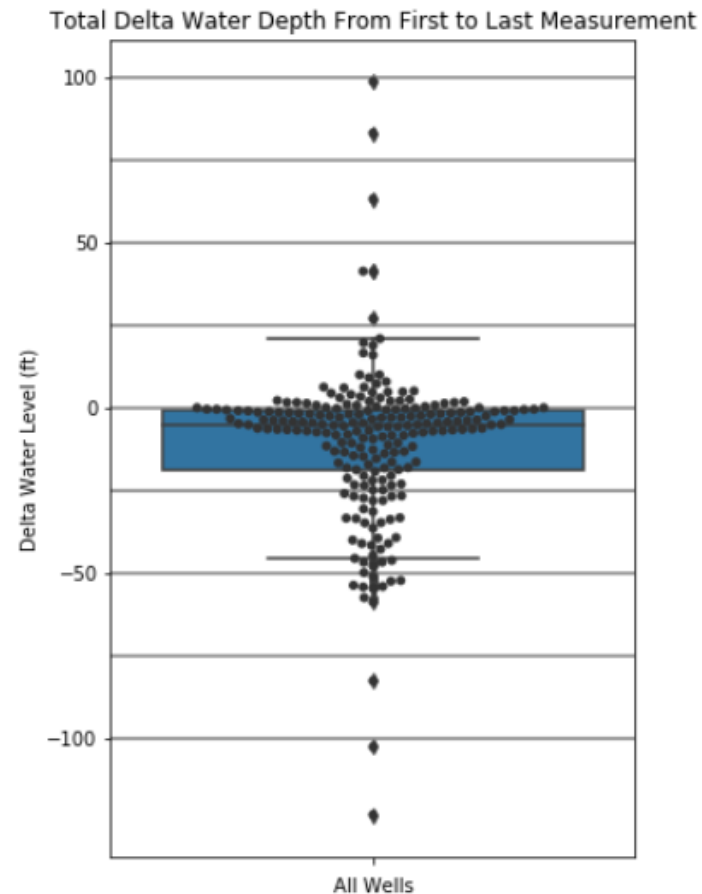
MEDIAN CHANGE IN WATER LEVELS: ALL WELL SITES



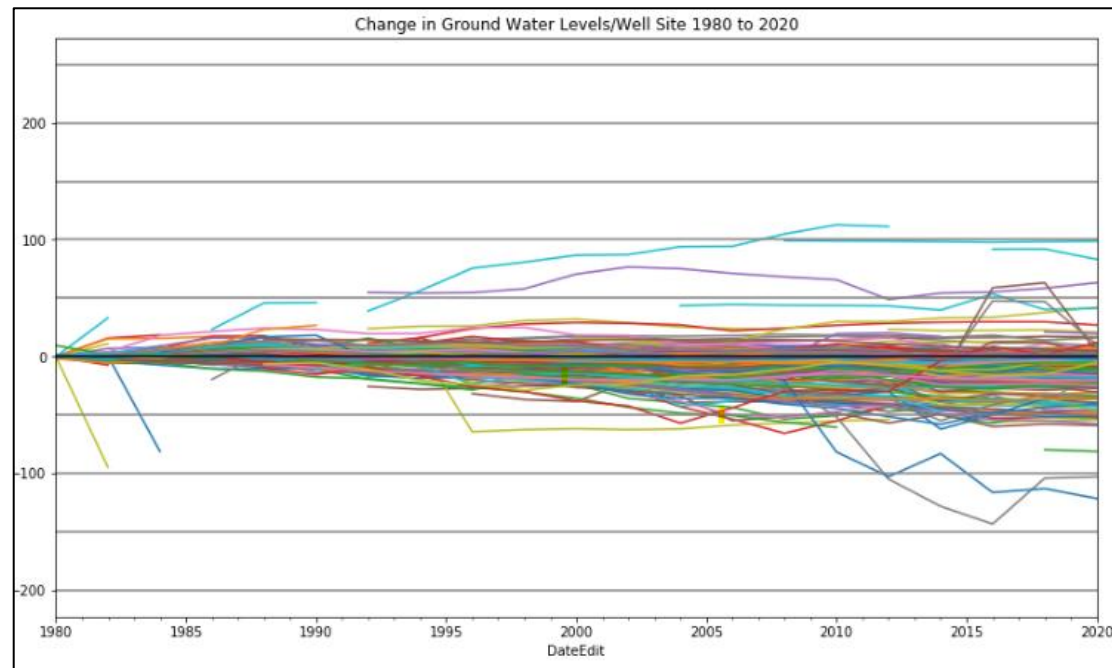
- Change in all well sites in the state of Colorado from populations measured 1980-1990 and 2010-2020 is a 4.4 ft of median decrease through time.
- 1980-1990, 1990-2000:
- 1990-2000, 2000-2010:
- 2000-2010, 2010-2020:

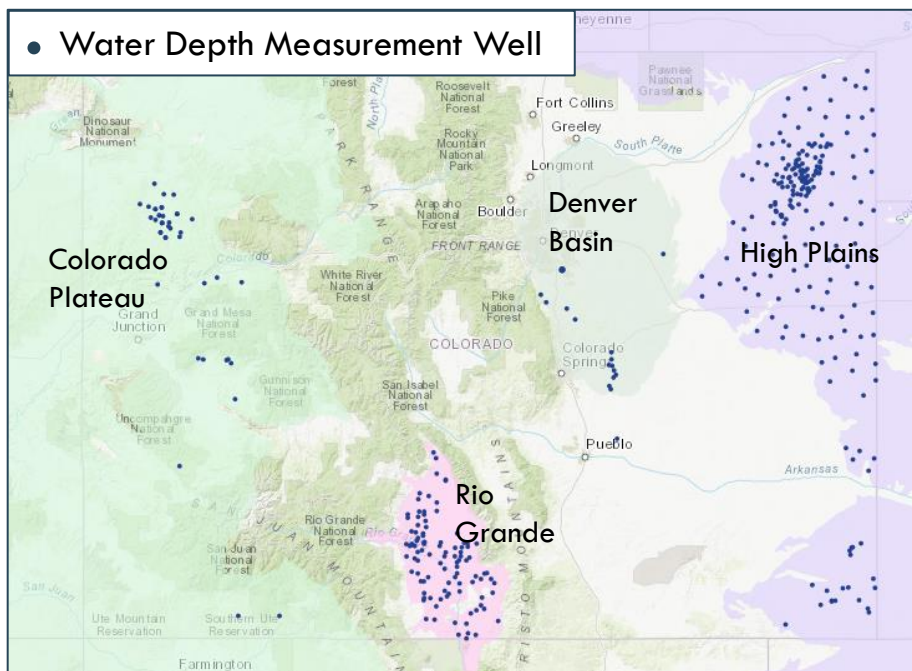
WATER LEVEL CHANGES FROM BASE LINE THROUGH TIME: ALL WELLS

	well	count	mean	std	min	25%	50%	75%	max
0	well	220.0	-10.637682	23.17882	-123.29	-18.7675	-5.295	-0.48	98.8



- The total change from each well was calculated (well depth start- well depth latest)
- On average well levels have fallen by at least 10' since 1980

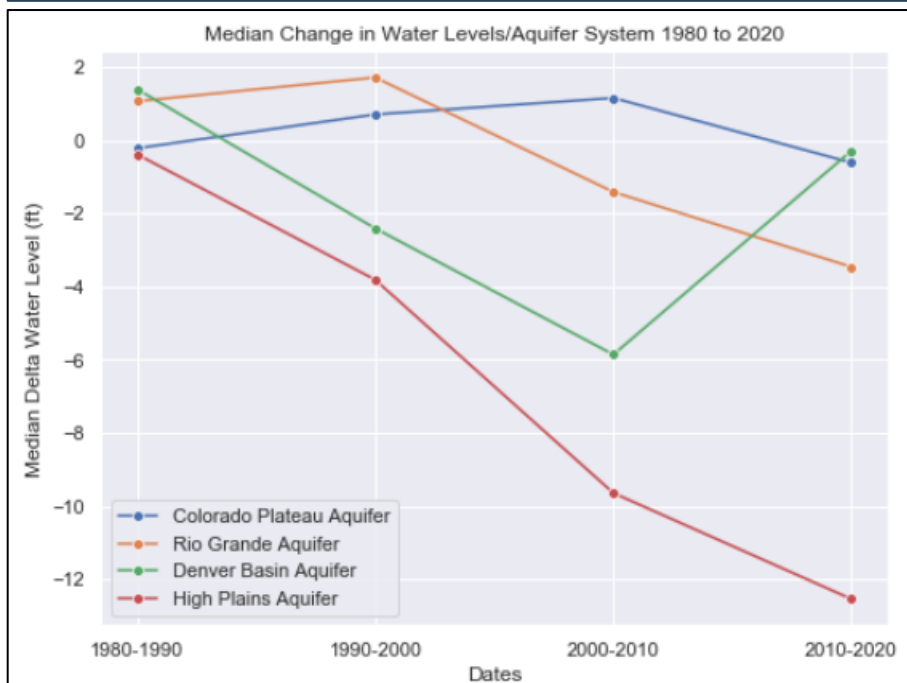




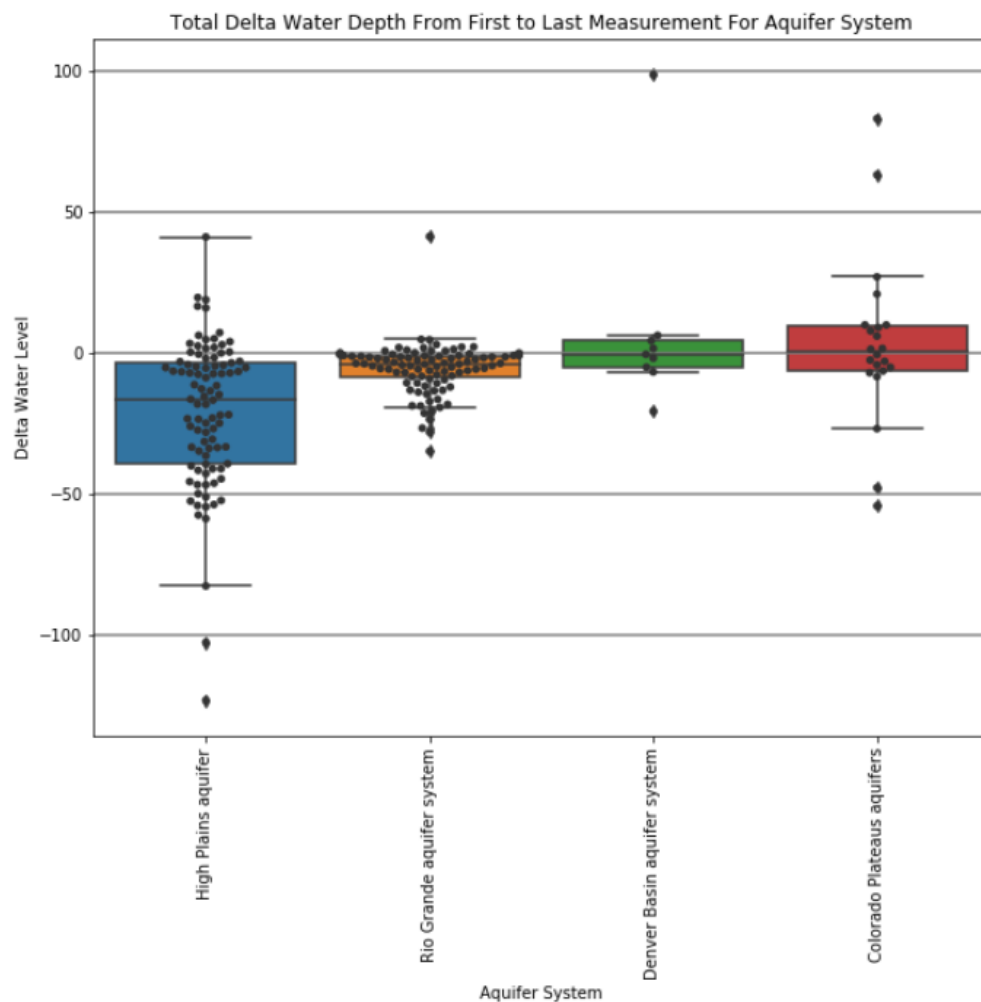
MEDIAN CHANGE IN WATER LEVELS: AQUIFER SYSTEM

■ Median change from 1980-1990 and 2010-2020 well site populations:

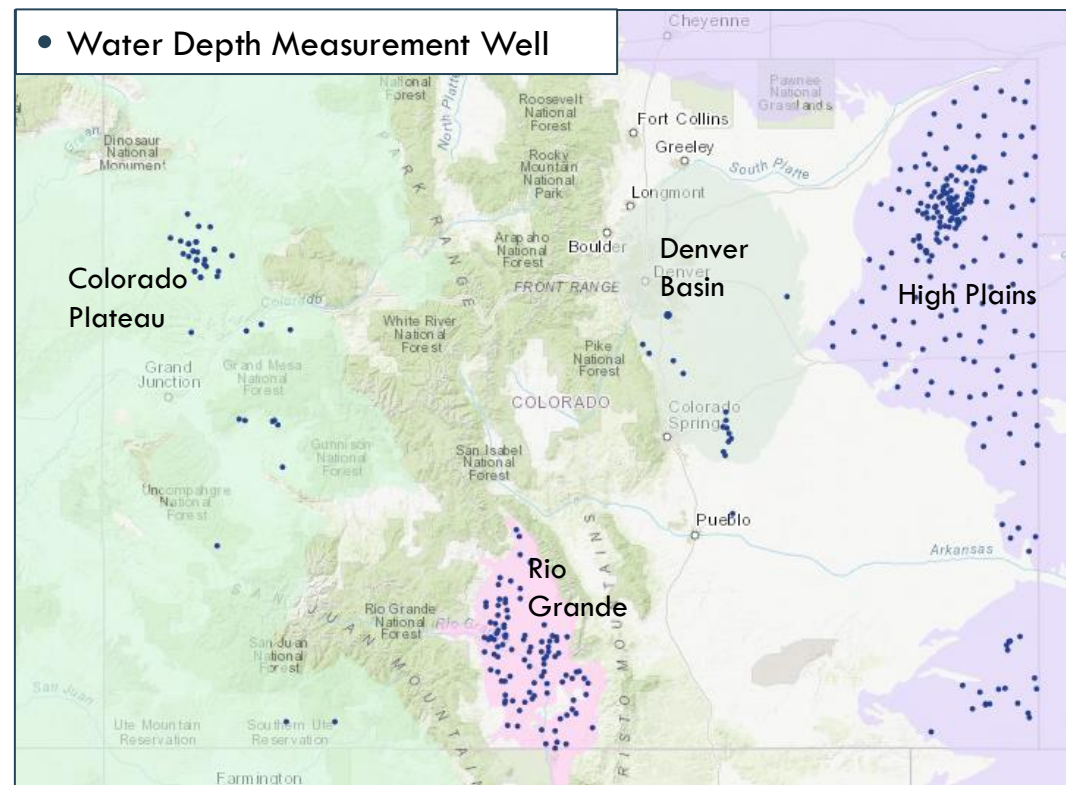
- Colorado Plateau Aquifer: + 0.4 feet
- Rio Grande Aquifer: - 4.4 feet
- Denver Basin Aquifer: + 1.7 feet
- High Plains Aquifer: + 10.7 feet



DELTA WATER LEVEL FROM BASE LINE TO 2020: AQUIFER SYSTEM



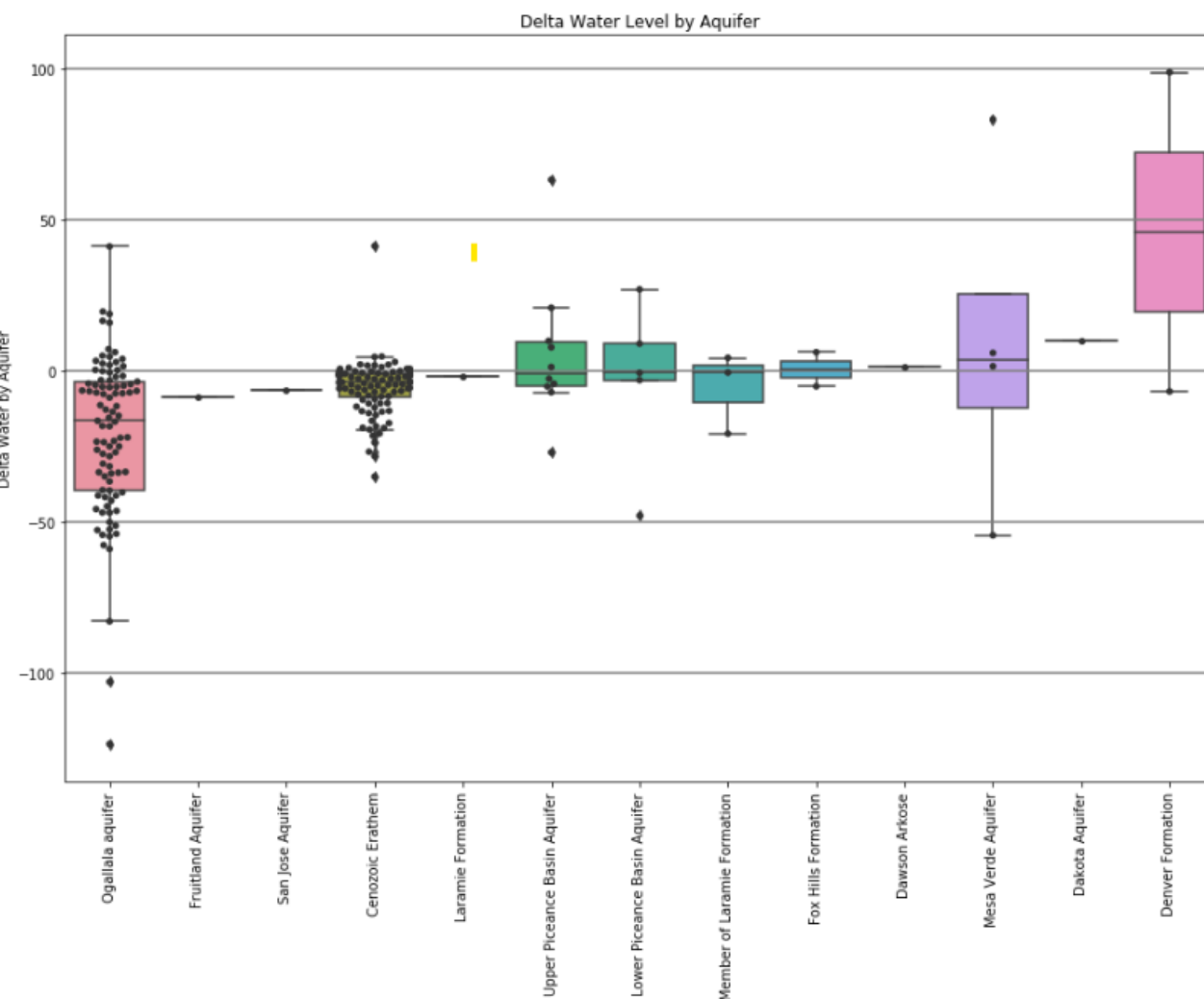
NatAqfrDesc	count	mean	std	min	25%	50%	75%	max
Colorado Plateaus aquifers	22.0	3.357273	29.603902	-54.32	-6.0825	0.365	9.7275	83.20
Denver Basin aquifer system	9.0	8.466667	34.784513	-20.69	-5.0600	-0.480	4.3800	98.80
High Plains aquifer	93.0	-21.053548	25.899947	-123.29	-39.3500	-16.440	-3.5000	41.19
Rio Grande aquifer system	96.0	-5.545521	8.996312	-34.90	-8.6125	-3.770	-0.8975	41.34



BONUS ANALYSIS

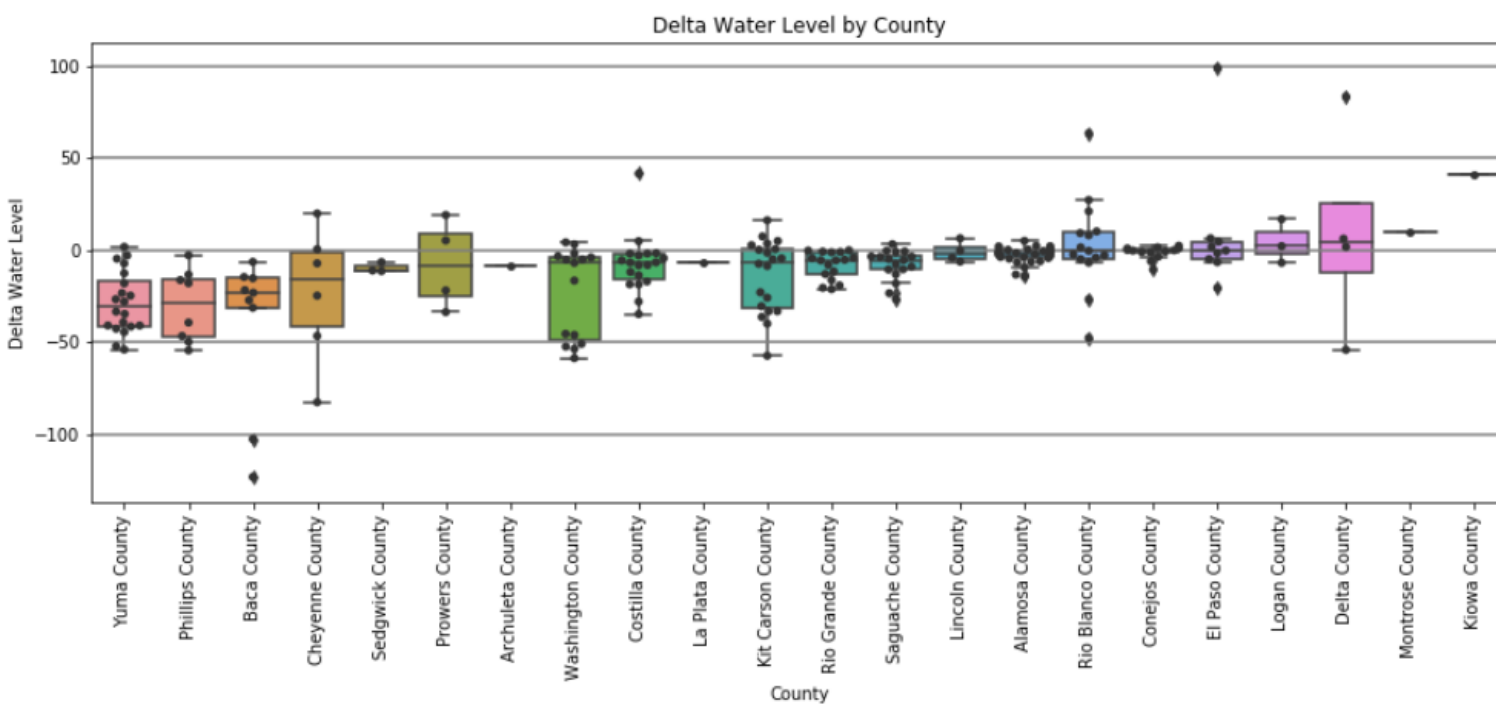
- Some water levels grouped by category did not have sufficient data to perform statistical testing
- The following analysis is a summary of these data and have not been tested statistically
- Areas for future evaluation

DELTA WATER LEVEL FROM BASE LINE TO 2020: BY AQUIFER FORMATION



	LocalAquiferName	count	mean	std	min	25%	50%	75%	max
10	Ogallala aquifer	93.0	-21.053548	25.899947	-123.29	-39.3500	-16.440	-3.5000	41.19
6	Fruitland Aquifer	1.0	-8.400000	NaN	-8.40	-8.4000	-8.400	-8.4000	-8.40
11	San Jose Aquifer	1.0	-6.410000	NaN	-6.41	-6.4100	-6.410	-6.4100	-6.41
0	Arapahoe Conglomerate Member of Laramie Formation	3.0	-5.596667	13.295166	-20.69	-10.5850	-0.480	1.9500	4.38
1	Cenozoic Erathem	96.0	-5.545521	8.996312	-34.90	-8.6125	-3.770	-0.8975	41.34
8	Lower Piceance Basin Aquifer	5.0	-3.066000	27.661627	-47.82	-2.9900	-0.590	9.0600	27.01
7	Laramie Formation	1.0	-1.860000	NaN	-1.86	-1.8600	-1.860	-1.8600	-1.86
5	Fox Hills Formation	2.0	0.585000	7.983236	-5.06	-2.2375	0.585	3.4075	6.23
3	Dawson Arkose	1.0	1.620000	NaN	1.62	1.6200	1.620	1.6200	1.62
12	Upper Piceance Basin Aquifer	10.0	5.758000	23.783486	-26.88	-4.8775	-0.610	9.4425	63.25
9	Mesa Verde Aquifer	4.0	9.117500	56.506387	-54.32	-12.3875	3.795	25.3000	83.20
2	Dakota Aquifer	1.0	9.950000	NaN	9.95	9.9500	9.950	9.9500	9.95
4	Denver Formation	2.0	46.030000	74.628050	-6.74	19.6450	46.030	72.4150	98.80

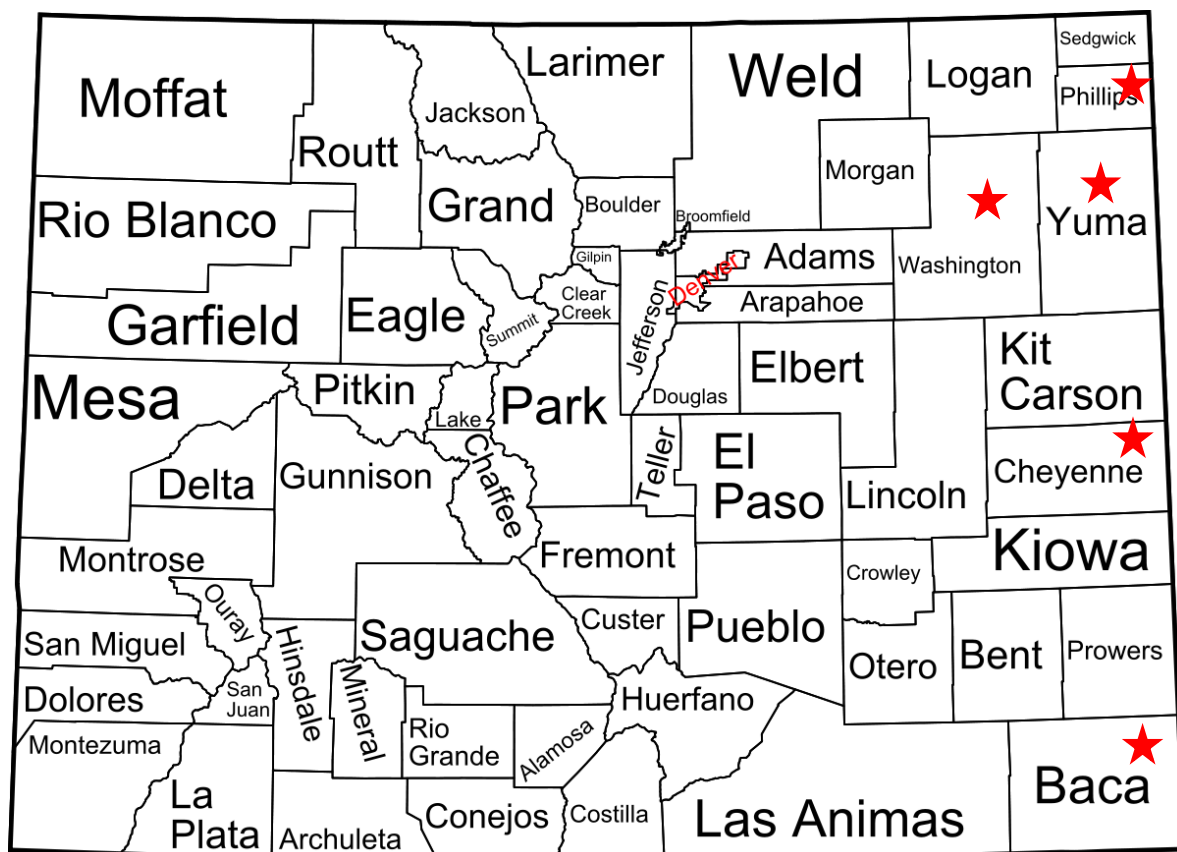
DELTA WATER LEVEL FROM BASE LINE TO 2020: BY AQUIFER FORMATION



CountyNm	count	mean	std	min	25%	50%	75%	max
Baca County	9.0	-40.770000	41.922882	-123.29	-31.4900	-23.350	-15.4500	-6.56
Phillips County	8.0	-30.242500	19.654271	-54.62	-47.6025	-28.820	-15.7025	-2.98
Yuma County	20.0	-28.698000	16.733393	-54.16	-41.2750	-30.875	-16.8675	1.60
Cheyenne County	6.0	-23.635000	36.723793	-82.74	-41.3050	-16.130	-1.6200	19.67
Washington County	15.0	-23.013333	24.573415	-58.83	-48.6700	-7.100	-3.8100	4.00
Kit Carson County	20.0	-13.716500	19.738361	-57.55	-31.3150	-6.390	0.8950	15.99
Sedgwick County	3.0	-9.843333	2.761781	-11.60	-11.4350	-11.270	-8.9650	-6.66
Archuleta County	1.0	-8.400000	NaN	-8.40	-8.4000	-8.400	-8.4000	-8.40
Saguache County	17.0	-8.322353	8.220366	-26.68	-10.7400	-5.550	-3.6100	3.01
Rio Grande County	17.0	-8.294706	7.397771	-21.38	-13.1800	-5.750	-1.3800	-0.28
Prowers County	4.0	-7.995000	24.214383	-33.85	-25.0150	-8.500	8.5200	18.87
Costilla County	19.0	-7.762632	15.356742	-34.90	-15.5600	-6.950	-2.5350	41.34
La Plata County	1.0	-6.410000	NaN	-6.41	-6.4100	-6.410	-6.4100	-6.41
Alamosa County	30.0	-2.745333	4.323777	-14.56	-4.3550	-1.990	-0.0175	4.82
Conejos County	13.0	-1.540769	3.512987	-10.69	-1.4400	-0.480	0.7300	2.16
Lincoln County	4.0	-1.247500	5.568150	-6.44	-4.8575	-2.390	1.2200	6.23
Rio Blanco County	15.0	2.816667	24.511067	-47.82	-4.6550	-0.590	9.5150	63.25
Logan County	3.0	3.833333	11.944506	-7.07	-2.5500	1.970	9.2850	16.60
El Paso County	9.0	8.466667	34.784513	-20.69	-5.0600	-0.480	4.3800	98.80
Delta County	4.0	9.117500	56.506387	-54.32	-12.3875	3.795	25.3000	83.20
Montrose County	1.0	9.950000	NaN	9.95	9.9500	9.950	9.9500	9.95
Kiowa County	1.0	41.190000	NaN	41.19	41.1900	41.190	41.1900	41.19

WATER LEVEL CHANGES FROM BASE LINE: BY COUNTY

★ Counties with > 20' decrease in average water levels



CountyNm	count	mean	std	min	25%	50%	75%	max
Baca County	9.0	-40.770000	41.922882	-123.29	-31.4900	-23.350	-15.4500	-6.56
Phillips County	8.0	-30.242500	19.654271	-54.62	-47.6025	-28.820	-15.7025	-2.98
Yuma County	20.0	-28.698000	16.733393	-54.16	-41.2750	-30.875	-16.8675	1.60
Cheyenne County	6.0	-23.635000	36.723793	-82.74	-41.3050	-16.130	-1.6200	19.67
Washington County	15.0	-23.013333	24.573415	-58.83	-48.6700	-7.100	-3.8100	4.00
Kit Carson County	20.0	-13.716500	19.738361	-57.55	-31.3150	-6.390	0.8950	15.99
Sedgwick County	3.0	-9.843333	2.761781	-11.60	-11.4350	-11.270	-8.9650	-6.66
Archuleta County	1.0	-8.400000	NaN	-8.40	-8.4000	-8.400	-8.4000	-8.40
Saguache County	17.0	-8.322353	8.220366	-26.68	-10.7400	-5.550	-3.6100	3.01
Rio Grande County	17.0	-8.294706	7.397771	-21.38	-13.1800	-5.750	-1.3800	-0.28
Prowers County	4.0	-7.995000	24.214383	-33.85	-25.0150	-8.500	8.5200	18.87
Costilla County	19.0	-7.762632	15.356742	-34.90	-15.5600	-6.950	-2.5350	41.34
La Plata County	1.0	-6.410000	NaN	-6.41	-6.4100	-6.410	-6.4100	-6.41
Alamosa County	30.0	-2.745333	4.323777	-14.56	-4.3550	-1.990	-0.0175	4.82
Conejos County	13.0	-1.540769	3.512987	-10.69	-1.4400	-0.480	0.7300	2.16
Lincoln County	4.0	-1.247500	5.568150	-6.44	-4.8575	-2.390	1.2200	6.23
Rio Blanco County	15.0	2.816667	24.511067	-47.82	-4.6550	-0.590	9.5150	63.25
Logan County	3.0	3.833333	11.944506	-7.07	-2.5500	1.970	9.2850	16.60
El Paso County	9.0	8.466667	34.784513	-20.69	-5.0600	-0.480	4.3800	98.80
Delta County	4.0	9.117500	56.506387	-54.32	-12.3875	3.795	25.3000	83.20
Montrose County	1.0	9.950000	NaN	9.95	9.9500	9.950	9.9500	9.95
Kiowa County	1.0	41.190000	NaN	41.19	41.1900	41.190	41.1900	41.19

SUMMARY

- Based upon 221 wells from the National Ground Water Monitoring Network in the state of Colorado, median ground water levels have fallen more than ~4.5' since 1980
- Comparing populations measured in 1980-1990 to 2010-2020, High Plains wells show a significant decrease in median water levels of >12'. These wells are located in eastern Colorado in areas of heavy agricultural water use, and in nearly all cases, draw from the Ogallala Formation

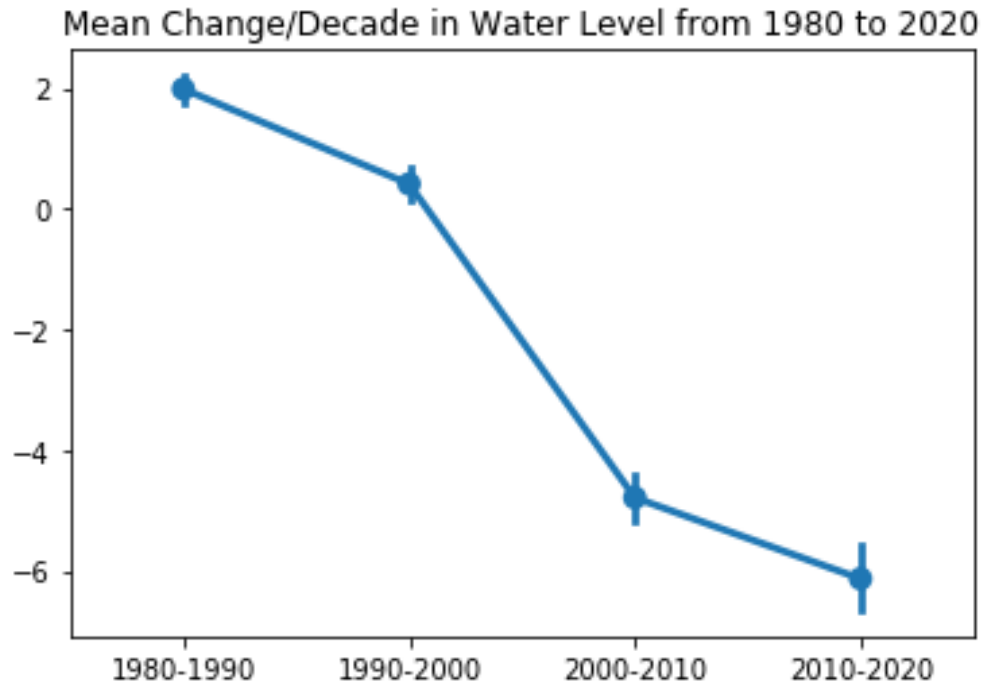
RECOMMENDATIONS

- To gain a better understanding of water levels throughout the state of Colorado, it is recommended more water level monitoring sites are added to the dataset.
- In areas with significant decreases in water depths water conservation practices should be implemented to conserve the remaining resource. Such actions are critical to maintaining economic and environmental sustainability.



APPPENDIX

STATISTICALLY SIGNIFICANT DIFFERENCE IN GROUND WATER LEVELS IN COLORADO FROM 1980 - 2020



- With 95% confidence, the mean change in ground water depth from measurements taken between 1980-1990 and 2010-2020 is between 7.1 and 8.5 ft