Climate trends at the headwaters of the White River
Summary of snotel and flow data

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This report summarizes temperature and precipitation records from the Flat Tops at the headwaters of the White River. It also includes flow records from the White River near Meeker, CO, along with analysis and brief commentary. The purpose of the report is to update regional climate and hydrologic data for reference by water managers and the public.

Temperature and precipitation measurements come from the Trappers Lake Snotel (9700 ft. elevation, Trappers Snotel); Ripple Creek Snotel (10,340 ft. elevation, Ripple Creek Snotel); and the Burro Mountain Snotel (9400 ft. elevation, Burro Mountain Snotel). I compare daily mean temperatures for water years 1987-1991 with daily mean temperatures for water years 2019-2023. I also plot trends in yearly accumulated precipitation from 1987 through 2023. Those dates include all available data from the snotels.

I analyze historical trends in White River discharge using data from the USGS continuous real time gauging station near Meeker (station 09304500 from water years 1910 through 2023. A "water year" in the USGS flow records runs from October 1 to September 30 with year date in January as the designated water year identifier. Data analysis includes peak flow volume, timing of peak flow, total runoff, and April vs. June runoff.

I evaluate trends using Mann-Kendall statistics. Graphs show trend lines calculated by least squares. The trend lines include all data, with outliers.

Results Summary

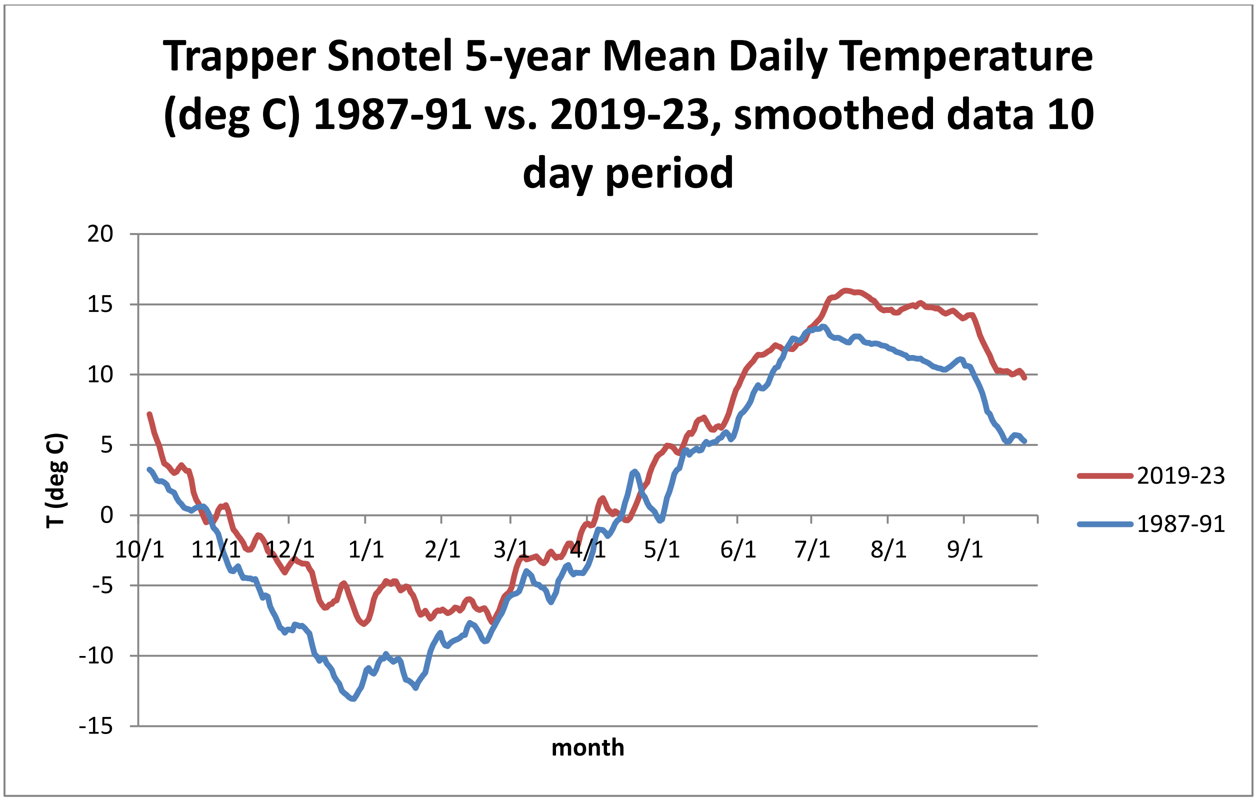
Mean daily temperatures in the period 2019-2023 were significantly warmer than 1987-1991 (Figure 1). Mean daily temperatures on the Flat Tops have increased significantly from 1987 to the present (Figure 2).

Cumulative yearly precipitation on the Flat Tops is decreasing. (Figure 3) Snowmelt is trending earlier (Figure 4).

Peak runoff in the White River occurs earlier in the Spring and is trending toward lower volume. (Figures 5, 6 and 7.) April runoff is increasing (Figure 8), and June runoff is trending downward (Figure 9). See comments accompanying the Figures for further analysis.

The patterns in temperature, precipitation, and runoff reported here are consistent with global and regional climate trends. See, for example, the *5th National Climate Assessment* (link in references at the end of this report). Global average temperatures are rising. Polar and alpine regions are changing more rapidly than general. The American Southwest is experiencing higher temperatures and more prolonged episodes of drought.

Figure 1a: Mean daily temperatures at Trappers Lake, average of water years 1987-1991 vs. 2019-2023. The most recent 5-year average daily temperature is significantly greater than the 1987-91 average; t-stat = -18.3, $p \ll 0.001$, paired t-test, n = 365. Plot is smoothed using ten-day running mean.



Comment: Mean daily temperatures in recent years are significantly higher than when data collection began thirty-seven years ago. Previous studies documented rising average daily mean temperatures at all three snotels in each successive five-year interval since 1987. The greatest increases in temperature occur in mid-winter and late summer. Higher summer temperatures at Trappers after 2000 may be confounded by snotel exposure after the fire. Temperatures at Ripple Creek and Burro Mountain show the same pattern (figures on next pages).

Figure 1b: Mean daily temperatures at Burro Mountain snotel, average of water years 1987-1991 (blue) vs. 2019-2023 (red). The most recent five-year average daily temperature is significantly greater than the 1987-97 average; t stat = -13.1, $p \ll 0.001$, paired t-test, n = 365. Plot is smoothed using ten-day running mean.

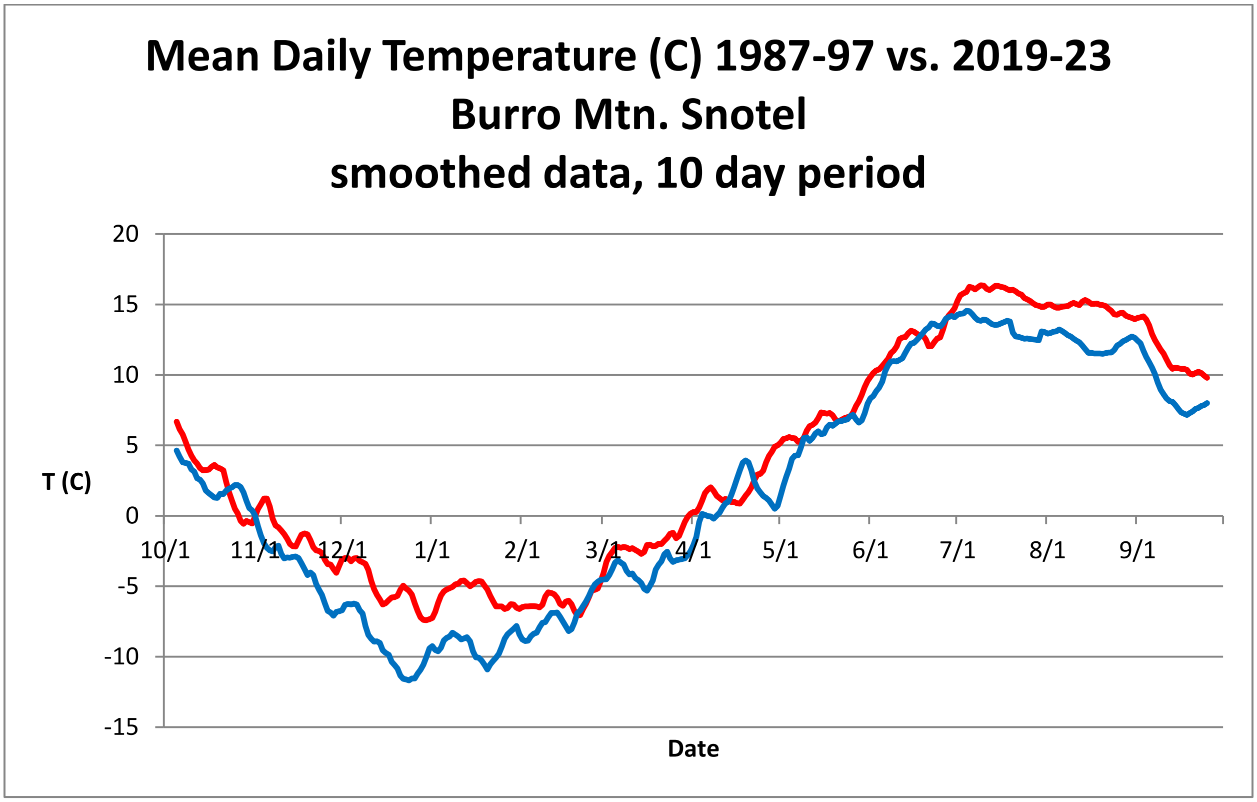


Figure 1c: Mean daily temperatures at Ripple Creek snotel, average of water years 1987-1991 vs. 2019-2023. The most recent five-year average daily temperature is significantly greater than the 1987-91 average; t-stat = -7.8, $p \ll 0.001$, paired t-test, n = 365. Plot is smoothed using ten-day running mean.

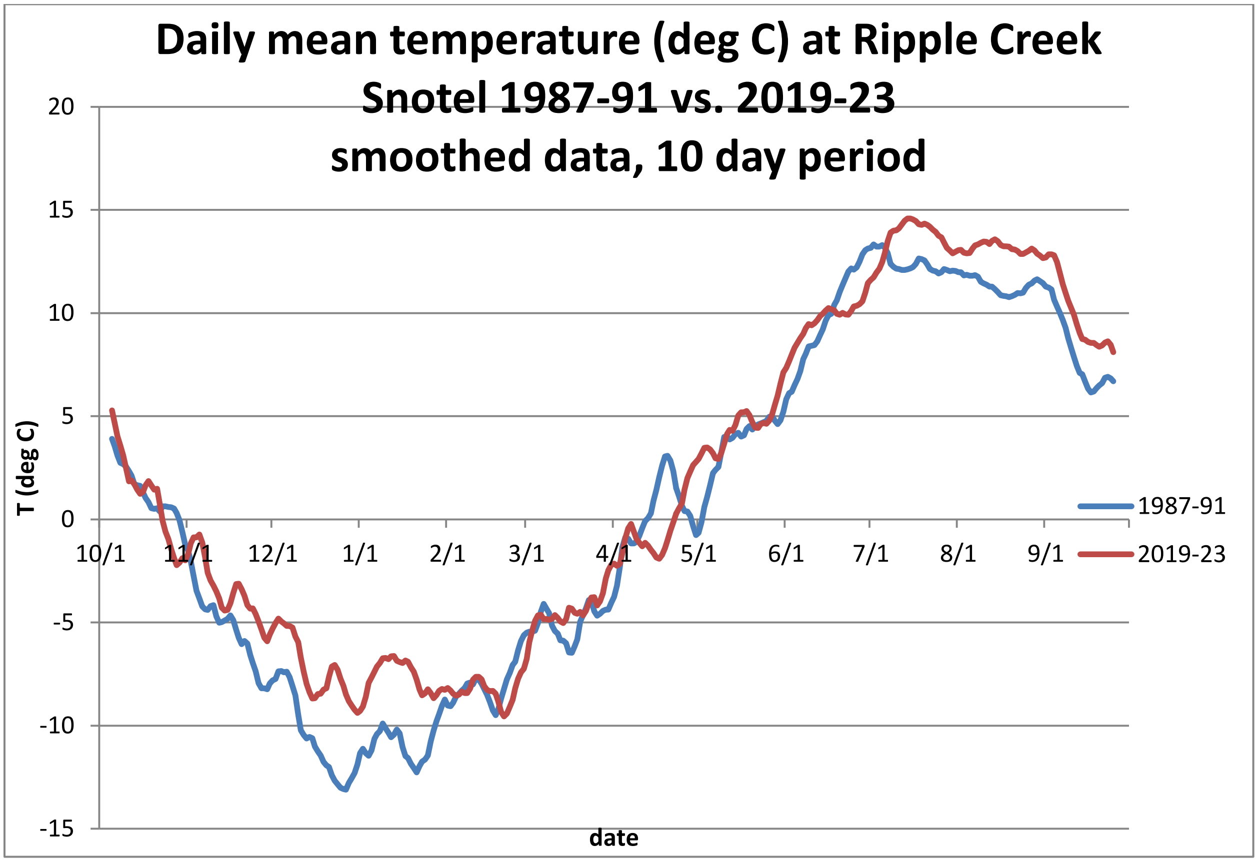
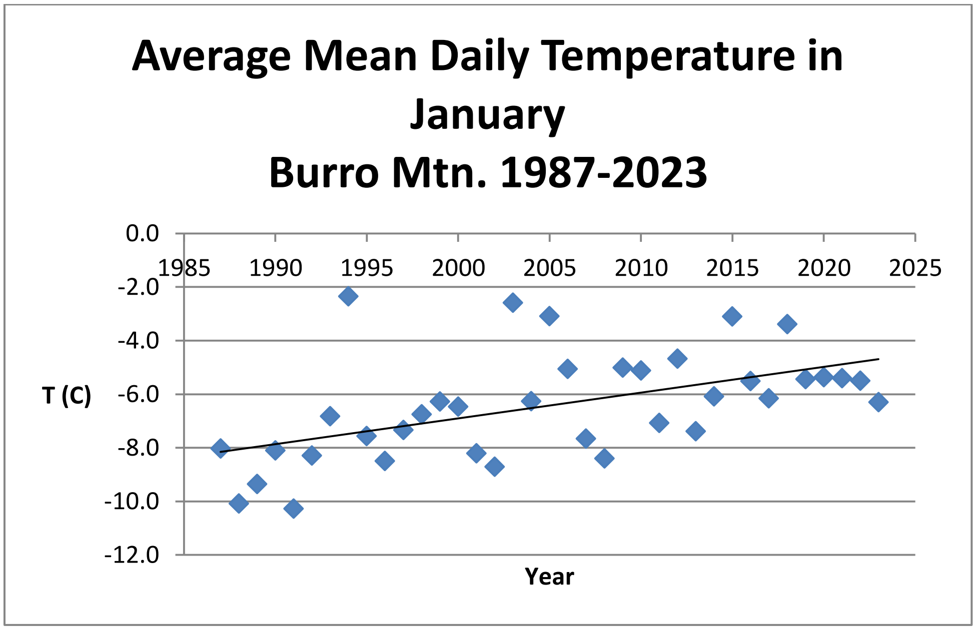
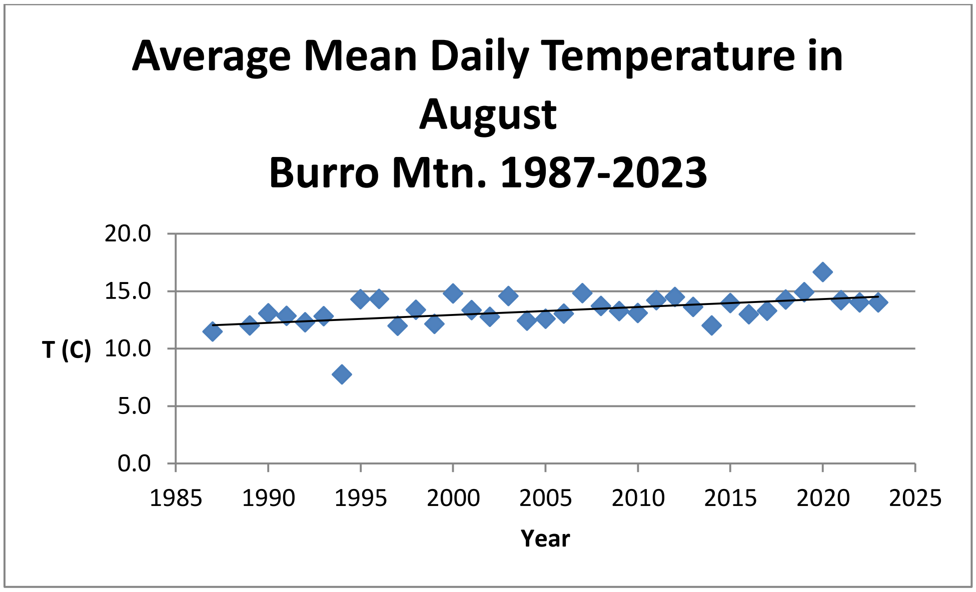


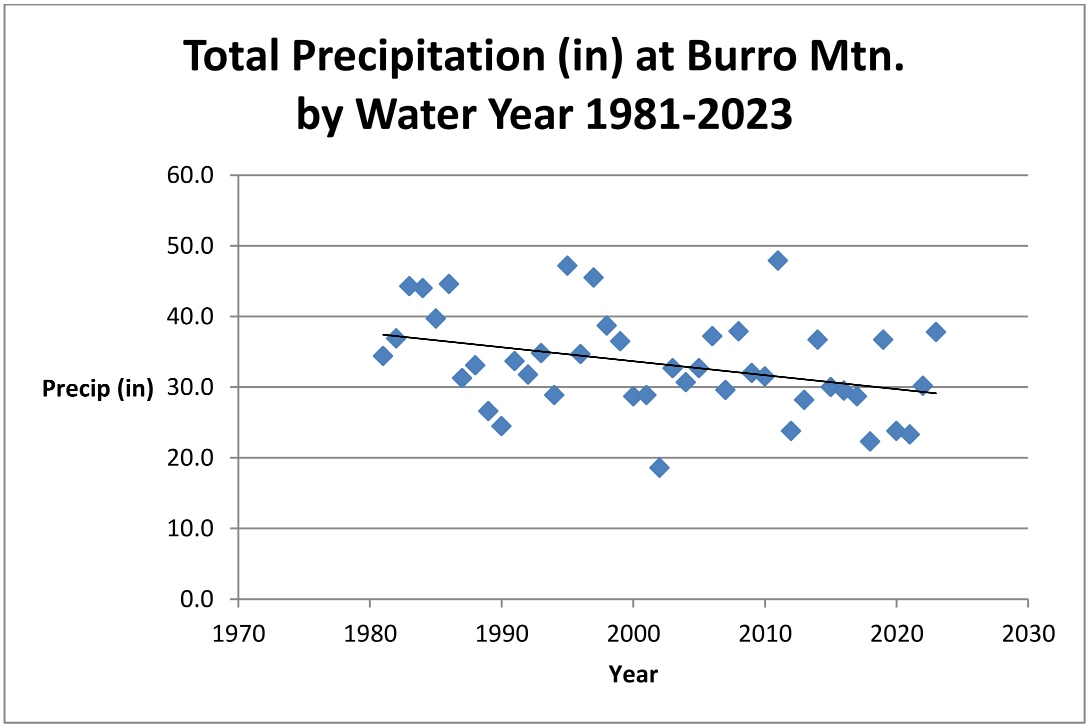
Figure 2. Mean daily temperatures in January and August at Burro Mtn, 1986 – 2023. Upward trend is significant; Mann-Kendall S = 270, Z = 3.52, $Z_{critical}$ = 1.96, n = 35. Trendline is best linear fit by least squares analysis. August trend Mann-Kendall S = 252, Z = 3.42, n = 35. Ripple Creek and Trappers Lake show the same January and August temperature trends as at Burro Mtn, with similar statistically significant upward trends in daily temperature.





Comment: January and August mean daily temperatures in the Flat Tops are increasing. These observations are consistent with larger climate studies.

Figure 3. Cumulative yearly precipitation at Burro Mtn, water years 1986-2023. Precipitation is decreasing at all three snotels. Burro Mtn. Mann-Kendall S = -221, Z = -2.32, $Z_{critical}$ = -1.96, n = 35. Trappers Lake and Ripple Creek show similar trends and statistics. (Trappers Lake and Ripple Creek data not shown.)



Comment: Precipitation on the Flat Tops is decreasing. There is less water, primarily from snowpack, for runoff into the headwaters of the White River. These trends are becoming more pronounced in recent years.

Figure 4a. Snow water equivalent (SWE) at Burro Mtn snotel water years 2019-23. Rainbow shading shows 20-percentile intervals for the period of record 1986-23: red(bottom 20th percentile)-yellow-green-turquoise-blue(top 20th percentile). Legend to the right identifies years by line color. Water year 2023 (purple) produced largest snowpack in the past five years. We're just starting water year 2024, black line at bottom left. Graph source: USDA Natural Resources Conservation Service, NWCC Interactive Map. Data from Burro Mtn snotel.

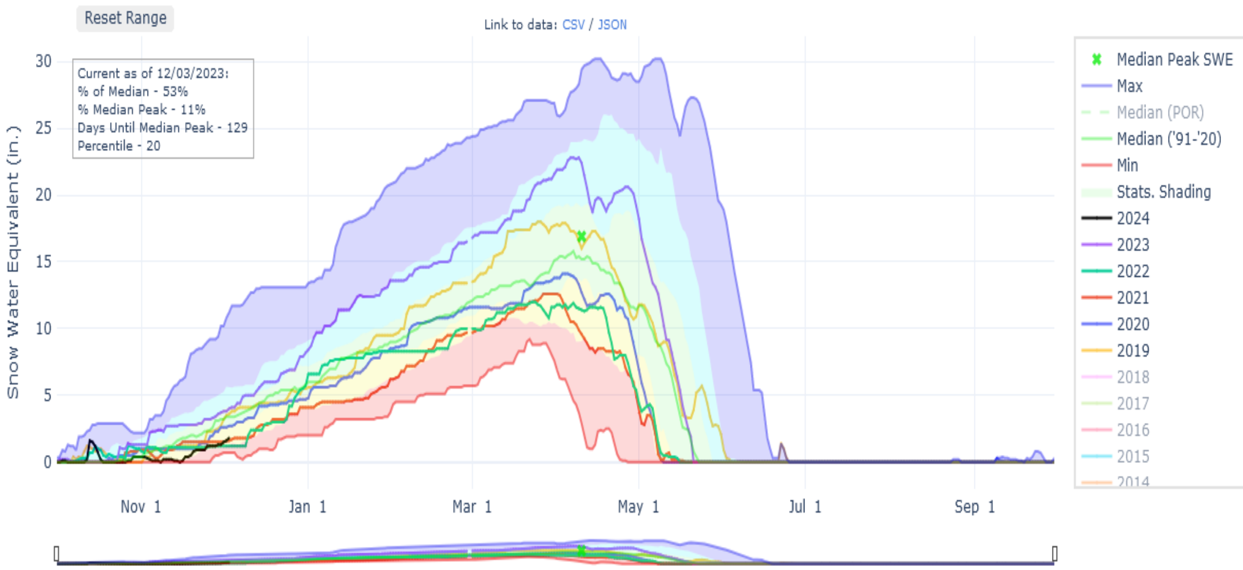


Figure 4b. Snow water equivalent at Ripple Creek snotel water years 2019-23. Note color legend is different from Figure 4a.

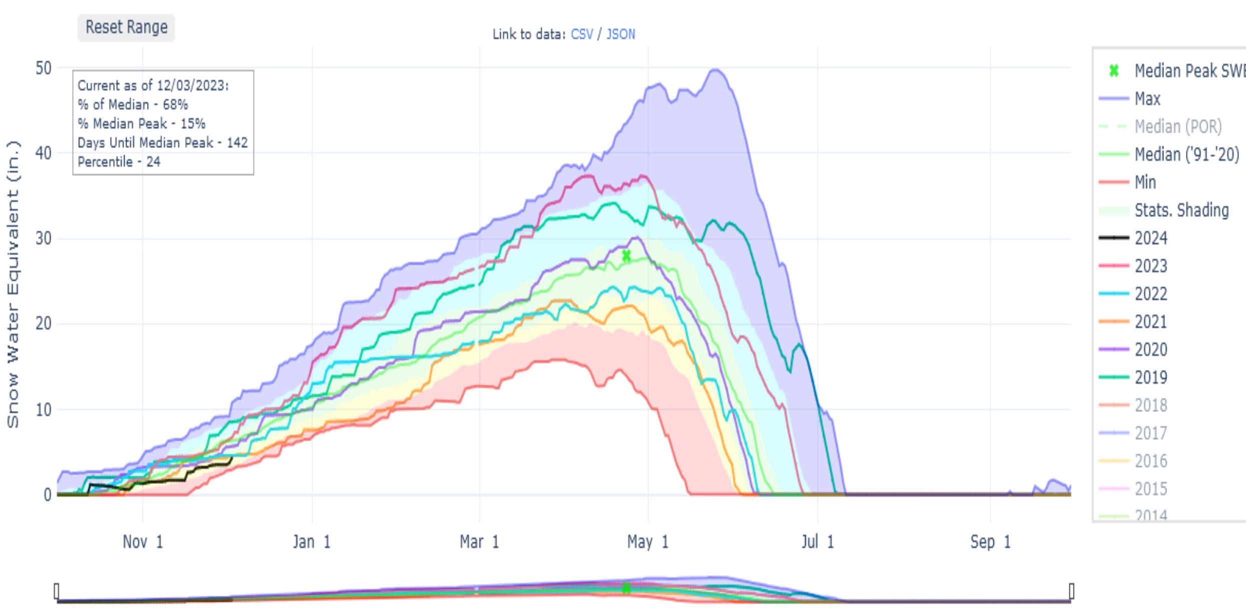


Figure 4c. Daily flow (black line) in the White River near Meeker vs. historical percentiles during water years 2019-23. brown = bottom 10% of historical mean flow for date, yellow = 10-25%, green = 25-75%, light blue = 75-90%, dark blue = top 10%. See the Water Watch web page for longer historical record of streamflow.

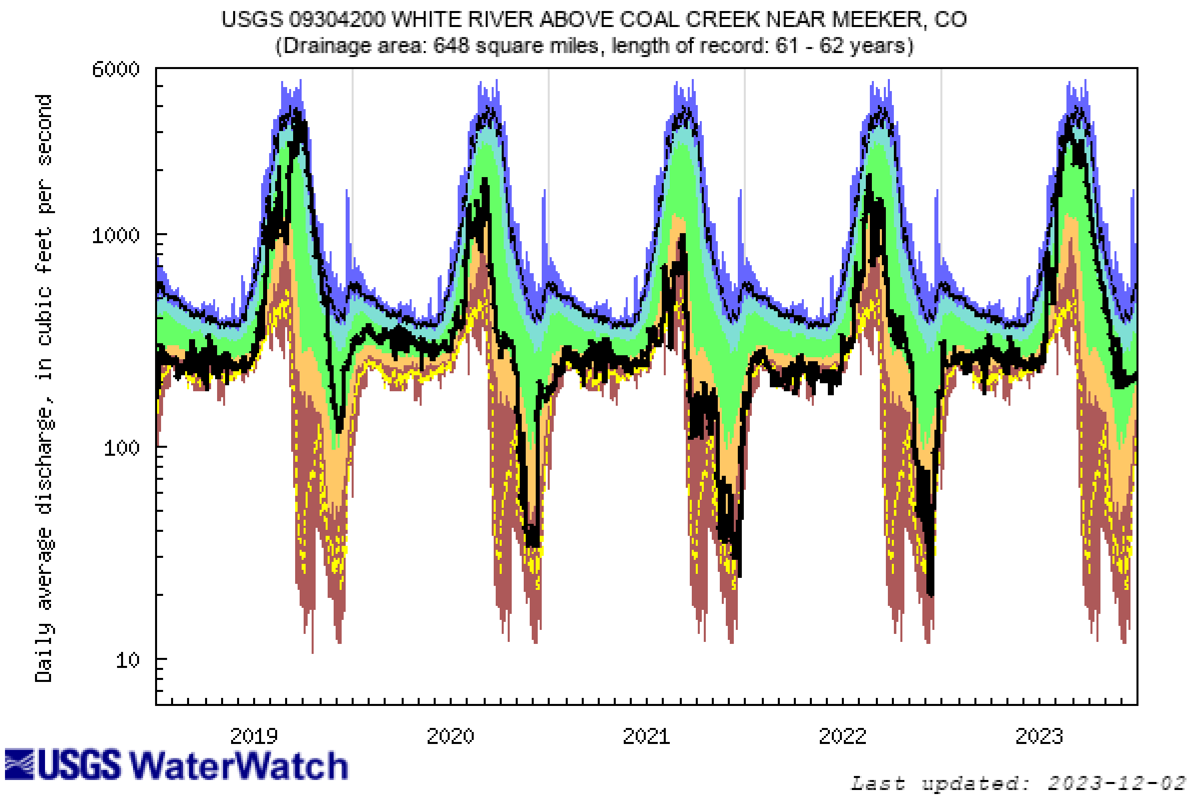
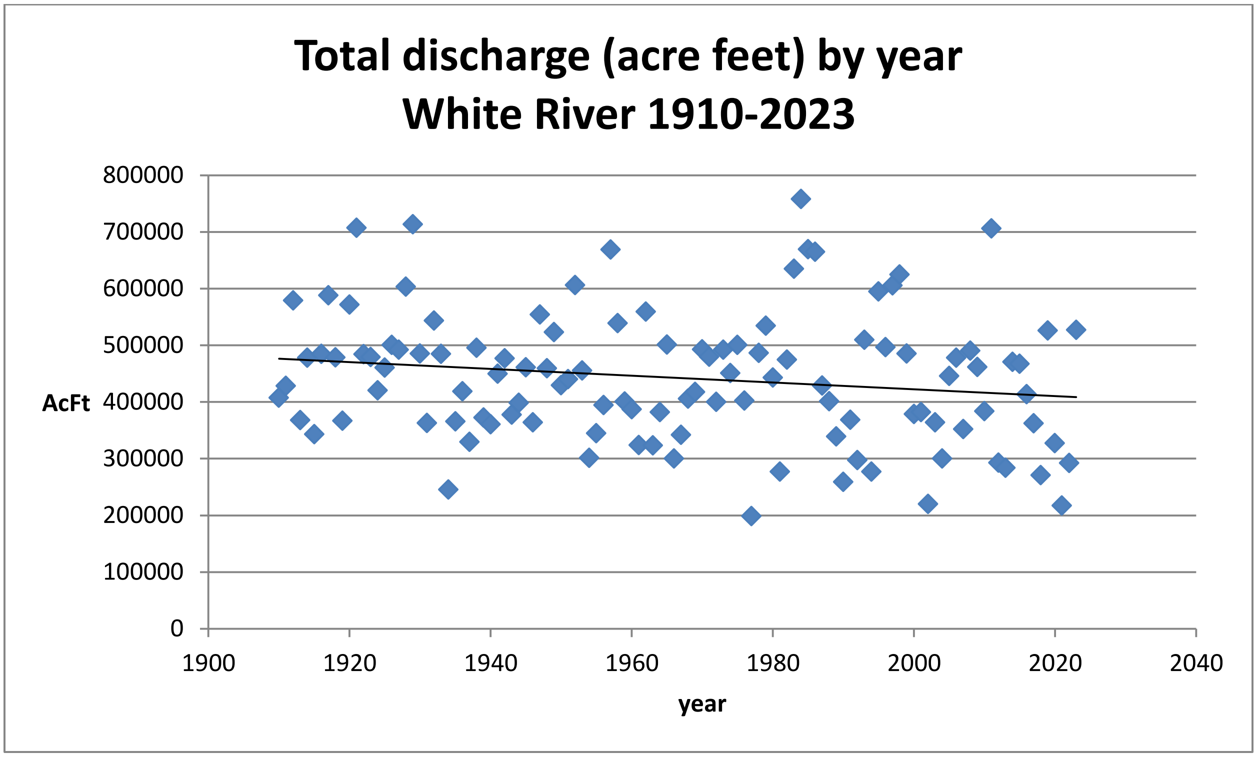
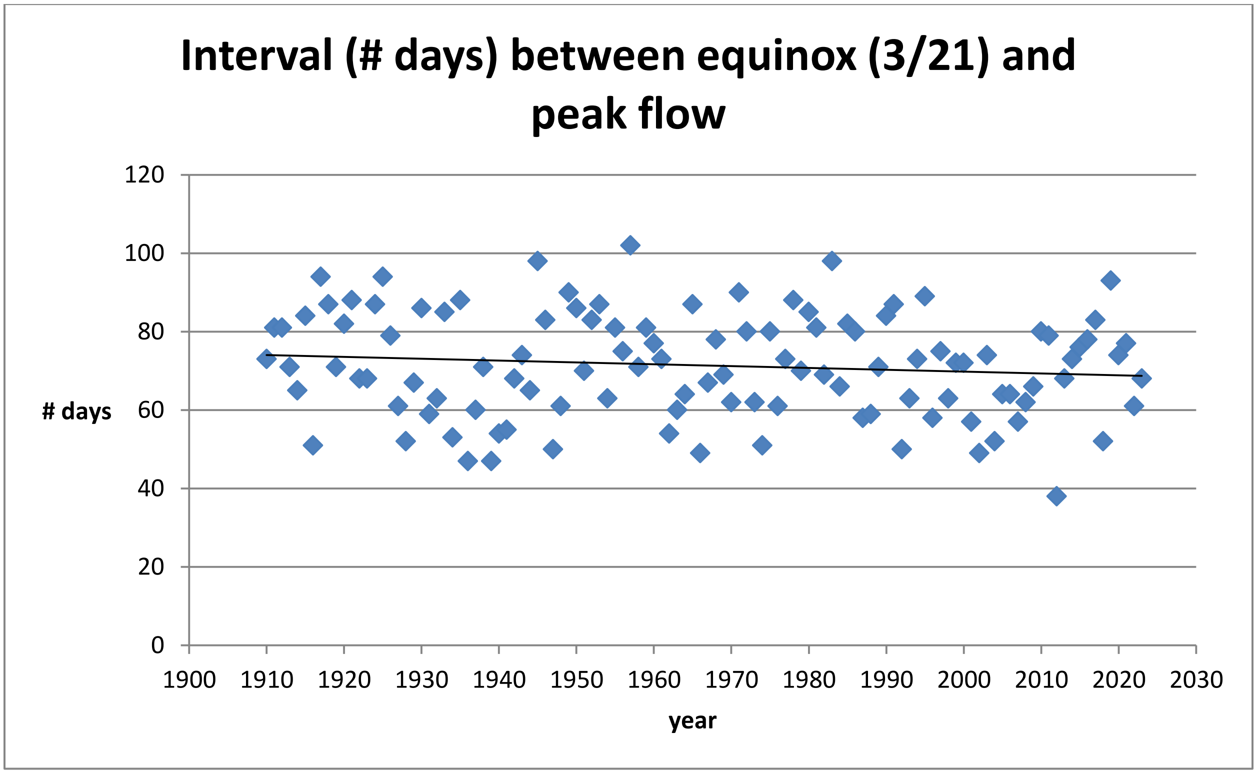


Figure 5. Total runoff (acre feet) down the White River by year from 1910 to 2023. Trend is downward. Mann-Kendall $S = -787,\ Z = -1.93$. $Z_{crit} = -1.96$.



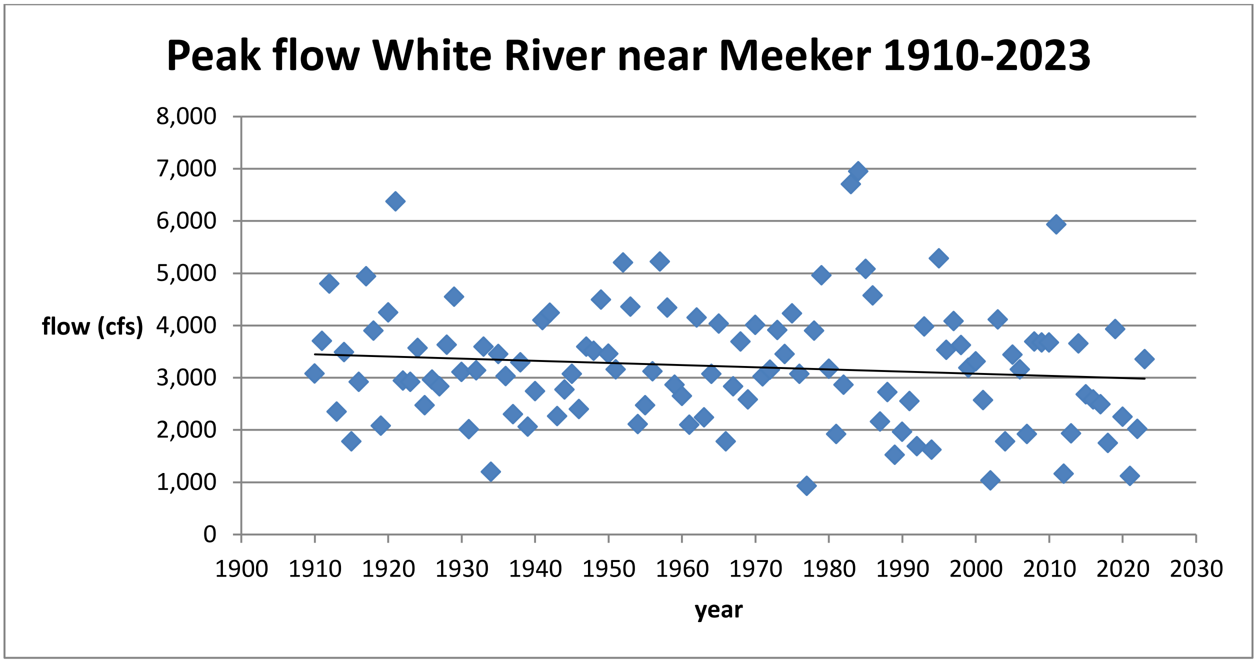
Comment: Total yearly runoff in the White River is decreasing, down by about 70,000 acre feet on average over the period of record. That represents about a 14% loss in water volume.

Figure 6. Date of peak flow in White River near the Town of Meeker (USGS gauging station 09304500) 1910-2023 plotted as interval number of days after the Spring equinox. Mann-Kendall S = -483, Z = -1.19, $Z_{critical}$ = -1.96, n = 124. Trendline is best linear fit by least squares analysis.



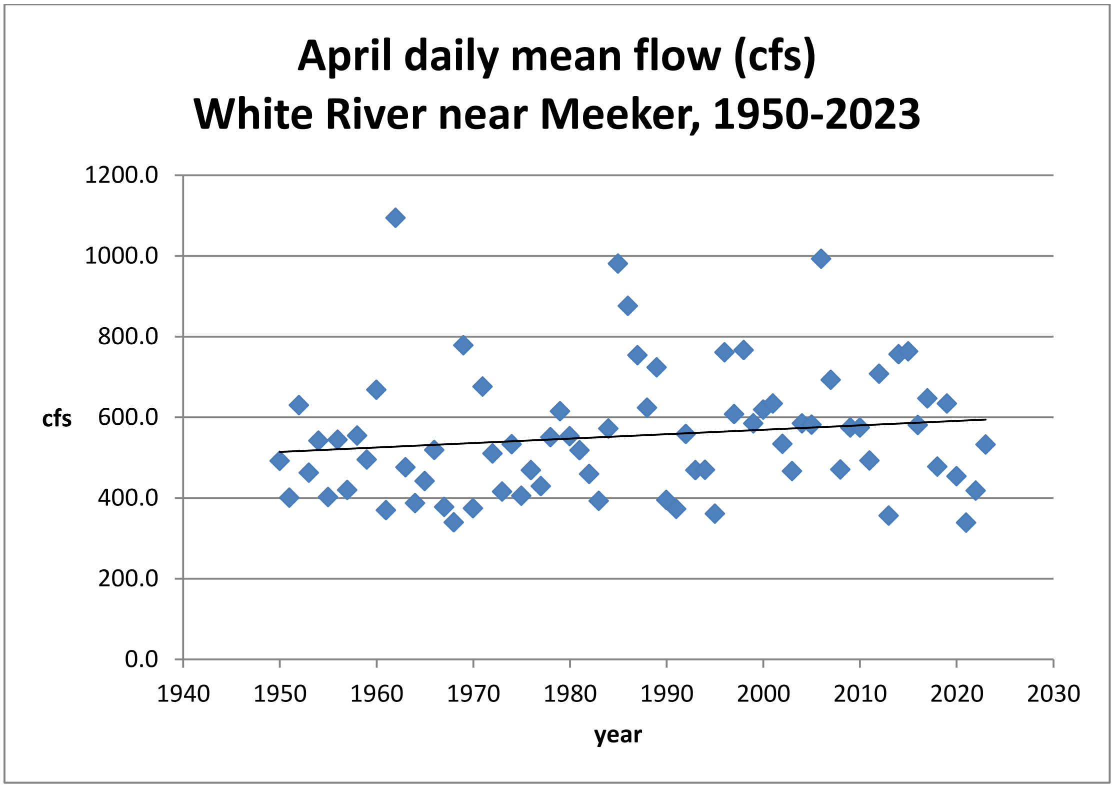
Comment: Spring runoff today occurs earlier than it did in the past. Earlier peak flow results in longer period of low flow in the summer and, potentially, higher water temperatures. Both effects may contribute to algae bloom and to fish stress.

Figure 7. Peak flow (cfs) in White River near Meeker (USGS gauging station 09304500) water years 1950-2022. Mean flow for the period is 3213 cfs. Mann-Kendall S = -527, Z = -1.29, $Z_{critical}$ = -1.96, n = 124. Trendline is best linear fit by least squares analysis.



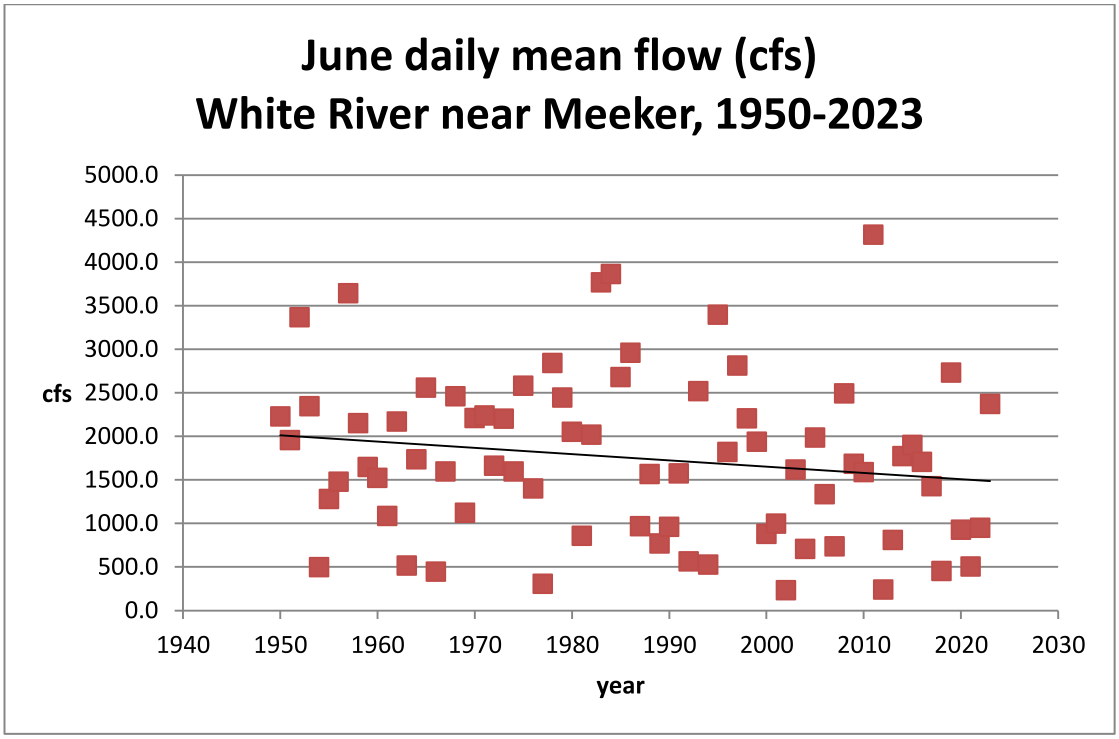
Comment: Peak flow is decreasing, now roughly 500 cfs lower on average than it was in 1910. Lower peak flow is less effective at scouring algae off the stream bed, and decreased flow changes sediment transport and fish habitat.

Figure 8. Mean flow in the White River near the Town of Meeker in the month of April, water years 1950-2023. Mann-Kendall S = 372. Z = 1.73, $Z_{critical}$ = 1.96, n = 73. Trendline is best linear fit by least squares analysis.



Comment: April flows are increasing. This reflects earlier Spring runoff. As shown in Figure 8, the tradeoff is lower flow in June and on into the summer.

Figure 9. Mean flow in the White River near the Town of Meeker in the month of June, water years 1950-2023. Mann-Kendall S = -320, Z = -1.50, $Z_{critical}$ = -1.96, n = 73. Trendline is best linear fit by least squares analysis.



Comment: Peak runoff historically occurred in early June, but peak is trending earlier. Longer periods of low flow in the summer provide favorable conditions for algae growth, increase stress on fish, and also decrease available irrigation and municipal water supplies.

References:

Snotels:
Burro Mountain Snotel. https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=378
Ripple Creek Snotel. https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=717
Trappers Snotel. https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=827

USDA Natural Resources Conservation Service. iMap. https://nwcc-apps.sc.egov.usda.gov/imap/

USGS Gauging Station: White River Near Meeker. https://waterdata.usgs.gov/co/nwis/uv?site_no=09304500

USGS Water Watch. https://waterwatch.usgs.gov/

U.S. Global Change Research Program. 2023. 5th National Climate Assessment. https://nca2023.globalchange.gov/