Report on the Environment
https://www.epa.gov/report-environment

Stream Flows

Flow is a critical aspect of the physical structure of stream ecosystems (Poff and Allan, 1995; Robinson et al., 2002). High flows shape the stream channel and clear silt and debris from the stream, and some fish species depend on high flows for spawning. Low flows define the smallest area available to stream biota during the year. In some cases, the lowest flow is no flow at all—particularly in arid and semi-arid regions where intermittent streams are common. Riparian vegetation and aquatic life in intermittent streams have evolved to complete their life histories during periods when water is available; however, extended periods of no flow can still impact their survival (Fisher, 1995). Changes in flow can be caused by dams, water withdrawals, ground water pumping (which can alter base flow), changes in land cover (e.g., deforestation or urbanization), and weather and climate (Calow and Petts, 1992).

This indicator, originally developed by the Heinz Center (2008), describes trends in stream flow volumes based on daily flow data collected by the U.S. Geological Survey's (USGS's) nationwide network of stream flow gauging sites from 1961 to 2019.

The first part of this indicator describes trends in high flow volume, low flow volume, and variability of flow in streams throughout the contiguous 48 states, relative to a baseline period of 1941-1960. Data were collected at two sets of USGS stream gauging stations: a set of approximately 700 "reference" streams that have not been substantially affected by dams and diversions and have had little change in land use over the measurement period, and a separate set of approximately 1,100 "non-reference" streams that reflect a variety of conditions (the exact number of sites with sufficient data varies from one metric to another). The indicator is based on each site's annual 3-day high flow volume, 7-day low flow volume, and variability (computed as the difference between the 1^{st} and 99^{th} percentile 1-day flow volumes in a given year, divided by the median 1-day flow). Annual values for each metric were examined using a rolling 5-year window to reduce the sensitivity to anomalous events. For each site, the median value for the 5-year window was compared to the median value for the 1941-1960 baseline period. The indicator shows the proportion of sites where high flow, low flow, or variability of flow was more than 30 percent higher or 30 percent lower than the baseline. It also shows differences of more than 60 percent.

This indicator also examines no-flow periods in streams in grassland and shrubland areas of the contiguous 48 states. Data represent 236 USGS "reference" and "non-reference" stream gauging sites in watersheds with at least 50 percent grass or shrub cover, as defined by the 2001 National Land Cover Database (NLCD) (MRLC Consortium, 2007). The indicator reports the percentage of these streams with at least one no-flow day in a given year, averaged over a rolling 5-year window. Results are displayed for all grassland/shrubland streams, as well as for three specific ecoregion divisions (Bailey, 1995). This indicator also reports on the duration of no-flow periods. For a subset of 132 grassland/shrubland streams that had at least one no-flow day during the study period, the duration of the maximum no-flow period in each year was averaged over a rolling 5-year window and compared with the average no-flow duration for the same site during the 1941-1960 baseline period. A no-flow period more than 14 days longer than the baseline was described as a "substantial increase"; a no-flow period more than 14 days shorter than the baseline was classified as a "substantial decrease."

What the Data Show

In an average year during the period of record, roughly 20 percent of streams had increases in high flow volume of more than 30 percent, relative to the 1941-1960 baseline (Exhibit 1). A similar percentage had decreases of more than 30 percent (Exhibit 1). Large fluctuations in high flow volume are apparent over time, with both sets of trends suggesting relatively wet periods in the early 1980s and mid-1990s and relatively dry periods around 1990 and the early 2000s. Reference and non-reference stream sites show similar patterns, although larger decreases in high flow volume were more common in the non-reference streams.

Since the early 1960s, more streams have shown increases in low flow volumes than have shown decreases, relative to the 1941-1960 baseline period (Exhibit 2). Among the many streams with larger low flows are a few (1 to 6 percent in a given year) with increases of more than 600 percent. Fluctuations over time are apparent, and while not as pronounced as the shifts in high flow (Exhibit 1), they generally tend to mirror the same relatively wet and dry periods since 1980. Reference and non-reference streams show similar low flow patterns over time, but reference sites are less likely to have experienced decreases in low flow.

Except for a few brief periods in the mid-1960s and again around 1980, decreased flow variability has been much more common than increased variability (Exhibit 3). Reference and non-reference streams have shown similar patterns in variability over time, although reference streams were slightly less likely to experience changes overall.

In areas with primarily grass or shrub cover, roughly 15 to 20 percent of stream sites typically have experienced periods of no flow in a given year (Exhibit 4). Overall, the number of streams experiencing no-flow periods has declined slightly since the 1960s. Streams in the California/Mediterranean ecoregion have shown the greatest decrease in no-flow frequency, but they still experience more no-flow periods than streams in the other two major grassland/shrubland ecoregion divisions. Among grassland/shrubland streams that have experienced at least one period of no flow since 1941, more streams have shown a substantial decrease in the duration of no-flow periods (relative to the 1941-1960 baseline) than a substantial increase (Exhibit 5).

Limitations

- The 1941-1960 baseline period was chosen to maximize the number of available reference sites and should provide a sufficiently long window to account for natural variability (Heinz Center, 2008); however, it does not necessarily reflect “undisturbed” conditions. Many dams and waterworks had already been constructed by 1941, and other anthropogenic changes (e.g., urbanization) were already widespread.

- Although the sites analyzed here are spread widely throughout the contiguous U.S., gauge placement by USGS is not a random process. Gauges are generally placed on larger, perennial streams and rivers, and changes seen in these larger systems may differ from those seen in smaller streams and rivers.

- This indicator does not characterize trends in the timing of high and low stream flows, which can affect species migration, reproduction, and other ecological processes.

Data Sources

Stream flow measurements can be obtained from the USGS National Water Information System (NWIS) database (USGS, 2020) (https://waterdata.usgs.gov/nwis). This indicator is based on stream flow records that USGS extracted from NWIS and provided to EPA.

References

Bailey, R.G. 1995. Description of the ecoregions of the United States. Second edition. Misc. Publ. No. 1391 (rev). Washington, DC: USDA Forest Service. https://www.fs.fed.us/land/ecosysmgmt/index.html.

Calow, P., and G.E. Petts, eds. 1992. The rivers handbook: Hydrological and ecological principles. Volume 1. Oxford, UK: Blackwell Scientific.

Fisher, S.G. 1995. Stream ecosystems of the western United States. In: Cushing, C.E., K.W. Cummings, and G.W. Minshall, eds. River and stream ecosystems, ecosystems of the world 22. New York, NY: Elsevier.

Heinz Center (The H. John Heinz III Center for Science, Economics, and the Environment). 2008. The state of the nation's ecosystems: Measuring the lands, waters, and living resources of the United States. 2008 update.

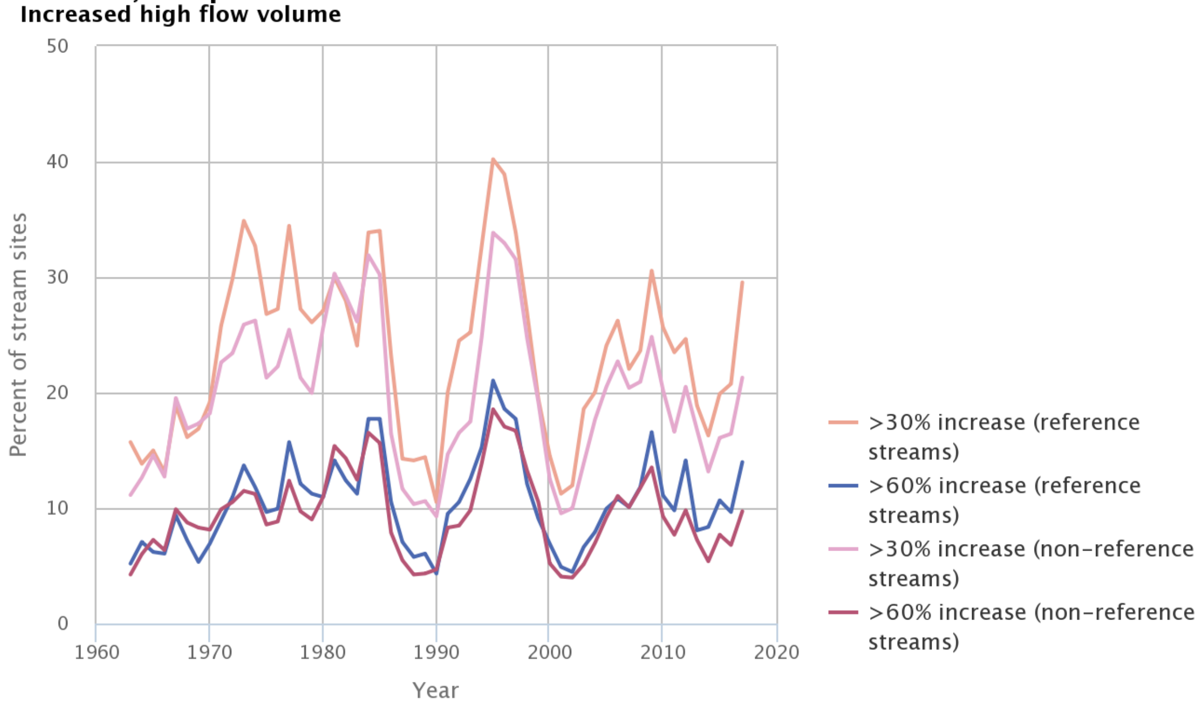
MRLC Consortium. 2007. National Land Cover Database 2001 (NLCD 2001). Accessed 2017. https://www.mrlc.gov/data?f%5B0%5D=year%3A2001.

Poff, N.L., and J.D. Allan. 1995. Functional organization of stream fish assemblages in relation to hydrologic variability. Ecology 76:606-627.

Robinson, C.T., K. Tockner, and J.V. Ward. 2002. The fauna of dynamic riverine landscapes. Freshwater Biol. 47:661-677.

USGS (United States Geological Survey). 2020. National Water Information System. Accessed 2020. https://waterdata.usgs.gov/nwis.

Exhibit 1. Changes in high flow in rivers and streams of the contiguous U.S., 1961–2019, compared with 1941–1960 baseline



Coverage: 1,826 stream gauging sites (694 reference, 1,132 non-reference) in the contiguous U.S. with flow data from 1941 to 2019. Reference streams have not been substantially affected by dams and diversions; non-reference streams may or may not have been affected in this way.

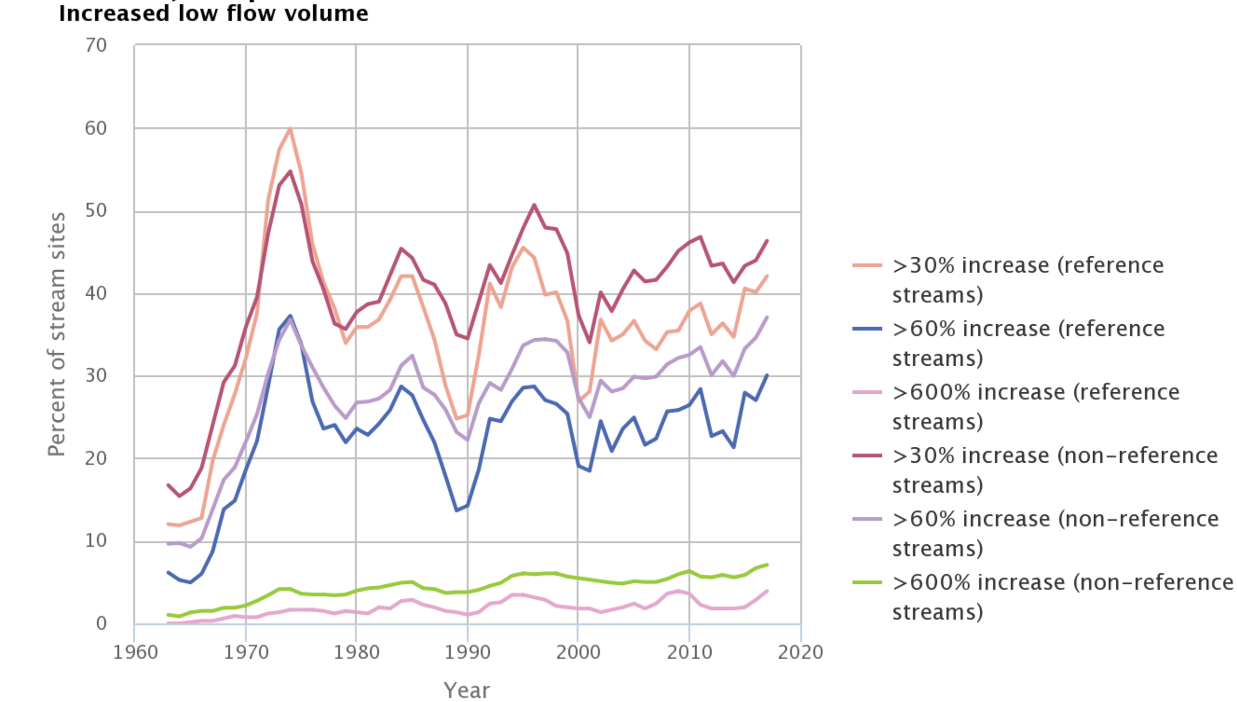
Based on the annual 3-day high flow. For each stream site, the median high flow was determined over a rolling 5-year window, then compared against the baseline. Results are plotted at the midpoint of each window. For example, the value for 2002-2006 is plotted at the year 2004.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: USGS, 2020

Visit https://www.epa.gov/roe to see the full exhibit.

Exhibit 2. Changes in low flow in rivers and streams of the contiguous U.S., 1961–2019, compared with 1941–1960 baseline



Coverage: 1,724 stream gauging sites (666 reference, 1,058 non-reference) in the contiguous U.S. with flow data from 1941 to 2019. Reference streams have not been substantially affected by dams and diversions; non-reference streams may or may not have been affected in this way.

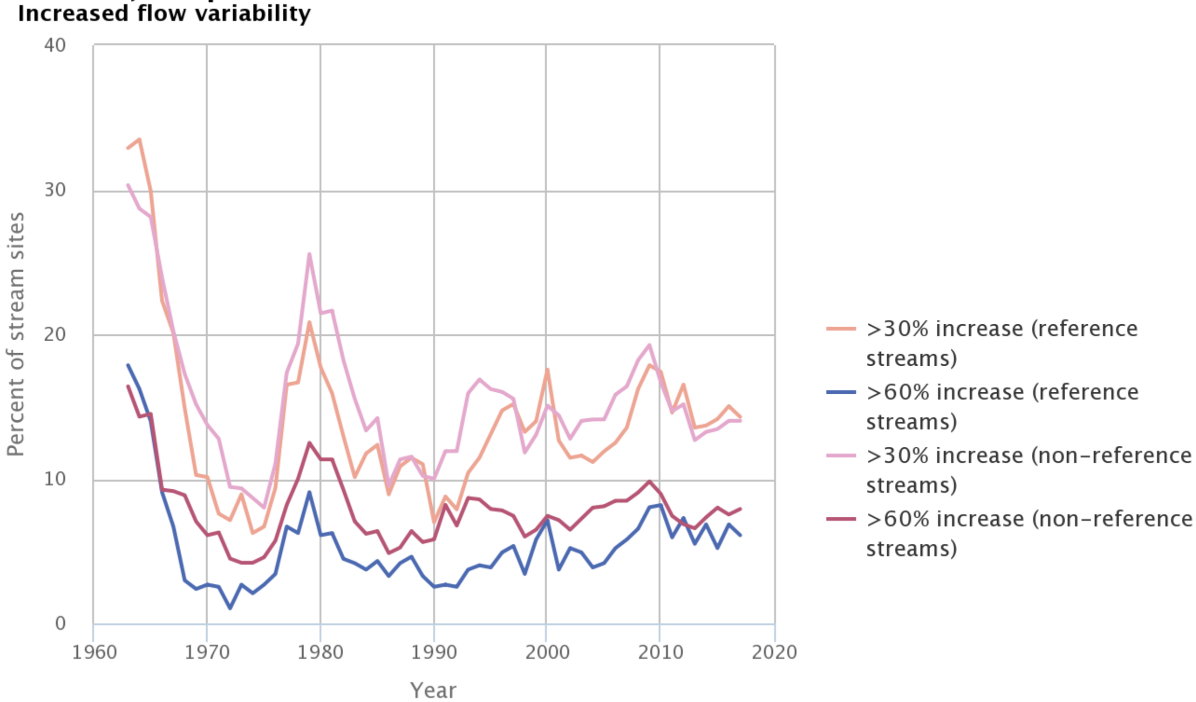
Based on the annual 7-day low flow. For each stream site, the median low flow was determined over a rolling 5-year window, then compared against the baseline. Results are plotted at the midpoint of each window. For example, the value for 2002–2006 is plotted at the year 2004.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: USGS, 2020

Visit https://www.epa.gov/roe to see the full exhibit.

Exhibit 3. Changes in flow variability in rivers and streams of the contiguous U.S., 1961–2019, compared with 1941–1960 baseline



Coverage: 1,721 stream gauging sites (672 reference, 1,049 non-reference) in the contiguous U.S. with flow data from 1941 to 2019. Reference streams have not been substantially affected by dams and diversions; non-reference streams may or may not have been affected in this way.

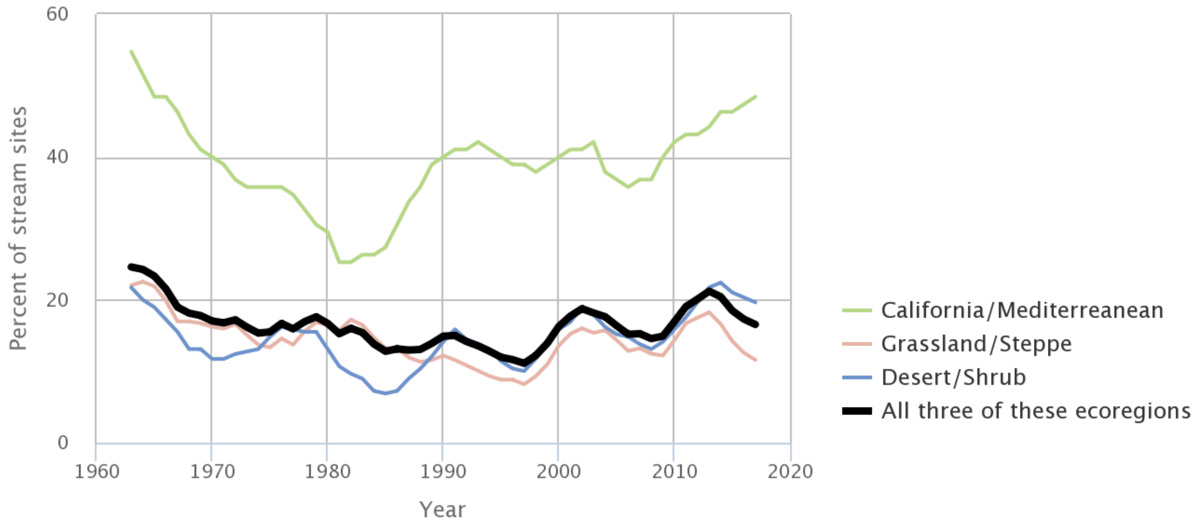
Based on the annual range of 1-day flows. For each stream site, the median variability was determined over a rolling 5-year window, then compared against the baseline. Results are plotted at the midpoint of each window. For example, the value for 2002–2006 is plotted at the year 2004.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: USGS, 2020

Visit https://www.epa.gov/roe to see the full exhibit.

Exhibit 4. Percent of grassland/shrubland streams in the contiguous U.S. experiencing periods of no flow, by ecoregion, 1961–2019



Coverage: 236 stream gauging sites in watersheds containing 50 percent or greater grass/shrub cover, with flow data from 1941 to 2019. Grass/shrub cover refers to classes 52 and 71 of the 2001 National Land Cover Dataset (NLCD).

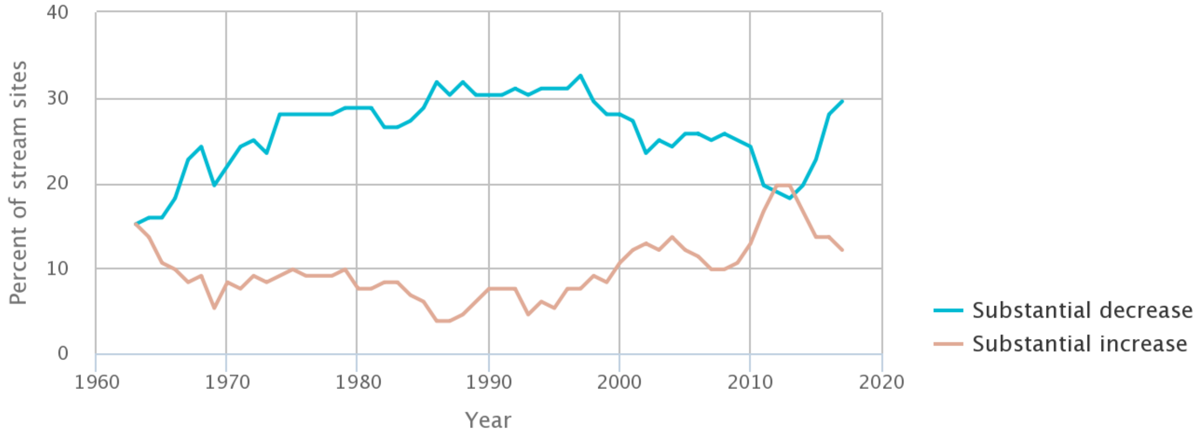
Streams were classified based on annual data, then the percentage of streams in each category was averaged over a rolling 5-year window. Results are plotted at the midpoint of each window. For example, the average for 2002–2006 is plotted at the year 2004.

Ecoregions based on Bailey (1995).

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: USGS, 2020

Exhibit 5. Changes in the maximum duration of no-flow periods in intermittent grassland/shrubland streams of the contiguous U.S., 1961–2019, compared with 1941–1960 baseline



Coverage: 132 stream gauging sites in watersheds containing 50 percent or greater grass/shrub cover, with flow data from 1941 to 2019 and at least one no-flow day during this period. Grass/shrub cover refers to classes 52 and 71 of the 2001 National Land Cover Dataset (NLCD).

For each stream site, the duration of the maximum no-flow period in each year was averaged over a rolling 5-year window. Results are plotted at the midpoint of each window. For example, the value for 2002–2006 is plotted at the year 2004.

A substantial increase means the no-flow period was more than 14 days longer than the average duration during the 1941–1960 baseline period; a substantial decrease means the no-flow period was more than 14 days shorter.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: USGS, 2020