Indicator Reference Sheet – March 6, 2022

Projected Hydrologic Change

U.S. Environmental Protection Agency

Indicator Names

- *% Projected Change in Annual Runoff*
- *% Projected Change in Annual Runoff, Inverse*
- *% Projected Change in Spring Runoff*
- *% Projected Change in Spring Runoff, Inverse*
- *% Projected Decrease in March Snow Water Equivalent*
- *% Projected Change in Annual Evaporative Deficit*

Indicator Category | **Stressor**

Subcategory | *Projected Climate and Hydrologic Change*

Available in RPS Tool files for all lower 48 states

Indicator Description

Background

The hydrologic cycle describes the movement of water between the Earth's atmosphere, surface, and subsurface. The US Geological Survey (USGS) has simulated the historical and projected future hydrologic cycle across the US with a water balance model[1] that uses projections of precipitation and air temperature under alternative greenhouse gas emission scenarios, known as *Representative Concentration Pathways (RCPs).*[1] Outputs of the water balance model include[1]:

- *Runoff* - the amount of water that moves across the landscape into waterbodies. Runoff is generated when rainfall or snowmelt occurs at a faster rate than the land surface can absorb, or when soils become saturated and cannot hold additional water.
- *Snow water equivalent (SWE)* - the amount of liquid water stored in the snowpack.
- *Evaporative deficit* - a measure of aridity or atmospheric water shortage, quantified as the difference between potential evapotranspiration and actual evapotranspiration.

What the Indicators Measure

These indicators measure projected future changes in hydrologic conditions in a HUC12 subwatershed* relative to historical conditions. The indicators reflect projections for a high greenhouse gas emission scenario, known as Representative Concentration Pathway (RCP) 8.5. Under this scenario, an increase in greenhouse gas emissions continues through the year 2100.[2] The indicators depict:

- ***% Projected Change in Annual Runoff*** – average annual runoff in the HUC12 that is projected for the years 2050 to 2074, expressed as a percentage change from the historical annual average during 1981 to 2010 (Figure 1).
- ***% Projected Change in Spring Runoff*** – average spring runoff in the HUC12 that is projected for the years 2050 to 2074, expressed as a percentage change from the historical spring average during 1981 to 2010. Spring is defined as March 1 through May 31.
- ***% Projected Decrease in March Snow Water Equivalent*** – average SWE in the HUC12 during the month of March that is projected for the years 2050 to 2074, expressed as a percentage change from the historical March average during 1981 to 2010. During the month of March, the snowpack is typically at or near its maximum depth in the western US.
- ***% Projected Change in Annual Evaporative Deficit*** – average annual evaporative deficit in the HUC12 that is projected for the years 2050 to 2074, expressed as a percentage change from the historical annual average during 1981 to 2010.

All HUC12s in the contiguous US have indicator values that correspond to decreased March SWE (reduced snowpack) and increased annual evaporative deficit (drier atmospheric conditions). However, runoff is projected to increase in some HUC12s and decrease in others (Figure 1). To provide flexibility in the application of these indicators, the RPS Tool also includes "inverse" versions of runoff change indicators:

- ***% Projected Change in Annual Runoff, Inverse*** – calculated by reversing the sign of the *% Projected Change in Annual Runoff* indicator so that positive values correspond to drier annual conditions (runoff decrease).
- ***% Projected Change in Spring Runoff, Inverse*** – calculated by reversing the sign of the *% Projected Change in Spring Runoff* indicator so that positive values correspond to drier spring conditions (runoff decrease).

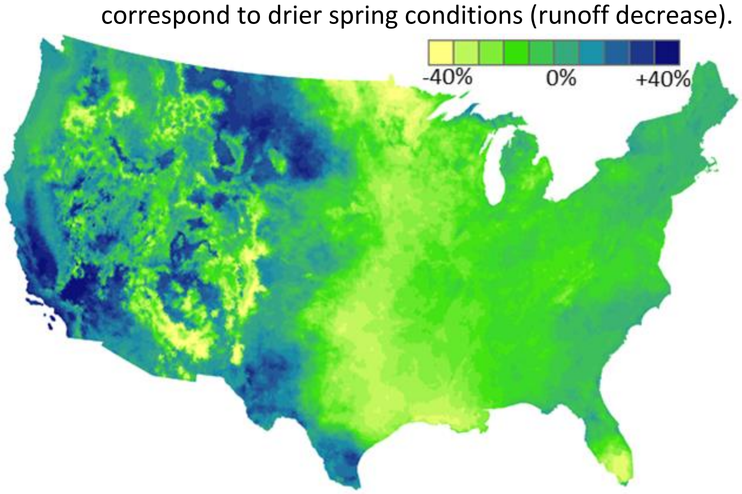

*Figure 1. Map of **% Projected Change in Annual Runoff** for HUC12s across the contiguous US.*

* HUC12s are subwatershed delineations in the National Watershed Boundary Dataset. HUC12s are referenced by their 12-digit Hydrologic Unit Code.

Relevance to Water Quality Restoration and Protection

The hydrologic cycle is a key factor affecting the physical, chemical, and biological makeup of a waterbody.[3] Alteration of historical patterns of hydrologic parameters such as runoff, snowmelt, and evapotranspiration can inhibit the ability of waters to provide ecosystem services (e.g., clean and plentiful drinking water, recreational opportunities, etc.) and support aquatic life.[3] For example:

- Increased runoff can correspond to greater flushing of pollutants from the land into waters, where they can harm environmental and human health.[4,5] Increased runoff may also result in severe flooding that can erode channels and shorelines, disturb aquatic habitat, and disrupt drinking water and wastewater systems.[4,6,7]
- Increased aridity and reduced runoff can contribute to water supply shortages and stress aquatic life by reducing and isolating available habitat, drawing down dissolved oxygen levels, and increasing water temperatures.[4,5,7] Stagnant pools of water can foster harmful algal blooms, and low water levels can reduce the capacity for rivers and lakes to dilute discharge from pollutant sources.[4,5]
- People and wildlife depend on spring snowmelt to replenish water supplies; thus, decreased SWE can contribute to water shortages.[4,8] Snowpack changes are also associated with altered timing of peak flows in rivers, which can disrupt aquatic life processes, such as fish spawning and reproduction.[7]

These indicators can be used to build awareness of projected hydrologic changes in one or more HUC12s and to assess the vulnerability of HUC12s to future degradation due to climate change. An assessment of watershed vulnerability may incorporate additional indicators to characterize the sensitivity of watershed processes and aquatic ecosystems to the expected changes in hydrology. For example, HUC12s with higher amounts of impervious cover may be more susceptible to degraded water quality with increasing runoff compared to HUC12s with higher vegetative cover. The inclusion of an impervious cover indicator in a vulnerability assessment, therefore, could provide a more complete picture of the likelihood of climate change impacts in HUC12s.

Processing Method

These indicators are derived from a water balance model developed by the USGS for the contiguous US for the National Climate Change Viewer (NCCV).[1] Key characteristics of inputs and outputs of the water balance model include:

- Inputs to the water balance model are projections of precipitation and air temperature from a climate projection dataset known as MACAv2-METDATA. The MACAv2-METDATA dataset is based on results of General Circulation Models (GCMs) developed for the 5th Climate Model Intercomparison Program (CMIP5)[9] of the Intergovernmental Panel on Climate Change (IPCC). Researchers produced the MACAv2-METDATA dataset by downscaling the results of GCMs, using statistical methods to transform the results of a model with relatively coarse spatial resolution into higher-resolution projections.[10]
- The MACAv2-METDATA dataset consists of historical and projected precipitation and air temperature for a 2.5-mile (4 kilometer) model grid over the contiguous US. The results of the water balance model are generated on the same model grid.[1]
- The MACAv2-METDATA dataset includes downscaled climate projections for 20 different GCMs. The USGS performed separate runs of the water balance model, each using projections of precipitation and air temperature from a different GCM as input.[1]

Results of the water balance model runs were averaged by USGS for the RCP 8.5 scenario to calculate historical (1981-2010) and future (2050-2074) hydrologic conditions and changes over time in each model grid cell. These summary grids of water balance model results were acquired from USGS in October 2021 and applied to calculate HUC12 values of runoff, SWE, and evaporative deficit change. HUC12 values were generated by overlaying the water balance model grids with HUC12 boundaries (Figure 2) and calculating a weighted average of grid cell values within a HUC12.

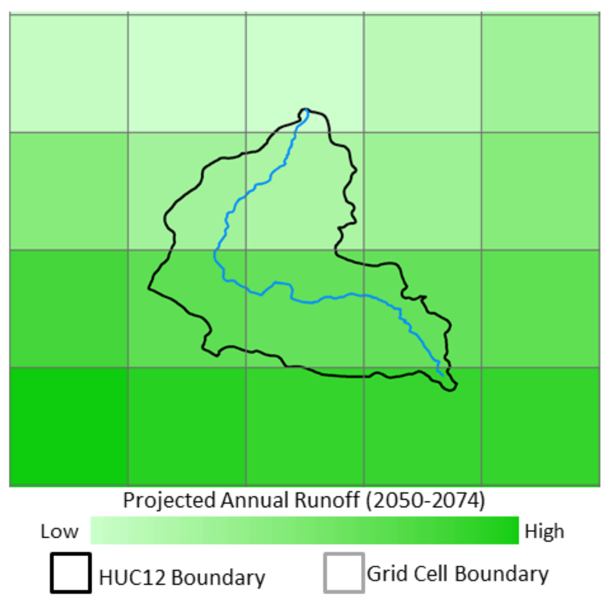

Figure 2. Example overlay map of the projected runoff grid and HUC12 boundaries.

Limitations

- The GCM projections input to the USGS water balance model have been subject to significant review and evaluation as part of the CMIP5 model comparison effort.[9] However, error and uncertainty are inherent in all models.
- These indicators do not *predict* future conditions but rather estimate potential conditions under the greenhouse gas emissions and related assumptions of the RCP 8.5 scenario.
- Projections of future climate change can vary significantly between different GCMs and greenhouse gas emission scenarios. Readers are encouraged to visit the USGS National Climate Change Viewer to review variation in projected climate and hydrologic conditions for their area of interest.
- When comparing multiple HUC12s, users should evaluate the magnitude of hydrologic changes among the HUC12s of interest. Small differences between HUC12s may fall within the range of uncertainty in model results.

Links to Access Data and Additional Information

HUC12 indicator data can be accessed within the EPA Restoration and Protection Screening (RPS) Tool, in downloadable data files, or as a web service. Visit the EPA RPS website for links to access the RPS Tool, HUC12 indicator database, and web service.

The source dataset for this indicator can be viewed on the USGS National Climate Change Viewer website.

References

[1]Alder, J. et al. 2021. National Climate Change Viewer Documentation. US Geological Survey.

[2]Van Vuuren, D., et al. 2011. The representative concentration pathways: an overview. *Climatic Change*. 109(5).

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[4]Pietrowsky, R., et al. 2012. Water Resources Sector Technical Input Report in Support of the U.S. Global Change Research Program, National Climate Assessment - 2013. 31 pp.

[5]Coffey, R, et al. 2019. A Review of Water Quality Responses to Air Temperature and Precipitation Changes 2: Nutrients, Algal Blooms, Sediment, Pathogens. *JAWRA Journal of the American Water Resources Association*. 55(4): 844-868.

[6]Talbot, C., et al. 2018. The impact of flooding on aquatic ecosystem services. *Biogeochemistry.* 141: 439–461.

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[8]Mote, P., et al. 2005. Declining mountain snowpack in western North America. *Bulletin of the American Meteorological Society*. 86(1): 39-50.

[9]Taylow, K., et al. 2012. An Overview of CMIP5 and the Experiment Design. *American Meteorological Society*. 93(4): 485-498.

[10]Abatzoglou, J., et al. 2012. A comparison of statistical downscaling methods suited for wildfire applications. *International Journal of Climatology*. 32(5): 772-780.