Appendix J. Assessing flow alteration

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The California Environmental Flow Framework (CEFF) Guidance Document describes a statewide approach to develop reference-based, stream segment-scale ecological flow criteria that are protective of functional flows. In Step 9 of the process, predicted functional flow metrics (FFMs) are evaluated against current conditions at locations of interest (LOIs). Here, we provide guidelines to evaluate reference-based FFMs against the same metrics calculated under current (observed or modeled) conditions to determine if functional flows are altered.

Alteration assessment for non-peak flow functional flow metrics

Predicted FFMs are expressed as a distribution, or range, of annual values occurring over a range of water year types. Assessing alteration requires comparing the distribution of predicted values to a distribution of current FFM values. The current values may be derived from existing flow gaging stations or from hydrologic models calibrated to simulate current hydrology at a LOI. We recommend that at least 15 years of contemporary FFM values be used to evaluate their distribution (Kennard et al. 2010). Shorter periods may be acceptable if specific FFMs show limited variation, whereas longer periods of record may be warranted if specific flow metrics show a high degree of variation or indicate a trend towards higher or lower values over time (i.e., non-stationarity) (see Williams 2017 for additional guidance).

To assess alteration, we first recommend that the distribution of current FFM values be visualized in relation to the distribution of predicted FFMs values as box plots. The box plots should display the median of the distribution and the 25th and 75th percentiles as the lower and upper ends of the box. “Whiskers” should be displayed for the 10th and 90th percentiles of the data (**Figure 1**).

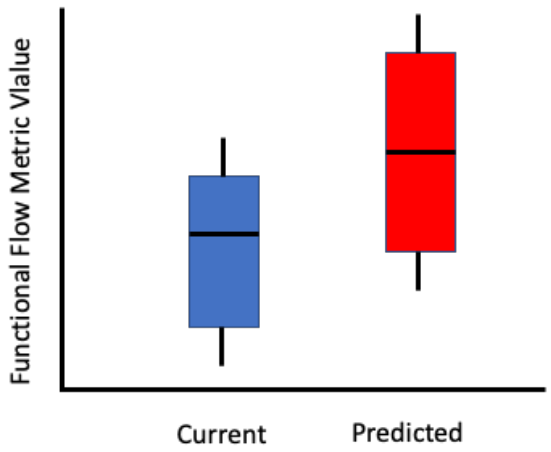


Figure 1. Example box plot of functional flow metric values, comparing current conditions to predicted, reference-based conditions

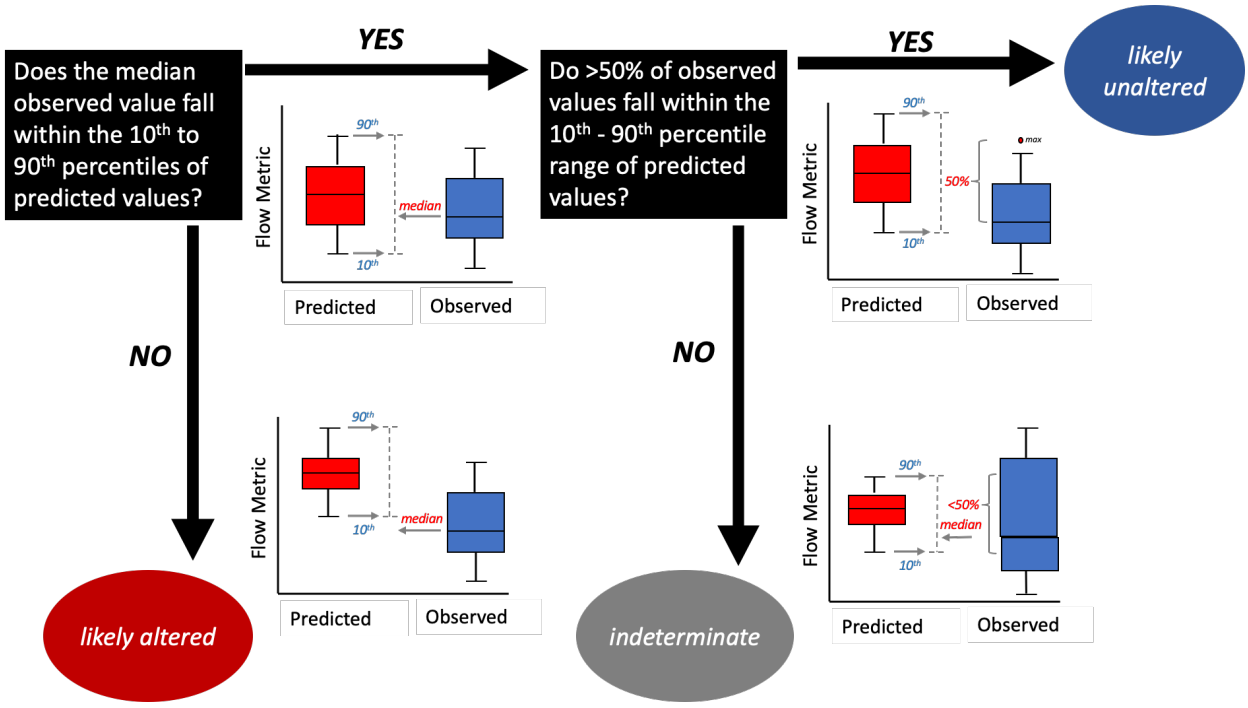
Next, determine if the current median FFM value falls within the 10th-90th percentile interval of predicted reference-based FFM values and calculate the proportion of current values that fall within this interval. Then apply the following rules to assign an alteration status for the metric (Figure 1):

- If the current median value falls within 10th-90th percentile interval of reference-based FFM values and more than 50% of current values fall within 10th-90th percentile, then the FFM is considered "likely unaltered"

- If median value falls outside of reference-based 10th-90th percentile prediction interval, then FFM is considered "likely altered." The median value relative to these intervals should be used to specify direction of alteration (e.g., depleted/augmented, early/late, etc.)

- If median current value falls within reference-based 10th-90th percentile prediction interval and fewer than 50% of current values fall within 10th-90th percentile, then FFM alteration status is considered "indeterminate"

Figure 1. Criteria for assigning alteration status.



Alteration assessment for peak flow functional flow metrics

Peak flow metrics are calculated as recurrence intervals from long-term records. Model predictions of peak flow magnitudes express a range of possible values, but the calculation of current peak flow metrics will result in a single value (e.g., 2-year recurrence interval peak flow magnitude). Estimates of recurrence intervals are highly sensitive to the length of record. USGS has not published specific guidelines on the minimum length of record needed to accurately estimate peak flood flows. However, a study from peak flows in Connecticut indicated that 18 or more years of observations were needed to accurately predict 10-year recurrence interval events (USGS 2003). Given that California rivers exhibit higher variability in flows than those in the eastern US, we recommend that alteration status of peak flows only be assessed if 20 or more years of peak flow data are available. To assess alteration, apply the following rules:

- If current value falls within 10th-90th percentile interval of predicted reference-based FFM values, then FFM is considered "likely unaltered"
- If current value falls outside of the reference-based 10th-90th percentile prediction interval, then FFM is considered "likely altered". The median value relative to these intervals should be used to specify direction of alteration.

Flow component alteration

A functional flow component is considered alterated, If any functional flow metric within that component is determined to be altered.

R-package

An R package has been developed to support the assessment of functional flow metric alteration. It can be accessed at: https://github.com/ceff-tech/ffc_api_client

The package includes a suite of functions designed to QA/QC the flow data used in an alteration assessment, run the functional flow calculator through an API to calculate current (observed) functional flow metrics at a gage or location of interest, and compare observed values with reference-based function flow predictions to assess alteration status, applying the criteria described above.

Important caveats

There are many sources of uncertainty that will influence alteration assessment results. These include the influence of highly variable and limited periods of record on calculated FFM values as well as model prediction error, both for reference-based FFM predictions and current values (if hydrologic models were used to generate them). For low flows and peak flows, streamflow measurement error can also be a substantial source of uncertainty. The user must exercise professional judgement in determining if calculated and modeled values are suitable for their application.

In addition, the user should keep in mind that the alteration assessment focuses on deviation from long-term ranges of reference-based values of FFMs. It does not focus on deviation from annual predicted reference-based values. It is possible that current conditions for a FFM in any one year may appear either altered or unaltered, but the overall assessment could classify the FFM as likely unaltered or altered, respectively.

Literature Cited

Kennard, M.J., Mackay, S.J., Pusey, B.J., Olden, J.D. and Marsh, N., 2010. Quantifying uncertainty in estimation of hydrologic metrics for ecohydrological studies. River Research and Applications, 26(2): 137-156.

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Williams, J.G., 2018. Building hydrologic foundations for applications of ELOHA: how long a record should you have? River Research and Applications, 34(1): 93-98.