Functional Flows Calculator
Technical Overview

September 11, 2018

CEFF Technical Team
California’s hydrology is complex

Stream Class
- (SM) Snowmelt
- (HSR) High-volume snowmelt and rain
- (LSR) Low-volume snowmelt and rain
- (RGW) Rain and seasonal groundwater
- (WS) Winter storms
- (GW) Groundwater
- (PGR) Perennial groundwater and rain
- (FER) Flashy, ephemeral rain
- (HLP) High elevation, low precipitation


https://eflows.gitbook.io/project/website_summary#stream-classification
Distinct flow signatures

High elevation, low precipitation

Low-volume Snowmelt and Rain

Perennial Groundwater and Rain

High-volume Snowmelt and Rain

Flashy, ephemeral rain
The natural flow regime is a primary control on ecological functioning.

Flow metrics are used to link key aspects of natural and altered hydrology to ecological response to inform environmental water management.

Many flow metrics have been proposed:
- Indicators of Hydrologic Alteration (TNC 1996)
- Hydrologic Index Tool (USGS 2006)
- ‘Statistically significant’ (Olden and Poff 2003, Archfield et al 2006, Yang et al 2008)

Appropriate selection of flow metrics remains a major challenge due to metric redundancy, limited statistical power and ecological relevance.
Sub-annual aspects of the natural flow regime expected to support key ecosystem functions

Constrain habitat, limiting for exotic species

Yarnell et al. 2015 *BioScience*
Conceptual Model

Functional Flow Components
- e.g. Winter Floods, Spring Recession
- Summer Baseflow

Flow characteristics
- e.g. Magnitude, Timing, Duration, Frequency, Rate of Change

Flow metrics
- e.g. 5% Exceedance flow, Julian Day, Percent decrease per day, Richards-Baker Flashiness Index

<table>
<thead>
<tr>
<th>Flow Characteristics</th>
<th>Wet Season Initiation</th>
<th>Peak Magnitude Flows</th>
<th>Spring Recession Flow</th>
<th>Dry Season Low Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnitude</td>
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</table>
Functional flow metrics

- 31 metrics
- 223 reference gauges in CA
- Annual metrics calculated for each reference Water Year (WY) on record (10 - 60 years)

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**Flow Component** | **Flow Characteristic** | **Units** | **Metric**
--- | --- | --- | ---
**Annual** | Magnitude | cfs | average annual flow
 | Rate of change | percent | coefficient of variation
**Wet Season Initiation Flow Event** | Magnitude | cfs | event peak magnitude
 | Timing | date | event start date
 | Duration | days | event duration
**Peak Magnitude Flows** | Timing | date | start date of wet season
 | Magnitude | cfs | wet season baseflow (10P)
 | Magnitude | cfs | peak magnitude: 2%, 5%, 10%, 20%
 | Timing | date | event start date: 2%, 5%, 10%, 20%
 | Duration | days | event duration: 2%, 5%, 10%, 20%
 | Frequency | count | # of events/year: 2%, 5%, 10%, 20%
**Spring Recession Flows** | Magnitude | cfs | magnitude at start of spring recession
 | Rate of change | percent | median daily flow percent decrease
 | Timing | date | start date of spring recession
 | Duration | days | from recession until dry season
**Dry Season Low Flows** | Magnitude | cfs | baseflow magnitude (10P)
 | Timing | date | start date of dry season
 | Duration | days | from dry season to start of wet season
 | Frequency | count | # of no-flow days

[https://eflows.gitbook.io/project/website_summary#functional-flow-calculator](https://eflows.gitbook.io/project/website_summary#functional-flow-calculator)
Functional flow metrics predicted for all stream reaches

Ecological Flow Criteria

Stream Classification

Dimensionless Reference Hydrographs (DRH) for each Reference Gage

Functional Flows Metrics at Reference Gages (calculated using FFC)
**Timing** metrics form foundation for all other functional flow metrics.
Wet Season Initiation Event

**Initiation event timing**
- First date from Oct 1 – Dec 15 that flow exceeds 2x previous dry season baseflow or 1 cfs, whichever is larger.

**Initiation event magnitude**
- Peak magnitude during initiation event.

**Initiation event duration**
- Number of days from the start to peak magnitude of initiation event.
Peak Magnitude Flows

For 2%, 5%, 10%, and 20% exceedance flows:

**High flow timing**
- Date of peak flow for each high flow exceedance event

**High flow magnitude**
- Peak magnitude above the high flow exceedance threshold

**High flow duration**
- Continuous duration that flow remains above threshold

**High flow frequency**
- Number of times threshold is exceeded per water year
Functional flow metrics

Peak Magnitude Flows

Two additional wet season metrics:

**Wet season start timing**
- First date flow is above 30% relative magnitude of difference between baseflow and smoothed wet season peak flow

**Wet season baseflow magnitude**
- 10th percentile daily flow from the start of the wet season to the start of the dry season.
Functional flow metrics

Spring Recession Flows

Recession start timing**
- Start of transition from wet season high flows to dry season low flows

Recession start magnitude
- Flow magnitude at start of recession.

Recession duration
- Duration from start of recession to start of dry season

Recession rate of change
- Median daily rate of change over recession duration, considering only days with negative rate of change.
Dry Season Low Flows

Dry season start timing
• First date from recession start to end of WY that magnitude <12.5% wet season max flow and rate of change -> zero.

Low flow magnitude
• 10th percentile daily flow from start of dry season to start of wet season.

Low flow duration
• Duration from start of dry season to start of wet season.

# no-flow days
• Number of days with zero flow magnitude during low flow period
Functional flow metrics

Annual

**Average annual daily flow**
- Mean daily flow over WY

**Coefficient of variation**
- Standard deviation of daily flow divided by average annual flow
Detailed Methods

Identification of relevant hydrologic features using signal processing techniques

- Smoothing
- Feature detection
- Windowing

*Hydrology - not calendar-driven*
Detailed Methods

**Example:** Spring Recession Start Timing

Step 1: Plot daily data by water year
Detailed Methods

Example: Spring Recession Start Timing

Step 2: Smooth data with Gaussian filter
Example: Spring Recession Start Timing

Step 3: Identify last major peak (center of mass of wet season)
Detailed Methods

**Example:** Spring Recession Start Timing

Step 4: Set dynamic search window around peak
Step 5: Apply a tighter smoothing curve within window (black) and calculate its derivative (red).
Example: Spring Recession Start Timing

Step 6: Identify local peaks where derivative (red) flips from + to -
Example: Spring Recession Start Timing

Step 7: Identify last peak with sufficient:
  - Relative magnitude
  - Duration
  - Rate of change
Step 8: Set start date 4 days after peak flow (to remove individual storm effects)
# Functional flow metrics

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Explore and visualize California's unimpaired streamflow patterns, including natural stream classes and functional flow metrics.

Stream Classification
California is organized into nine stream classes with distinct natural flow regime patterns and watershed controls.

Dimensionless Reference Hydrographs
Summary stream class hydrographs illustrate season and inter-annual daily flow patterns.

Functional Flow Metrics
Flow metrics quantify key aspects of the natural flow regime linked to critical ecosystem functions.

Metrics

Documentation

https://eflows.ucdavis.edu
Functional Flows Calculator (FFC)

223 Ref. Gauges

Dimensionless Reference Hydrograph

Low-volume snowmelt and rain
ID: 3

Percentiles: 10th, 25th, 50th, 75th, 90th
FFC – Reference Gauge

Water year hydrograph for 1975

Overview
Boxplot Summary

Snowmelt
Gauge Count: 23

High-volume snowmelt and rain
Gauge Count: 7

Low-volume snowmelt and rain
Gauge Count: 65

Winter storms
Gauge Count: 34

Groundwater
Gauge Count: 1

Perennial groundwater and rain
Gauge Count: 56

Flashy, ephemeral rain
Gauge Count: 12

Fixed Y-axis
Y-axis Percentile
0.99

Hydrograph Overlay
eFlows Website Purpose

The eFlows Functional Flow Calculator (FFC) quantifies key hydrologic aspects of the annual flow regime from any daily streamflow time series. The FFC produces dimensionless reference hydrographs (defined below) and a suite of functional flow metrics that quantify functional flow components, referring to portions of the annual flow regime expected to serve distinct geomorphic or ecological functions (Yarnell et al. 2015). Results are presented visually and data can be directly downloaded. Users of the FFC can also install and run the FFC on their own computer; for more information see the FFC Installation section. The hydrographs and metrics enable comparisons of streamflow patterns across regions, natural stream classes, and various forms and magnitudes of flow alteration. The FFC generates 31 metrics describing aspects of streamflow timing, magnitude, duration, frequency, and rate of change, organized into four functional flow components: 1) wet season initiation flows, 2) peak magnitude flows, 3) spring recession flows, and 4) dry season low flows (Table 1).

Stream Classification
Introduction

Last updated 26 days ago

About

The functional flows calculator (FFC) quantifies key aspects of the annual flow regime based on long-term daily streamflow time series data, producing a broad suite of descriptive functional flow metrics. These metrics are meant to characterize ecologically relevant components of any flow regime in a robust, objective manner to enable comparisons of streamflow across regions, natural stream classes, and various forms and magnitudes of flow alteration. The FFC generates metrics describing aspects of streamflow timing, magnitude, duration, frequency, and rate of change, organized into four seasonally-based functional flow components: 1) wet season initiation flows, 2) peak magnitude flows, 3) spring recession flows, and 4) dry season low flows.

This project uses Python3 for its processing algorithm, React, Mapbox, and D3 for front end web development, and Express, Sequelize, and Postgres for the server.

https://eflows.gitbook.io/project
Thank you!