Establishing Environmental Flows for California Streams

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California’s Legacy of Water Management
Greatest Impact: Loss of Hydrologic Variability

![Graph showing discharge (cfs) over time with key points labeled: Camanche Dam Release, Cosumnes River at Michigan Bar.]

- Fundamentally altered flow regime
  - Lower winter flows
  - Few flood events
  - Higher summer flows
  - Disconnect river from floodplain
  - Reduced sediment transport
  - Channel morphology more static
  - Biotic Repercussions
What Do We Know About the Status of Flows Statewide?

• First comprehensive study recently published
  – Statistical analysis of gauged locations

• 95% of gauged locations have at least some altered flows; 11% have pervasive alteration
  – Depletion of high flows
  – Augmentation of low flows
  – Reduction in seasonal variability

• Results NOT related to any ecological endpoints

Depletion of high flows  Augmentation of low flows

Zimmerman et al. 2017

Need an approach to define “flow impairment”
Statewide Needs for Environmental Flows

• Set instream flow standards to protect biological communities
  – Process for selecting appropriate ecological endpoints

• Assess vulnerability of streams to future changes in flow conditions
  – Prioritize areas for restoration/management

• Evaluate/inform management actions
  – e.g., reservoir operations, water withdrawals
What are Environmental Flows?

The magnitude, timing, duration, rate of change, and frequency of flows and associated water levels necessary to sustain the biological composition, ecological function, and habitat processes within a water body and its margins.

Environmental flows are not necessarily “natural flows”. They allow for some degree of hydrologic alteration due to other uses. However, environmental flows are intended to mimic the patterns and ecological outcomes of the natural flow regime.
Irrigation Diversions

Stormwater Retention

Use or Reuse of Treated Effluent

Groundwater withdrawals?
Setting Flow Targets to Inform Management Decisions

Select approach based on:
- Stream type
- Ecological endpoint
- Management need
Challenges

• California is a very complex/diverse state

• Hard to balance environmental flow needs with a broad range of other demands

• No mechanism for coordination and information sharing among agencies and with the public
California E-flows Framework

Statewide approach for setting coarse scale ecological flow criteria

Regional and Site specific e-flows where necessary

Data sharing (open data) + information dissemination to the public
Statewide approach for setting coarse scale flow targets

- Stream classification
- Dimensionless hydrographs
- Functional flow metrics and ecological endpoints
- E-flow targets: rapid, comprehensive, coarse
Catchment Properties

Rainfall Patterns

Geology

Soil Properties

Lane et al., in review

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

Develop reference hydrographs and identify flow components

Reference hydrograph for LSR Stream Class

Tier 1 Flow Criteria

<table>
<thead>
<tr>
<th>Flow Component</th>
<th>Magnitude</th>
<th>Timing</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter High Flows</td>
<td>2,000 cfs</td>
<td>Jan 3</td>
<td>7 days</td>
</tr>
<tr>
<td>First Fall Flush</td>
<td>200 cfs</td>
<td>Nov 22</td>
<td>3 days</td>
</tr>
<tr>
<td>Spring Transition</td>
<td>-10 cfs/day</td>
<td>May 19</td>
<td>82 days</td>
</tr>
<tr>
<td>Summer Baseflow</td>
<td>50</td>
<td>Aug 20</td>
<td>123 days</td>
</tr>
</tbody>
</table>

Estimate and Predict Functional Flow Metrics

Develop quantitative flow criteria
Site specific e-flows where necessary

- Assess available methodologies
- Define ecological and management context
- Tailor approach to hydrologic alteration, stream class, management needs, biological outcomes
- **E-flow targets: specific, objectives-based**
There are Many Technical Approaches

Presumptive Standard – Richter et al. 2013

Functional Flows - Yarnell et al. 2015

statistical

hybrid

ELOHA -Carlisle et al. 2015

resumptive Standard – Richter et al. 2013

mechanistic

Functional Flows - Yarnell et al. 2015
Incorporate Local Data

Hydrology

Geomorphology  Ecology

Reach scale environmental flow methods

Flow targets
Out of 10,732 km of streams in the region:
- 8,782 km are poorly gaged
- 1,950 km are well gaged

Out of 433 gages in the region:
- 283 gages are inactive
- 150 gages are active

Approximately 900 sites sampled
Approximately 30% considered intact
Ecological Limits of Hydrologic Alteration (ELOHA)

- Estimate degree of hydrologic alteration
  - Calculate a series of flow metrics
  - Current vs. “natural” conditions

- Compare hydrologic change to response of the biological community
  - Based on benthic invertebrate CSCI
  - Establish thresholds of biological response

- Develop a regional index of hydrologic alteration based on priority metrics

- Apply index to evaluate management options in terms of their likely effect on biological communities
Estimating Hydrologic Change

Compare reference vs. current flow to produce measures of hydrologic change
Consider a Broad Suite of Flow Metrics

- **Magnitude**
  - streamflow (mean, max)
  - median annual number of high flow events

- **Variability**
  - median percent daily change in streamflow
  - Interannual variability (min, max, median)

- **Duration**
  - Storm flow recession
  - Duration above baseflow

- **Timing**
  - month of minimum streamflow
  - Frequency of high flow events

Evaluate for multiple climatic conditions
- Average years
- Wet years
- Dry years
- All years
Establish Thresholds; example High Duration (days)

Logistic regression: **Likelihood** of healthy biology at each level of hydrologic alteration

Produce plots for all flow metrics
Select Priority Metrics

Affects in-stream biology

Differentiate reference vs. non-reference

Non redundant, cover all aspects of flow

Amenable to management actions
## Priority Metrics
*(expressed as CHANGE in metric value)*

<table>
<thead>
<tr>
<th>Hydrograph Component</th>
<th>Metric Definition</th>
<th>Critical precipitation condition</th>
<th>Decreasing Threshold</th>
<th>Increasing Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Duration (days)</strong></td>
<td>longest number of consecutive days that flow is between the low and high flow threshold</td>
<td>Average</td>
<td>-64</td>
<td>NT</td>
</tr>
<tr>
<td></td>
<td>longest number of consecutive days that flow was greater than the high flow threshold</td>
<td>Wet</td>
<td>-3</td>
<td>24</td>
</tr>
<tr>
<td><strong>Magnitude (cms)</strong></td>
<td>Maximum mean monthly streamflow</td>
<td>Wet</td>
<td>NT</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>streamflow exceeded 99% of the time</td>
<td>Wet</td>
<td>NT</td>
<td>32</td>
</tr>
<tr>
<td><strong>Variability (unitless)</strong></td>
<td>Richards-Baker index of stream flashiness</td>
<td>Dry</td>
<td>NT</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Frequency (# of events)</strong></td>
<td>number of events that flow was greater than high flow threshold</td>
<td>Dry</td>
<td>NT</td>
<td>3</td>
</tr>
</tbody>
</table>
### Regional Hydrologic Condition

<table>
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<tr>
<th>Poor hydrologic condition</th>
<th>Good hydrologic condition</th>
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<tr>
<td>Poor biology (CSCI &lt; 0.79)</td>
<td>Flow Management:</td>
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<td></td>
<td>Prioritize flow management relative to other stressors</td>
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<td></td>
<td>Other Stressors</td>
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<td>Management/Causal Assessment:</td>
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<tr>
<td>Good biology (CSCI &gt; 0.79)</td>
<td>Monitor</td>
</tr>
<tr>
<td></td>
<td>Protect</td>
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</table>
Regional Management Priorities

Recommended action
- Protect
- Monitor
- Evaluate flow
- Evaluate other stressors
Are Our Aquatic Ecosystems Healthy?

California has many types of aquatic habitats. Follow the links below to learn more...

**Wetlands Portal**
Wetlands form along the shallow margins of deepwater ecosystems such as lakes, estuaries, and rivers. They also form in upland settings where groundwater or runoff makes the ground too wet for upland vegetation.

**Streams & Rivers Portal**
California's streams and rivers flow through diverse habitats, from mountain canyons, valleys, deserts, estuaries and urban areas. Riparian woodlands develop along stream banks and floodplains, linking forest, chaparral, scrubland, grassland, and wetlands. California lakes, supporting deep water, wetlands, riparian woodlands, offer a quiet refuge for plants, animals and humans alike.

**Estuaries Portal**
Estuaries are unique habitats found where rivers and the ocean mix. They feature a diverse array of plants and animals adapted to life along the mixing zone.

**Ocean & Coastal Portal**
California has 1,100 miles of shoreline and 220,000 square miles of state and federal oceanic habitat, featuring one of the world's most diverse marine ecosystems.
The mission of the California Environmental Flows Workgroup is to advance the science of environmental flows assessment and its application for supporting management decisions aimed at balancing natural resource needs with consumptive water uses.

**Technical Products**
- Analytical frameworks
- Classification systems
- Assessment tools
- Modeling approaches and models
- Databases
- Statistical analysis of patterns and relationships

**Implementation Products**
- Guidance for environmental flow criteria
- Appropriate application of tools, databases and models
- Prioritize knowledge gaps for funding
- Interpretation tools
- Communication approaches
- Ways to reconcile different approaches
Ca. Env. Flows Workgroup Members

**Technical Participants**

- University of California, Davis
- University of California, Berkeley
- University of California Agriculture and Natural Resources
- Utah State University
- Southern California Coastal Water Research Project
- The Nature Conservancy
- California Trout
- US Geological Survey

**Agency Members**

- State Water Board - Water Quality
- State Water Board - Water Rights
- Department of Water Resources
- California Department of Fish and Wildlife
- US Fish and Wildlife Service
- US Forest Service
- US Geological Survey
- Regional Water Quality Control Boards
- Bureau of Reclamation
- NOAA Fisheries
Improve Information Dissemination

To preserve, enhance, and restore the quality of California’s water resources and drinking water for the protection of the environment, public health, and all beneficial uses, and to ensure proper water resource allocation and efficient use, for the benefit of present and future generations.

California State Water Resources Control Board

Water Boards

ArcGIS - My Map

Contents

- Hydrology streamclasses
  - Reconciled Hyd Classification Base
    - SWIR Snowmelt
    - [HBR] High-volume snowmelt and rain
    - [LSR] Low-volume snowmelt and rain
    - [RIV] Rain and seasonal groundwater
    - [WSR] Winter storms
    - [GW] Groundwater
    - [GR] Perennial groundwater and rain
    - [FER] Flashy, ephemeral rain
    - [HLR] High elevation, low precipitation
  - Topographic
Final Thoughts

• Lots of emerging science around environmental flows
  – Moving beyond dams and fish to a broader set of ecological endpoints and management needs

• Statewide framework provides tools and approaches for coordination and collaboration

• Opportunities for partnership in Tier 2 case studies and trial implementation of environmental flow products
Need to estimate hydrologic change at all these sites....  
.... but very few are gauged
Stream Gages

Sites of Interest

Local Targets

Input

Output

$x_1$

$y_1$

$x_2$

$y_2$

$\ldots$

$\ldots$

$x_n$

$y_m$

Simulation Model

Reach scale environmental flow methods

Flow targets

Geomorphology

Ecology

Flow targets
CEFF - Two Tiered Approach

**Statewide rapid approach for setting flow criteria:**
*comprehensive & coarse*
- Define a natural stream classification
- Develop dimensionless reference hydrographs
- Estimate functional flow metrics
- Predict flow metrics at all stream segments
- Flow metric ranges at locations of interest

**Regional, local or site specific flow criteria:**
*specific & objective-based*
- Define context and objectives:
  spatial-temporal scale, ecological endpoints, hydrologic conditions, water management system
- Characterize and compile data
- Select appropriate E-flow method
- Consider Policy and Management Needs:
  balance objectives, implementation, monitoring, adaptive management

Databases + guidelines + tools + information accessible to the public

Where necessary

Ecological Flow Criteria
Functional Flows Approach

Focus on hydrograph flow components that:

– Support natural disturbances
– Promote physical dynamics
– Drive ecosystem functions
– Support high biodiversity

Consideration of geomorphic setting and channel-floodplain dynamics

(Yarnell et al. 2010)
Statewide

Regional

ELOHA

Local Case Study

Statewide Classification

Compile Bioassessment Data

Estimate Hydrologic Alteration

Compare Bio and Hydro Alteration Data

Select Priority Flow Metrics

Evaluate Local Management Actions

Regional Survey

Regional Hydro Models

Logistic Regression

Metric Screening
Inform land planning process
Flow Management Zones

Management Zone
- Altered, Unhealthy
- Altered, Healthy
- Unaltered, Unhealthy
- Unaltered, Healthy

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- Monitor
- Protect
Scenario Analysis: Alvarado Creek Stormwater Management

Current imperviousness is 50%
Change effective imperviousness to 5%, 10% and 25%
Capture 85% rain
<table>
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<tr>
<th>Metric</th>
<th>Units</th>
<th>Imperviousness</th>
<th>Target</th>
</tr>
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<tbody>
<tr>
<td>MaxMonthQ</td>
<td>cms</td>
<td>0.22 0.56 1.12 2.81</td>
<td>0.2</td>
</tr>
<tr>
<td>Q99</td>
<td>cms</td>
<td>6 31 69 71</td>
<td>70</td>
</tr>
<tr>
<td>RBI</td>
<td>unitless</td>
<td>0.15 0.25 0.33 0.41</td>
<td>1.4</td>
</tr>
</tbody>
</table>

- 85% capture produces hydrologic conditions associated with healthy invertebrates
- Must reduce effective imperviousness to 2-5% to provide optimal hydrologic conditions
- Flashiness not an issue for this site
Changes in Wastewater and Stormwater Management

Annual minimum flows at Glendale Narrows

Increased WRP discharge
Need for Coordination

Important to Combine Technical and Policy Discussions in a Single Workgroup
Statewide bioassessment data provides a way to relate flow alteration to ecological effects at a **statewide** level.

- S. Ca is data rich
- Regional program
- Opportunity to develop flow-ecology tools
Bioassessment

Most waterbodies (*streams, wetlands, lakes, oceans*) contain diverse groups of plants and animals that have predictable responses to different stressors.

Resident organisms integrate stream conditions over time.

Monitoring biology provides a direct measure of stream health.

Incorporates responses to chemical AND non-chemical stresses.
Management Based on Benthic Macroinvertebrate Indices

California Stream Condition Index (CSCI)

- Score / Index
- 0.79
- impacted
- healthy

Midges
Beetles
Dragonflies
Stoneflies
Mayflies
Caddisflies

1 inch
There are Lots of Regulatory Drivers

- Stormwater and non-point source programs
- Freshwater Bioobjectives (Bio-integrity)
- Wetland and Riparian Area Protection Policy
- Hydromodification & Flow Management
- Nutrient Numeric Endpoints
- Sustainable Groundwater Management Act