The South Orange County, California Flow Ecology Study: Part 2, Flow Ecology Approach for Flow Management Prioritization

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Highlights

- Understanding when and where flows are altered and the degree to which alteration is impacting ecology is critical when prioritizing areas for flow management.
- High priority areas were located where both stormflows and dry season flows were augmented.
- Flow ecology approach can be applied to other urban areas where flow alteration is extensive.

Introduction

Flow alteration is a pervasive issue across highly urbanized watersheds that can impact the physical and biological condition of streams (Poff & Zimmerman, 2010). In southern California, many naturally intermittent streams have become perennialized due to augmented urban runoff during the dry season, which can lead to the expansion of non-native species and decline of native species. Stormflows have also become flashier, often leading to geomorphic instability and biological degradation. Prioritizing where to focus flow management efforts and establishing flow management targets in highly urbanized systems can be a challenge when alteration is widespread across broad spatial scales and multiple aspects of the flow regime.

Orange County (OC) Public Works, on behalf of the South OC Municipal Separate Storm Sewer System (MS4) Co-permittees, is conducting a Flow Ecology Special Study for six urban watersheds in the South OC Watershed Management Area in California. The goal of this study is to quantify unnatural flows and develop relationships between levels of flow alteration and ecological condition to inform prioritization and design of flow management and stream rehabilitation projects. The study aims to develop tools and datasets to support future projects, including (1) recovery of stream ecosystems from negative impacts of urbanization, and (2) increased resilience of ecological communities during a drier future. This study was divided into two parts: watershed hydrology and flow ecology.

Building off the watershed hydrology modelling (part 1), part 2 of this presentation describes the flow ecology approach to evaluate the effects of flow alteration and aid in prioritizing where to focus flow management actions. Rather than managing for the full natural flow regime, which is oftentimes unrealistic and undesirable in highly altered systems, we utilized a functional flows approach that focused on identifying and managing for discrete aspects of the annual hydrograph that are associated with ecological and geomorphic processes (Yarnell et al., 2015). By understanding which functional flow components are altered and where alteration may impact ecology, priority areas for flow management and stream rehabilitation can be identified.

Methodology

The flow ecology approach developed includes the following steps: assessing hydrologic alteration based on deviation from reference, determining where hydrologic alteration is likely affecting biological communities, and identifying priority locations for addressing alteration.

Hydrologic alteration based on deviation from reference

Modelled reference and current hydrology from 60 subbasins, described in Part 1, were characterized by quantifying key components of the annual hydrograph that support a broad suite of ecological functions, referred to as functional flow components (Yarnell et al., 2020). In California, functional flow components include the fall pulse flow, winter baseflows, peak flows, spring recession flows, and summer baseflows. A suite of 24 functional flow metrics (FFM), such as dry-season baseflow magnitude and wet season duration, were calculated on an annual basis from the modelled flow timeseries using the Functional Flows Calculator (FFC) API client package in R (version 0.9.7.2, https://github.com/ceff-tech/ffc_api_client), which uses hydrologic feature detection algorithms developed by Patterson et al. (2020) and the FFC Python package (https://github.com/NoellePatterson/ffc-readme). We evaluated alteration across all FFM by comparing the distribution of FFM values under current and reference conditions. By utilizing the distribution of flows across the full period of record, as opposed to a year-by-year comparison, this approach assessed the general trends in flow conditions over time.

Biologic flow alteration based on biotic indices

Flow ecology relationships for established biotic indices, the California Stream Condition Index (CSCI, Mazor et al. 2016) for benthic macroinvertebrates and the Algal Stream Condition Index (ASCI, Theroux et al. 2020) for benthic algae, were used to determine where hydrologic alteration is associated with a decline in biological condition. Flow ecology relationships relate the change in functional flow metric values from reference to current (Delta FFM) to the probability of supporting a healthy biological community (i.e., a CSCI score of 0.79 out of 1). These relationships can be used to define biologically relevant flow alteration based on series of decisions (i.e., probability thresholds, percentage of years altered, number of altered FFM). To be useful, the assessment should have sufficient discriminatory power to allow locations to be prioritized.

Rather than using all 24 FFM, we performed boosted regression trees to rank FFM by relative importance and selected the 3 most relevant FFM to focus the analysis on. For each FFM, we identified Delta H limits based on a percent probability of achieving healthy CSCI/ASCI score. Applying these limits, the FFM were annually classified at each subbasin using the following criteria:

- Biologically Altered: if change in FFM falls outside of Delta FFM limits
- Biologically Unaltered: if change in FFM falls within Delta FFM limits

Biologically altered years were summarized as a percentage of the modelled period, which was then used to synthesize alteration across all FFM within the subbasin. The subbasin was classified as “likely altered” if at least two of the three relevant FFM were altered for >50 percent of years. For prioritization, the following criteria was applied to synthesize alteration across biotic indices:

- High priority: Both indices indicate biologically altered flow
- Medium priority: One index indicates biologically altered flow
- Low priority: Neither index indicates biologically altered flow

Outputs were tested using a range of thresholds and choices. The final thresholds applied in the analysis were chosen to provide the highest discriminatory power for prioritization.

Results and discussion

A total of 11 out of 60 subbasins were identified as high priority for flow management under current conditions and were primarily located in urban areas where the wet and dry season baseflow and peak flow magnitudes were augmented (Figure 1). The flow ecology approach was also used to identify the most relevant metrics associated with supporting the biotic indices and the direction of alteration for each FFM which are critical information for the design of flow management projects tailored to support ecology.

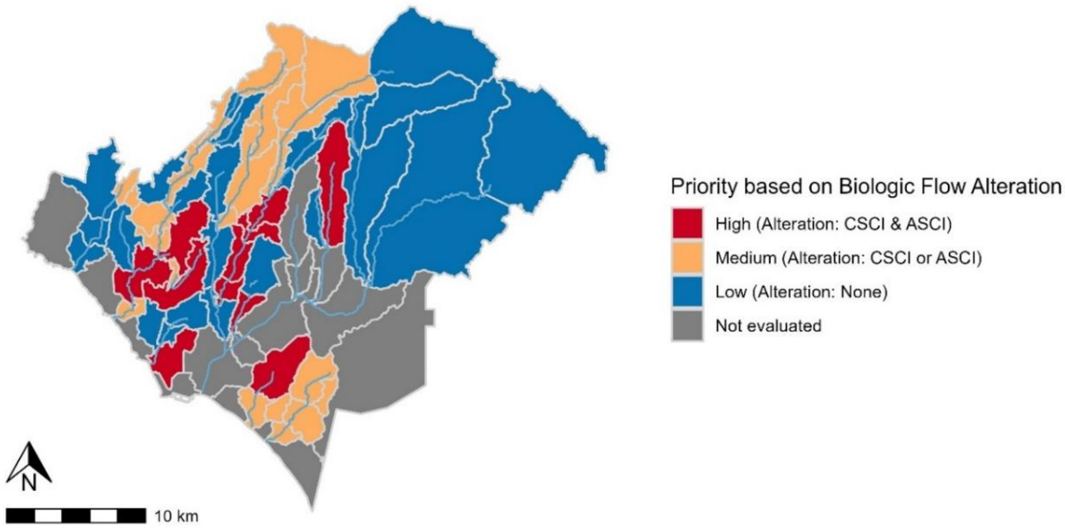

Figure 1. Prioritization for flow management based on biologic flow alteration for biotic indices, CSCI and ASCI.

Conclusions and future work

For successful ecosystem rehabilitation, flow management should prioritize locations where hydrologic alteration is impacting biology and focus on aspects of the annual hydrograph that are linked to biotic and geomorphic functions. The approach developed herein leveraged regional data on biotic indices and was used to map priority areas to focus flow management. This approach will be used to inform current and future priorities to foster more resilient decision-making in light of projected future changes in climate, water use, and flow management and can be applied to other urban watersheds.

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