Introduction

Floodplains, intermittently inundated lands next to river channels, are some of the most productive terrestrial habitats on earth. Urban development and agricultural use have caused many rivers to lose access to their floodplains; some estimate that up to 90% of floodplains in North America and Europe are functionally extinct (Tockner and Stanford 2002). Efforts to characterize existing floodplain habitat and plan future floodplain restoration should include assessment of flow dynamics, including timing, duration, and frequency of flow events (Williams et al. 2009).

Objective

A new method and metric for quantifying the basic inundation characteristics that define the value of a floodplain for a variety of functions and species

Methods

The approach for quantifying floodplain habitat involves (1) statistical hydrological analysis of ecologically relevant flows (based on long-term records of daily streamflow data); (2) hydraulic modeling; and (3) integration of these results using flow criteria (Fig. 1). The integration of statistical and hydraulic modeling outputs is presented in graphs and summary metrics. While the tools and input data are not new, this work proposes a new standard method of correlating and combining disparate model results, habitat requirements, and scenarios into singular evaluation criteria.

Results/Discussion

We walk through a hypothetical case study of a 14-mile reach of the Lower San Joaquin River, California, to examine the lateral and temporal dimensions of river-floodplain connectivity that are necessary for species of concern and the food web upon which they ultimately rely. We used the ADF-EAH method to quantify the area-duration-frequency curves for existing conditions and a hypothetical levee setback scenario and evaluated the frequency in which floodplain areas are inundated for specific durations (1 day and 14 days). Longer flood durations are necessary for many ecological functions.

Step 1) Ecology + Hydrology

- Analyze daily flow data in ecologically relevant statistical terms. The temporal variables describing ecological flows were distilled using the U.S. Army Corps of Engineers (USACE) ecosystems function model (HEC-EFM) Version 2.0 (USACE 2009). The HEC-EFM model is populated with daily flows at gaging stations located on a river reach of interest and then scans the time series and filters for season, duration, and rate of change. The tool then provides the flow and/or stage that occur in each year that meets the requirements defined by flow criteria for ecological functions.

- Standard probability statistics were applied to the HEC-EFM processed data set to create flow-frequency relationships for timing and duration criteria. The U.S. Army Corps of Engineers statistical software package (HEC-SSP) Version 2.0 was used to define these frequency relationships and associated confidence intervals (USACE 2010a). The end product of this hydrologic analysis is a flow-frequency relationship for each flood timing/duration of interest.

Step 2) Hydraulics

- Define spatial characteristics using a hydraulic model such as HEC River Analysis System (HEC-RAS)(USACE 2010b).

- Run through the entire suite of flows the system could encounter at regular intervals.

- The output is a curve that relates inundated area to flow.

Step 3) Integration

- Combine the hydraulic and hydraulic analysis. By correlating the hydraulic model flow results for potential habitat area to the hydrologic flow-frequency relationships, create probability distributions for the amount of habitat expected for each flood timing and duration combination

The result is a set of area-duration-frequency (ADF) curves that define the potential floodplain habitat as a function of frequency for each season-duration.

By integrating each ADF curve over the range of flood probabilities, expected annual habitat (EAH) values are generated that give the long-term statistical average quantity of habitat.

The probability density function is used to calculate the probability weighted average habitat area with the following numerical integration:

\[ EAH = \int_0^1 f(H) dH \]

where EAH = expected annual habitat; H = the area of habitat that occurs with probability f(H).

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