Two-Dimensional Hydrodynamic Modeling to Quantify Effects of Peak-Flow Management on Channel Morphology and Salmon-Spawning Habitat in the Cedar River, Washington

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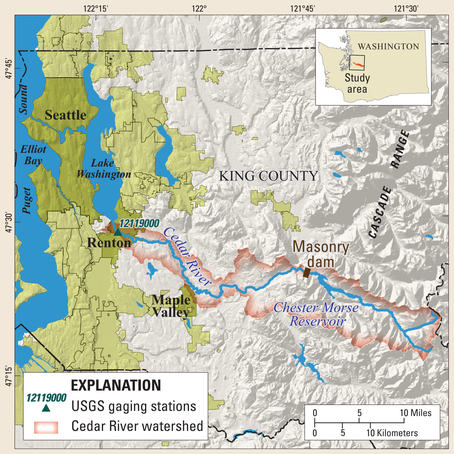

Figure 1. Location of the Cedar River watershed, Washington.

Introduction

The Cedar River originates on the western slope of the Cascade Range and drains to Lake Washington (fig. 1). The upper 123 square miles of the 186 square-mile watershed is protected to provide two-thirds of the public-water supply to Seattle metropolitan area (City of Seattle, 2000). The watershed supports a productive salmon habitat; however, numerous species are currently, or at risk of being, listed as threatened or endangered under the Endangered Species Act. Species of greatest concern include Sockeye salmon (*Oncorhynchus nerka*), Coho salmon (*O. kisutch*), Chinook salmon (*O. tshawytscha*), and Steelhead trout (*O. mykiss*) (City of Seattle, 2000).

The Habitat Conservation Plan (HCP) was established under the Endangered Species Act by the City of Seattle to address declining wildlife populations, including salmon and steelhead (City of Seattle, 2000). The primary concerns of the HCP are:

- Managing the watershed
- Fish passage upstream of the dam
- Managing river flows

Seattle Public Utilities manages the water-supply infrastructure, operating under the HCP and is guided by the Cedar River Instream Flow Commission. Adaptive-management provisions allow research and monitoring to determine effects of management strategies, and changes in operation if supported by new information (City of Seattle, 2000). Water managers require detailed information on how best to manage high-flow releases from Chester Morse Reservoir during periods of heavy precipitation to minimize flooding and mitigate negative effects on fish populations, while recognizing that occasional large flows provide beneficial geomorphic resetting and maintenance of habitat areas.

Overall Study Questions:

- What are the best methods to manage high-flow releases to minimize flooding, promote river health, and protect fish populations?
- What are the effects of peak flows (magnitude, duration, frequency) on biological factors and geomorphic processes?
- Specifically, what is the effect of decreasing magnitude and increasing duration of peak flows on salmon redds?

Cedar River Hydrology

High flows generally occur in the rainy winter season and less so with spring snowmelt (fig. 2). At the U.S. Geological Survey (USGS) streamflow-gaging station 12119000, Cedar River at Renton, WA, the two largest peak flows on record (1945–2010) are:

- November 24, 1990: 300 m^3/s
- January 8, 2009: 266 m^3/s

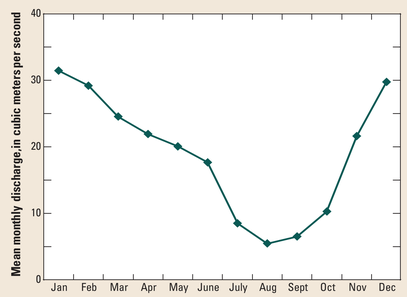

Figure 2. Mean monthly discharge for USGS streamflow-gaging station 12119000, Cedar River at Renton, Washington, 1945–2010.

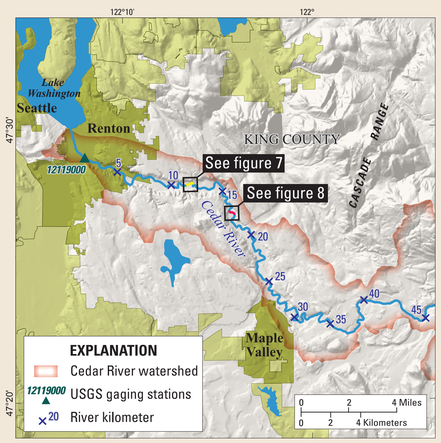

Figure 3. Locations of Belmondo and Confined 1 study reaches along the Cedar River, Washington.

Hydrodynamic Modeling

The 2-D model, Flow and Sediment Transport Morphological Evolution of Channels (FaSTMECH) (Nelson and Smith, 1989) within International River Interface Cooperative (iRIC) (formerly known as MD_SWMS; McDonald and others, 2010), is being used to simulate water velocity, benthic shear stress, flood inundation, and morphologic changes in the gravel-bedded river under the current and alternative flood-release strategies. Inputs to the model include discharge, detailed channel topography, and channel roughness.

Two 0.5-km reaches were selected that represent typical morphologies of reaches with confined and unconfined banks in the Cedar River. Belmondo Reach is a relatively unconfined reach at river kilometer (RKM) 16.9–17.4 (figs. 3 and 4) and Confined 1 Reach is a relatively confined reach at RKM 11.4–11.9 (figs. 3 and 5).

Detailed bathymetric data were collected in November 2009–February 2010 using a real-time kinematic (RTK) global positioning system (GPS) and an acoustic Doppler current profiler (ADCP) (figs. 6*A* and 6*B*). Surveyed data were combined with a LiDAR-derived digital elevation model in the overbank area to develop a computational terrain mesh for each study reach (figs. 7 and 8).

For use in model calibration and verification, water-surface elevations were surveyed with RTK-GPS throughout the study reaches during several small to moderate flows during 2010. During high flows in the winter season 2010/2011, we will be continuously recording stage in each reach. Additionally, water-surface elevations will be measured with with RTK-GPS and discharge and velocities will be measured with an ADCP.

Figure 4. Belmondo Reach on the Cedar River, Washington, August 24, 2010.

Figure 5. Confined 1 Reach on the Cedar River, Washington, February 21, 2010.

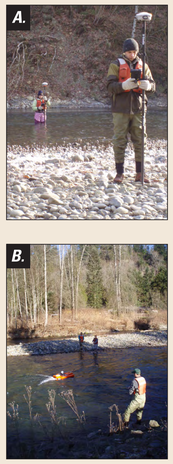

Figure 6. Bathymetric survey methods using (*A*) RTK-GPS in Belmondo Reach, December 10, 2009, and (*B*) ADCP in Confined 1 Reach, February 21, 2010, along the Cedar River.

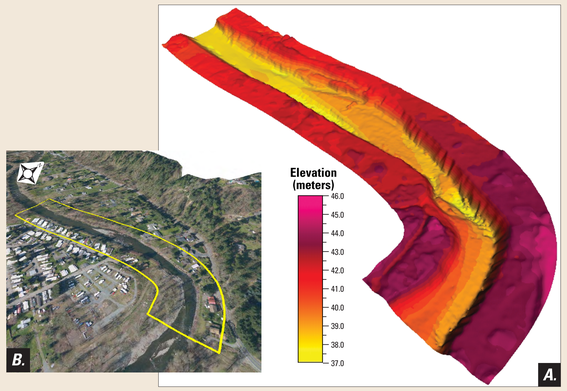

Figure 7. Confined 1 Reach (*A*) computational mesh (vertically exaggerated by a factor of three) and (*B*) oblique aerial view along the Cedar River. (Aerial image from Watershed Sciences, 2010.)

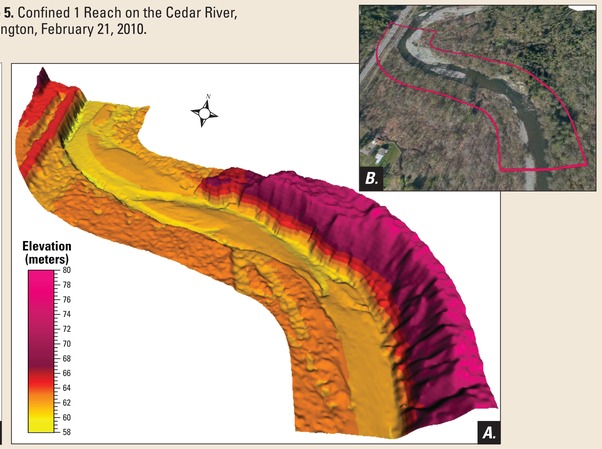

Figure 8. Belmondo (*A*) computational mesh (vertically exaggerated by a factor of three) and (*B*) oblique aerial view along the Cedar River. (Aerial image from Watershed Sciences, 2010.)

What is a redd?

Salmon and steelhead are anadromous species. They are born in freshwater, migrate downstream to the sea, and then return to spawn in their home river. Female salmon dig a nest, or redd, in the streambed gravels and release their eggs into the redd to be fertilized by males. Eggs are incubated in the gravels until late winter or spring when young fish hatch.

High winter flows are a major threat to survival of eggs and alevins. Redd scour on the Cedar River starts when flow at Renton (gaging station 12119000) exceeds approximately 51–57 m^3/s (City of Seattle, 2000). The 2-D hydrodynamic modeling study will investigate how the magnitude and duration of flood hydrographs affect the amount of redd scour.

Migrating salmon on the Cedar River.

Spawning salmon.

Preliminary Modeling Results

Preliminary model simulation results in the study reaches simulate flow depths and velocities for calibration events of 13 m^3/s (figs. 9 and 10) and 52 m^3/s (figs. 11 and 12).

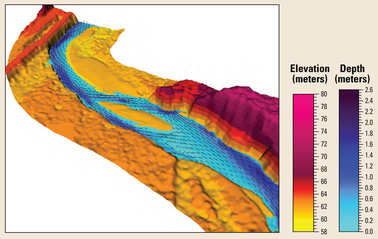

Figure 9. Simulated flow depth and velocity vectors in Belmondo Reach for a discharge of 13 m^3/s.

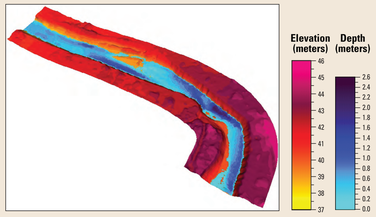

Figure 10. Simulated flow depth in Confined 1 Reach for a discharge of 13 m^3/s.

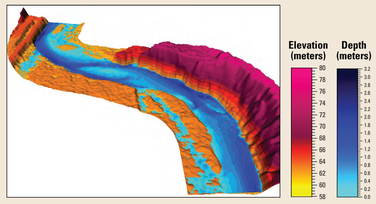

Figure 11. Simulated flow depth in Belmondo Reach for a discharge of 52 m^3/s.

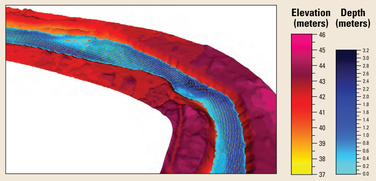

Figure 12. Simulated flow depth and velocity vectors in Confined 1 Reach or a discharge of 52 m^3/s.

Next Steps

Results from the 2-D hydrodynamic modeling will be used in conjunction with field measurements (scour chains, accelerometers, hydrophones) and a geomorphic assessment of the Cedar River to develop simulations of salmon-redd scour and geomorphic response under different release strategies, as well as metrics for a long-term adaptive management and monitoring program. The model simulation results can be incorporated by water-resource managers into adaptive management of peak flows in the Cedar River.

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For More Information

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