Navigability Potential of Washington Rivers and Streams Determined with Hydraulic Geometry and a Geographic Information System

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Downstream hydraulic geometry is a channel evaluation technique originally developed by Leopold and Maddock (1953) that relates width and depth in stream channels to discharge. Using U.S. Geological Survey (USGS) streamflow-gaging station data collected throughout the United States on rivers spanning several orders of magnitude of discharge, Leopold and Maddock (1953) found channel depth and width (as well as mean velocity and suspended-sediment load) correlated exponentially with discharge, Q, in the form

$$y = aQ^b \quad , \tag{1}$$

where

y is the channel variable of interest, and
a and b are constants determined by regression.

The concept of hydraulic geometry has since become a widely applied tool in analyzing the hydrology and channel morphology of rivers worldwide (Ferguson, 1986) including rivers in the Pacific Northwest (Castro and Jackson, 2001). Although commonly applied to the alluvial channels, which have a tendency to alter and reshape their geometries (Huang and Nanson, 2000; Chew and Ashmore, 2001), exponential relations of depth and width to discharge have been found to apply to bedrock channels as well (Montgomery and Gran, 2001). Although the relations hold best for larger rivers and have some limitations for smaller, steep-gradient streams (Wohl, 2004), the technique of hydraulic geometry does, nonetheless, hold true for most rivers and streams.

By applying the principles of hydraulic geometry to empirical data from rivers and streams in Washington, a statewide relation between discharge and channel metrics can be derived. Applied to existing slope and discharge data within a GIS framework, these relations provide a methodology for deriving channel metrics and an assessment, with the DNR thresholds in table 1, of navigability potential for any stream or river in the State.

Purpose and Scope

This study, by applying principles of hydraulic geometry to statewide discharge and slope data within a GIS, develops a methodology to predict the physical characteristics of streams and rivers in the State of Washington. Confidence intervals of the predictions, based on the variance in the data, also are presented. The specific channel characteristics of interest (that is, channel depth, top width, bottom width, and channel slope) are compared to thresholds established by DNR (table 1) to produce a map and dataset of navigability potential for all streams and rivers in the State of Washington. These products will enable DNR to decide which rivers and streams may have navigability potential. The tools and methodology developed in this study do not predict or assert navigability. Instead, they predict the physical characteristics of a given river reach, which, in turn, can indicate the navigability potential of that reach.

Table 1. Thresholds of physical river-channel characteristics determined for river flows equal to the mean annual discharge that predicts the navigability potential of a stream or river reach in the State of Washington.

[Thresholds provided by the Washington State Department of Natural Resources (DNR).
Abbreviations: <, less than; >, greater than; n/a, not applicable]

Channel characteristics	DNR Thresholds		
	Navigable		
	Probably not	May be depending on balance of factors	Probably
Mean depth, D_h (feet)	$D_h < 2$	$2 < D_h < 3.5$	$D_h > 3.5$
Top width, W_t (feet)	$W_t < 24$	$24 < W_t < 40$	$W_t > 40$
Bottom width, W_b (feet)	$W_b < 18$	n/a	$W_b > 18$
Gradient or slope, S (feet/foot)	$S > 0.0047$	$0.0019 < S < 0.0047$	$S < 0.0019$