USE OF DIMENSIONLESS RATIOS IN STREAM RESTORATION PLANNING

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Abstract: Measuring the success of a restoration project for a natural stream channel can be difficult and subjective if there is no common frame of natural morphological reference for the evaluator. For this reason, the "geomorphic reference site (GRS)" is used as the basis for measuring the degree of departure of a given stream segment from the desired reference condition. A GRS is a stream segment that has natural morphologic stability within a specific valley type and climatic regime. Over time, it neither aggrades nor degrades, maintaining its profile, cross-section, and plan view within a range of natural variability. A set of morphometric measurements can be made in the field and developed into a template of dimensionless ratios for the GRS. This template can then be used to make quantifiable comparisons between segments of different streams or between segments of the same stream - provided the segments share similar hydrophysiographic characteristics with the GRS. Dimensionless ratios are also used as a basis for natural channel restoration. Examples are illustrated and discussed.

INTRODUCTION

The reference reach concept is based on the idea that there is a most probable form for any given stream reach (Leopold, 1994). A reference reach should reflect a minimum expenditure of energy moving toward an equal distribution of stream power. A major assumption used in natural channel restoration is that stream segments in similar hydrophysiographic areas and geologic settings evolve similar geomorphic dimensions within predictable ranges.

Geomorphic dimensions (e.g., bankfull width, depth) were described by Rosgen (1994) and combined into dimensional ratios (e.g., width to depth ratio) for use in his stream classification system. Rosgen (1998) expanded the original set of dimensionless ratios to more fully describe the longitudinal profile, cross-section and planview (planform) of a given stream reach.

RESOURCE CONCERN

Some of the more common reasons for design failures are due to the following:

1. Lack of stream and valley stratification;
2. Using one equation - analytical or empirical – to fit all stream types;
3. Lack of understanding of natural geomorphic potential and channel evolutionary stage;
4. Lack of understanding of dimension, longitudinal profile, and planform and how they integrate into stable bedload transport.

BACKGROUND

During summer-fall 2002, numerous sources (contour maps, aerial photos, etc.) and site visitations were used to select 218 potential GRS sites for streams flowing through 32 glacial-fluvial valleys in the Cascade Mountains of northern Washington State (Southerland, 2003). They were divided into west slope (high precipitation) and east slope (low precipitation) drainages. In each group, a random population was chosen for field review.

Morphologic measurements (using laser equipment), stream-gage data, and instream features were recorded for 58 of the most stable-appearing sites. The data were used to create templates of dimensionless ratios to describe the natural stable form for each site.

Dimensionless ratios can define reasonable ranges of physical variability for natural channel restoration for a proposed restoration site. The dimensionless ratios template from a GRS can be used to make quantifiable comparisons between different streams or between segments of the same stream - provided the GRS and the segment being compared share similar hydrophysiographic characteristics.

EXAMPLES

1. Dimensionless ratios used as a measure of departure from reference site conditions:

Table 1 includes a selection of dimensionless ratios for the two sites shown in Figures 1 and 2. The “reach of interest (ROI)” site is located just upstream of the GRS. Note the inclusion of root density and root matrix measurements in the table. Biological attributes such as fish, macro-invertebrates and native streambank vegetation could also be compared and indexed at the GRS and ROI sites. Stream morphometric measurements of longitudinal profile, dimension, planform, and root density measurements similar to the measured features described in Tables 1 and 2 can be surveyed over a given monitoring period. This data can be used to estimate the change in departure between the geomorphic reference and reach of interest sites.

Figure 1 Entiat River GRS

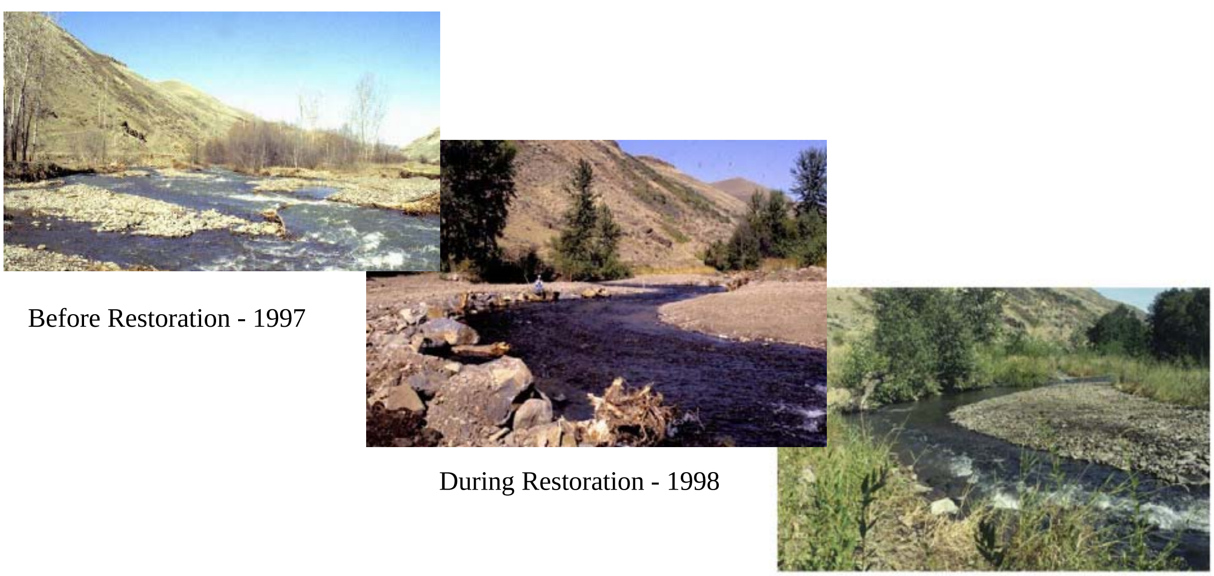
Figure 2 Entiat River ROI

Table 1 Selected Dimensionless Ratios for Entiat River

Measured Feature (Apex of Meander)	**Reference Reach (GRS)**	**Reach of Interest (ROI)**	**Erosion Potential of ROI**	**Percent Departure of ROI**
Bank Height Ratio	1.07	1.25	Moderate	17%
Root Density	70%	25%	High	64%
Root Matrix	.78	.30	Low	62%
Width to Depth Ratio	19	42	High Lateral Shear Stress	121%
Mean Pool Depth/Mean Bankfull Depth	2.2	1.5	N/A	32%

2. Dimensionless ratios used to reconstruct a stable stream channel:

The mainstem of Asotin Creek as it flowed through the Frank Koch property had an unstable, braided channel. Steelhead trout, native to Asotin Creek, no longer spawned in this reach and riparian woody vegetation was not able to become established along most of its length (Figure 3). Using dimensionless ratios from Salmon Creek Table 2, similar hydrophysiographic area located on the East Cascade slope, this reach was restored to a single-thread, stable channel. Spawning steelhead and reds have since been documented at the site and woody vegetation is well-established.



Before Restoration - 1997

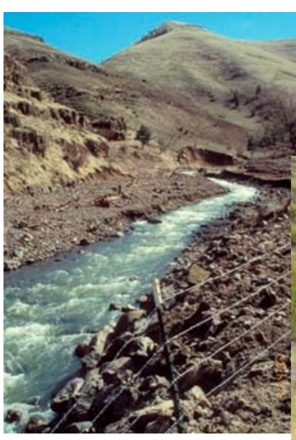
During Restoration - 1998

Post Restoration - 2003

Figure 3 Geomorphic Restoration of a Braided Stream System

Table 2 Sample Template of GRS Dimensionless Ratios for Koch Project

	Mean	Range
Profile		
Pool bankfull depth/Average bankfull depth, ft/ft	2.2	1.6-3.2
Riffle bankfull depth/Average bankfull depth, ft/ft	0.85	0.59-0.92
Run bankfull depth/Average bankfull depth, ft/ft	1.4	1.2-1.6
Glide bankfull depth/Average bankfull depth, ft/ft	1.2	1.1-1.5
Cross-sections		
Width to depth ratio, riffles	18	15-21
Width to depth ratio, pools	21	18-29
Width to depth ratio, runs	15	12-21
Width to depth ratio, glides	20	15-26
Plan-view		
Sinuosity, ft/ft	1.46	1.2-2.2
Radius of curvature/Meander belt width, ft/ft	2.2	1.8-2.7
Meander wavelength × Average bankfull width	12.2	8.9-14.8
Slope (water surface)		
Pool bankfull slope/Average bankfull slope, %/%	0.35	0.21-0.42
Riffle bankfull slope/Average bankfull slope, %/%	1.5	1.3-1.9
Run bankfull slope/Average bankfull slope, %/%	1.1	1.05-1.3
Glide bankfull slope/Average bankfull slope, %/%	0.40	0.26-0.45
Other		
Root Matrix = Root depth/ Bank height	0.78	0.54 -1.0
Bank Height Ratio = Bank height/Bankfull depth, ft/ft	1.07	1.01-1.21



1996: Incised – Post Flood

2002: Post Restoration

2003: Post Restoration

Figure 4 Geomorphic Restoration of an Incised Stream System

On the J-Bar Ranch (Figure 4), the channel of the South Fork Asotin Creek was straight and incised. Again, no steelhead spawning occurred there, and the riparian woody vegetation was non-existent. Meander reconstruction, using dimensionless ratio templates from a GRS in the same hydrophysiographic area, was very successful. Both of these Blue Mountain projects have successfully maintained their stability even though there have been some very high, out-of-bank flows.

DISCUSSION

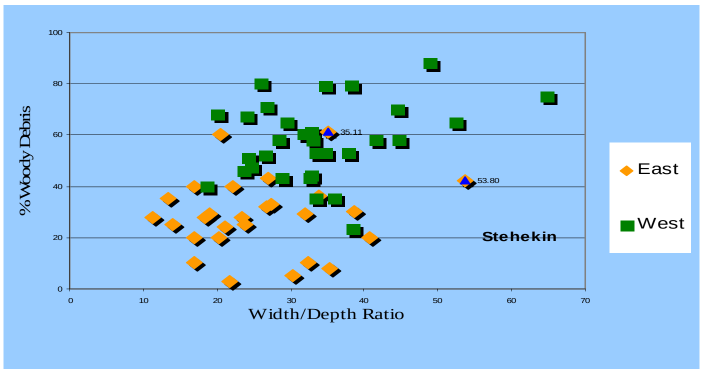


Figure 5 Width to Depth Ratio – East vs. West

Some dimensionless ratios may vary significantly within the same Rosgen geomorphic stream type if hydrophysiographic areas are different. In Figure 5, note that the width to depth ratio increases with the % woody debris, but at a higher rate on the west slope where there is more annual precipitation than the east slope. Thus, dimensionless ratios developed on one side of the mountains are likely not to work on the other side within the same geomorphic stream classification. However, in the above streams, the range of variability for each key classification parameter still falls within both the Rosgen and the Montgomery and Buffington (1993) classification systems.

To meet reference site conditions, a stream segment must have certain physically measurable attributes that are reproducible and meet specific criteria. These measurable attributes can be combined with others to develop dimensionless ratios that spatially describe the planview, profile, bedload, woody debris, and floodplain attachment of the stream system. Understanding the degree of departure that a reach of interest has from the reference site can aide the technician and/or land operator in identifying channel evolutionary changes such as those described in Schumm, Harvey, and Watson (1984).

CONCLUSION

To meet reference site conditions, a stream must manifest certain physically measurable attributes that are reproducible and meet specific criteria. These measurable attributes are relative ratios that are identifiable features in the field. Answers to approaches of management and restoration of streams and riparian communities can be acquired with a better understanding of the geomorphic processes, natural channel stability, and reference reach comparisons discussed in this paper. Dimensionless ratios are successfully being used for both stream restoration and a measure of departure from stable conditions.

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