A Tool for Beaver Dam Analogue Design

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Abstract

Beaver populations can be powerful tools in restoring stream and riparian habitats since their dams control and influence fluxes of water, sediment and nutrients. Beaver dam analogues (BDAs) are temporary, channel-spanning structures built by humans that mimic or reinforce natural beaver dams, and in many cases are eventually used and enhanced by beaver. Although most BDA design and construction has relied on professional judgment, quantitative design can reduce the risk of premature failure and suboptimal use of available resources. To assist designers, we present a macro-enabled Excel spreadsheet that may be used to perform simple analyses leading to computation of three safety factors. This tool allows the user interactively game key design parameters (e.g. flood recurrence interval, rock sizing, post material, sizing and embedment depth) to evaluate failure scenarios and to obtain design solutions that meet their stability and design life objectives.

Introduction

BDAs are constructed by driving posts in a row perpendicular to the channel; weaving a mat of willow stems to create a weir supported by the posts; and placing a berm of sediment, stone and plant material on the upstream face of the weir. Variations on this basic design also occur. Like natural beaver dams, BDAs are porous, temporary features on the landscape with functions that change in response to the effects of flowing water, sediment, and beaver activity (Castro et al. 2015).

The BDA design tool is a macro-enabled Excel file with separate sheets for various components of design as shown below. Completion of the analysis produces a set of safety factors and rough estimates of material volumes and construction costs. Support for inexperienced users is provided in the form notes and default values within the Excel file and a users' manual.

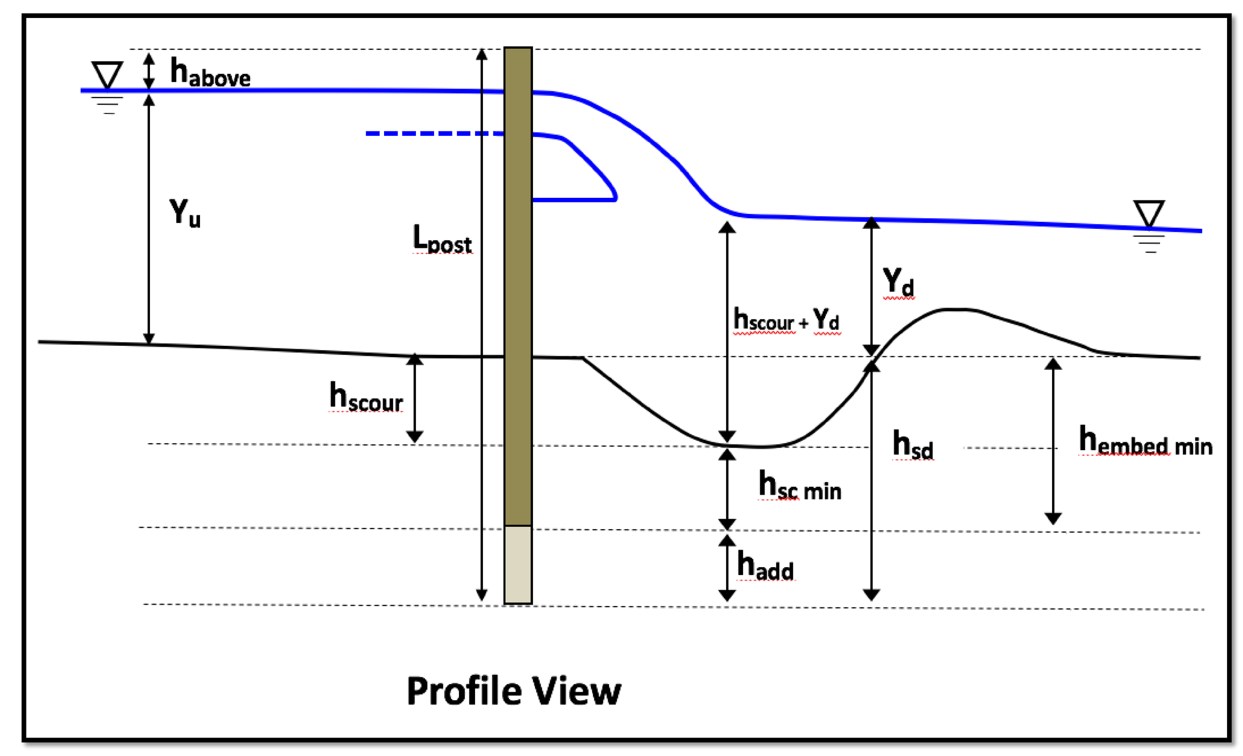
Upstream view of Beaver Dam Analogue during baseflow

Design Tool Contents

Design summary	Tabulates metadata and safety factors for vertical movement and post breakage and overturning
Hydrology	Select design discharge and compare return interval to desired design life
Structure dimensions	User specifies structure height, width, side slopes, etc.
Channel geometry	User provides cross section for BDA site. Sheet provides a cross section plot to visualize and check.
Uniform flow computations	Pre-BDA hydraulics at design discharge from NRCS sheet, Xsecanalyzer
Hydraulics	Post-BDA hydraulics assuming critical flow over weir crest
Scour and downstream rock sizing	Scour depth related to hydraulics and rock size using empirical formula (D'Agostino and Ferro 2004)
Upstream rock sizing	Cobble or coarse gravel is normally placed on upstream face. Size needed to remain stable even if underflow occurs is computed using four formulas for rock chutes. User selects desired result.
Impact force	Force on BDA due to impact of floating log.
Posts-overturning and breakage	Minimum post embedment depth to resist overturning computed using Brom's (1964) method for pilings in noncohesive material.
Posts-vertical forces	Post skin friction compared to buoyant force using method from Knutson and Fealko (2014)
Material volumes	Quantities primarily based on dimensions specified by user in Structure dimensions worksheet
Cost estimate	Based on material volumes and unit costs provided by user
Constants and lookup	Drag coefficients, weir constants, minimum safety factors, etc.
Soil properties	Bulk density, friction angle, coefficient of lateral earth pressure, etc.
Wood properties	Unit weight, modulus of rupture
Natural beaver dam dimensions	Tabulated from 16 publications

Post embedment depth

The tool computes the post embedment depth needed to resist the horizontal loading forces: fluid drag, hydrostatic force, and impact from floating logs. Both forces and moments are summed. An iterative approach is used to compute the post embedment depth because the minimum post embedment depends on the resisting moment, which depends on the embedment depth. Moments due to each type of horizontal loading force are summed about the buried tip of the post. Drag and hydrostatic forces are assumed to act at a point midway between the water surface and the stream bed. Impact forces are assumed to act at the crest of the weir. Moments are summed for the entire BDA but divided by the number of posts in order to get the moment acting on each post. The minimum required post embedment is computed using the method presented by Broms (1964) for posts in noncohesive soils or sediments.

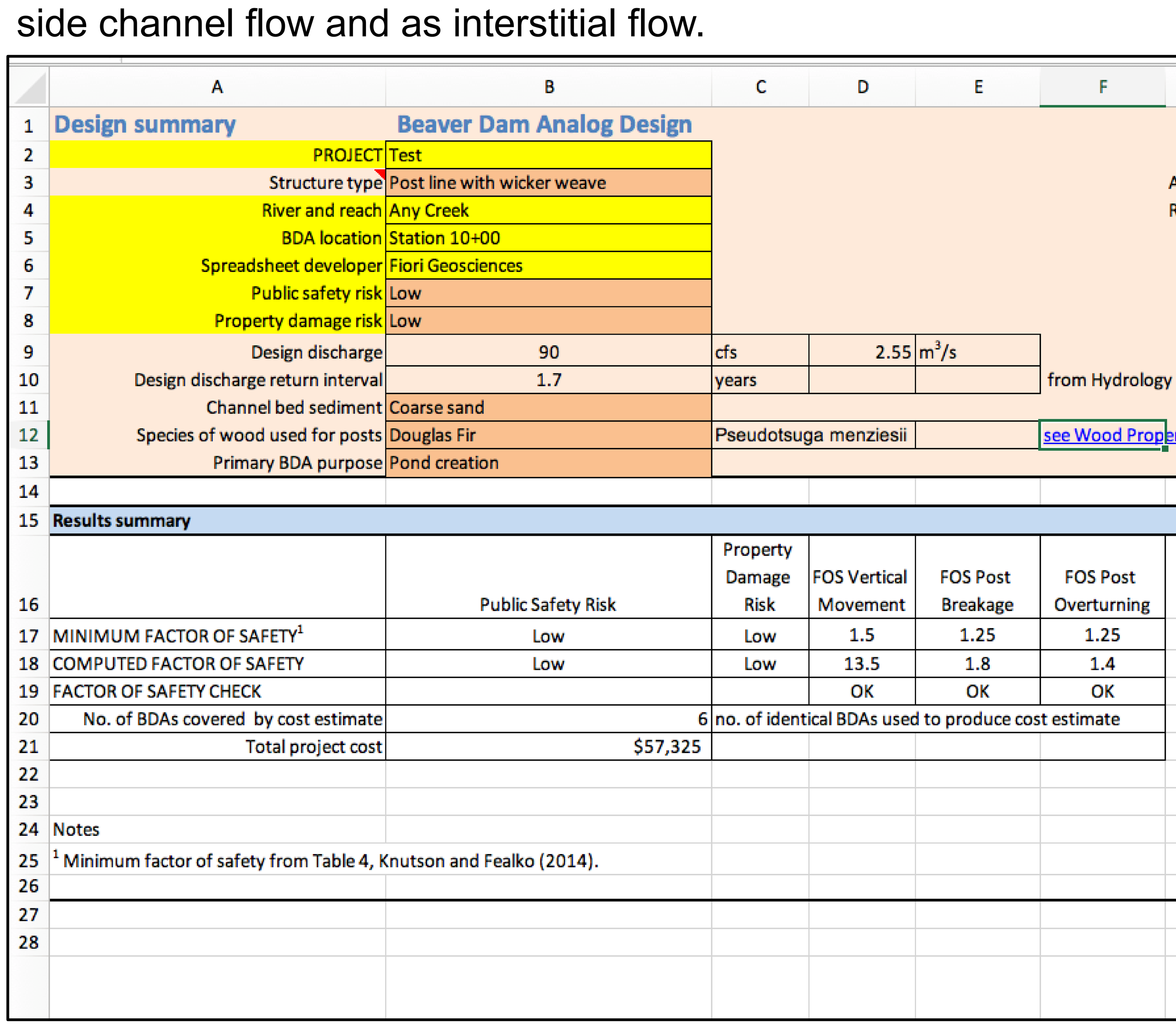


Definition sketch for post depth calculations

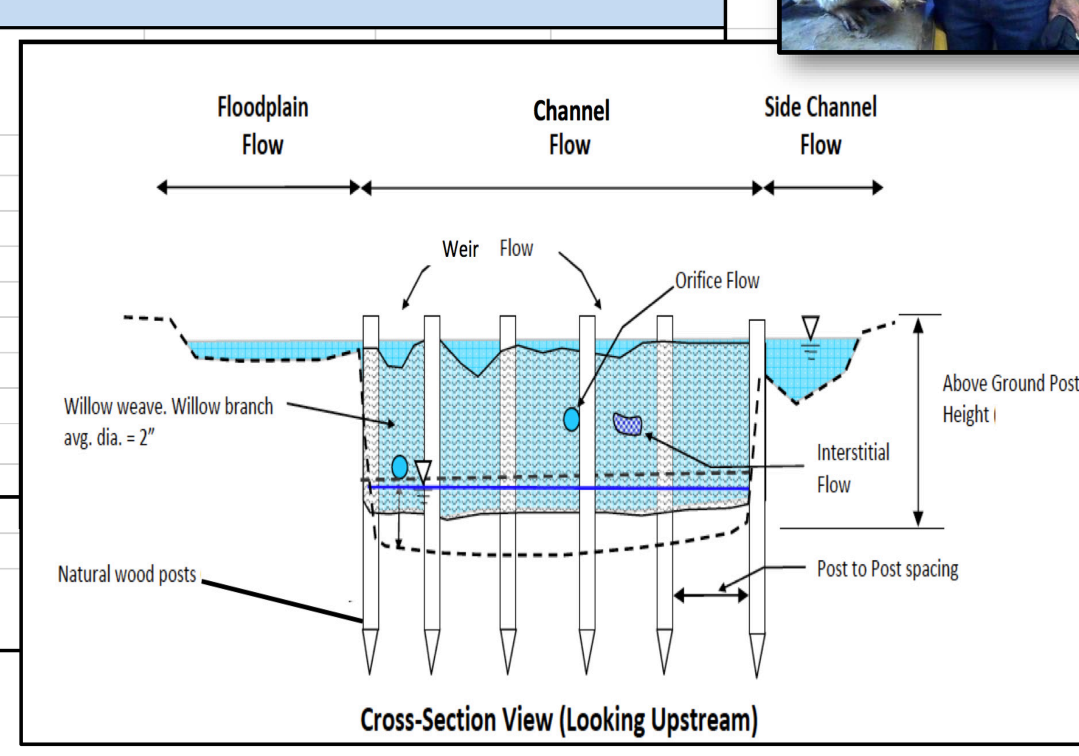
Courtesy North Yakima Conservation District

Hydrology and hydraulics

Flow frequency distribution generated from annual series supplied by user, Streamstats regression formula, or entered by user based on estimate or other information. User then selects design discharge. Pre-BDA hydraulics computed based on USDA-NRCS uniform flow spreadsheet, xsecAnalyzerVer17.xlsm, which is embedded in BDA Design Tool. Post-BDA hydraulics is based on assumption of critical flow over BDA crest. User must supply estimate of percentage of design discharge passing the BDA over the crest, as floodplain or side channel flow and as interstitial flow.

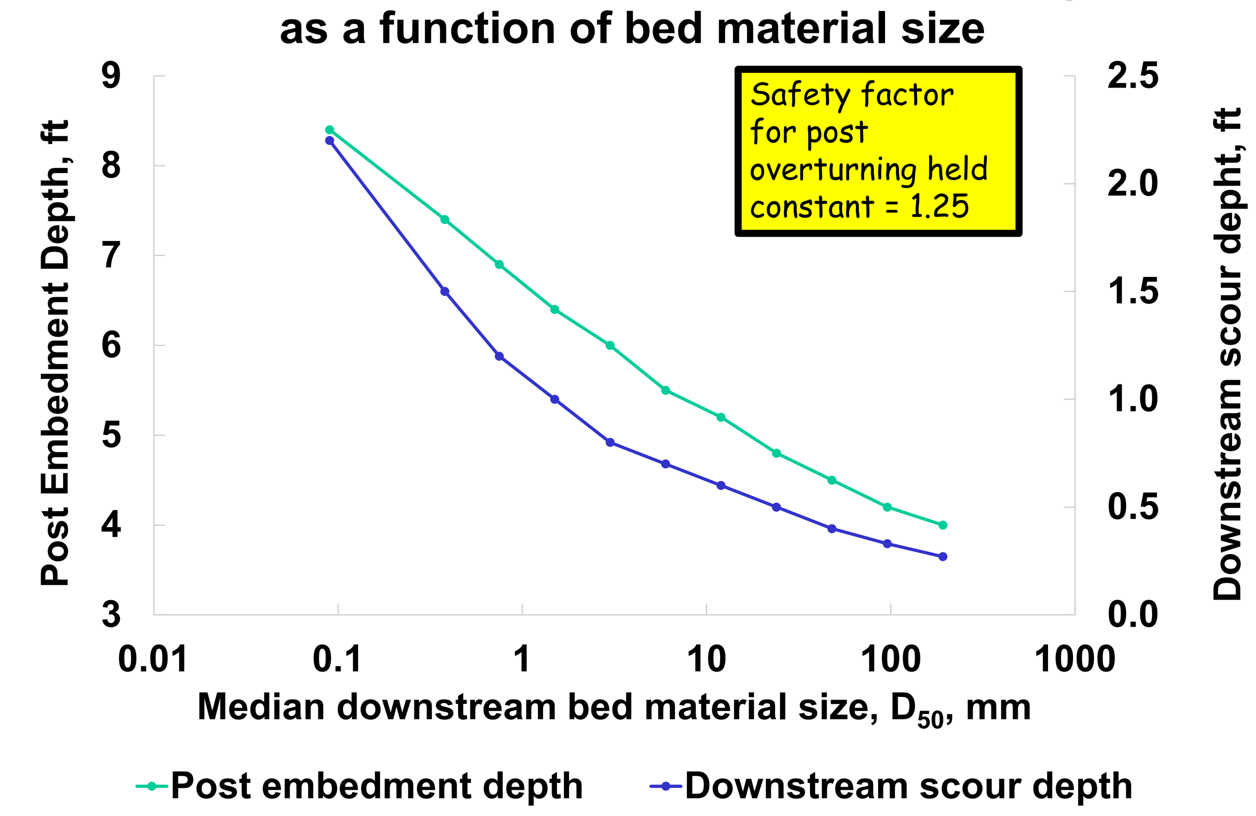


	A	B	C	D	E	F	G	H	I
1	Design summary	Beaver Dam Analog Design						Version 1.0	
2	PROJECT	Test							DATE
3	Structure type	Post line with wicker weave					ANALYST	I. M. Beaver	10/13/17
4	River and reach	Any Creek					REVIEWER	C. Canadensis	10/13/17
5	BDA location	Station 10+00							
6	Spreadsheet developer	Fiori Geosciences							
7	Public safety risk	Low							
8	Property damage risk	Low							
9	Design discharge	90	cfs	2.55	m^3/s				
10	Design discharge return interval	1.7	years			from Hydrology worksheet			
11	Channel bed sediment	Coarse sand							
12	Species of wood used for posts	Douglas Fir	Pseudotsuga menziesii			see Wood Properties Table for information about several species			
13	Primary BDA purpose	Pond creation							
14									
15	Results summary								
16		Public Safety Risk	Property Damage Risk	FOS Vertical Movement	FOS Post Breakage	FOS Post Overturning			
17	MINIMUM FACTOR OF SAFETY[1]	Low	Low	1.5	1.25	1.25			
18	COMPUTED FACTOR OF SAFETY	Low	Low	13.5	1.8	1.4			
19	FACTOR OF SAFETY CHECK			OK	OK	OK			
20	No. of BDAs covered by cost estimate	6	no. of identical BDAs used to produce cost estimate						
21	Total project cost	$57,325							
22									
23									
24	Notes								
25	[1] Minimum factor of safety from Table 4, Knutson and Fealko (2014).								
26									
27									
28									



Screenshot of Design Summary Sheet

Post embedment and downstream scour depth as a function of bed material size



References

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