Welcome to Riparian Book Club

Large Wood Stability Analysis with Michael Rafferty, Inter-Fluve

CRA Host: Julie Ash, P.E., Senior Engineer with Parametrix
COCO Host: Maria Brandt, Outreach & Development Director
Technical Hosts: Michael Rafferty, PE, P.Eng., LEED AP, Inter-Fluve

June 2026

Riparian Book Club

Bridging the gap between academic research on stream/wetland systems and applied restoration design. These book club discussions are targeted toward those tasked with stream-wetland restoration design and project planning, connecting them to pivotal scientific papers that can help them in daily work tasks.

View previous webinars at CO-CO.org > Resilient Communities > Riparian Book Club

Colorado Riparian Association

Formed in 1989 by a small group of dreamers who believed that our riparian zones should not become sacrifice areas.

Promoting the conservation, restoration, and preservation of Colorado's riparian areas and wetlands.

Coalitions & Collaboratives

We believe in working together. No single individual, business, organization, or government can fix the difficulties facing our planet and its people, but by working together, we can drive positive change for people and the planet.

To advance healthy and resilient communities through collaborative conservation and restoration.

Using Mentimeter

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- Follow along and participate in the webinar
- Polling is anonymous. Please be respectful and professional.
- Using Menti and Zoom to engage
- Welcome to add questions to Menti during presentation

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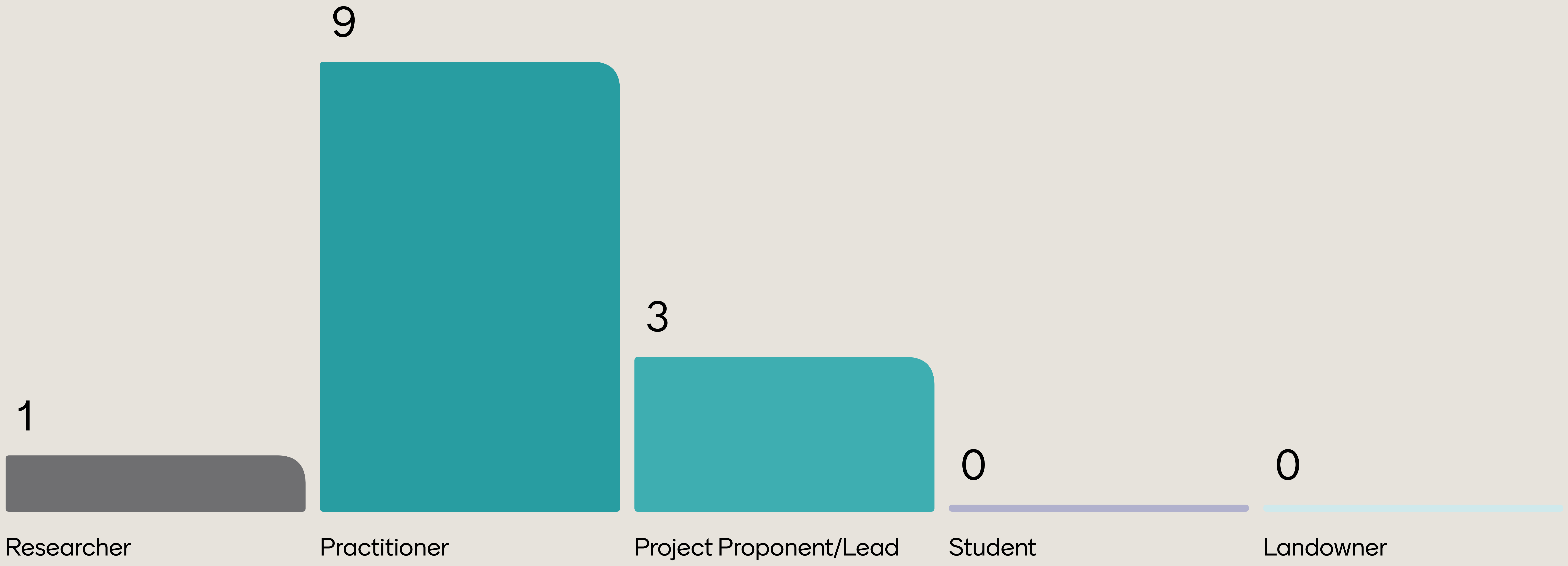
I'm a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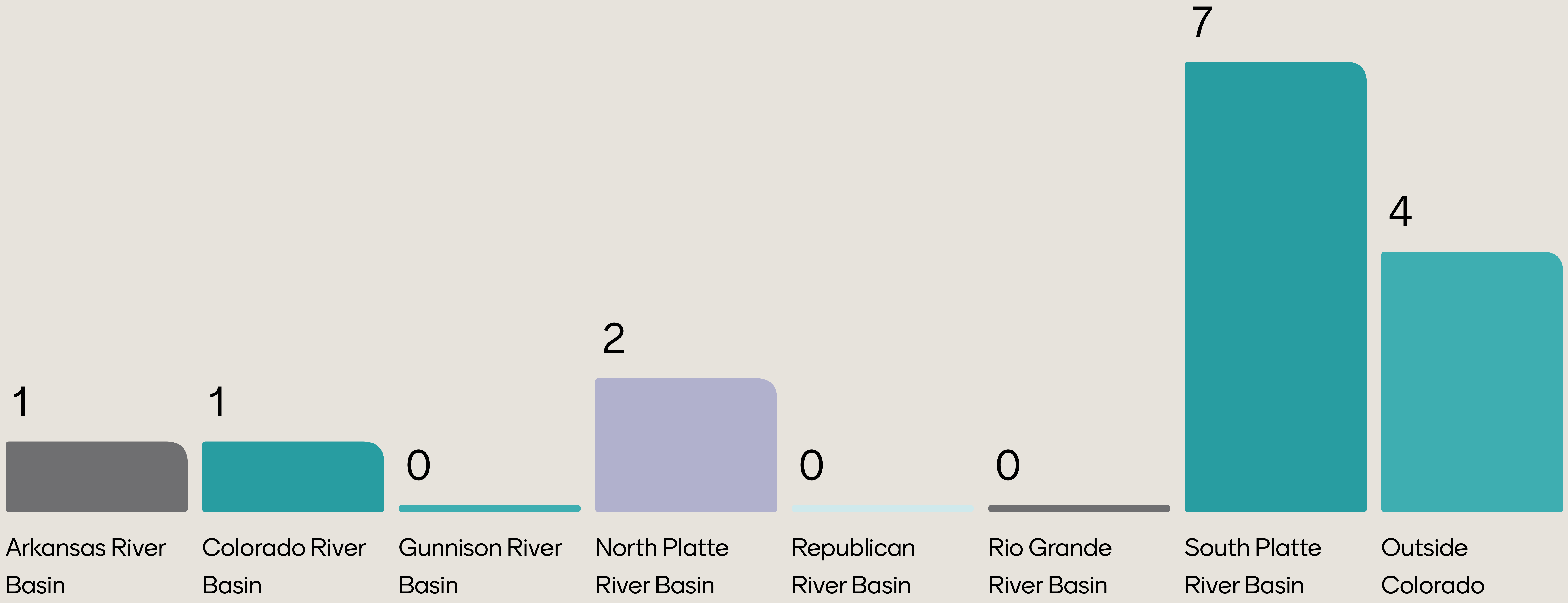
Researcher
Practitioner
Project Proponent/Lead
Student
Landowner

What geographic location are you joining us from?



What do you hope to get from this online workshop?

BMPs on KW placement

See updates on the tool

A deeper understanding of the tool that I already use all the time

Best practices when using the tool!

Curious about updates to the tool we use on almost every project on the north coast of CA

Learn to use the tool better! Both from the perspective of showing wood stability AND instability.

Overview of updates

Pile driven stability calcs

What do you hope to get from this online workshop?

When can wood be allowed to move?

Changes made to the tool

More information on the assumptions for piles

how to go about calculating large wood stability.

Lively discussion on tool assumptions and limitations and how to best navigate

2026 Schedule

April 2026 Book Club
CPW's Beaver Conservation & Management Strategy
Tuesday 4/28/26 12-1p MDT

June 2026 Book Club
Computational Design Tool for Evaluating the Stability of Large Wood Structures
Tuesday 6/30/26 12-1p MDT

September 2026 Book Club
Steep Channel Toolbox
TBD in September

November 2026 Book Club
Colorado Native Fishes
TBD in November

Michael Rafferty, PE, P.Eng., LEED AP

Michael is a senior water resources engineer with 24 years of experience integrating stream restoration, geomorphology, water resources, and civil design. He currently works at Inter-Fluve's Hood River, Oregon office where he has had the opportunity to lead the design of aquatic habitat improvements throughout the United States and Canada.

As part of his Master's Degree thesis at Colorado State University, he developed a publicly-available design tool to evaluate the stability of large wood structures. The tool and supporting documentation were published in 2016 through the US Forest Service as Technical Note 103.2.


Large Wood Structure
Stability Analysis Tool v2.0
Michael Rafferty, PE
June 30, 2026
inter·fluve


1. Introduction to Wood Design
2. Design Methodology
3. Stability Analysis Tool
Cedar River
King County, WA

Introduction

Large wood plays a critical role in many streams through its influence on aquatic habitat and geomorphic processes.

Naturally **stable** "key pieces" have often been removed from the landscape.

Re-introduction of large wood is a frequent objective of stream restoration projects, but **engineering analysis** can be complex and time consuming.

Spreadsheet tool was developed to incorporate the latest design guidelines and science to streamline design and benefit the restoration community.

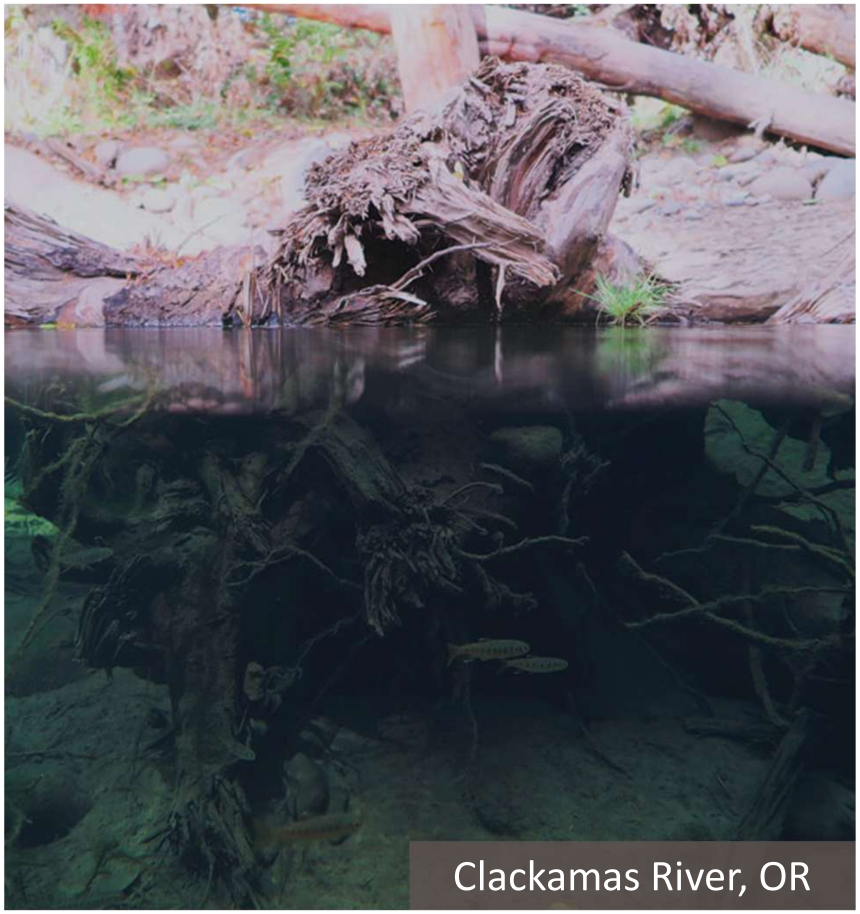
Rootwad of a "key piece" on Vancouver Island

Benefits of Wood in River Corridors

Wood projects are typically **dual purpose** (e.g., bank stabilization & fish habitat)

Physical Effects:

- Hydraulic complexity
- Channel morphology
- Pool scour
- Sediment sorting
- Stream power & roughness
- Hyporheic exchange
- Influence recruitment and retention of other wood



Biological Effects:

- Habitat complexity
- Cover habitat
- Spawning habitat
- Velocity refuge
- Nutrient cycling
- Macroinvertebrate production
- Wildlife habitat
- Thermal regulation

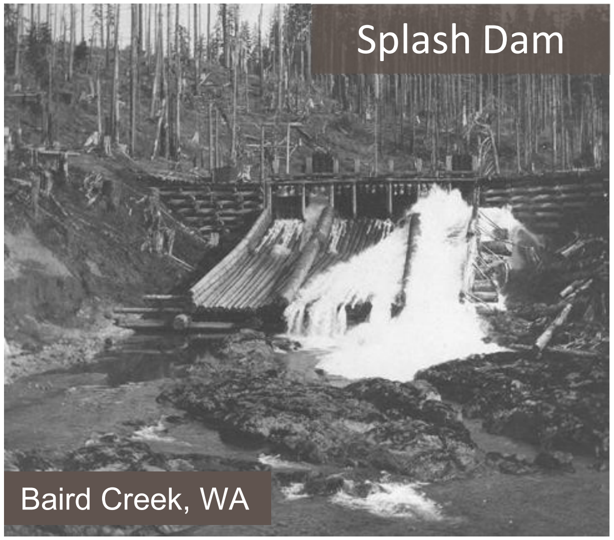
Anthropogenic Impacts to Wood Processes

Direct Removal:

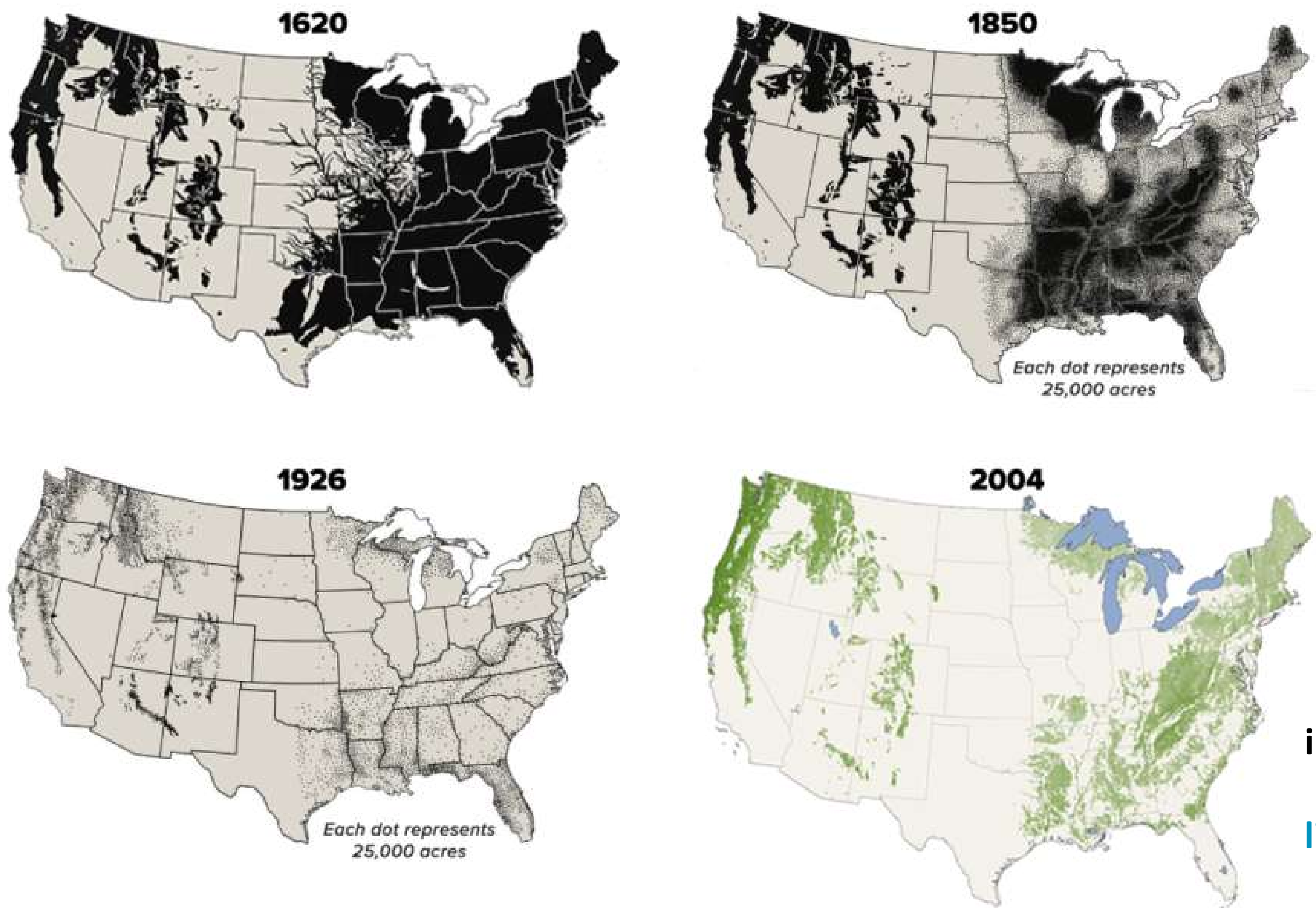
- Clear-cutting of riparian zone
- Snag removal for navigation and “flood relief”

Recruitment and Retention Impacts:

- Immature riparian stands lack “key pieces”
- Channelization has increased wood transport and reduced recruitment through channel migration
- Beaver extirpations have reduced wood input and retention rates
- Fire intensity has stunted riparian growth



Deforestation and Reforestation



SOURCES: W.B. GREELEY / US FOREST SERVICE; NASA EARTH OBSERVATORY /
IMAGE BY JESSE ALLEN AND ROBERT SIMMON / BASED ON DATA FROM MICHAEL LEFSKY

KNOWABLE MAGAZINE

Forest cover has increased over the past century, but limited old growth forests remain

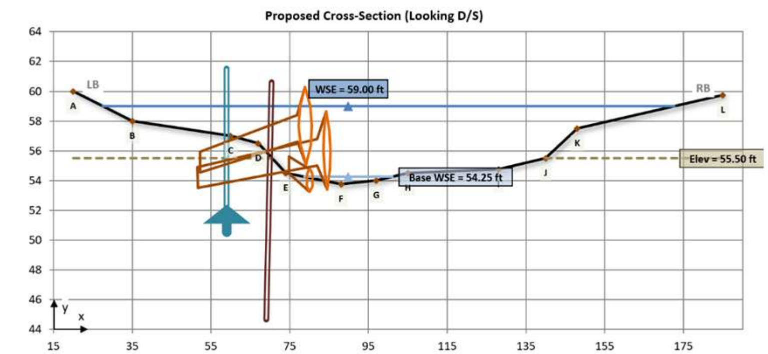
Engineered Log Jam (ELJ) Structure Types

Other ELJ Types:

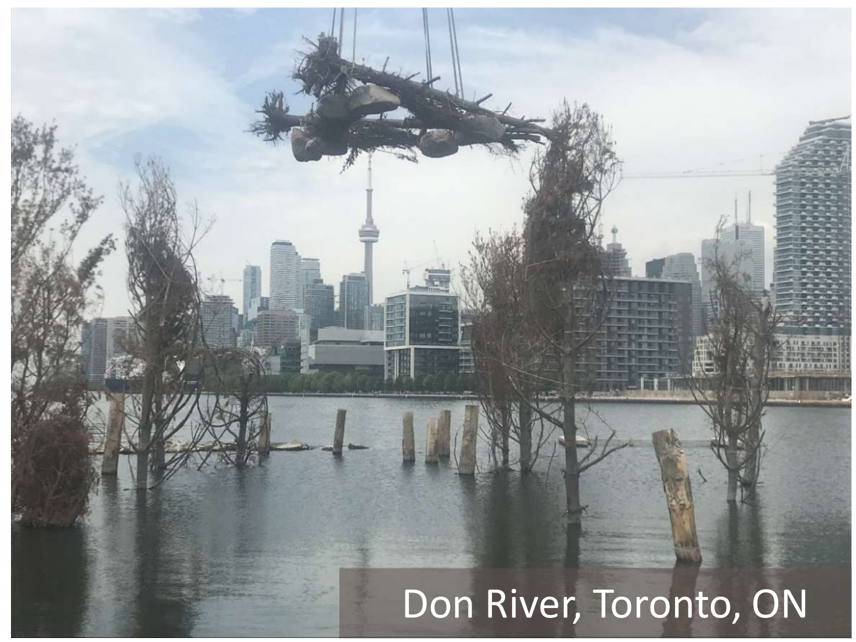
- Toe Protection
- Bank Revetment
- Crib Wall
- Shoreline Protection
- Channel Spanning
- Log Steps & Sills
- Log Vane
- Sunken Shelter

Typical Large Wood Anchoring Methods

- Partial Burial
- Boulder Ballast or Bedrock Anchors
- Timber Piles or Bracing against Trees
- Self-weight



Pile Load Testing


Don River, Toronto, ON

Large Wood Stability Requirements

Code of Ethics for Engineers requires practitioners to hold paramount the protection of the environment, infrastructure, and public safety.

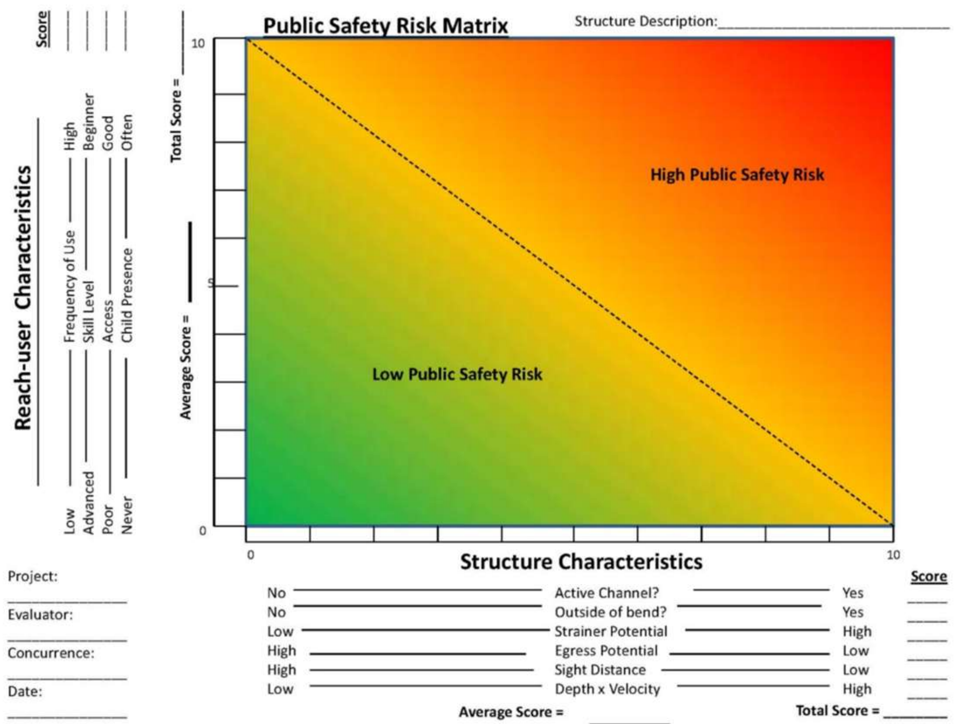
Acceptable level of **risk** and target **factor of safety** are commensurate with the project setting.

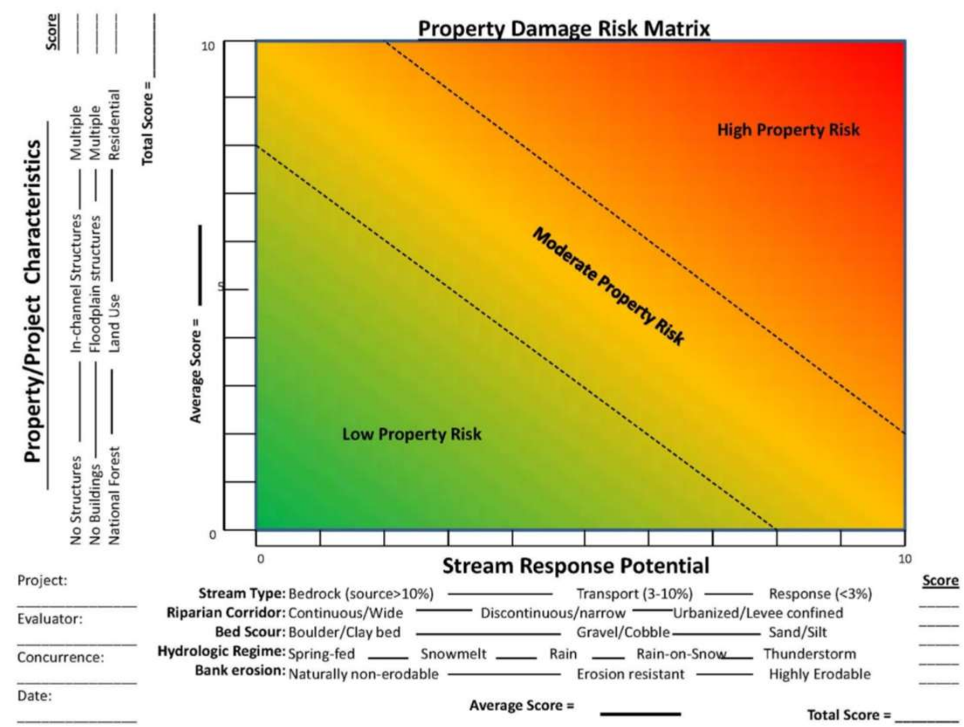
Risk Assessment

Assess risks to **Public Safety** and **Property Damage** to inform selection of target **Design Flow** and **Factor of Safety** (FOS)

Public Safety Risk	Property Damage Risk	Stability Design Flow Criteria	$FOS_{sliding}$	$FOS_{bouyancy}$	$FOS_{rotation}$ $FOS_{overturning}$
High	High	100-year	1.75	2.0	1.75
High	Moderate	50-year	1.5	1.75	1.5
High	Low	25-year	1.5	1.75	1.5
Low	High	100-year	1.75	2.0	1.75
Low	Moderate	25-year	1.5	1.75	1.5
Low	Low	10=year	1.25	1.5	1.25

Source: BOR Manual (2014)



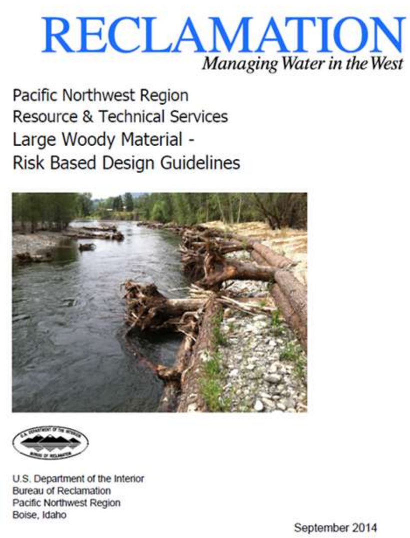


Stability Evaluation Methodology

The **Force Balance Method** was pioneered in the late 1990's and remains the basis of recently published large wood design guidelines

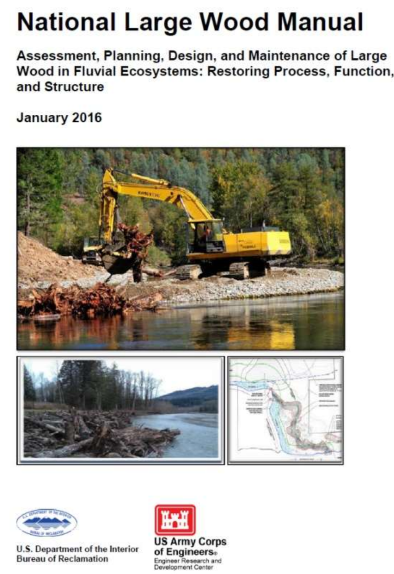
NRCS

2007



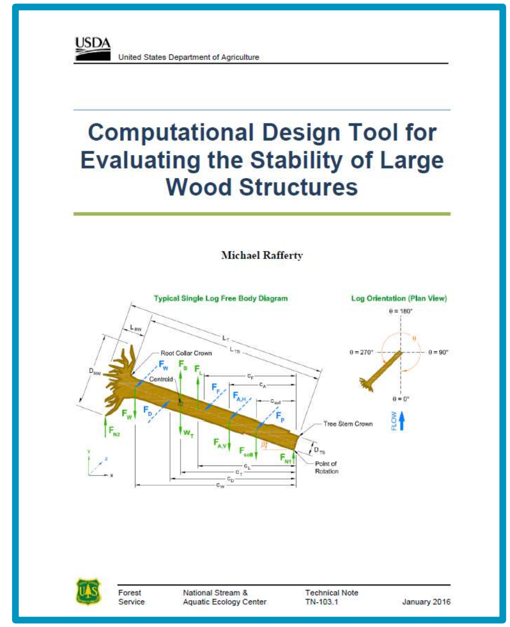
BOR

2014



USACE & BOR

2016



USFS TN 103.2

Developed in 2013
Published in 2016

Force Balance Analysis

Vertical Forces (Floating)

Driving: Buoyancy and Lift

Resisting: Weight of Log, Soil Ballast, and Anchors

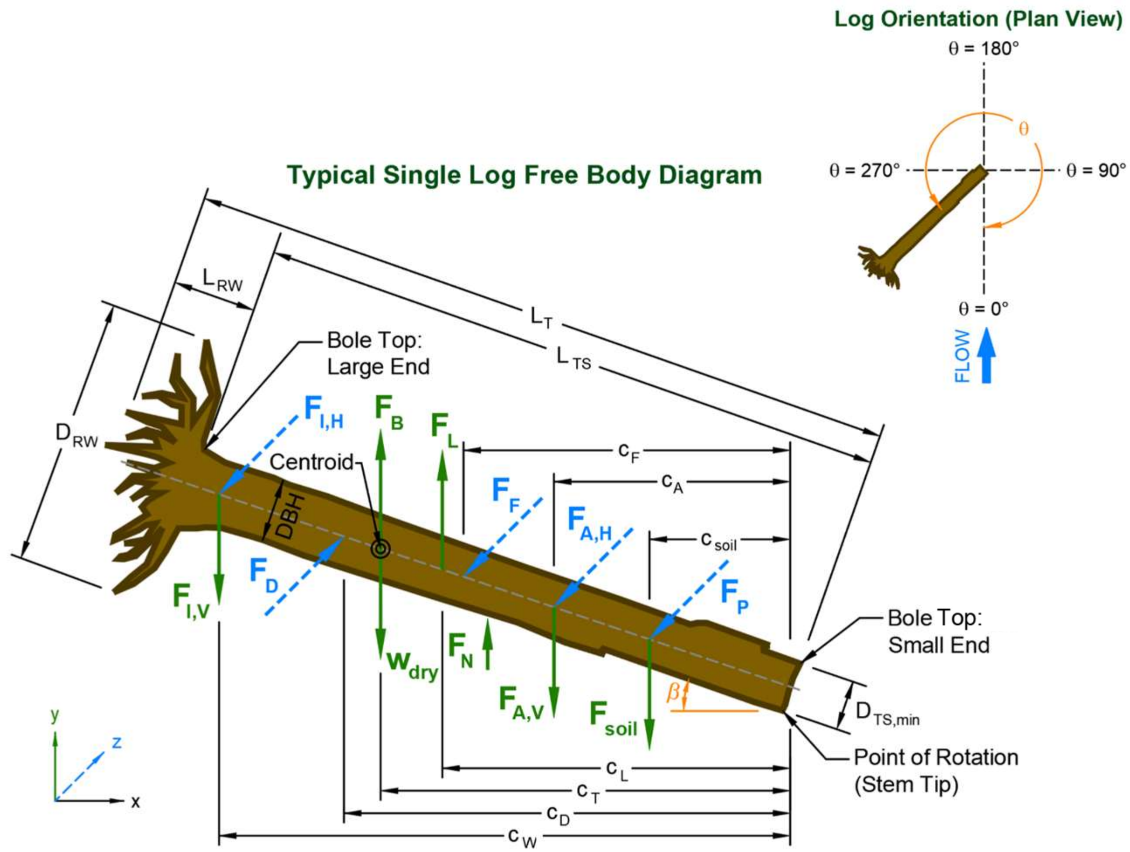
Horizontal Forces (Sliding)

Driving: Drag

Resisting: Friction, Passive Soil Pressure, and Anchors

Moment Forces (Rotating)

Moment arms of Driving and Resisting Forces



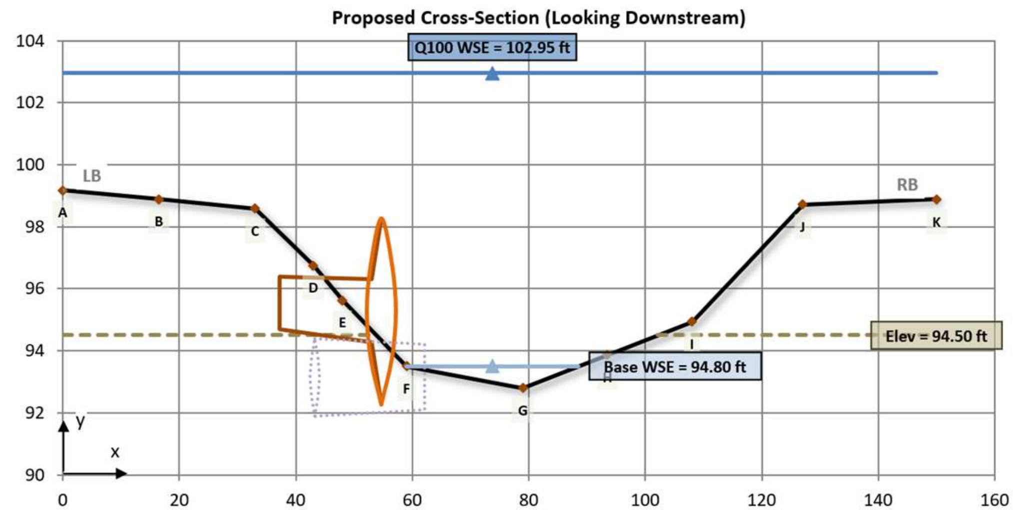
Large Wood Stability Analysis Tool Overview

Tool was originally developed in 2013, published through USFS is 2016, and **Version 2.0** was posted to the WSDOT Hydraulics & Hydrology website in 2025.

- Spreadsheet tool automates the stability evaluation to the extent feasible
- Applicable to wide range of structure configurations and anchoring techniques
- Best suited for assessing small to medium large wood structures (and larger structures with repetitive geometry)
- Forces are computed along 200+ slices of each log

Single Log Stability Analysis Model Inputs

Structure Name	Station	Layer	Log ID	Log Qty	u_{des} (ft/s)
Multiple Log	12+00	Layer 1	Top #3	1	4.63



Wood Species	Rootwad	L_T (ft)	DBH (ft)	Taper (ft/ft)	$D_{TS,eq}$ (ft)	L_{RW} (ft)	D_{RW} (ft)
Douglas-fir, Interior west	Yes	32.0	2.00	0.0125	1.69	3.00	6.00

Log Geometry	Relative: Log Crossing	
Defined Point of Log	Place Bole Over Another Log	
Log Orientation, θ	33.0	deg
Stem Tilt Angle, β	0.5	deg
Horizontal Position	51.21	ft
Vertical Position	94.31	ft

Input the distance from both stem tips to the log intersection in cells 'G32:G33'. Do not edit formulas in cells 'C32:C33'.

Relative:

Log ID	Foot #1	
Lower Log: Dist to Tip	18.40	ft
Upper Log: Dist to Tip	25.72	ft

Burial & Projection

$L_{T,em}$ (ft)	13.82
$d_{b,avg}$ (ft)	0.74
$d_{b,max}$ (ft)	1.42
A_{Tp} (ft^2)	24.84
Shield %	0%

Data Requirements

Topography
- Cross-section

Hydrology
- High and (optional) low flows

Hydraulics
- Depth, velocity, and wetted area

Bed and Bank Characteristics
- Bed substrate gradations
- Bank materials

Wood Properties
- Species
- Dimensions
- Structure configuration

Cedar River Side Channel
King County, WA

Tool Updates

Multiple Log Structure Summary Sheet

TN 103.2 Examples Applications

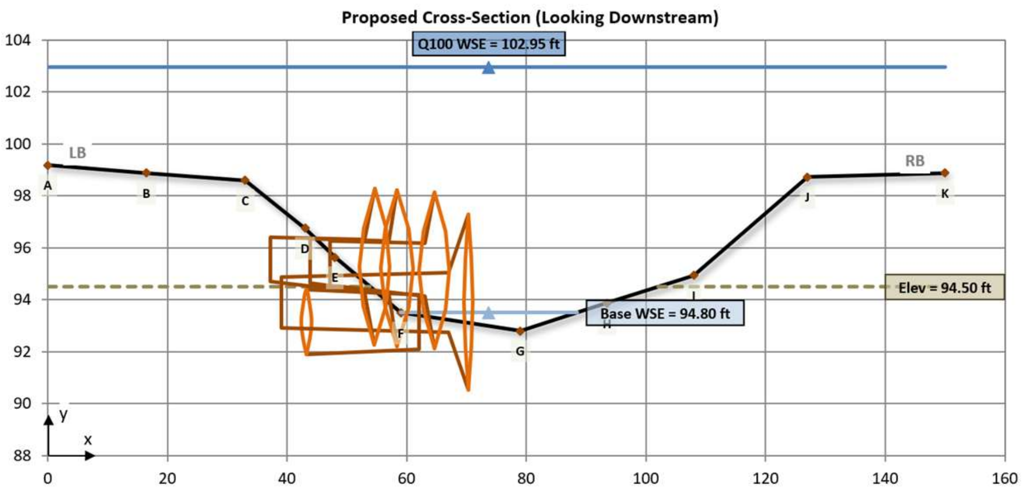
Structure Name	Station
Multiple Log	12+00

Wood Material Schedule

Type	EA	Notes
Logs (Bole Only)	1	
Logs with Roots	4	
Pinned Connections	6	

Anchor Quantities

Graph	Type	Qty	Notes
N/A	Boulders	6	4.5+ ft dia
Yes	Timber Piles	0	
N/A	Earth Anchor	0	
N/A	Soil Ballast	0	CY



Stability Evaluation

Graph	Log ID	Layer	Quantity	Rootwad	L_T (ft)	Dia (ft)	θ (deg)	β (deg)	$L_{T,em}$ (ft)	$d_{b,avg}$ (ft)	$d_{b,max}$ (ft)	FS_V	FS_H	FS_M
Yes	Foot #1	Footer	1	No	32.0	2.50	324.0	0.0	20.04	1.11	2.30	4.45	314.49	15.25
Yes	Foot #2	Footer	1	Yes	32.0	2.25	102.0	0.0	12.75	1.32	2.61	2.96	23.91	5.88
Yes	Top #1	Layer 1	1	Yes	32.0	2.00	33.0	0.5	0.00	0.00	0.00	1.55	14.00	6.72
Yes	Top #2	Layer 1	1	Yes	32.0	2.00	27.0	0.5	2.19	0.11	0.22	1.53	18.27	5.04
Yes	Top #3	Layer 1	1	Yes	32.0	2.00	33.0	0.5	13.82	0.74	1.42	2.15	26.69	6.40
Yes														
Yes														
Yes														
Yes														
Yes														
Yes														
Yes														
Yes														
Yes														
Yes														
									Total Structure Factor of Safety Check			1.63	14.35	

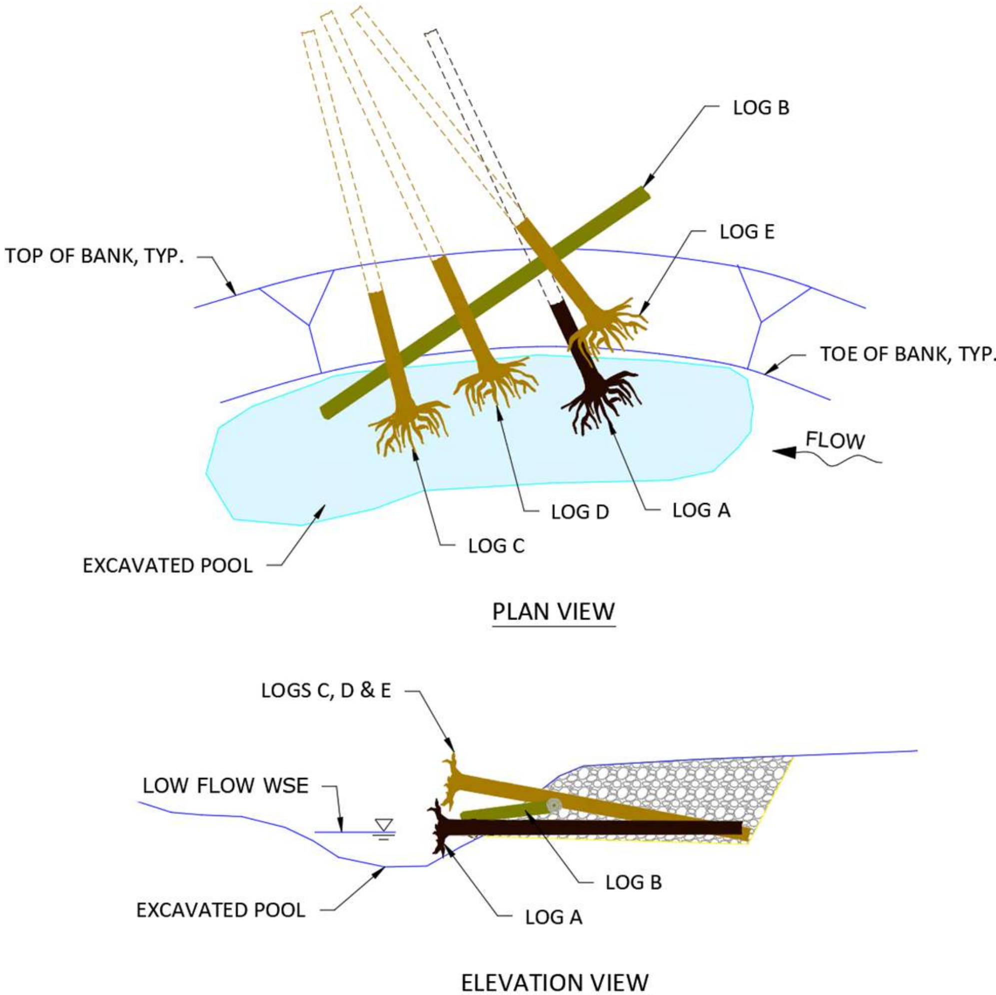
Spreadsheet Organization

- New "Site" tab combines old "H&H" and "Soil" tabs
- Added "**Summary**" tab

Expanded functionality

- More cross-section geometry points, boulder ballast connections, and log interactions
- 2-D model data inputs
- Define bank stratigraphy and low flow WSE
- Added stem taper rate
- Added timber piles
- Log lookup prompts to automate some data entry
- Revised multi-log design methodology

Sample Application



Live Demo

(Switch to Excel Spreadsheet)

Limits of Applicability

Tool may not be applicable or may require manual adjustments for the following scenarios:

- Larger jams with complex geometry
- Logs with split boles or branches
- High energy streams and sites with easily erodible margins
- High wood recruitment potential
- Streams with high ice loading (impact forces)

Additional Design Considerations

- Fish habitat preferences
- Decay rates of wood
- Bed scour potential
- Suitability of soils for piles
- Landowner concerns
- Regulatory codes (e.g., no-rise)
- Post-decay stability (e.g., planting)
- Construction considerations

Questions?

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mrafferty@interfluve.com

Tranquil Creek
British Columbia

Acknowledgments

Large Wood Design Tool v2.0 and USFS TN 103.2 are available for download at:

https://wsdot.wa.gov/engineering-standards/design-topics/hydraulics-hydrology

(click on the green tab labeled “Tools, templates, & links”)

Riparian Book Club Discussion

Do you account for an area's natural wood supply when deciding how much wood to add to a project? For example, would you add wood to a system that has no future natural wood inputs?

What distance downstream does risk need to be assessed?

Do you have recommendations for laymen's communication of the results of stability analysis using this tool to stakeholders, landowners, and community groups?

What would you say is the most significant simplifying assumption this tool makes - or the biggest uncertainty it can't address - and how do you recommend managing the limitations?

What is your favorite improvement to the tool in the recent update?

When would you achieve stability by reducing log protrusion versus adding ballast versus using piles?

Does anyone else have a favorite update they've found so far that you can share with Michael?

Thank You

A recording of this webinar will be available at CO-CO.ORG -> Resilient Communities ->Riparian Book Club