Large Wood Technical Field School

Presentations from the Salmonid Restoration Federation Large Wood Technical Field School held on the Mendocino Coast October 30-31, 2018.

Field School Overview

- In partnership with:
  - Trout Unlimited
  - State Water Resources Control Board

This two-day field school provided training for forestry and restoration professionals in both engineered and non-engineered large wood augmentation techniques that have been proven effective in restoring stream habitats on the Northern California coast. Participants learned how to effectively design and implement large wood restoration projects by learning how to identify geomorphic conditions of a treatment stream and select appropriate implementation methods to achieve desired results. Each day included classroom lectures, hands-on activities, field demonstrations, project site tours, and ample group discussion.

Hands-on group activities included buoyancy and other engineering computations and the construction of large wood site scenarios in the classroom. Field school contributors provided an on-site overview of heavy equipment implementation techniques. Additional discussion topics during the field school included project site identification, project layout, and design considerations.

Presentations

(Slide 4) **Accelerated Recruitment: Cost-effective Restoration Techniques for Enhancing Instream Habitat in California Coho Streams**
Chris Blencowe – Blencowe Watershed Management, Inc.

(Slide 65) **Restoring Wood's Essential Role in Controlling Channel Grade and Stability in Small Streams**
Mike Love – Michael Love and Associates, Inc.

(Slide 100) **How to Keep Your Wood from Floating Downstream: Interactive Computations for Stability of Large Wood Structures**
Rachel Shea – Michael Love and Associates, Inc.

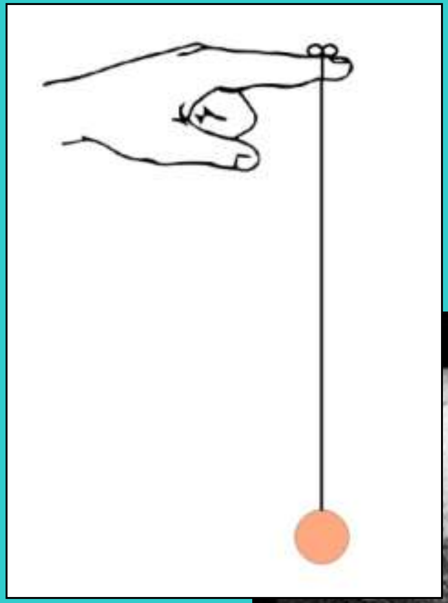
(Slide 132) **30 Years in the Making: California Conservation Corps Instream Large Wood Restoration Techniques**
California Conservation Corps

(Slide 152) **When is a Large Wood Project a Success?**
Margie Caisley, California Department of Fish and Wildlife

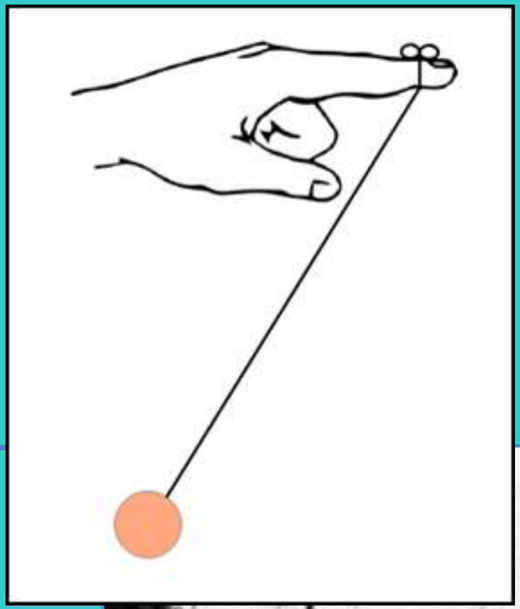
Accelerated Recruitment: Cost-Efficient Restoration Techniques for Enhancing Instream Habitat

Large Wood Technical Field School 10/30/18

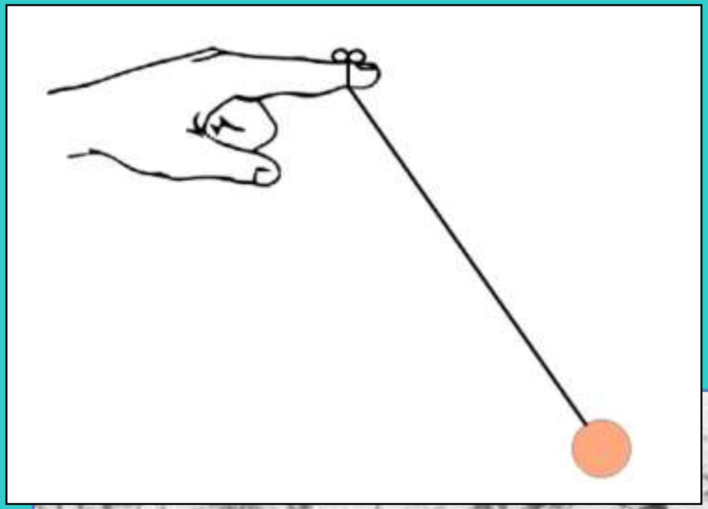
Christopher Blencowe RPF, Blencowe Watershed Management in partnership with Ken Smith LTO, Pacific Inland



Phase 1: 1,000,000+ years of wood loading

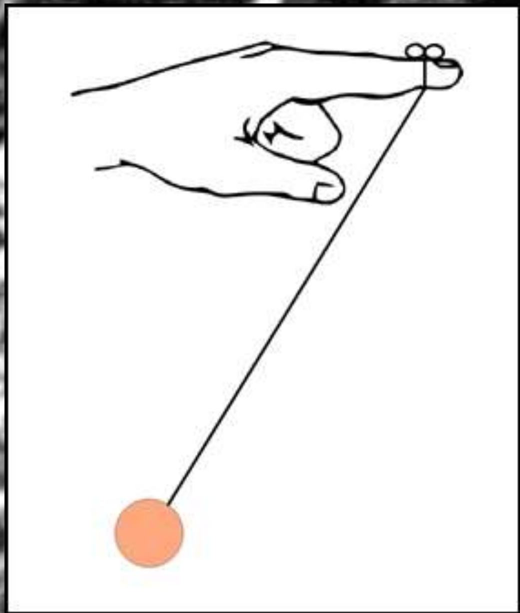


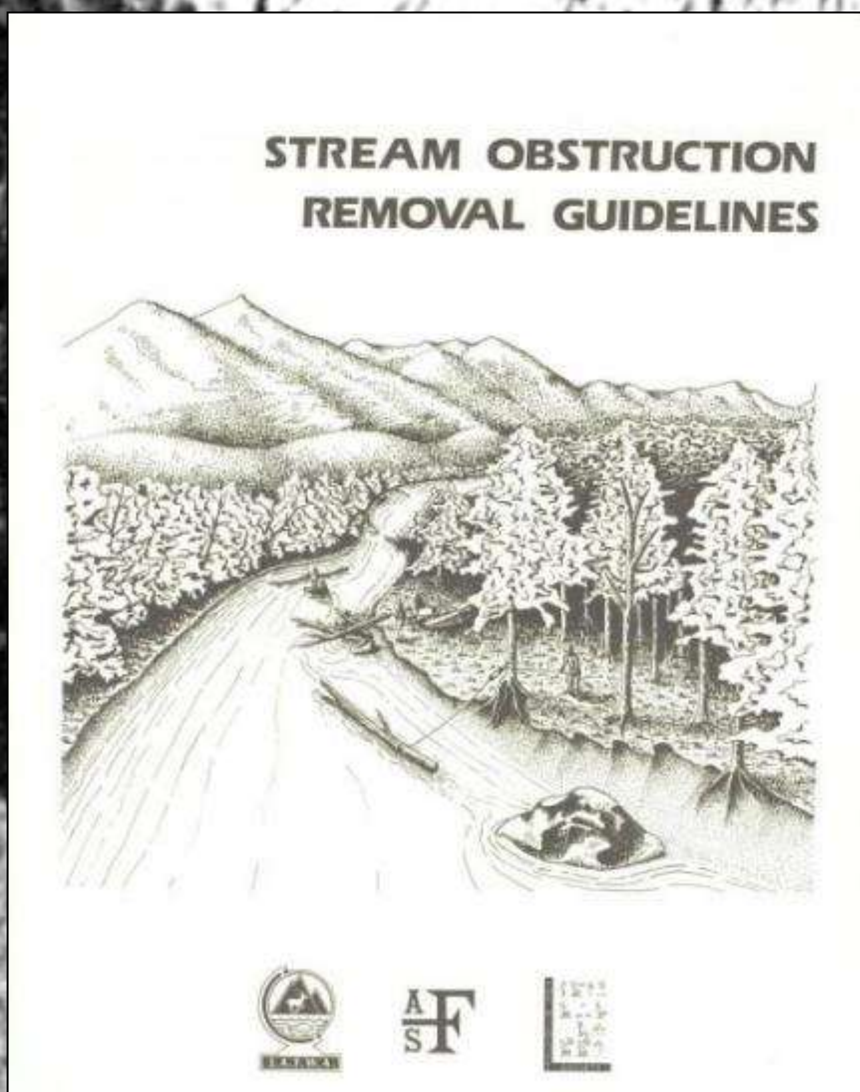
Phase 2: Early Logging (1860s – 1920s)
Instream and streamside tree and wood clearing/splash dam logging

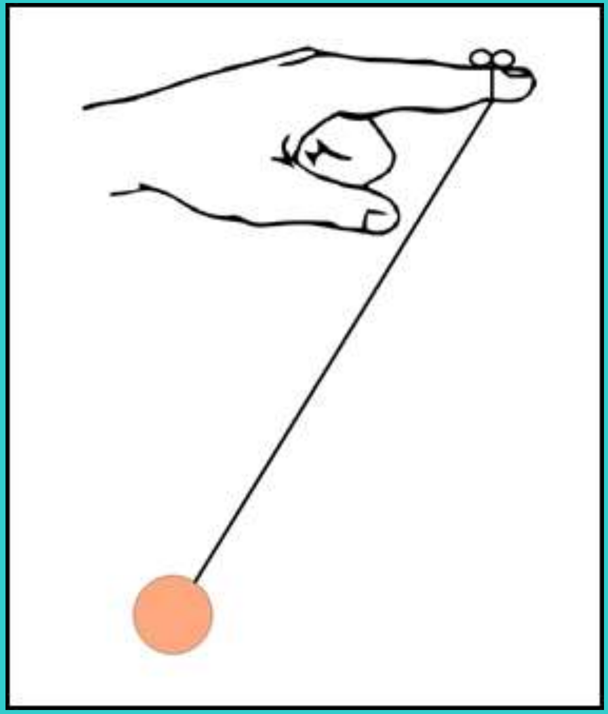


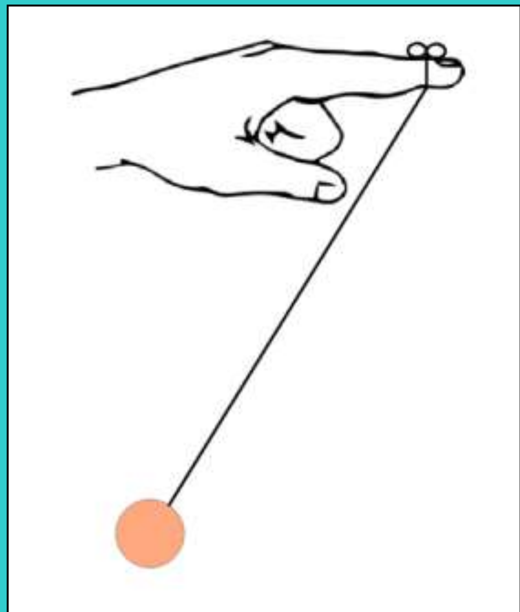
Phase 3: Post WW-II Logging
(1940s – 1970s) Excessive wood loading

Phase 4: Stream Clearing (1970-80s)

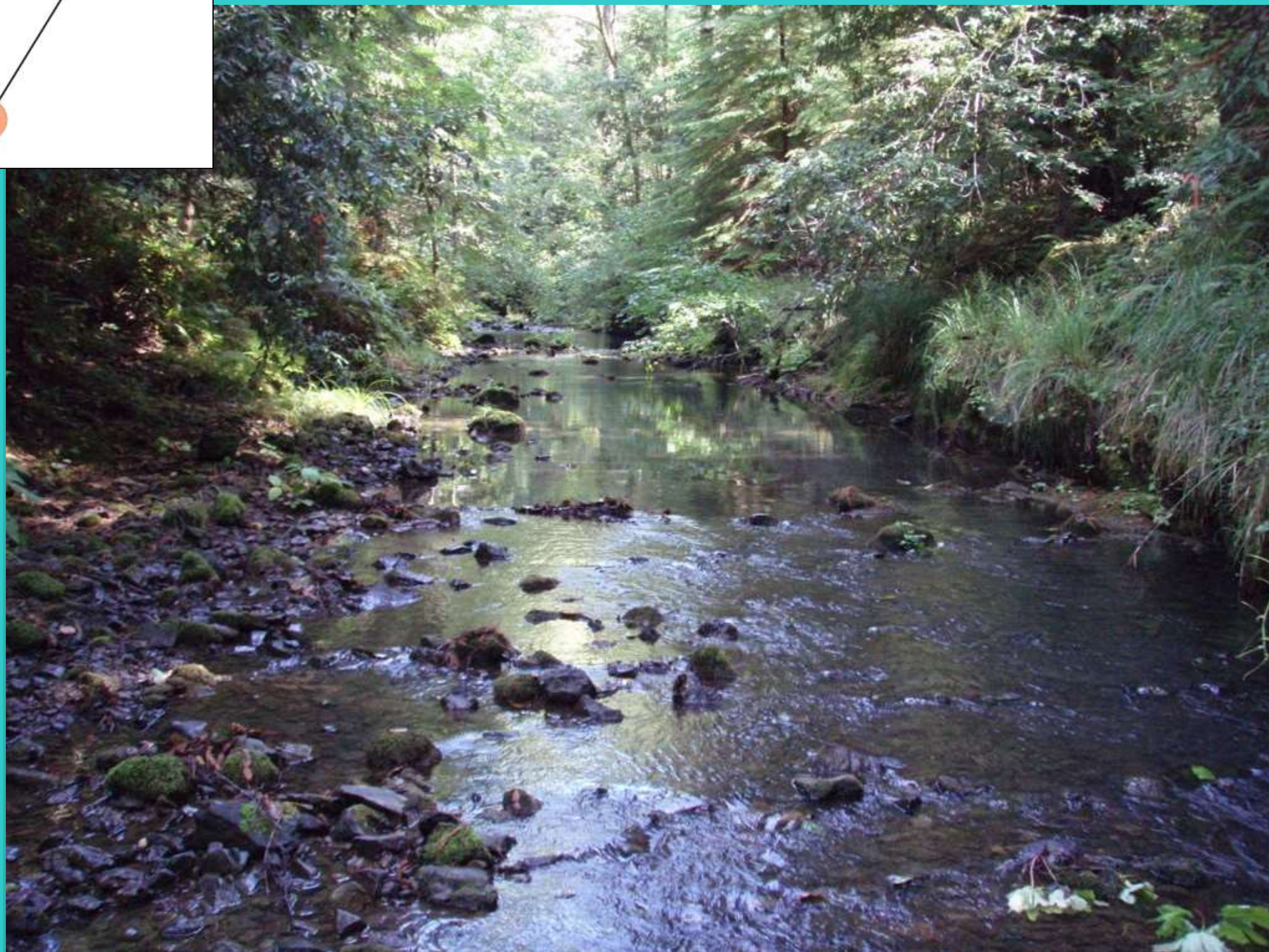








Phase 5 (Present)
Waiting for riparian corridors to mature

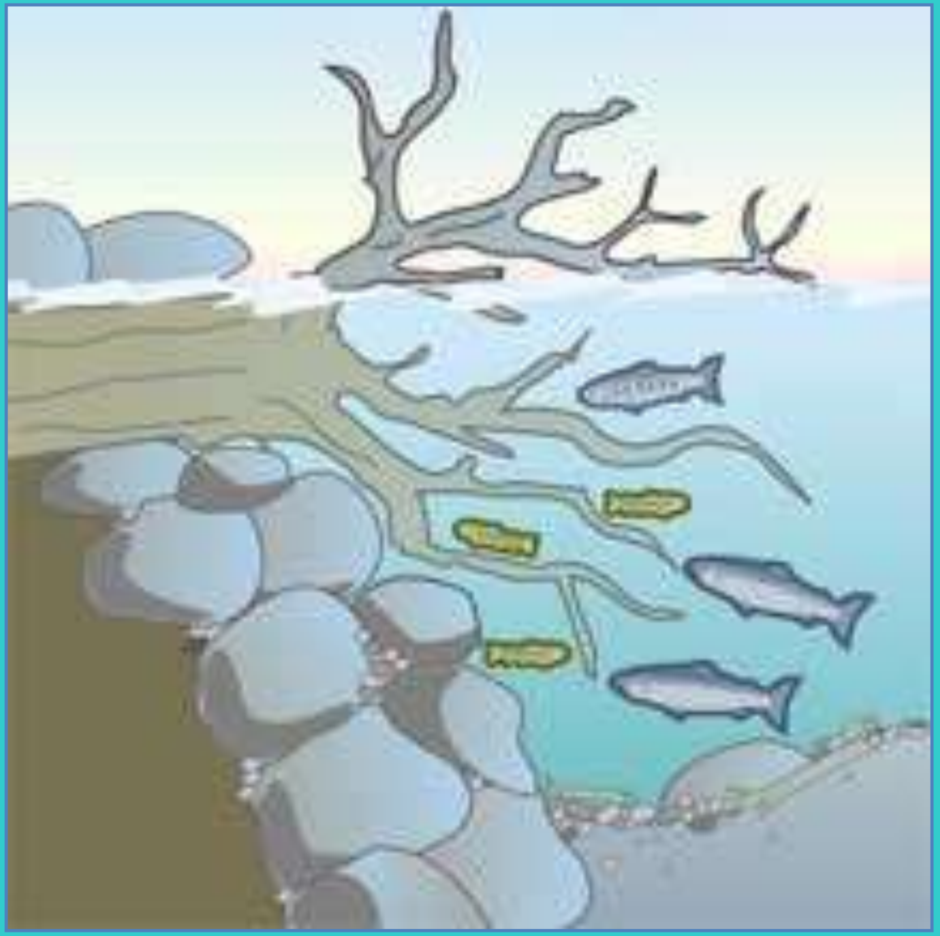


Large Woody Debris (LWD) Function

- Create/maintain pool scour, backwater and side channel habitat
- Sort/store sediments including spawning gravel and increase floodplain connectivity
- Function as cover from predation, increase stream production and food availability
- Provide high velocity refugia during winter

Restoration Strategies

- Our strategy:
  - Increase pace and scale
  - Rapid, efficient accelerated recruitment of large wood as a stop-gap measure
  - ‘Nucleate’ the stream with functional large wood
  - Natural LWD recruitment is the goal



Techniques through Experience

- 11 years working together
- 49 number of unique projects
- 2600 structures
- 5700 pieces of LWD
- Not professionally trained in engineering or similar. Field based, evolution through ‘trial and error’
- This is just one tool in the restoration tool box

Design/Build Approach

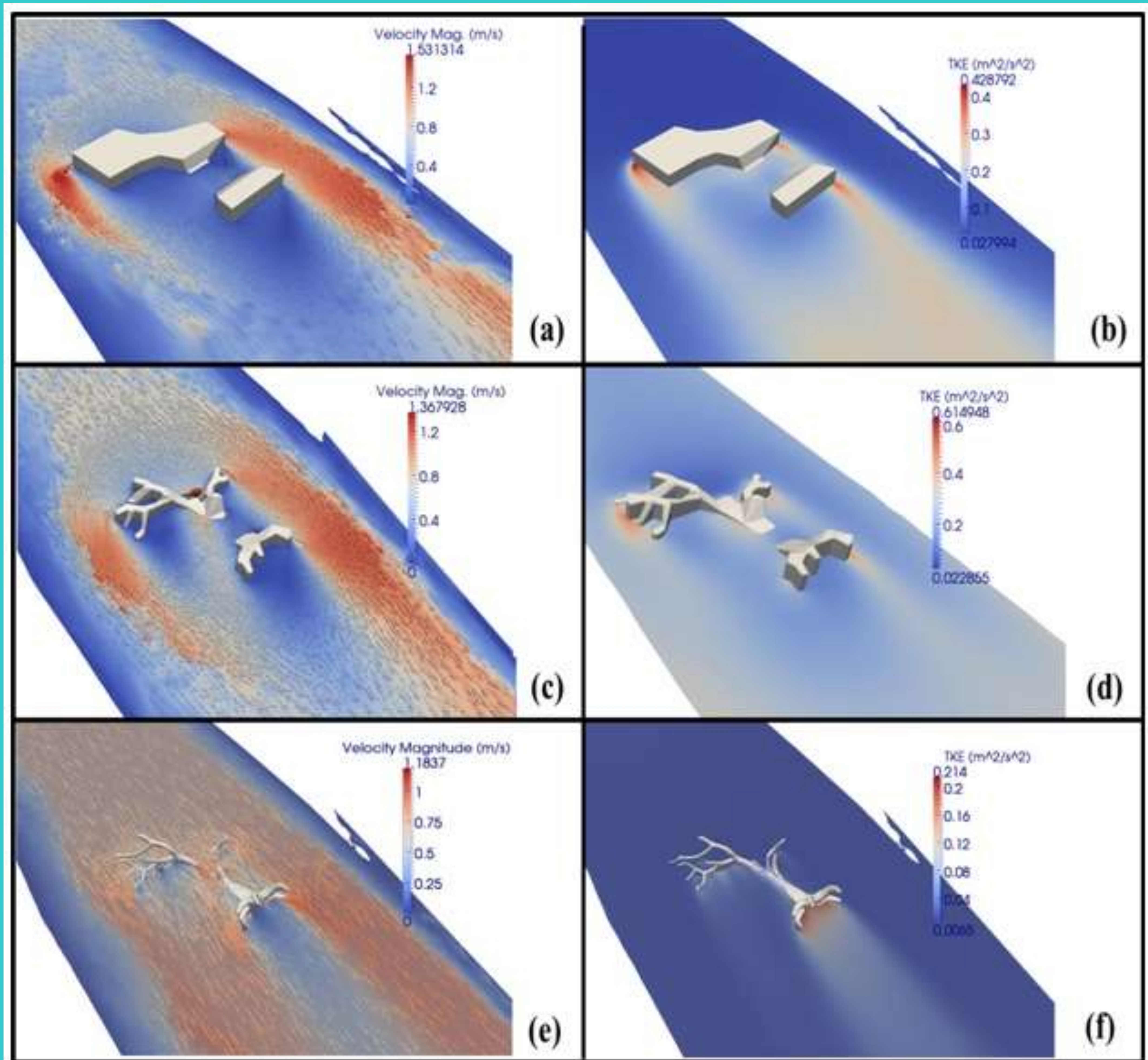
- Structure designer is onsite for implementation everyday
- Oversees and modifies designs in real time as necessary ‘field fitting’
- Refined/revised through real world, on the ground situations and processes
- Critical to success of any one piece of wood, structure, project, etc

Implementation Methods

- Use rubber tired equipment to directly place (wedge) logs (onsite/offsite) through riparian roughness elements
- Use skidder to winch logs from onsite
- Direct falling near-stream conifers where appropriate
- Whole tree tipping

Structure Design Considerations

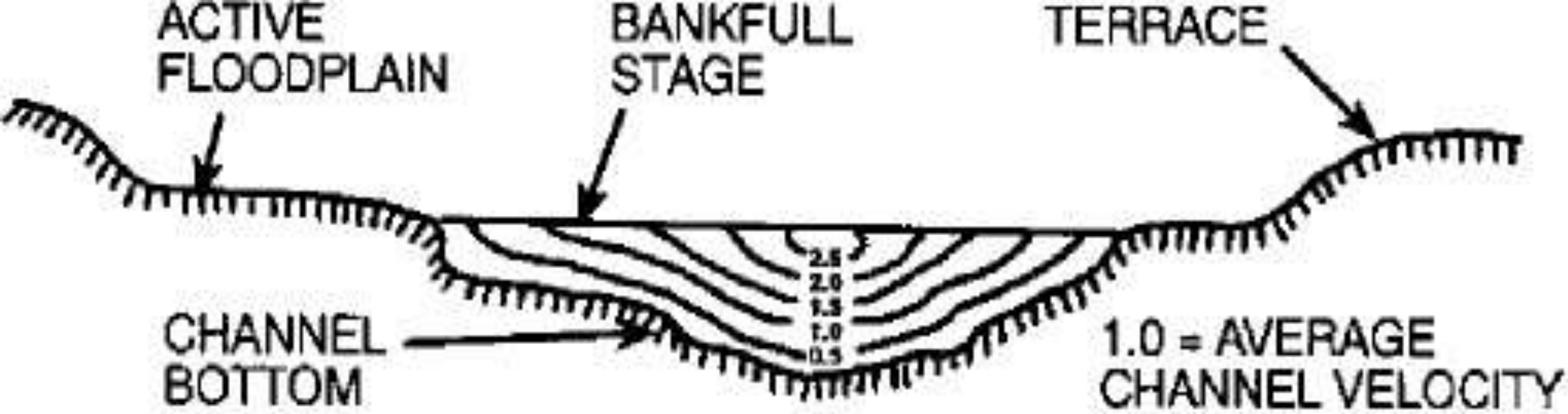
1. Evaluation of pre-existing in stream conditions including local channel morphology/thalweg location and quality of instream shelter. Prioritization of aggradated pools, flatwater, avoid tail outs/riffles
2. Orientation of riparian roughness elements for wedging/anchoring of LWD
3. Availability of favorable equipment access
4. Availability of suitable material trees for direct falling, or upslope tree falling and/or salvageable downed wood for potential placement.
5. Potential disturbance to riparian resources
6. Infrastructure/ aesthetic concerns



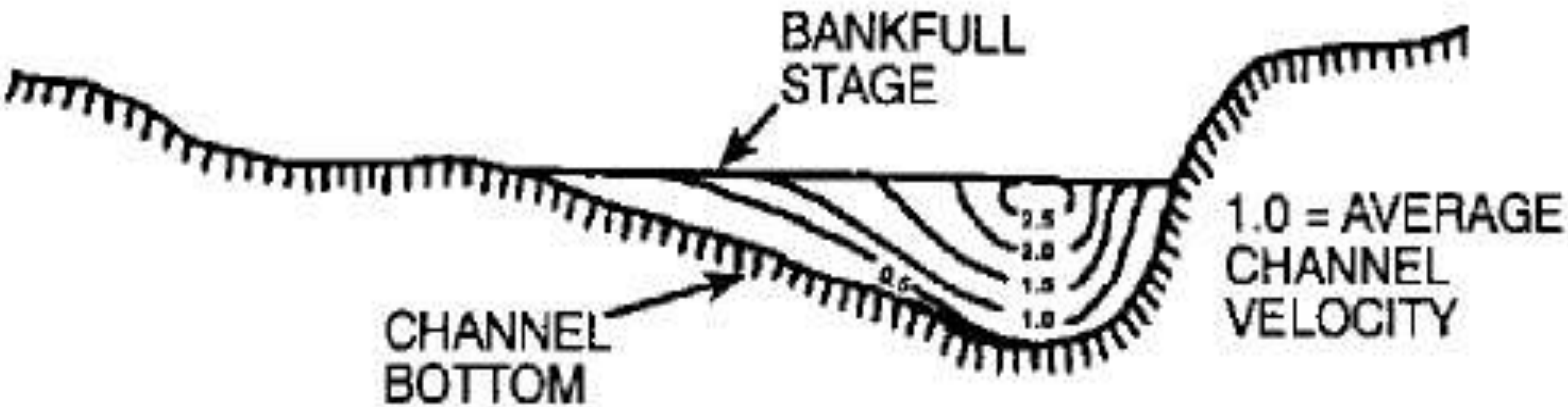
Characterizing the Impact of Geometric Simplification on Large Woody Debris Using CFD

Jeffrey B. Allen [1], David L. Smith

[1]Information Technology Laboratory, U.S. Army Engineer Research and Development Center, ATTN: CEERD-IE-C, 3909 Halls Ferry Road, Vicksburg, Mississippi, 39180, USAEnvironmental Laboratory, U.S. Army Engineer Research and Development Center, ATTN: CEERD-IE-C, 3909 Halls Ferry Road, Vicksburg, Mississippi, 39180, USA



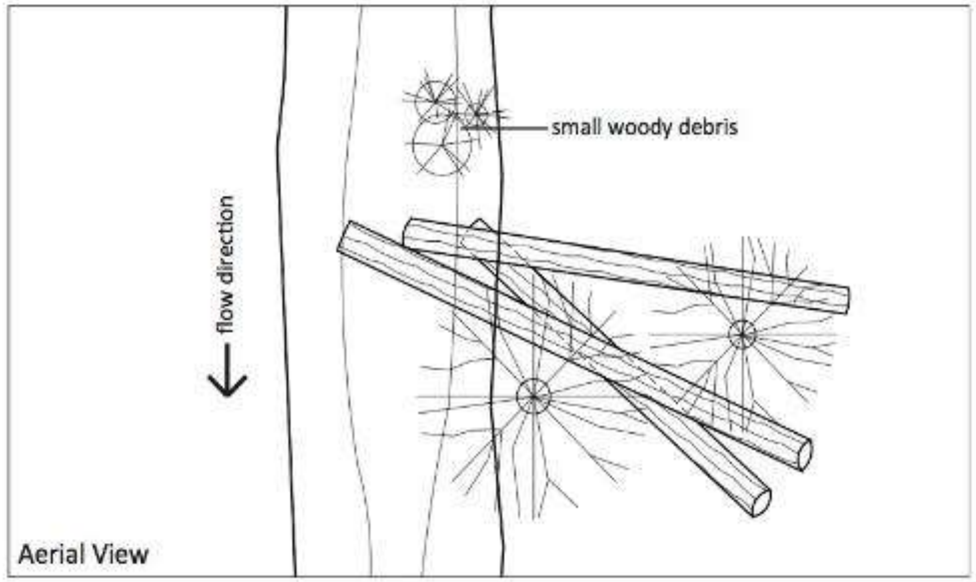
(a) STRAIGHT CHANNEL

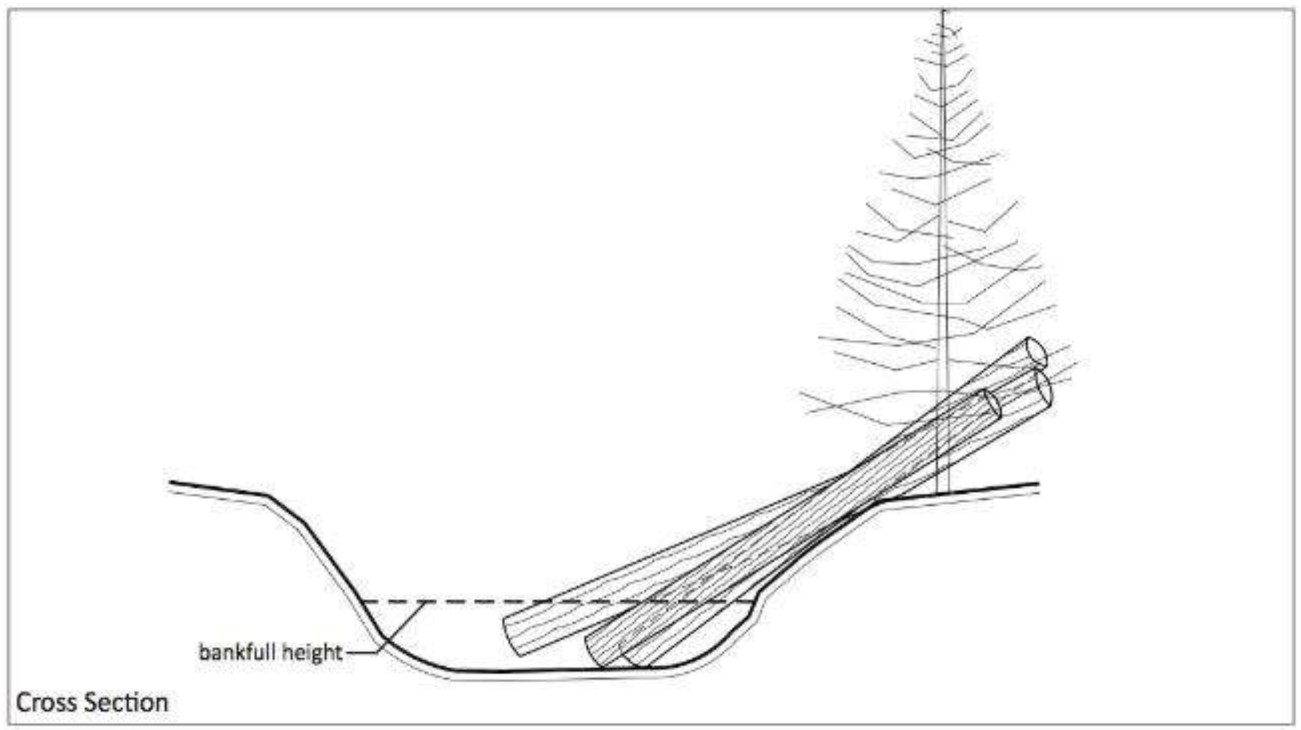


(b) CHANNEL BEND

‘Throttle the Channel’

- Increase x-sectional surface area of project wood





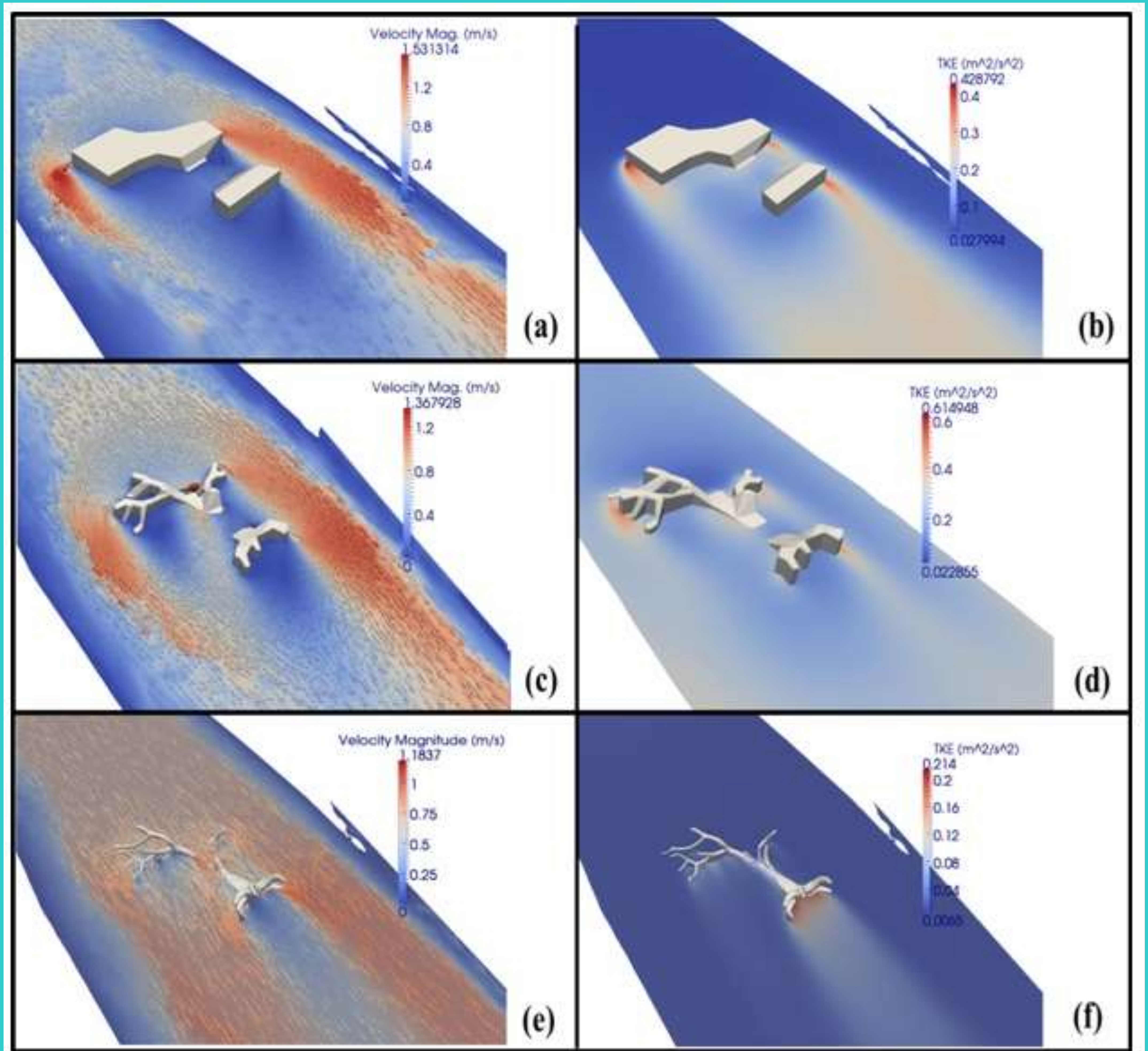
SITE DESIGN 3

RECOMMENDATIONS

- *2-4 log structure with non-traditional anchoring designed to create debris accumulation and/or scour pool*
- *Instream ends of logs placed at unequal distances from the bank along a perpendicular plane configuration to downstream flow to create a 'debris fence'*
- *Logs placed at a 45° to 90° orientation to downstream flow*
- *SWD can be added immediately upstream of logs*
- *Target log length is 1.5 times or greater the bankfull width*

‘Throttle the Channel’

- Increase x-sectional surface area of project wood
- Increase velocity/TKE around obstruction

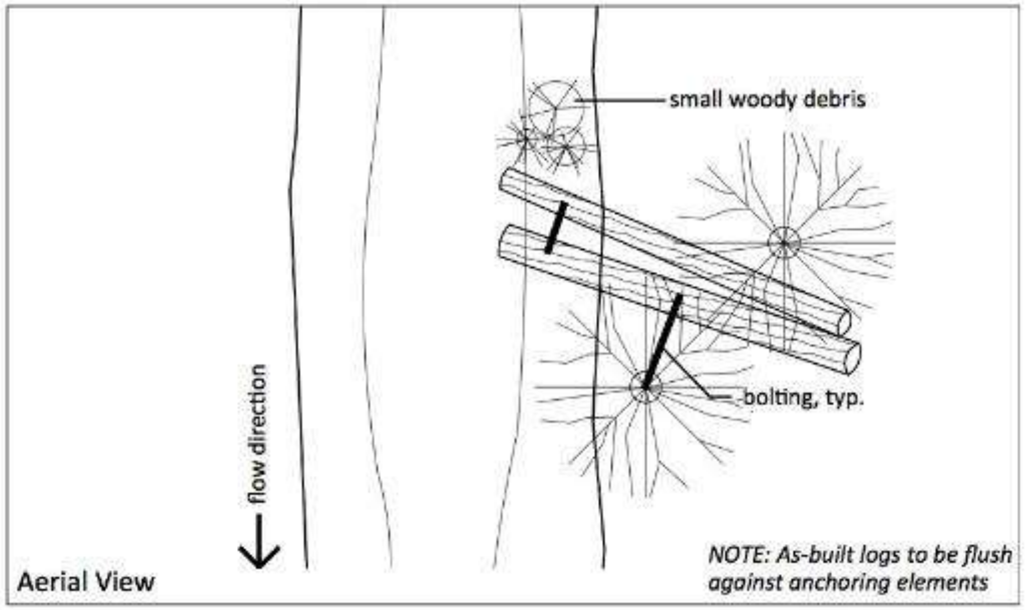

Velocity Mag. (m/s)
1.531314
1.2
0.8
0.4
(a)
TKE (m^2/s^2)
0.428792
0.4
0.3
0.2
0.1
0.027994
(b)
Velocity Mag. (m/s)
1.367928
1.2
0.8
0.4
0
(c)
TKE (m^2/s^2)
0.614948
0.6
0.4
0.2
0.022855
(d)
Velocity Magnitude (m/s)
1.1837
1
0.75
0.5
0.25
0
(e)
TKE (m^2/s^2)
0.214
0.2
0.16
0.12
0.08
(f)

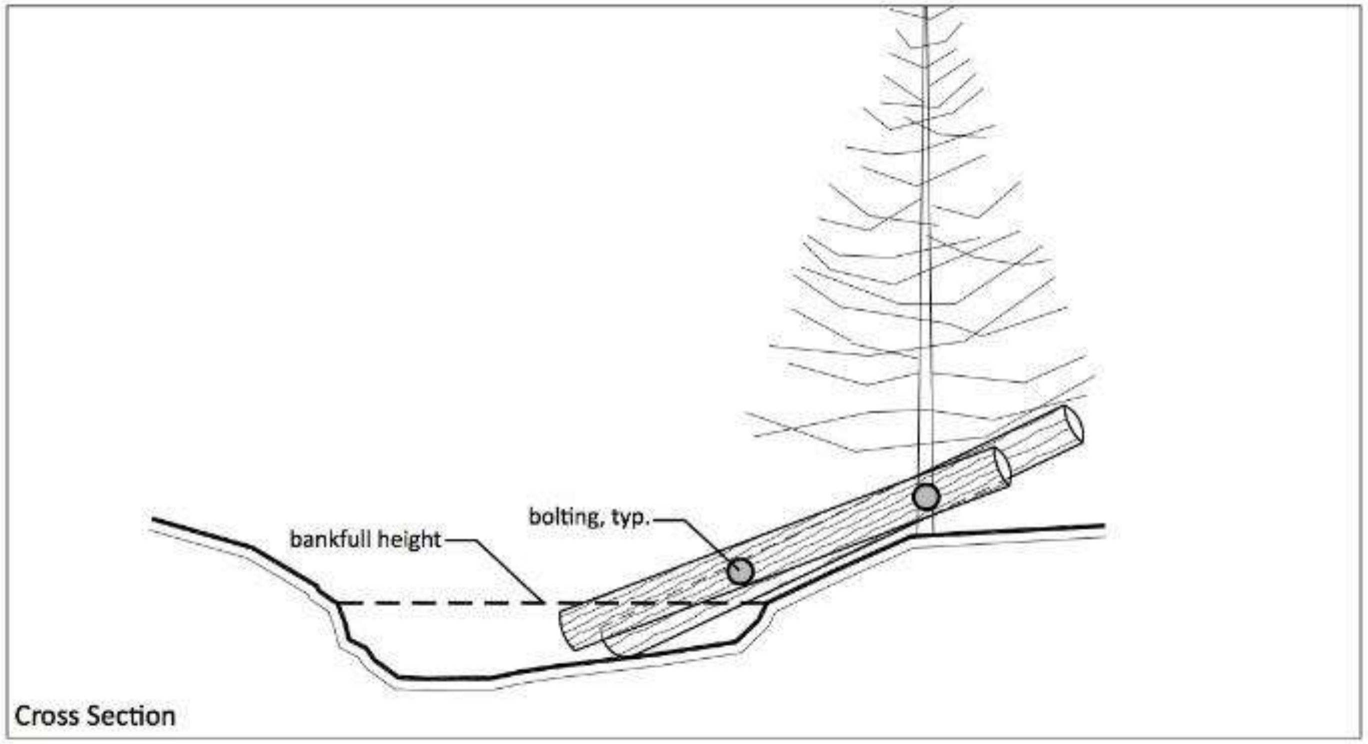
‘Throttle the Channel’

- Increase x-sectional surface area of project wood
- Increase velocity/TKE around obstruction
- Scour pool, create slow water refugia, sort store gravels
- Ability to rack and retain existing instream SWD/MWD/LWD
- Must design and size wood/anchoring appropriate for channel

Dynamic Anchoring

- Generally all wood is designed to be retained at structure location
- Wood is ‘wedged’ amongst riparian roughness elements providing the structural anchoring mechanisms
- Dynamic Anchoring can be with or without hardware
- Onsite logistics dictate feasibility





SITE DESIGN 1

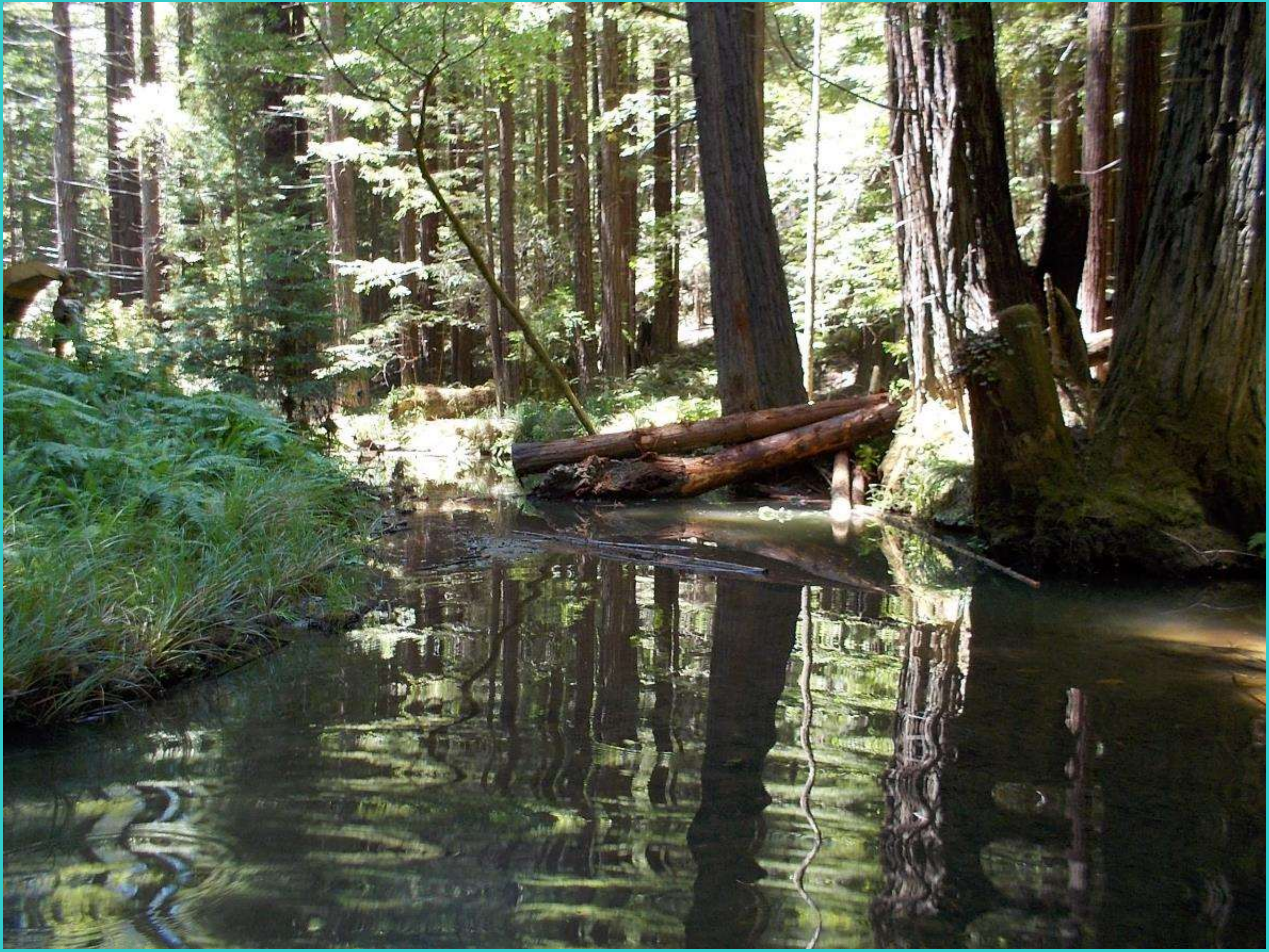
RECOMMENDATIONS

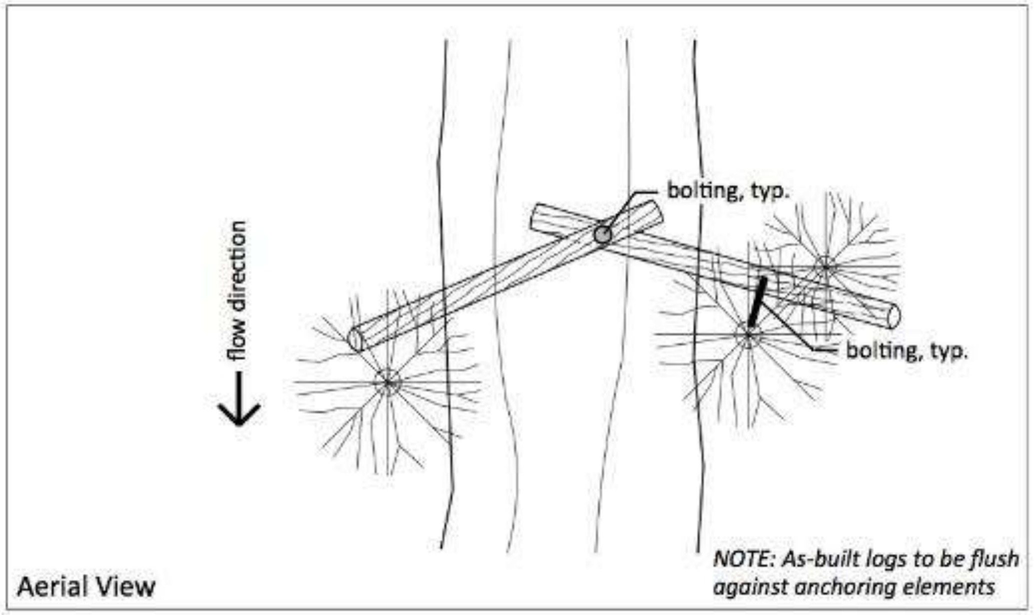
- *1-2 log structure with at least one anchor point utilizing traditional 1" threaded rebar and washer/nut anchoring designed to create/enhance pool habitat*
- *Instream ends of logs placed adjacent the thalweg*
- *Logs placed at a 30° to 90° orientation to downstream flow*
- *Logs with rootwads attached may be substituted*
- *SWD may be added immediately upstream of logs*
- *Target log length is 1.5 times or greater the bankfull width*

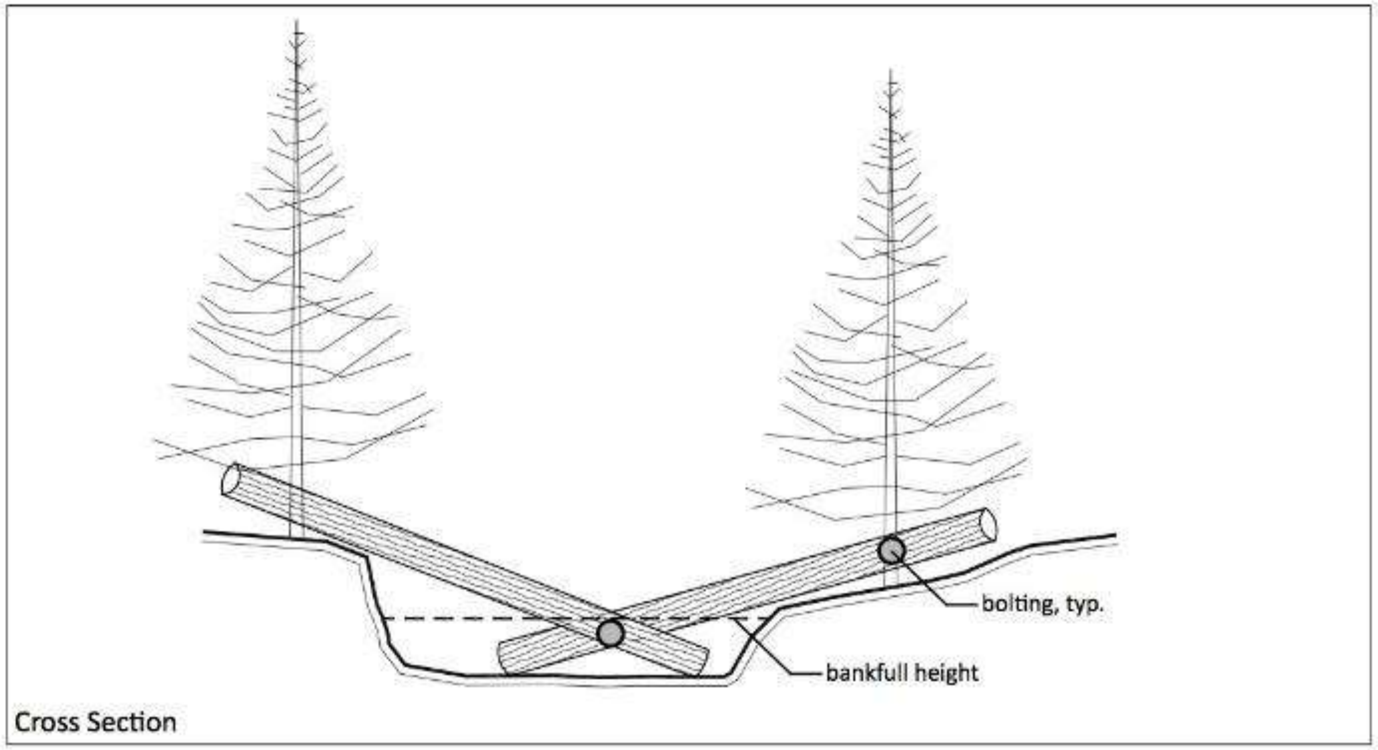
BWM

BLENCOWE WATERSHED MANAGEMENT

3-2015







SITE DESIGN 6

RECOMMENDATIONS

- *2 log structure with at least one anchor point utilizing traditional 1" threaded rebar and washer/nut anchoring designed to create mid-channel debris accumulation and/or scour pool*
- *Instream end of logs cross up at or near bankfull height*
- *Log to be placed at a 30° to 90° orientation to downstream flow*
- *Some logs with small rootwads may be substituted*
- *Target log length is 1.5 times or greater the bankfull width*

BWM

BLENCOWE WATERSHED MANAGEMENT

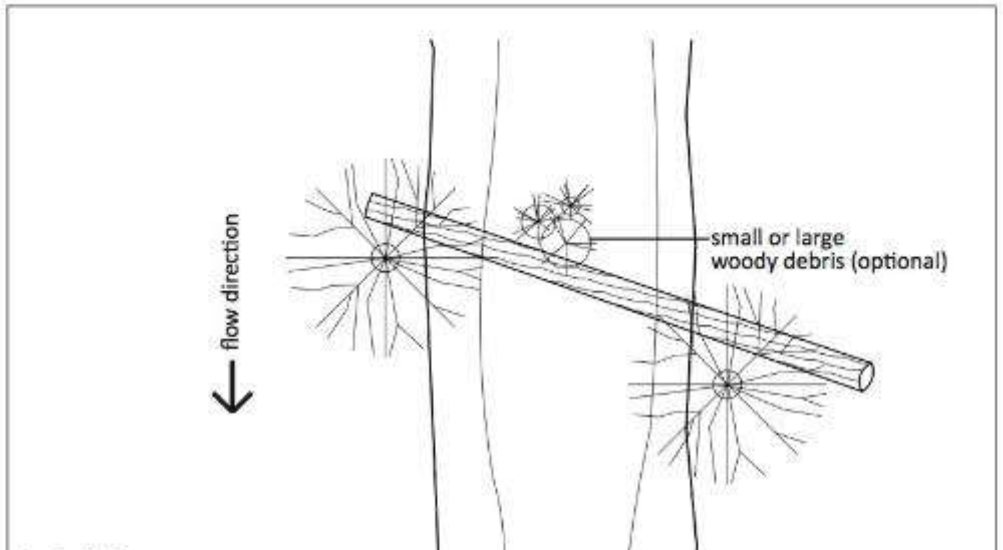
3-2015

Small Woody Debris (SWD)

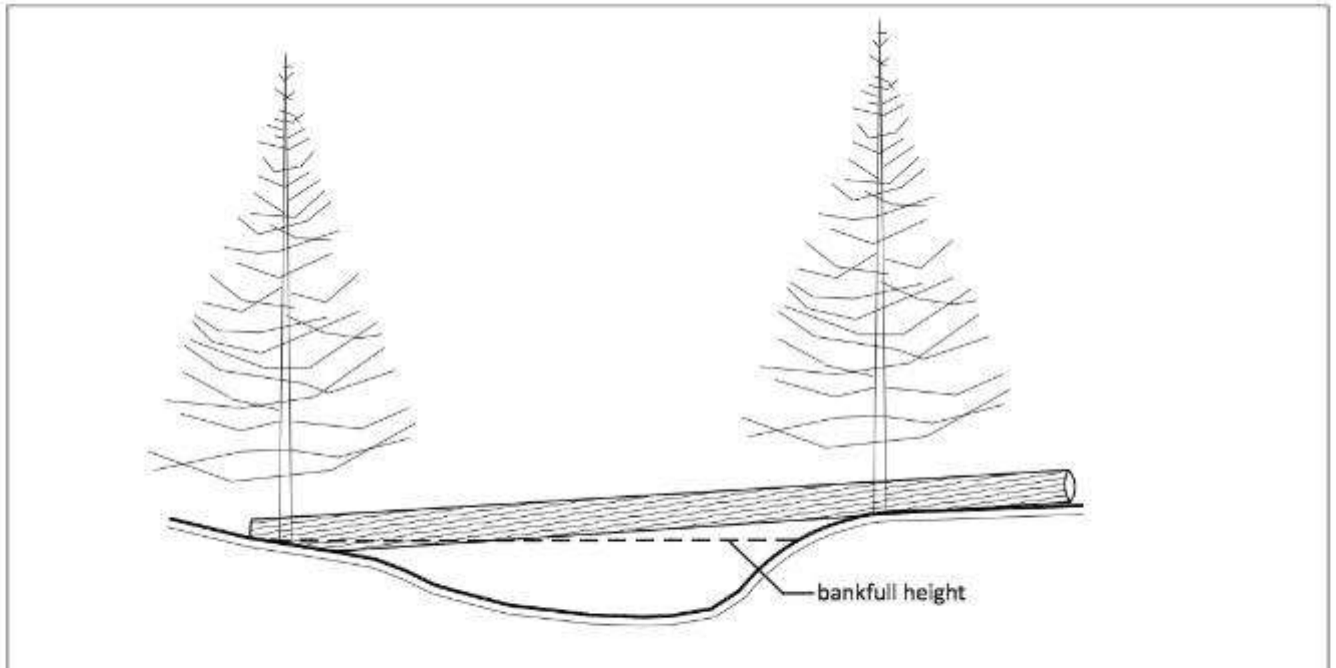
- SWD is may be manually added where appropriate
- Direct falling indirectly contributes SWD
- Stobbing of limbs
- High quality material that can be activated during winter flows. May be staggered up bank/channel
- SWD may be removed from wetted channel and even active channel
- SWD not always desirable

Some Design Concerns

- Locations without appropriate upslope anchors and lack of suitable onsite material
- Large deep pools with little cover
  - -Real concern for slowing velocities and contributing to aggradation
  - -Promote overhead cover and less LWD surface area into thalweg
  - -Difficult to design for, less aggressive, passive structure



Aerial View



Cross Section

SITE DESIGN 7

RECOMMENDATIONS

- *One log structure with non-traditional anchoring designed to enhance floodplain inundation, provide high water refugia, and create debris accumulation*
- *Instream end of log to be at or near bankfull height*
- *Log length should be as close to bankfull height as possible*
- *Log to be placed at a 50° to 90° orientation to downstream flow*
- *LWD and/or SWD can be added upstream of log*

BWM

BLENCOWE WATERSHED MANAGEMENT

3-2014

Lessons Learned

- Successfully falling trees into channel zone is much more difficult then expected
- Need to design for highest flow events, including buoyancy and racking capabilities, “Throttle the channel”
- All LWD is not created equal, design important
- Onsite wood is often the best
- SWD/MWD often difference between good/great structure
- 50ft max width for traditional Acc Recruc.
- Realistic structure designs for local conditions
- Size wood/anchors appropriately
- Good operators is critical to success

Costs of Engineered vs. Unanchored LWD

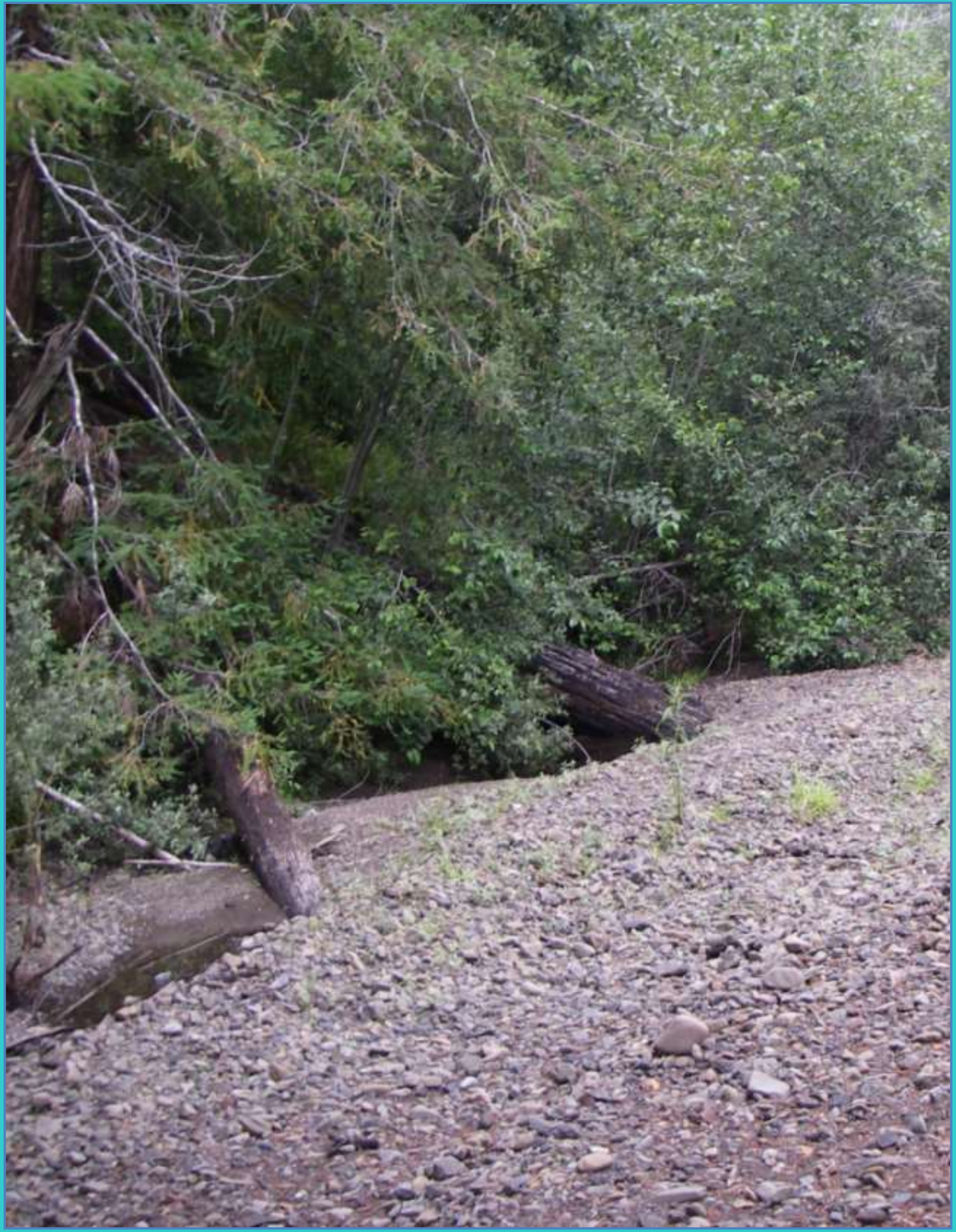
Cost Comparison of Engineered vs. Unanchored on SF Ten Mile River

<u>Anchored Project on SF Ten Mile River (2005) (FRGP, CTM):</u>

•3 mile reach treated
•40 logs
•11 sites
•Total cost: $41,000
•$1000 per log
•13 logs/mi

<u>Accelerated Recruitment Project on SF Ten Mile River (2007-2008) (FRGP, CTM):</u>

•9.4 mile reach treated
•309 logs
•133 sites
•Total cost: $73,000
•$236 per log
•32 logs/mi



Performance Metrics

- Pre- and post-treatment surveys

  -DFW Stream Habitat Typing Level II w/LWD survey

  -Longitudinal profile
- Tagging/GPS project wood
- Photo points

Survey results by CDFW's Coastal Restoration Monitoring and Evaluation Program on SF Ten Mile, July 2012

- 82% of original pieces of tagged LWD pieces were located.
- 93% tagged LWD are currently considered to be positively functioning.
- 92% sites had minimal movement and/or maintained their original position.
- A significant increase (393%) in large (L>20ft) LWD.
- No significant percent change in maximum pool depth and residual pool depth was seen between 2007 and 2012.

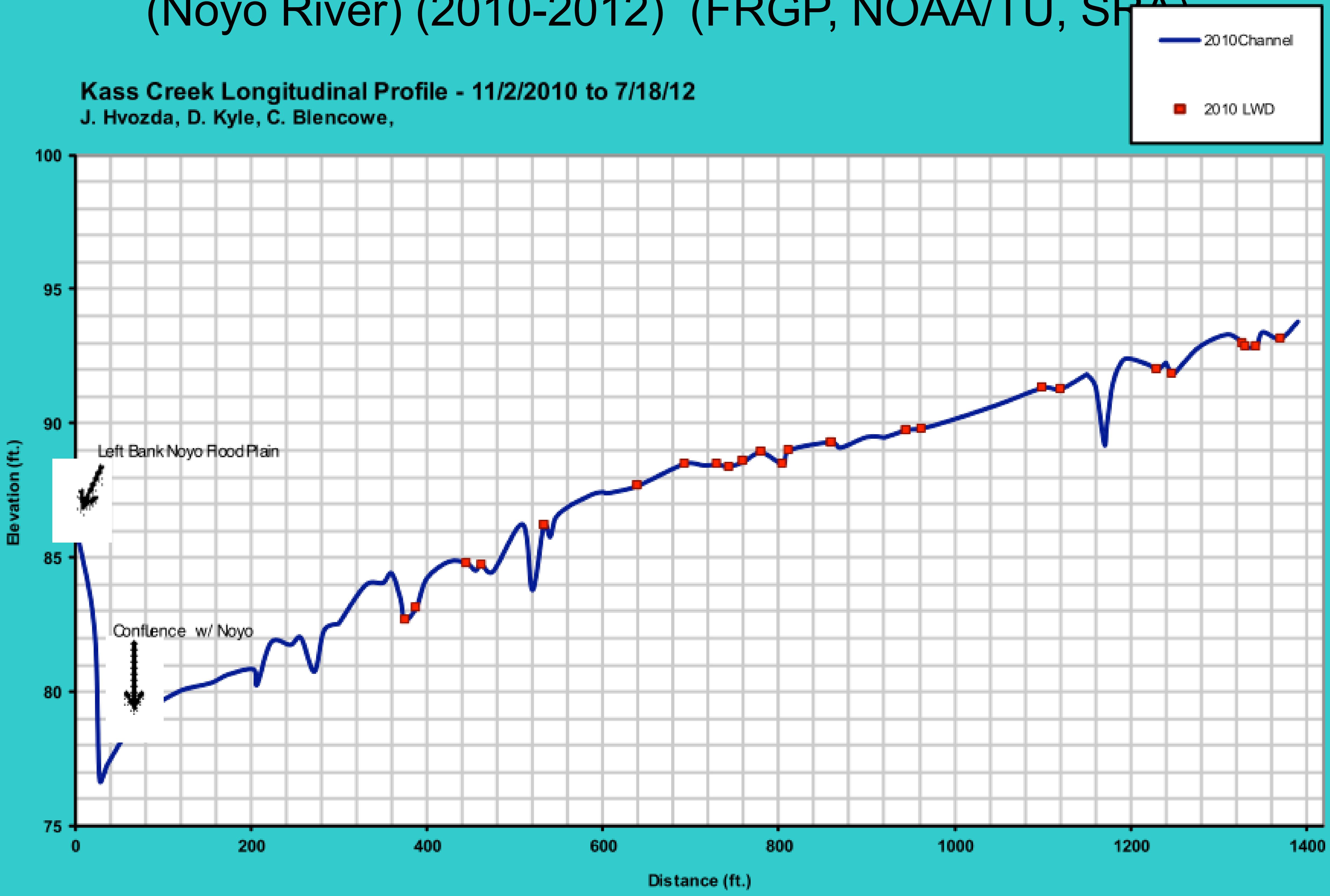
This was a survey of a lower 3.5 mile reach of the 2007 project area by Trevor Lucas et al (2012)

Summary of Percent Change in Key Habitat Variables in Six Mendocino County Streams

Percent Change in Several Key Variables in Six Mendocino County Streams After Project Implementatio)

	% Pools by Total Length	Total LWD (6'-19')	Total LWD (≥20')	Residual Pool Depths	# of Pools 3.0' - 3.9'	# of Pools ≥ 4.0'	Pool Shelter Rating	% shelter is LW	% shelter is SW
Signal Creek	38.0%	46.0%	113.0%	-4.0%	11.0%	33.0%	5.0%	81.0%	47.0%
SF Big River (Wegner Reach)	25.0%	22.0%	9800.0%	-11.0%	-30.0%	-33.0%	60.0%	1300.0%	2100.0%
LNF Big River	6.0%	10.0%	97.0%	4.0%	14.0%	50.0%	37.0%	12.0%	18.0%
Kass Creek (lower 1400 ft)	24.0%	13.0%	62.0%	0.0%	-100.0%	0.0%	24.0%	49.0%	24.0%
Lower Inman Creek	24.0%	123.0%	327.0%	3.0%	0.0%	100.0%	86.0%	277.0%	587.0%
NF Garcia	10.0%	-7.0%	152.0%	-9.0%	233.0%	0.0%	36.0%	78.0%	76.0%
Mean	21.2%	34.5%	1758.5%	-2.8%	21.3%	25.0%	41.3%	299.5%	475.3%
SD	11.6%	46.7%	3940.6%	6.2%	112.0%	46.8%	28.3%	498.7%	825.6%

Longitudinal Profile of Lower 1400’ Project Reach in Kass Creek (Noyo River) (2010-2012) (FRGP, NOAA/TU, SRA)



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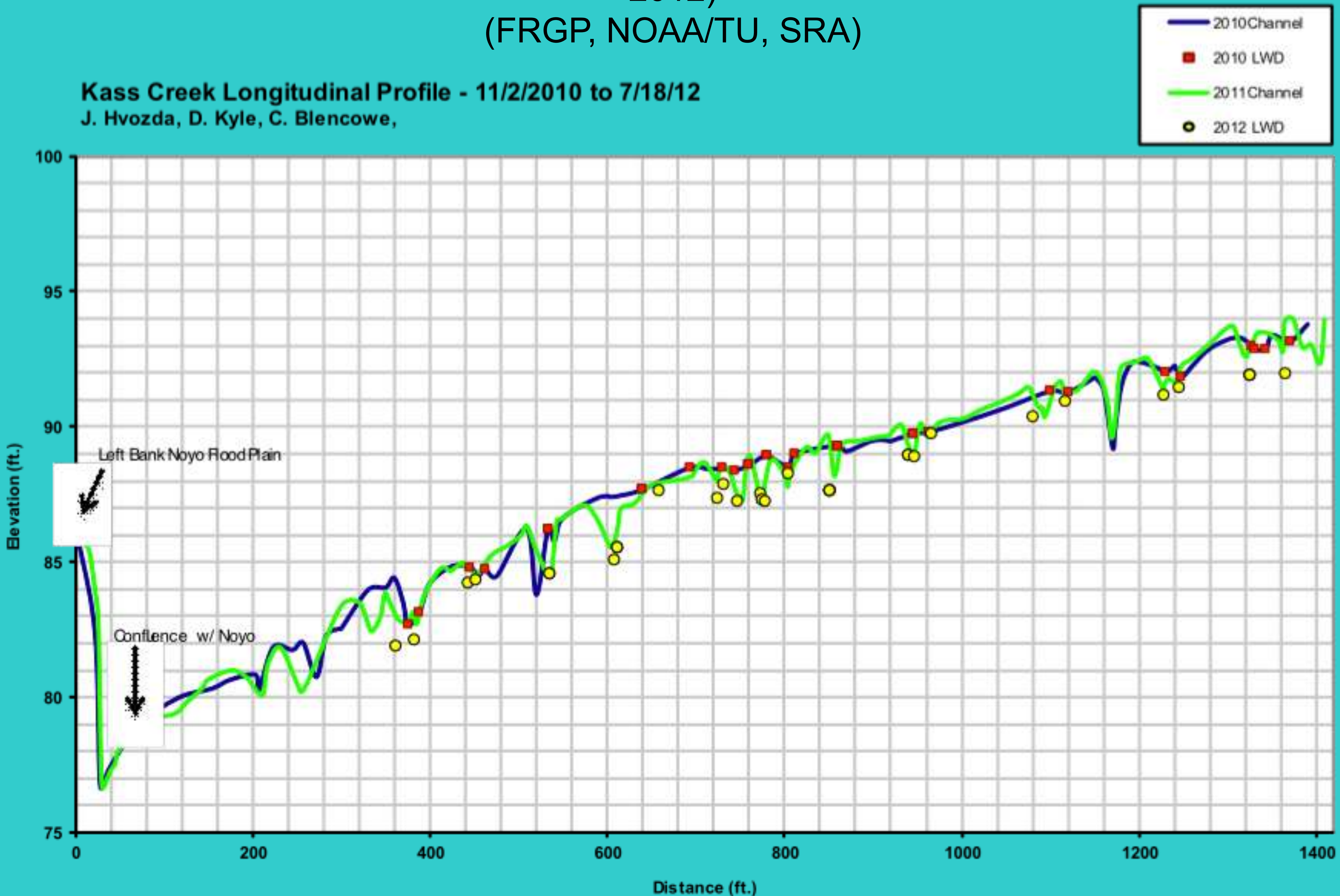
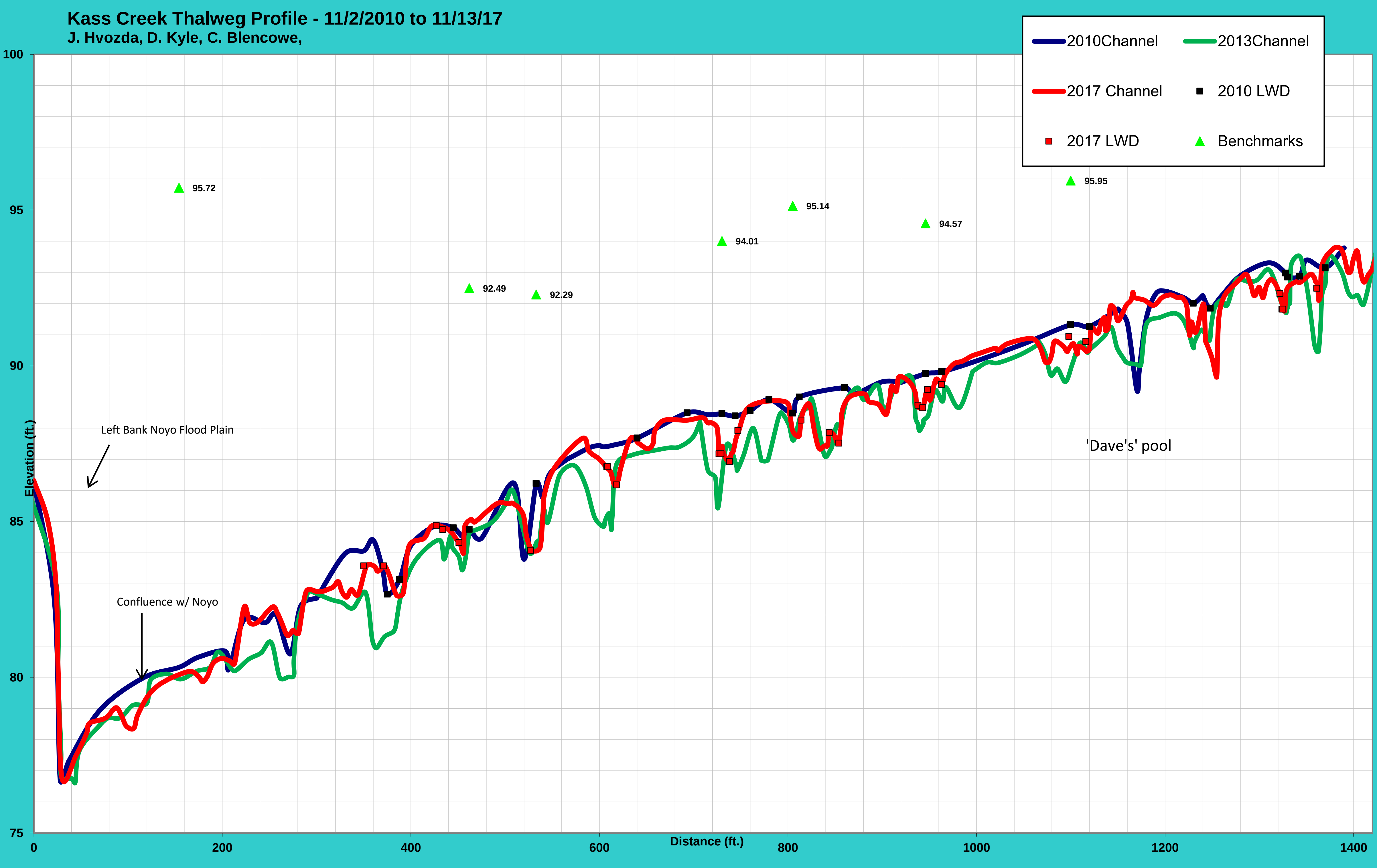


Longitudinal Profile of Lower 1400' Project Reach in Kass Creek (Noyo River) 2010 and 2013 and 2017 (FRGP, NOAA/TU, SRA)



Big Questions:

- How much wood is good?
- How much wood can we reasonably add to these watersheds without causing problems to the channels and without depleting the still young riparian corridor?

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- How much wood can we reasonably add to these watersheds without causing problems to the channels and without depleting the still young riparian corridor?
- Does wood actually make more fish? The biological component is missing.

The Pudding Creek Project: a BACI Study

- A partnership between Lyme Timber, CDFW, TNC, TU
- Six years of baseline data on coho life history metrics
- Approximately 80% of the fish bearing habitat will be treated using accelerated recruitment
- Caspar Creek, a similar watershed with a similar monitoring history, will be the control stream
- Changes in biological (e.g., spawner to smolt) and physical indices will be closely monitored for six years after treatment

Limitations/Applicability

- Landowners with large holdings, lots of trees and little risk to infrastructure
- The 18 largest landowners own 81% of the properties in Mendocino County's CCC ESU Coho Core Areas

Limitations/Applicability

- Bankfull widths up to 50 feet
- Direct falling best in 20’-30’ bankfull
- Low gradient alluvial streams
- Willing, supportive landowners

- Avoid deeply entrenched, flashy high volume channels

Low-Cost Restoration Techniques for Rapidly Increasing Wood Cover in Coastal Coho Salmon Streams

Jennifer K. Carah[a], Christopher C. Blencowe[b], David W. Wright[c] & Lisa A. Bolton[d]

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ARTICLE

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Abstract

Like many rivers and streams in forests of the Pacific Northwest, California north coast rivers and streams have been depleted of downed wood through timber harvest and direct wood removal. Due to the important role of wood in creating and maintaining salmonid habitat, wood augmentation has become a common element of stream restoration. Restoration efforts in North America often focus on building anchored, engineered wood structures at the site scale; however, these projects can fail to meet restoration goals at the watershed scale, do not closely mimic natural wood loading processes or dynamics, and can be expensive to implement. For critically imperiled populations of Coho Salmon *Oncorhynchus kisutch* in California, there is a strong impetus to achieve as much habitat restoration as possible in priority watersheds in the shortest time and with limited resources, so cost-efficient techniques are necessary. In this multi-site project, we investigated unanchored techniques for wood loading to evaluate cost and contribution to salmonid habitat in Mendocino County, California. Over a period of 6 years, 72.4 km of stream were treated with 1,973 pieces of strategically placed wood. We found that unanchored wood loading techniques were much less costly than commonly used anchored techniques, reliably improved habitat, and retained wood at high rates (mean = 92%) in small- to moderate-sized streams, at least over the short term (<6 years). The average cost of design and construction for the unanchored projects was US$259 per log, equivalent to 22% of the cost associated with the anchored wood augmentation methods examined here. Our results suggest that this unanchored wood loading approach has the potential to increase the pace and scale at which wood augmentation projects are implemented in the Pacific Northwest and beyond.

Downed wood plays an essential role in stream morphology and productivity, particularly in salmon-bearing streams of the Pacific Northwest (House and Boehne 1986; Bisson et al. 1987; National Research Council 1996; Abbe et al. 2003a) and northern California (Keller et al. 1981; Lisle 1986; Lassettre and Harris 2001). Wood influences instream erosion and deposition processes by locally altering water velocities and shear stress (Lisle 1986; Abbe and Montgomery 1996). These processes trap sediments, increase bar and other depositional features, provide gravels necessary for salmon spawning, and increase floodplain development and connectivity (Lisle 1986; Bisson et al. 1987; Fetherston et al. 1995). Wood can increase scour in other areas, creating slow-water habitats like pools, backwaters, and side channels, thus providing both oversummer and overwinter

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- Scott Monday, DFW
- Jonathan Warmerdam, NCRWQCB
- Jen Carah, TNC
- All other project partners

Salmonid Restoration Federation 2018

Restoring Wood's Essential Roll in Controlling Channel Grade and Stability in Small Streams

Cedar Creek, Jedediah Smith State Park, California

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Arcata, California

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Michael Love & Associates

Hydrologic Solutions

Presentation Outline

1. Role of large wood in controlling profiles of streams
2. Causes and Process of channel incision in historically wood controlled streams
3. Impact of incision on geomorphic stability, water quality, and aquatic habitat
4. Identifying channel incision
5. Restoration of incised channels through reintroduction of wood

Large Wood in Small Streams

Clarks Creek, Jedediah Smith State Park, California

Geomorphic Role of Large Wood in Small Mountain Streams

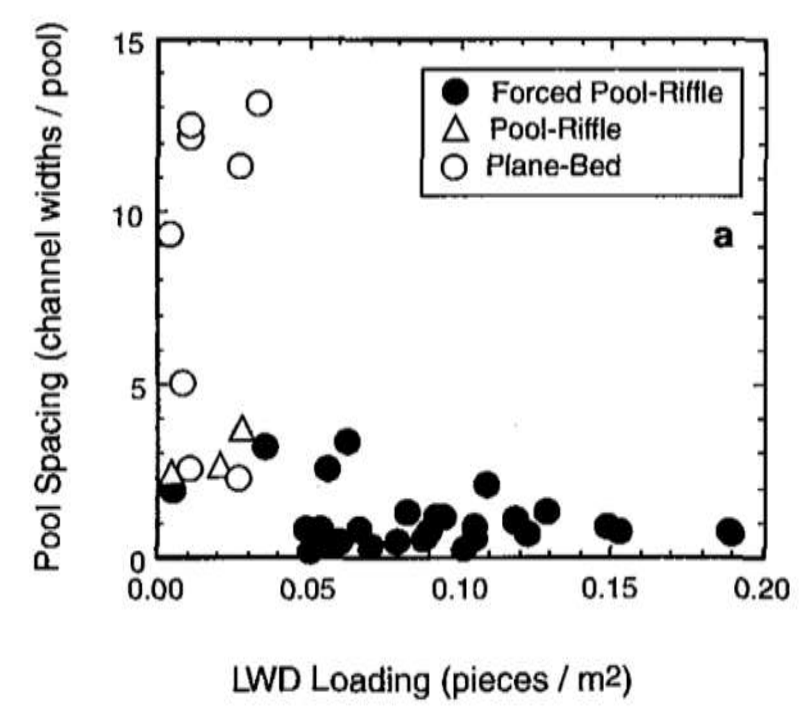
- ✓ Racks smaller wood & traps sediment
- ✓ Raises/maintains channel bed elevation
- ✓ Promotes connectivity to benches/floodplain
- ✓ Forces overall profile of the channel
- ✓ Scours pools and sorts bed material
- ✓ Slows the flow and raises groundwater
- ✓ Provides long-term structural controls

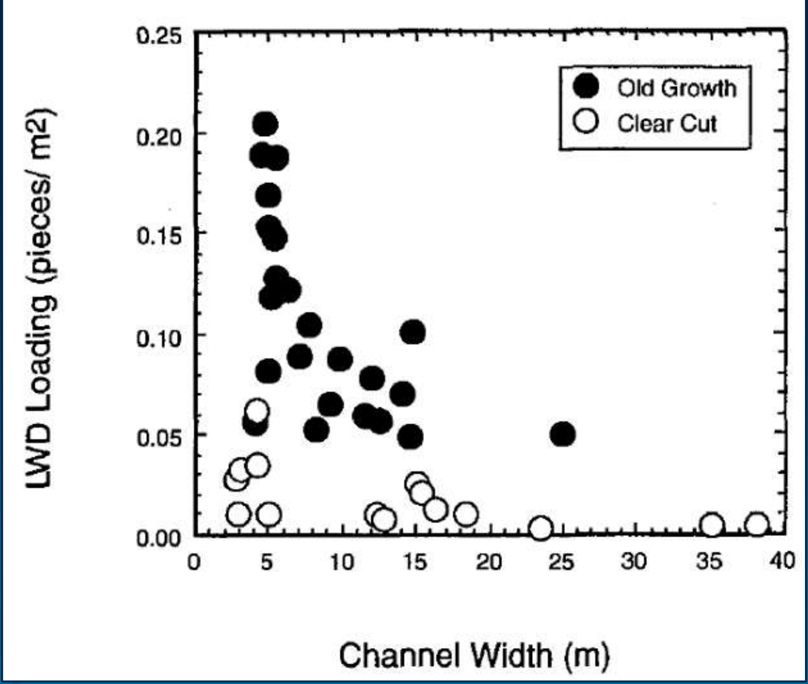
Wood Forced Morphologies in Mountain Streams

Montgomery & Buffington (1997):

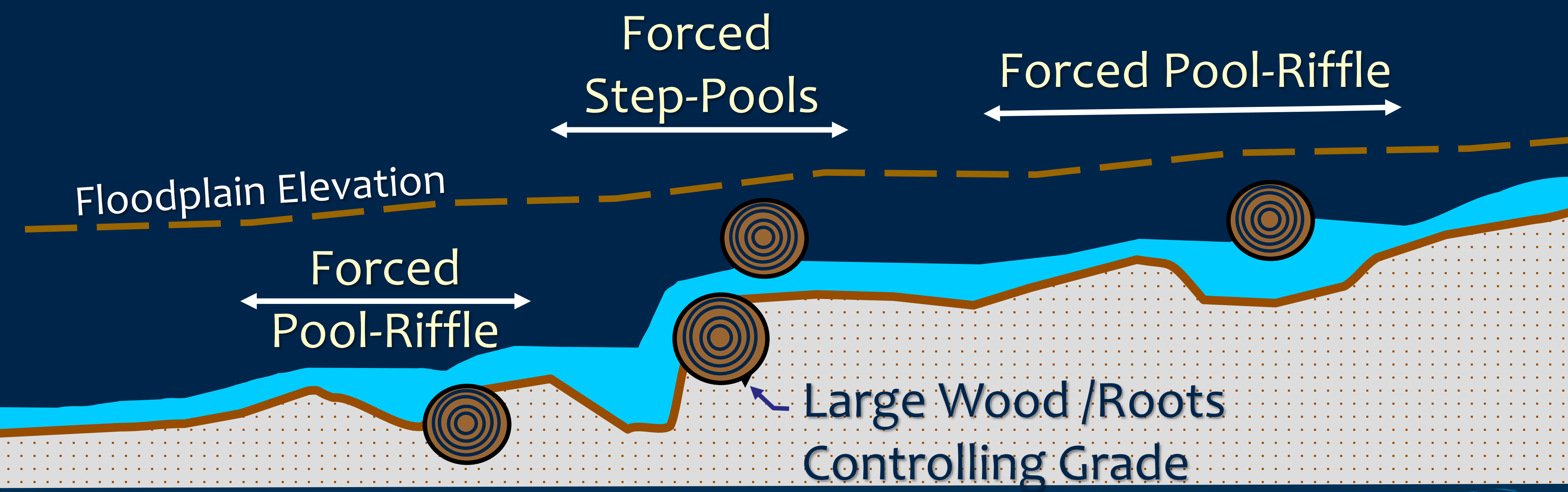
- Wood obstructions force the channel morphology and slope
- Wood forced pool-riffle and step-pool channels most common
- Wood forced morphologies can maintain steeper gradients than their analogous free-formed morphologies

From Montgomery et al. (1995) >>





Wood-Forced Channel Morphology in Mountain Drainage Basins



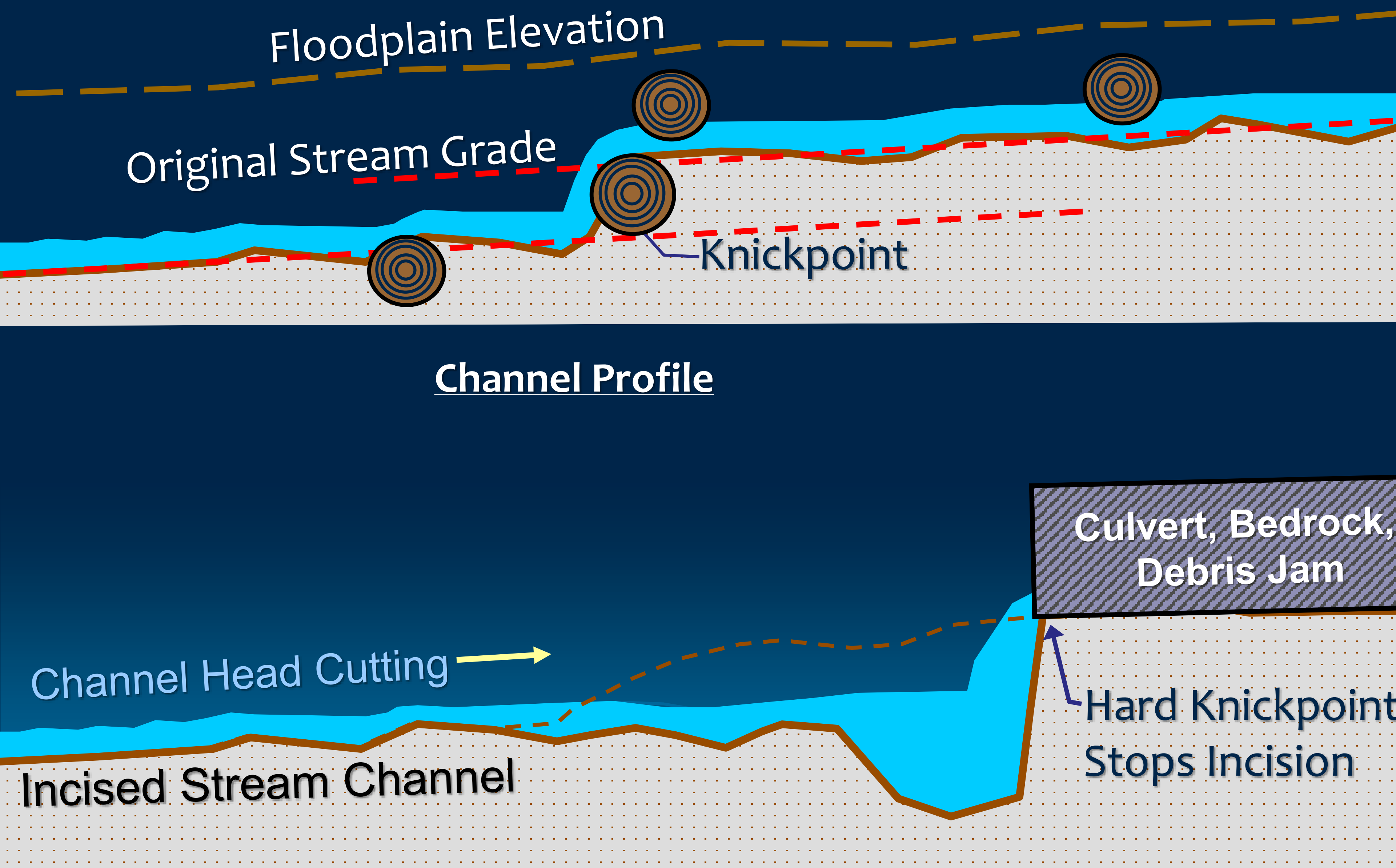
Wood Forced Channel Profile

Large Wood in Small Streams

Dunn Creek, coastal northern Mendocino County

Process of Incision Following Wood Removal

Headward Migration



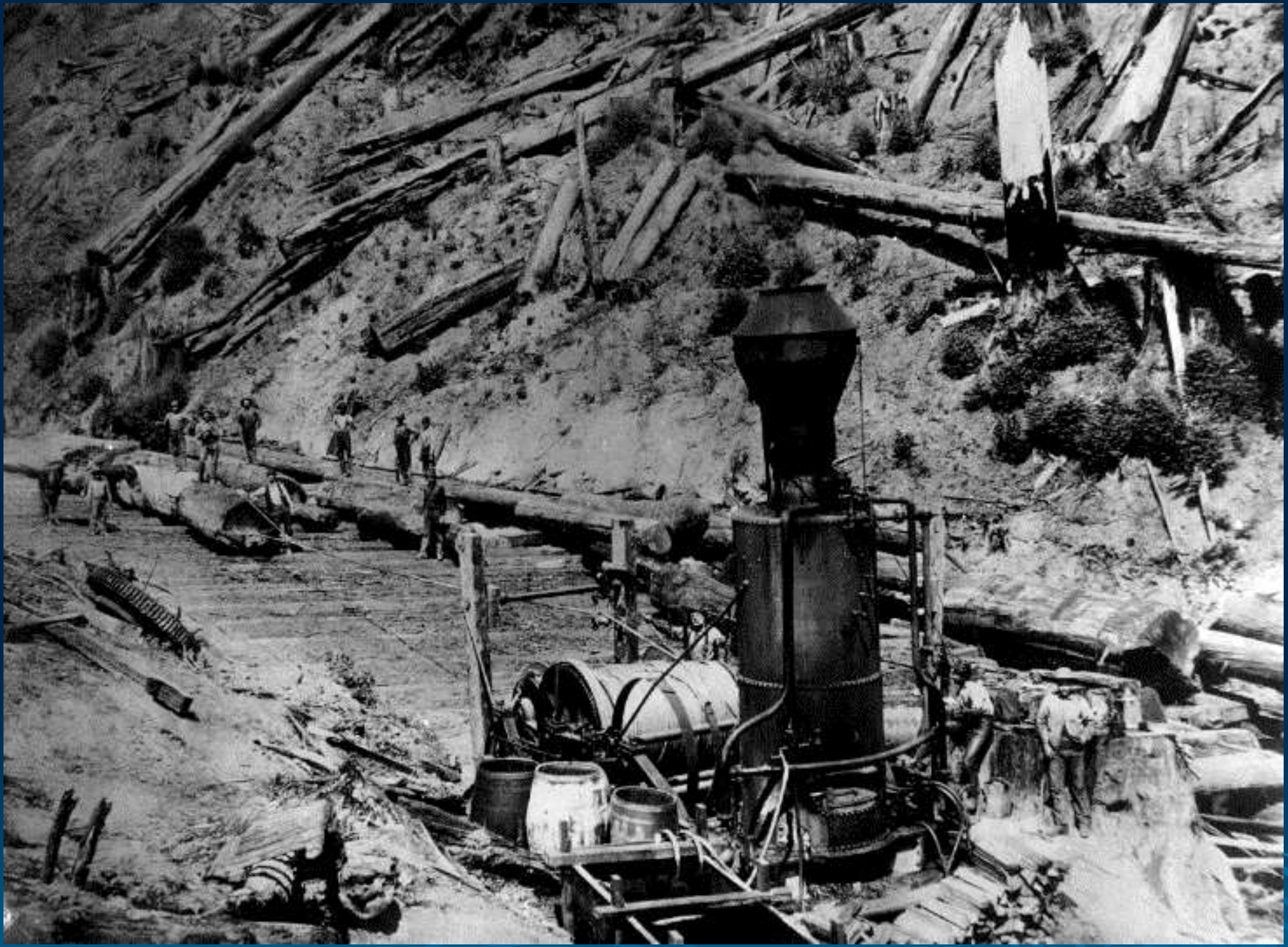
Arrested Kickpoints

Loss of Wood Controls

Causes

- Old-growth wood removed as part of historical logging
- Tractor logging in channels
- “Stream cleaning” to remove debris jams, fish passage, flood conveyance
- Fire burns in-channel wood
- Lack of riparian wood recruitment

Historical Logging in Stream Beds



Logging using Corduroy and Steam Donkey in Tributary to Big River
Mendocino County, CA

From KRIS

Stream Cleaning

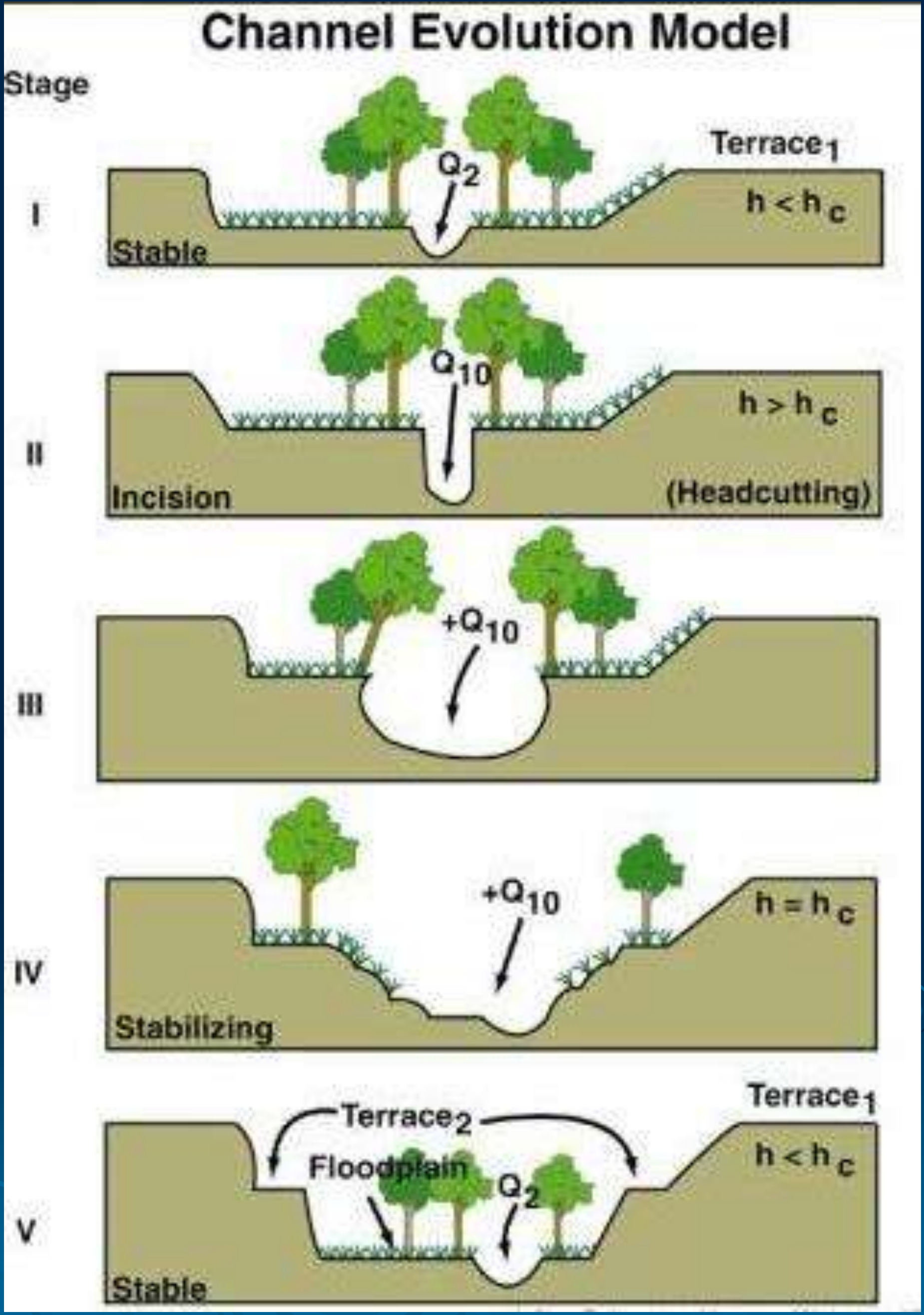
Gulch C, Tributary to Noyo River
Mendocino County, CA

Incising Channel 100-years Later

Logged circa 1916 by Rail
Manly Gulch, Trib. to Little North Fork Big River
Mendocino County, CA

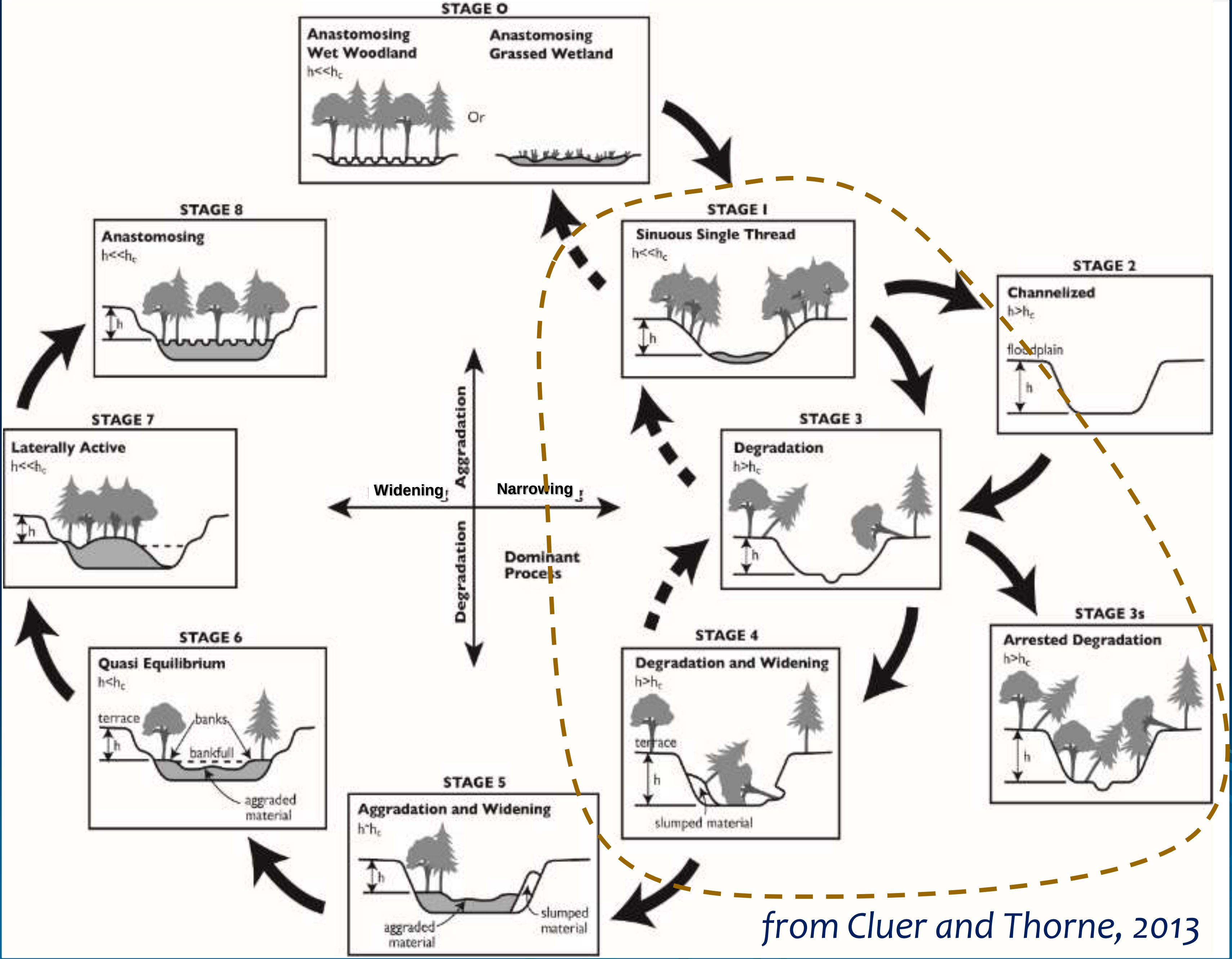
Channel Evolution Model (CEM)

Stage III: Incised and Widening



from Schumm, Harvey, and Watson. 1984.

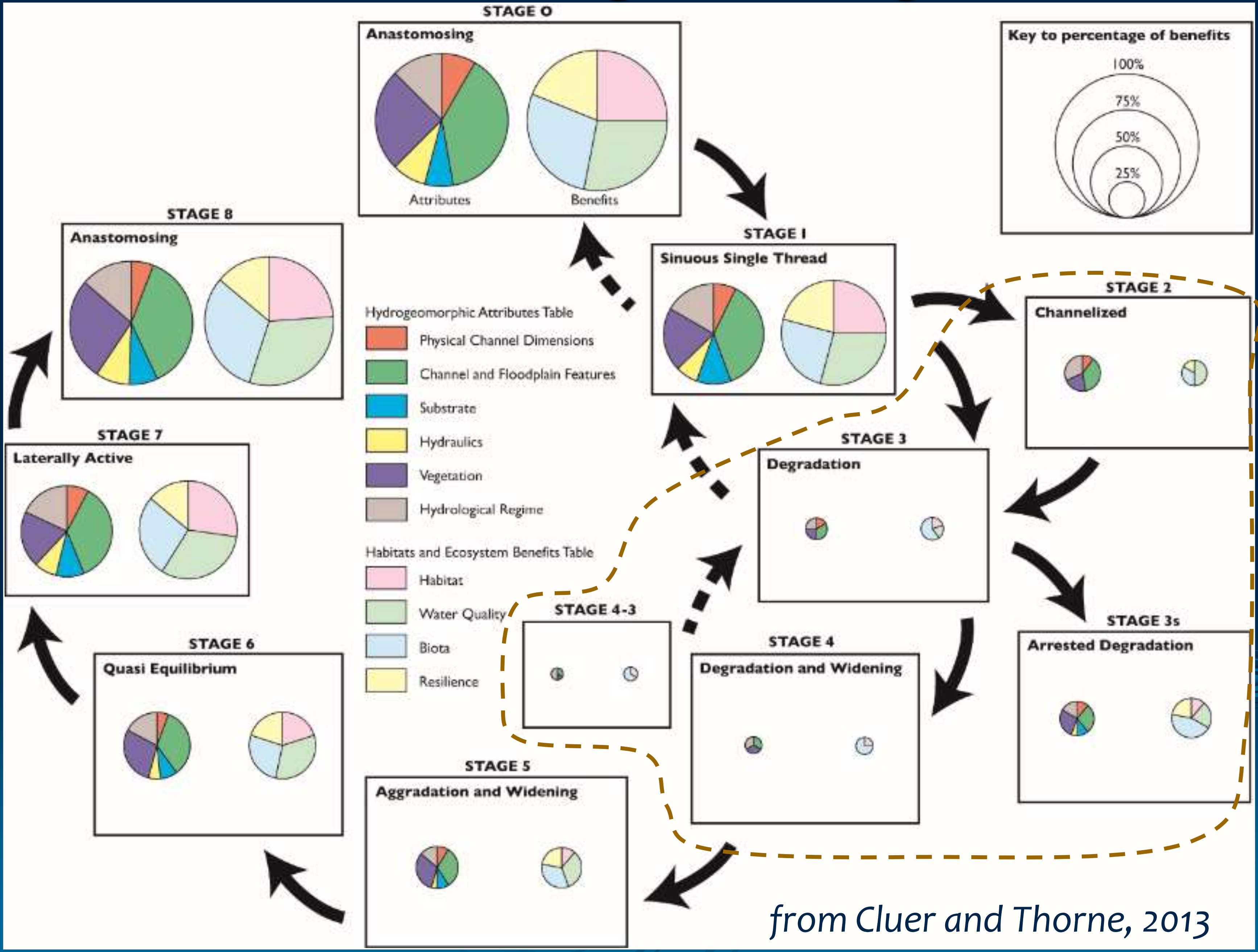
Stream Evolution Model (SEM)



from Cluer and Thorne, 2013

Multiple Paths
Dead Ends

Stream Evolutionary Stage vs. Ecological Benefits



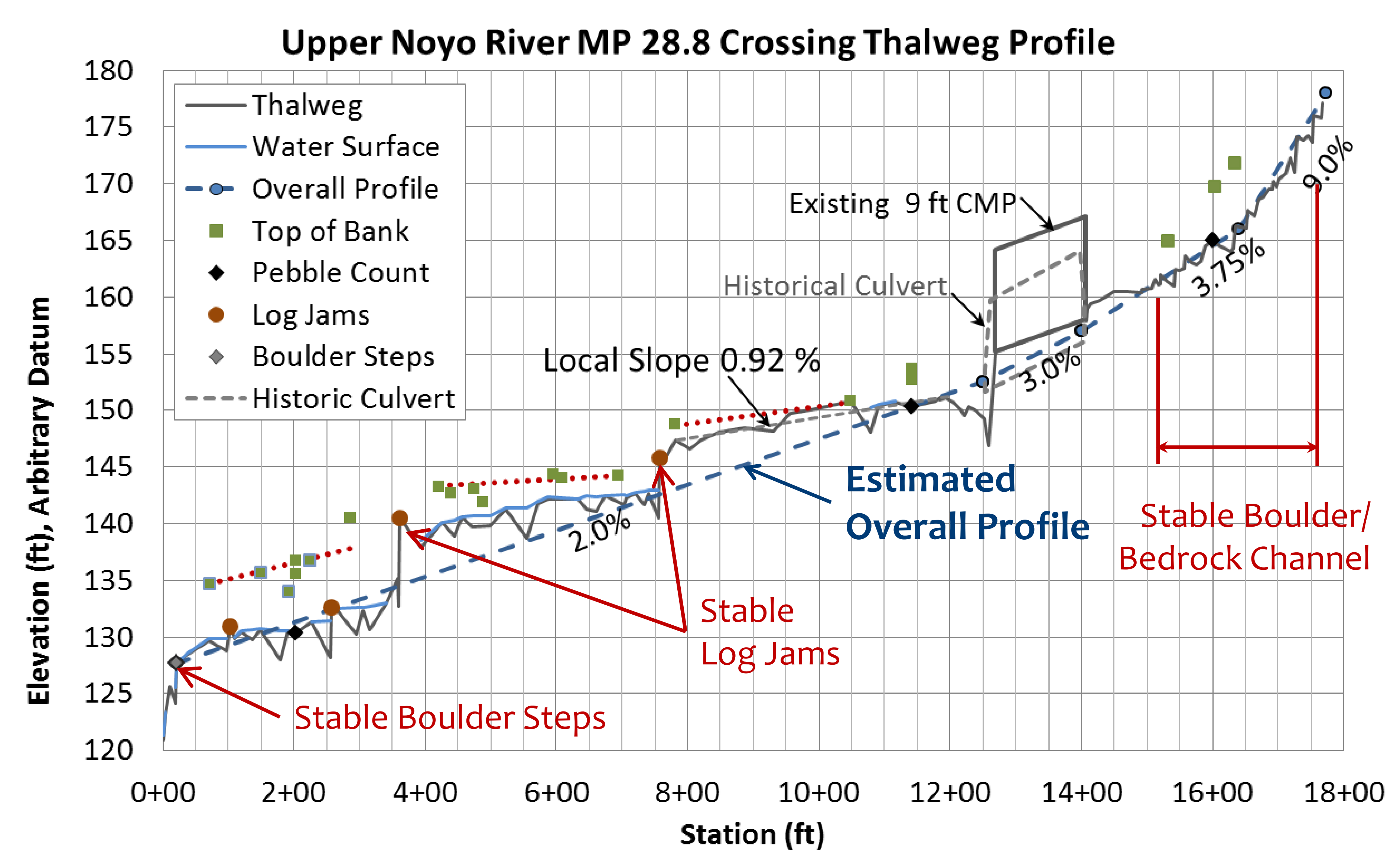
from Cluer and Thorne, 2013

The Stream Channel Incision Syndrome
Loss of Habitat and Ecosystem Benefits

"We conclude channel incision presents a syndrome that is characterized by perturbed hydrology, degraded physical habitat, elevated nonpoint source pollution, and depleted fish species richness and that is extremely deleterious to instream ecosystem services."

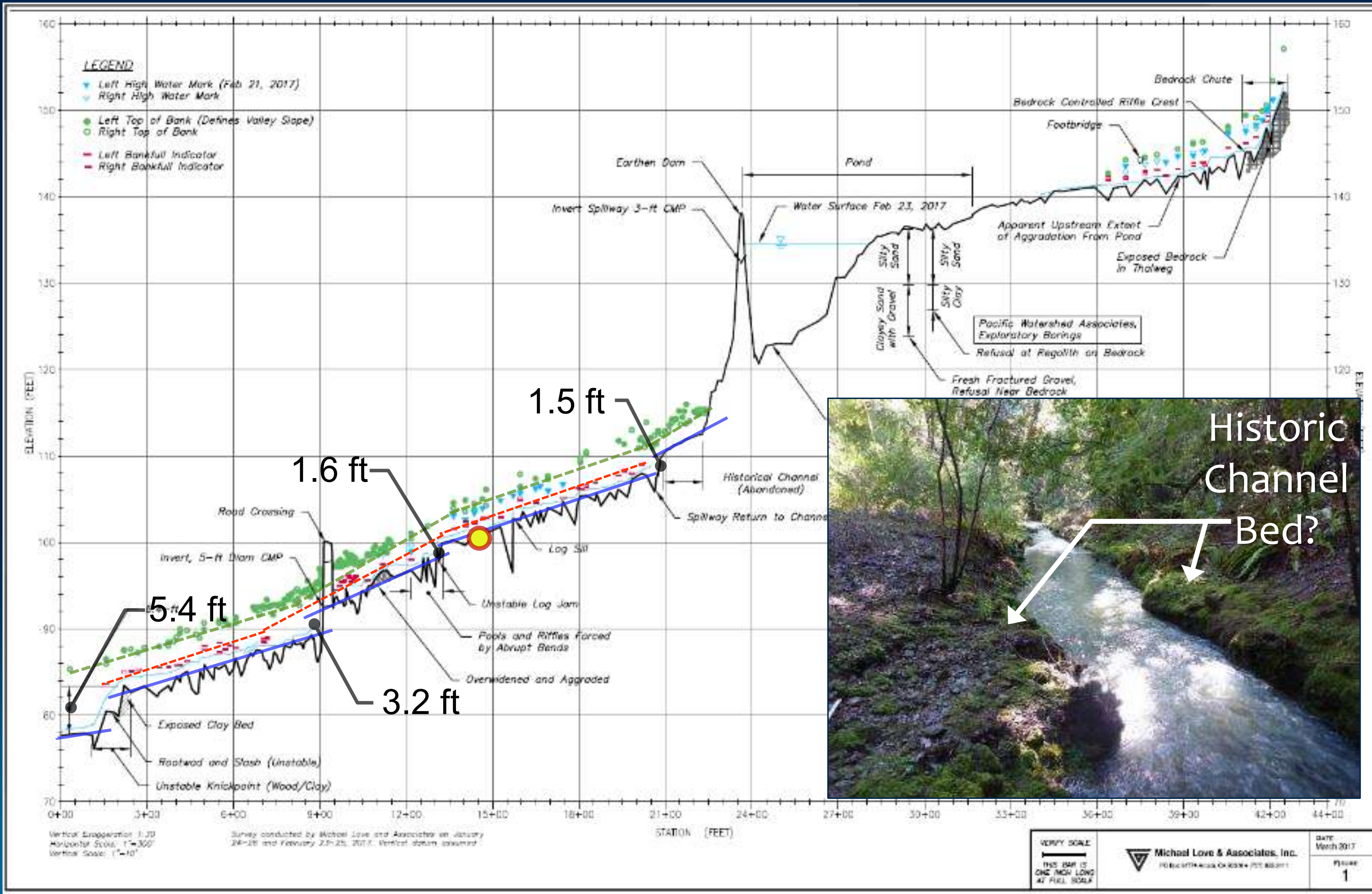
Shields et al. 2010. *The stream channel incision syndrome and water quality.* Journal of Ecological Engineering

Identifying Incision Using Channel Profile Analysis



No Incision Evident. Wood Controlling Channel Profile from 0+25 to Culvert

Combined Field and Thalweg Profile Interpretation
Neefus Gulch – Navarro River Watershed

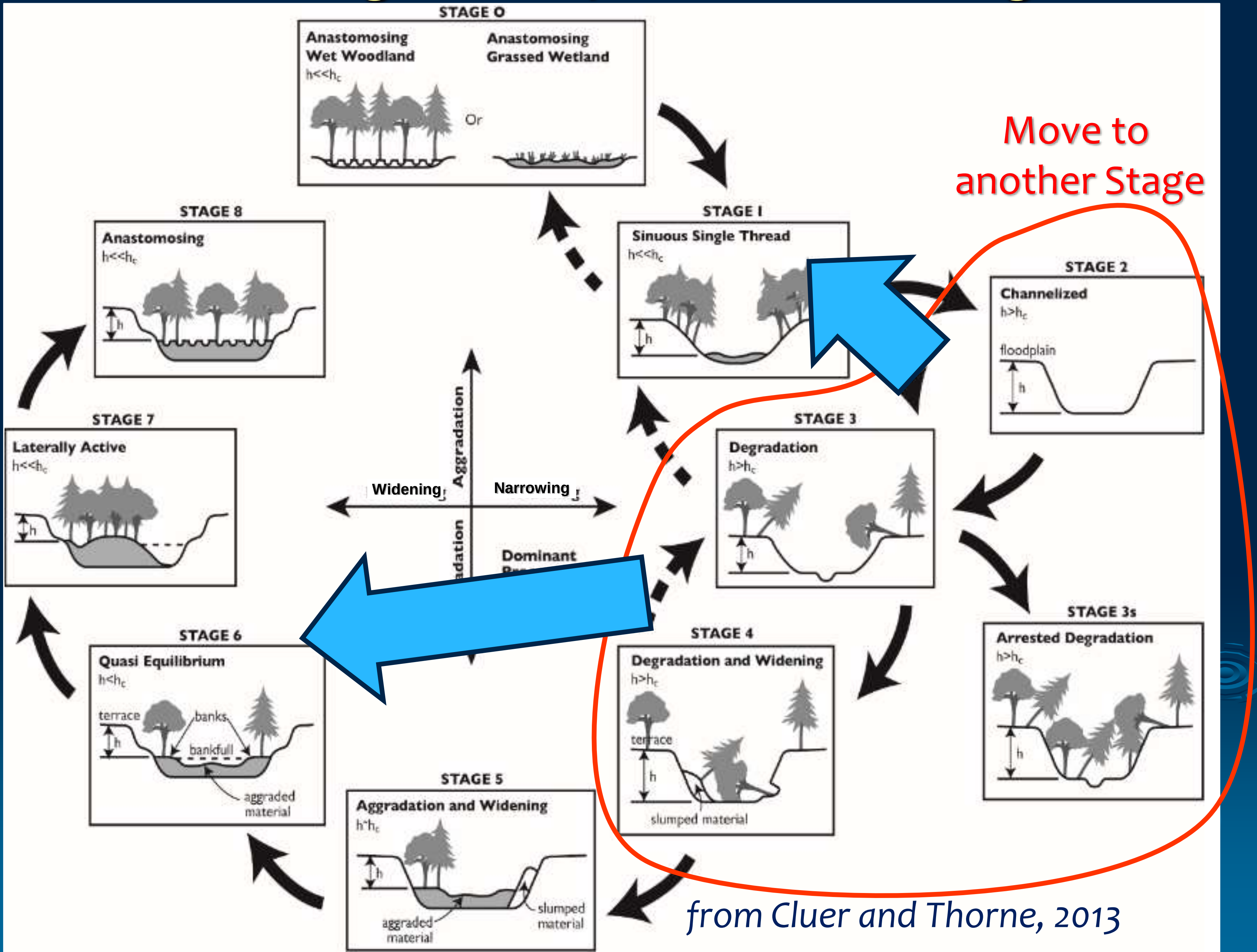


Other Channel Incision Indicators

- **Lack of Sediment Deposition**
  Erosion of channel bed down to
  bedrock or other resistant soil layers
- **Toe of Bank is Vertical**
  Exposed roots, lack of sediment layering at
  streambed-banks interface
- **Actively Widening**
  Active bank failures, low depositional bars
- **Lack of Pools**
  Long reaches of riffles/runs without pools
- **Cultural Features Exposed**
  Perched culverts or exposed
  bridge footings, aprons, and pipelines

List adapted from J. Castro, 2003

Restoring Stability – Choose a Stage



from Cluer and Thorne, 2013

Restoring Incised Channels and Connectivity

Placing Wood - Profile Restoration

Baker Creek
Sanctuary Forest

photos: Sam Flanagan, BLM

Profile Restoration
Outlet Creek
Washington State

Upstream of Culvert
No Incision Experienced >>

<< Downstream of Perched Culvert Crossing was Incised to "Hardpan"

Photos from Kozmo Bates

Profile Restoration
Outlet Creek

- Large Wood Placed to Trap Small Wood and Retain Bedload
- Raised Channel Bed to Pre-Incision Elevation
- Constructed 2000; Photos from 2005

Photos from Kozmo Bates

Incising Channel 100-years Later

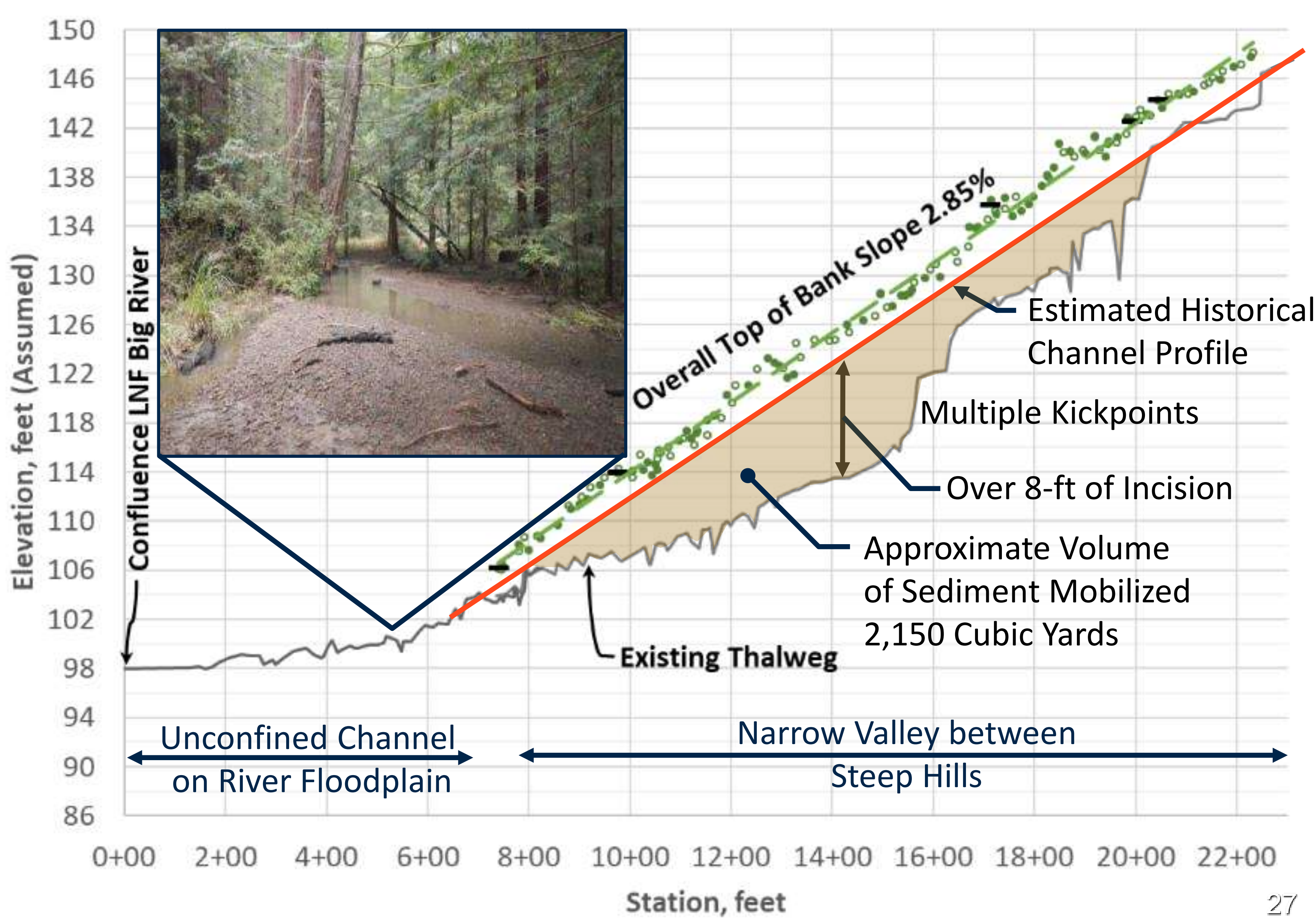
Logged circa 1916 by Rail
Manly Gulch, Trib. to Little North Fork Big River
Mendocino County, CA

Historical Logging in Stream Bed
Manly Gulch?

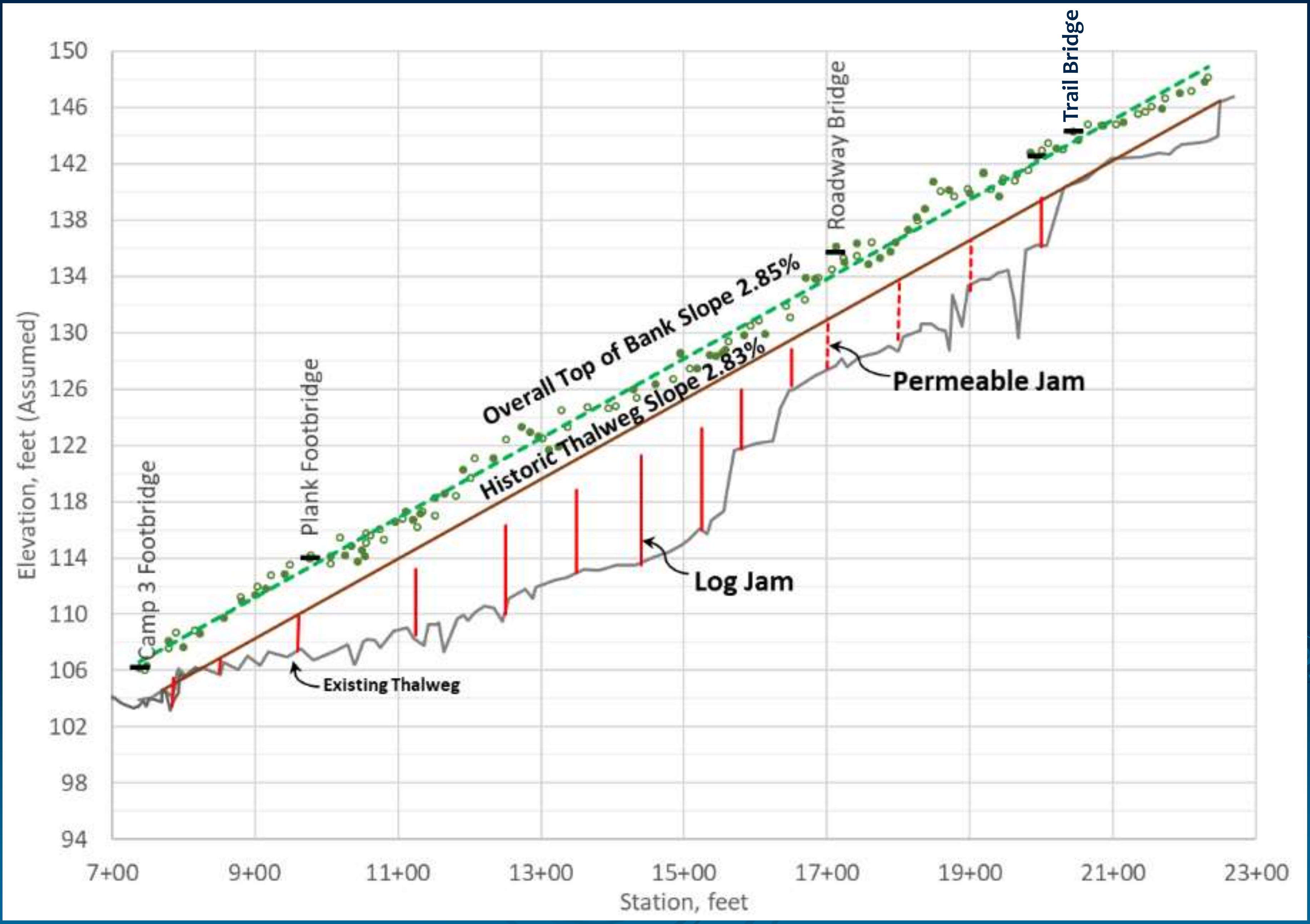
Logging by Rail in Tributary to Little North Fork Big River
Mendocino County, CA

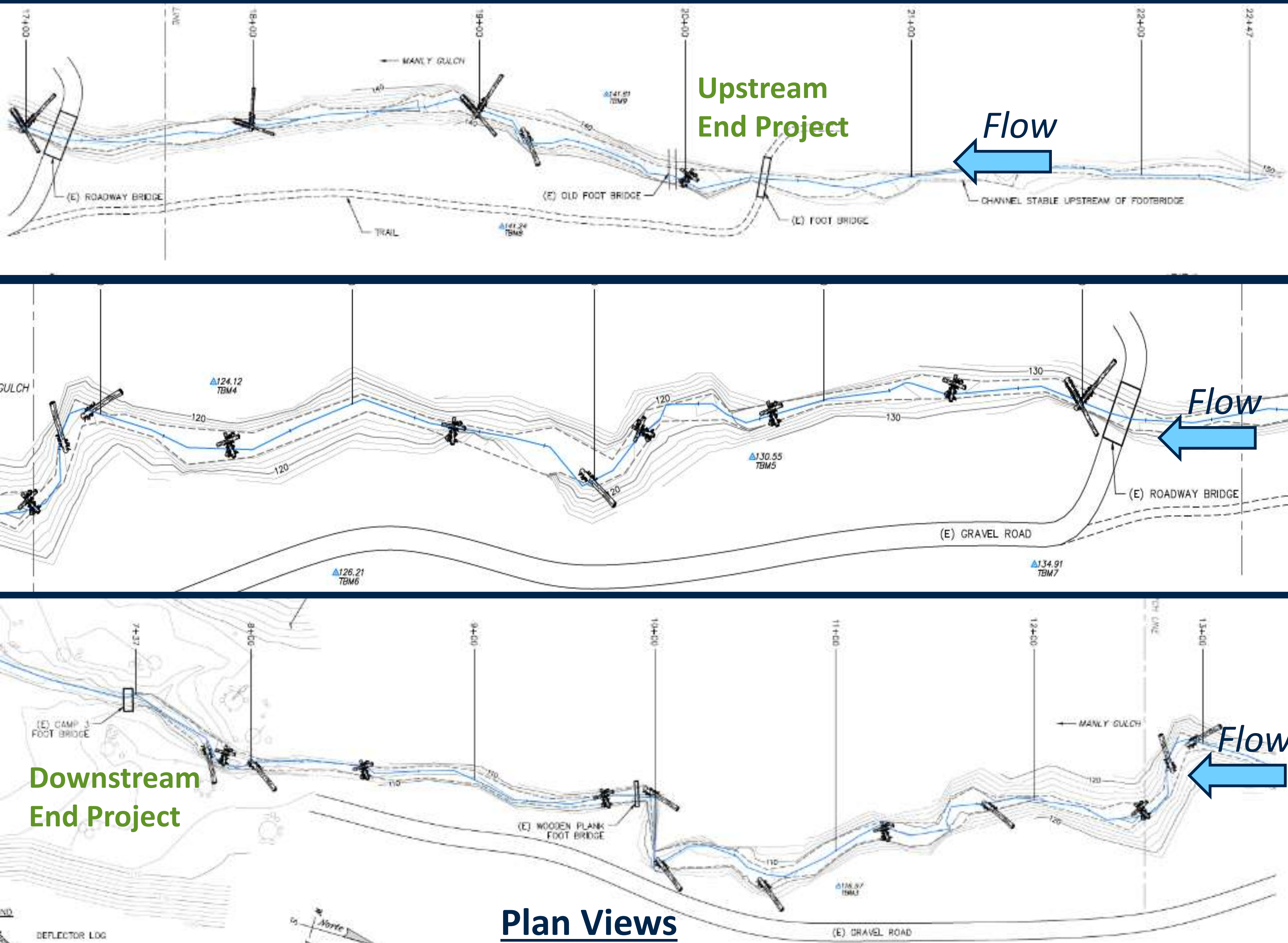
From KRIS

Manly Gulch Incising Channel Profile

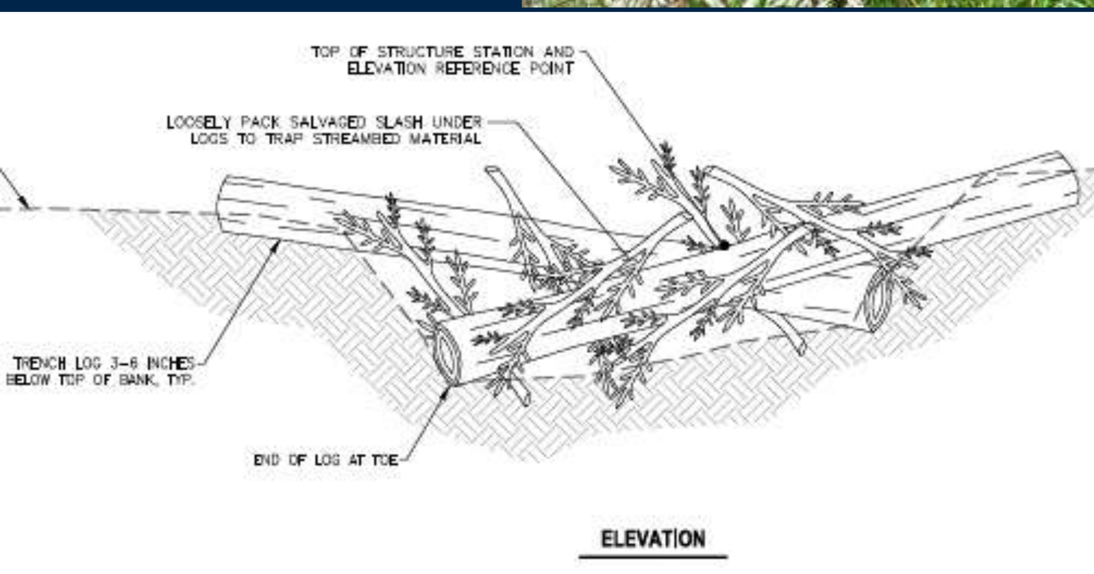


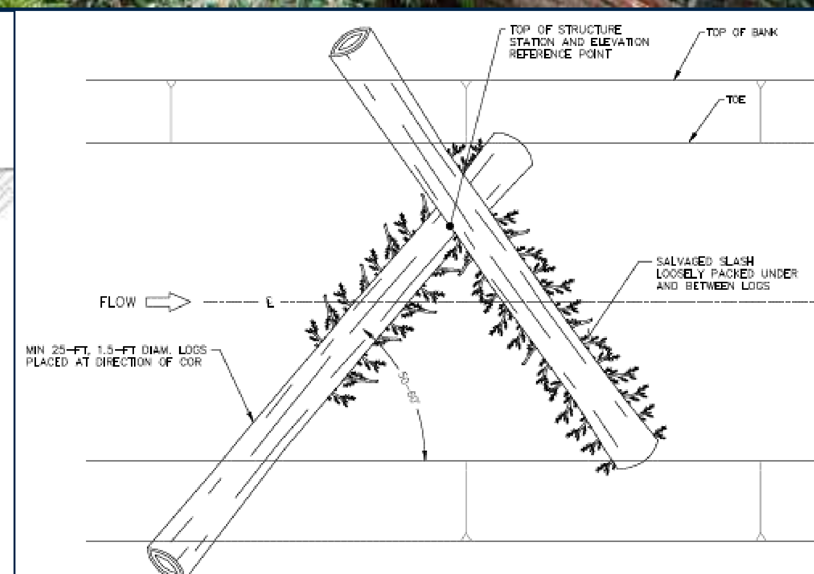
Manly Gulch Channel Profile Restoration Design

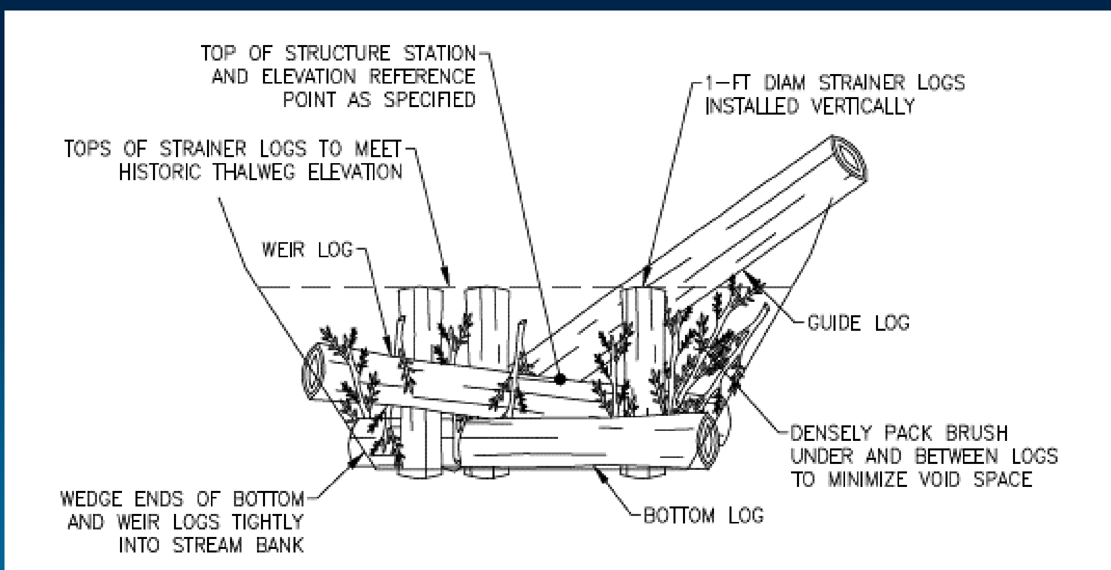



Upstream
End Project
Flow
(E) ROADWAY BRIDGE
TRAIL
(E) OLD FOOT BRIDGE
(E) FOOT BRIDGE
CHANNEL STABLE UPSTREAM OF FOOTBRIDGE
MANLY GULCH
Flow
(E) ROADWAY BRIDGE
(E) GRAVEL ROAD
Flow
Downstream
End Project
(E) CAMP 3 FOOT BRIDGE
(E) WOODEN PLANK FOOT BRIDGE
MANLY GULCH
(E) GRAVEL ROAD
DEFLECTOR LOG

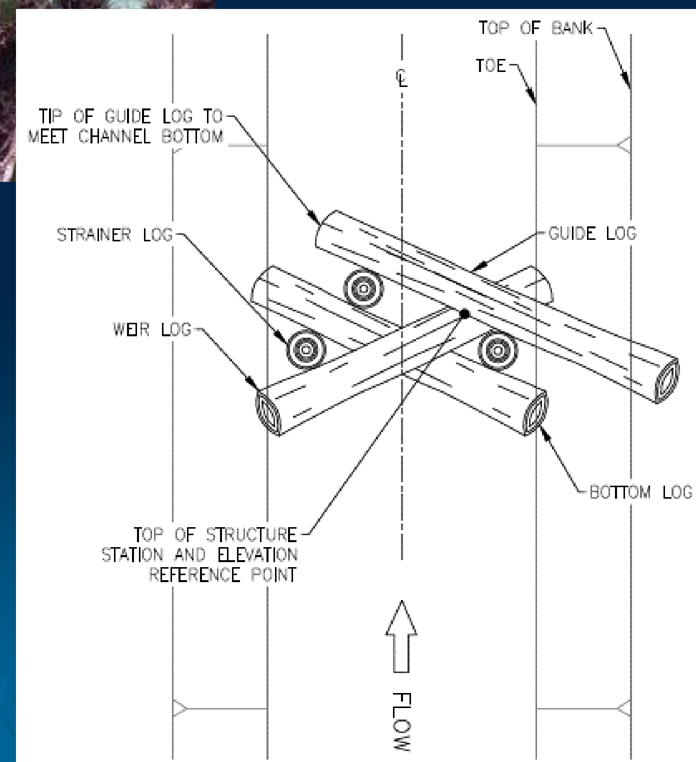
Plan Views


TOP OF STRUCTURE STATION AND
ELEVATION REFERENCE POINT
LOOSELY PACK SALVAGED SLASH UNDER
LOGS TO TRAP STREAMBED MATERIAL
TRENCH LOG 3-6 INCHES
BELOW TOP OF BANK, TYP.
END OF LOG AT TOE
ELEVATION

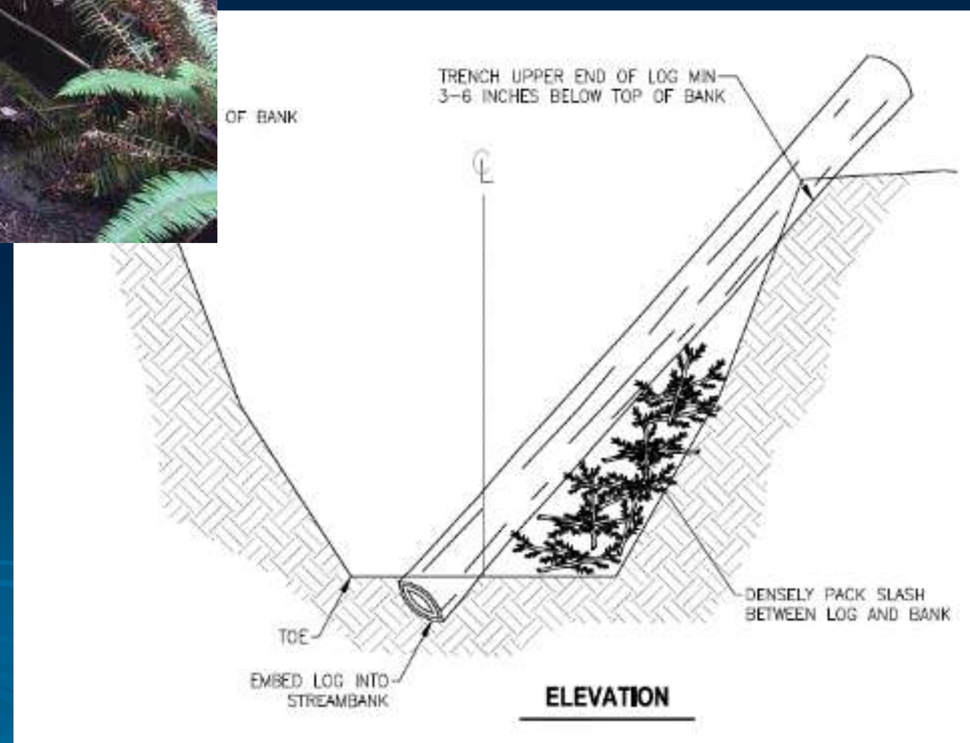

TOP OF STRUCTURE
STATION AND ELEVATION
REFERENCE POINT
TOP OF BANK
TOE
SALVAGED SLASH
LOOSELY PACKED UNDER
AND BETWEEN LOGS
FLOW
MIN 25-FT, 1.5-FT DIAM. LOGS
PLACED AT DIRECTION OF COR



TOP OF STRUCTURE STATION AND ELEVATION REFERENCE POINT AS SPECIFIED
1–FT DIAM STRAINER LOGS INSTALLED VERTICALLY
TOPS OF STRAINER LOGS TO MEET HISTORIC THALWEG ELEVATION
WEIR LOG
GUIDE LOG
DENSELY PACK BRUSH UNDER AND BETWEEN LOGS TO MINIMIZE VOID SPACE
WEDGE ENDS OF BOTTOM AND WEIR LOGS TIGHTLY INTO STREAM BANK
BOTTOM LOG



TOP OF BANK
TOE
℄
TIP OF GUIDE LOG TO MEET CHANNEL BOTTOM
STRAINER LOG
GUIDE LOG
WEIR LOG
BOTTOM LOG
TOP OF STRUCTURE STATION AND ELEVATION REFERENCE POINT
FLOW



TRENCH UPPER END OF LOG MIN 3–6 INCHES BELOW TOP OF BANK
OF BANK
TOE
EMBED LOG INTO STREAMBANK
DENSELY PACK SLASH BETWEEN LOG AND BANK
ELEVATION

Summary

- Large wood in small streams controls the channel morphology and profile
- Loss of wood controls results in
  - Dramatic incision & channel instabilities,
  - Delivery of large volumes of sediment to downstream
  - Degradation of Habitat
- Determine depth & extent of incision and current SEM stage using annotated channel profile surveys & field interpretation
- Adding high densities of large wood to small streams may restore the channel profile, improve downstream water quality, and restore fisheries habitat

Questions?

Salmonid Restoration Federation 2018 Large Wood Technical Field School

How to Keep Your Wood From Floating Downstream: Interactive Computations for Stability of Large Wood Structures

Rachel Shea P.E.

Arcata, California

shea@h2odesigns.com

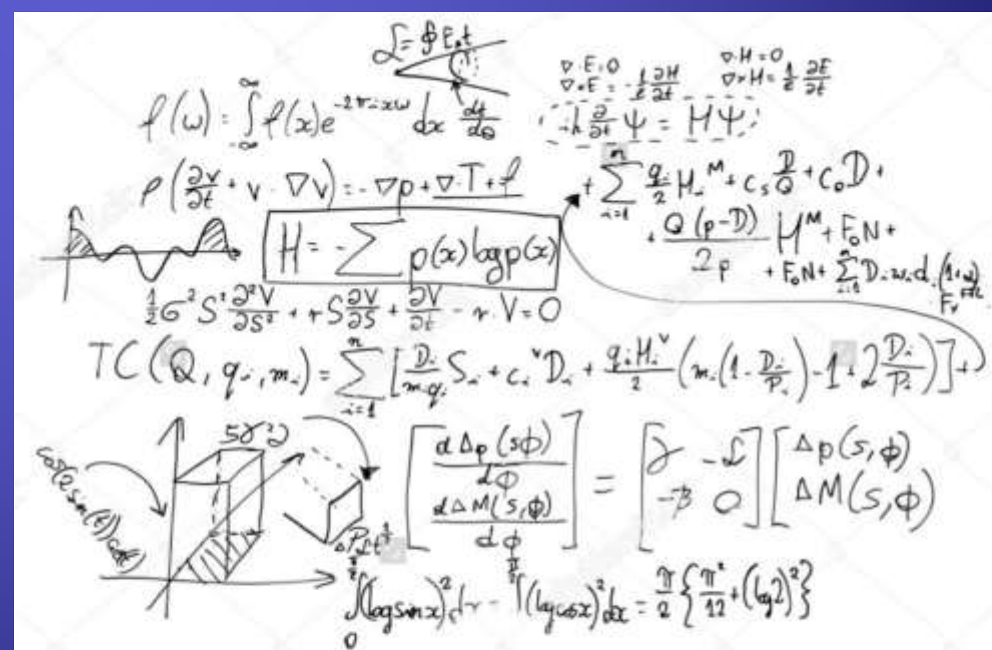
707-822-2411

Michael Love & Associates

Hydrologic Solutions

Purpose of Presentation

1. Understand the basic forces on in-stream large wood
2. Give you basic computational tools
3. Understand some of the uncertainties



Presentation Outline

1. Driving and resisting factors on log structures
2. Sample calculations for stability against buoyancy
3. Hands-on computations for 4 different scenarios (groups)
4. Review of computations and discussion
5. TEST
6. References

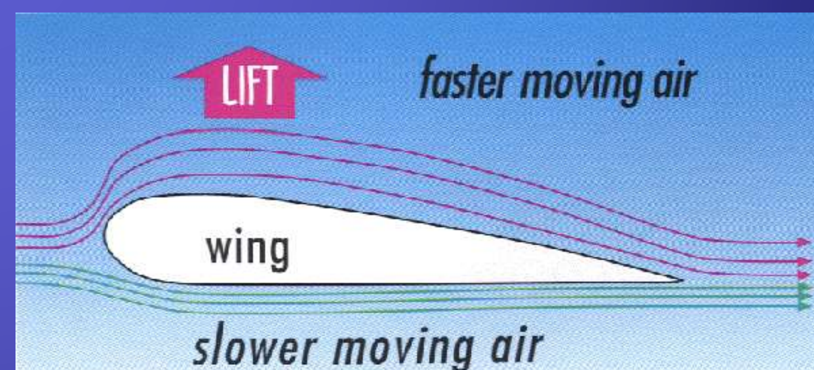
Driving Forces on Logs

Vertical

1. Buoyancy
2. Lift

Horizontal

1. Drag
2. Overturning



Resisting Forces on Logs

Vertical

1. Weight of logs
2. Weight of soil
3. Ballast (Rocks, etc)

Vertical and Horizontal

1. Posts/Piles
2. Active/passive earth pressure

Is it Stable?

Resisting Forces vs Driving Force

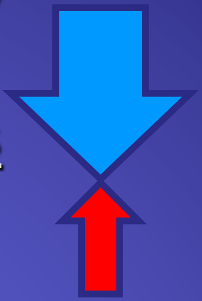
VS

Not Stable

- Stable when Resisting Forces are Greater than Driving Forces
- Factor of Safety

Factor of Safety

$$\textbf{FS} = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$



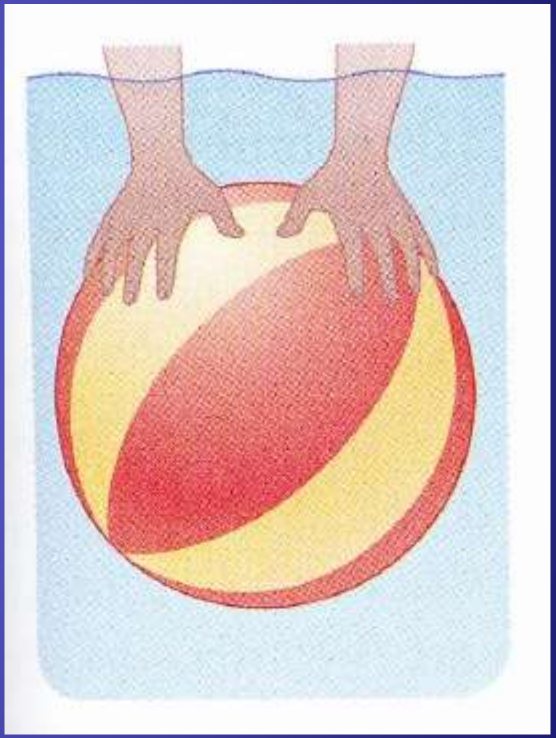
- Stable when FS > 1
- Risk Analysis and Selection of FS….

Buoyancy

Buoyancy

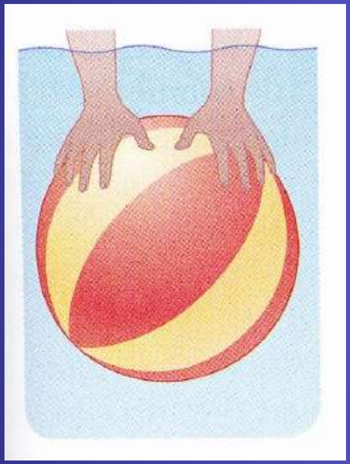
Archimedes Principle:

The buoyant force on an object submerged in a fluid is equal to the weight of the fluid that is displaced by that object.



Resisting Buoyancy

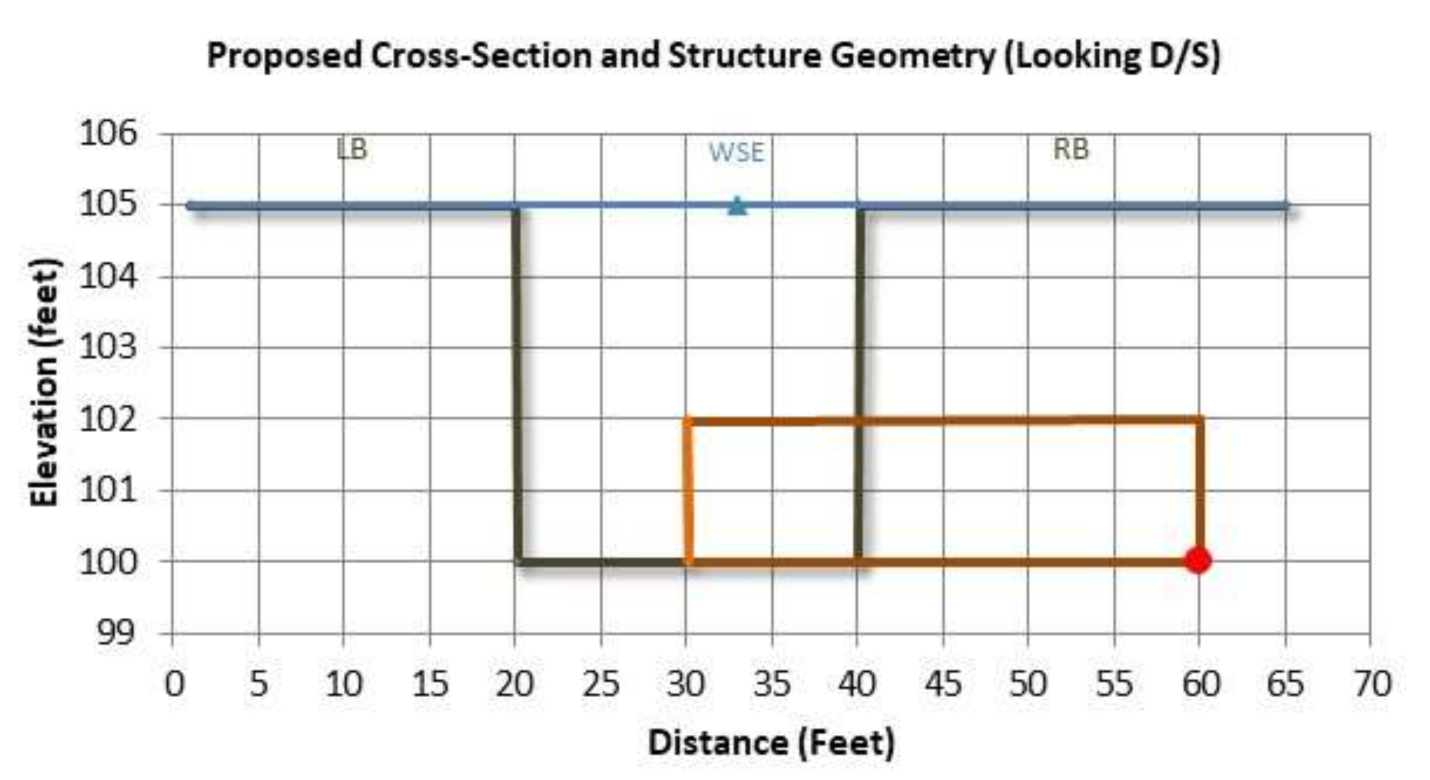
Resisting Forces (Downwards)



Driving Forces (Upwards)

Buoyant Stability of a Buried Log: Testing the 2/3 Embedment Rule

- 2 foot diameter redwood log, 30 feet log, no root wad
- Buried 3 feet deep in silt, projecting 10 feet into stream channel
- Assume full submergence, dry wood



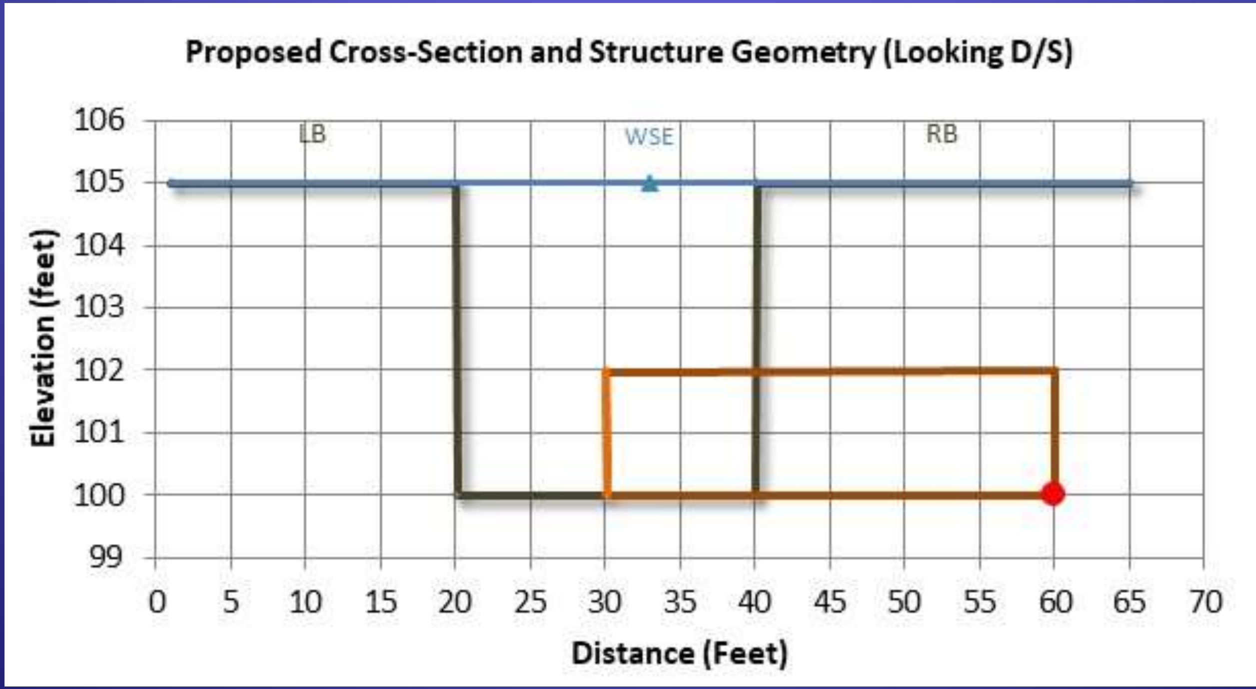
Buoyancy of a Buried Redwood Log: Forces Acting on Log

Driving Forces

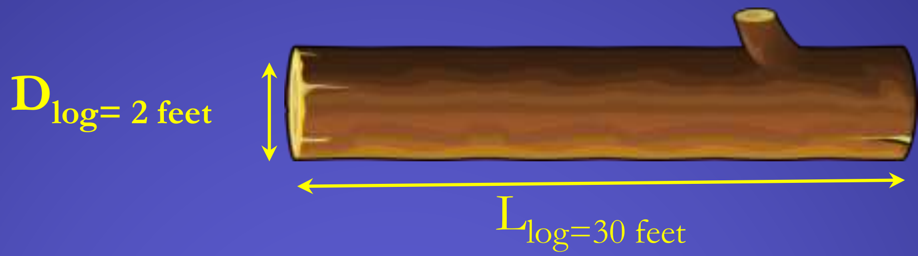
- Buoyancy

Resisting Forces

- Weight of Log
- Weight of soil (submerged)



Buoyancy of a Buried Redwood Log: Log Volume



Buoyancy (B) is the Weight of water displaced by the volume of the log

$$B_{log} = V_{log}\gamma_{water}$$

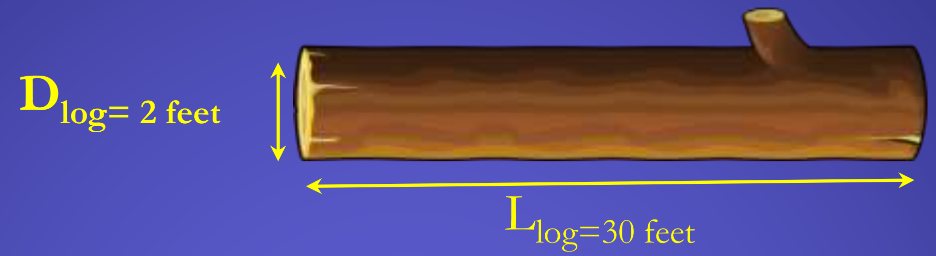
Volume of Log:

$$V_{log} = \pi R^2 L_{log}$$

$$V_{log} = \pi \; x \; 1ft^2 \; x \; 30ft$$

$$V_{log} = \underline{\mathbf{94.2\ ft^3}}$$

Buoyancy of a Buried Redwood Log: Buoyant Force of Log



- Buoyancy (B) is the Weight of water displaced by the volume of the log

$$B_{log=}V_{log}\gamma_{water}$$

γ_{water} = Density Water (62.4 lbs/ft^3)

$$B_{log=}94.2ft^3\ x\ 62.4\ \text{lbs}/ft^3$$

$$B_{log} = \mathbf{5,878}\ \boldsymbol{lbs}$$

Buoyancy of a Buried Log: Resisting Force: Weight of Log

Weight of Log

$$W_{log} = V_{log} \gamma_{wood}$$

γ_{wood} = Density Dry Redwood (24.5 lbs/ft^3)

$$W_{log} = 94.2\ ft^3 \times 24.5\ lbs/ft^3$$

$$\boldsymbol{W_{log} = 2,308\ lbs}$$

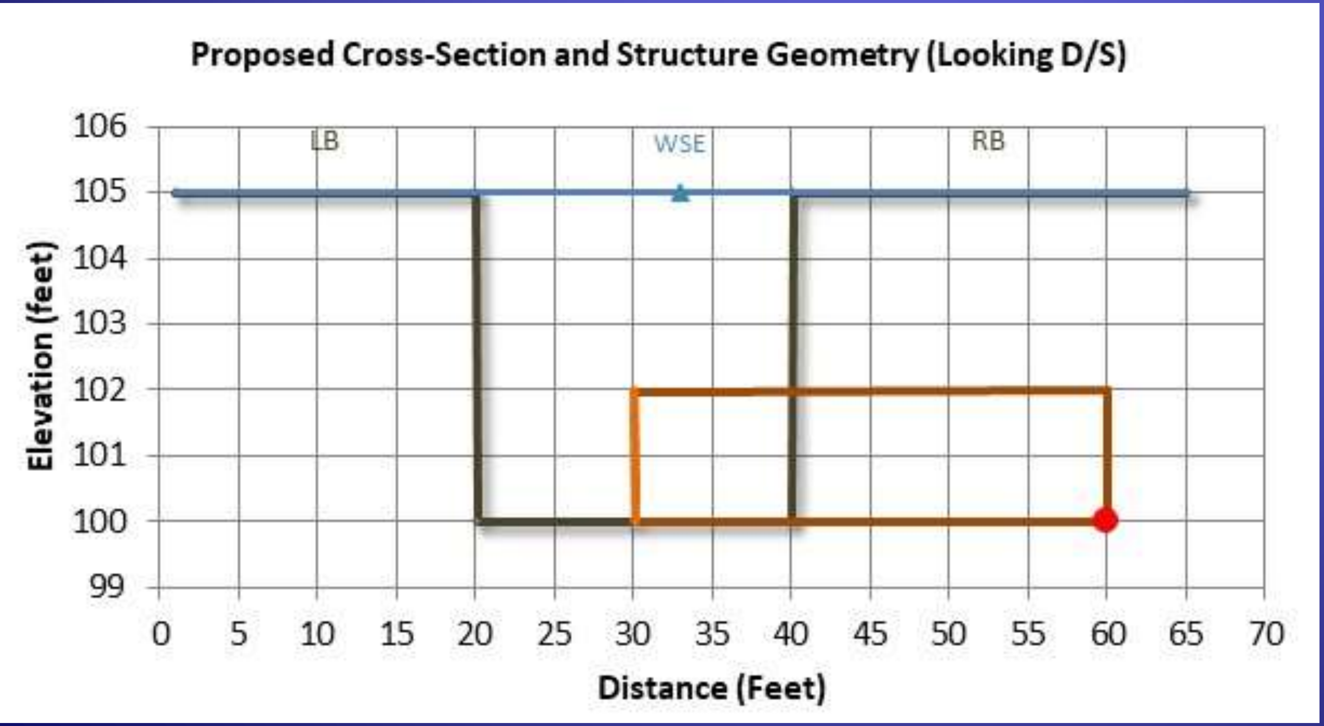
Buoyancy of a Buried Log:
Resisting Force: Weight of Soil Over Log

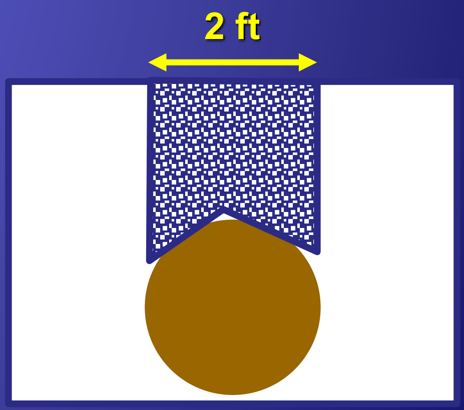
Volume of Soil Over Log

$$V_{soil=}\ L_{lemb} D_{log} D_{emb}$$

$$V_{soil=}\ 20\ feet\ x\ 3\ feet\ Deep\ \ x\ 2\ feet\ Log\ Width$$

$$\boldsymbol{V_{soil=}\ \ 120\ ft^3}$$





Cross Section of Log showing Soil Acting on Log

Buoyancy of a Buried Redwood Log: Resisting Force: Weight of Soil Over Log

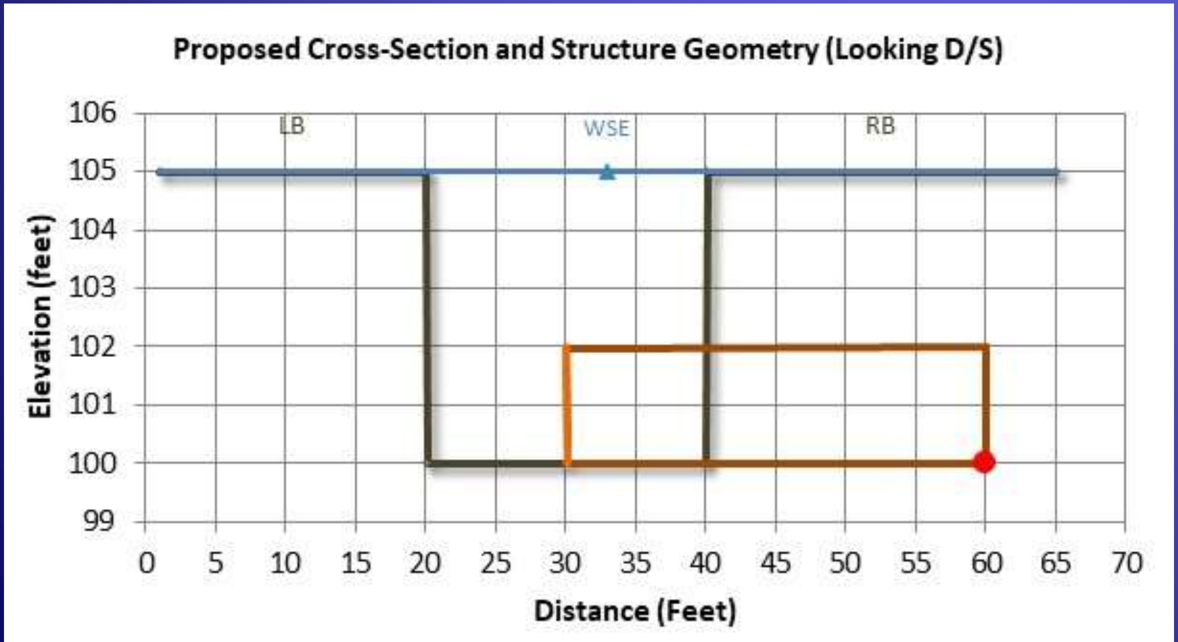
Submerged Weight of Soil Over Log

$$W_{soil=}V_{soil}\gamma_{soil}$$

γ_{soil} = Submerged Density Firm Silt (56.0 lbs/ft^3)

$$W_{soil=}120\ ft\ 3\ x\ 56.0\ lbs/ft^3$$

$$W_{soil=}6{,}720\ lbs$$

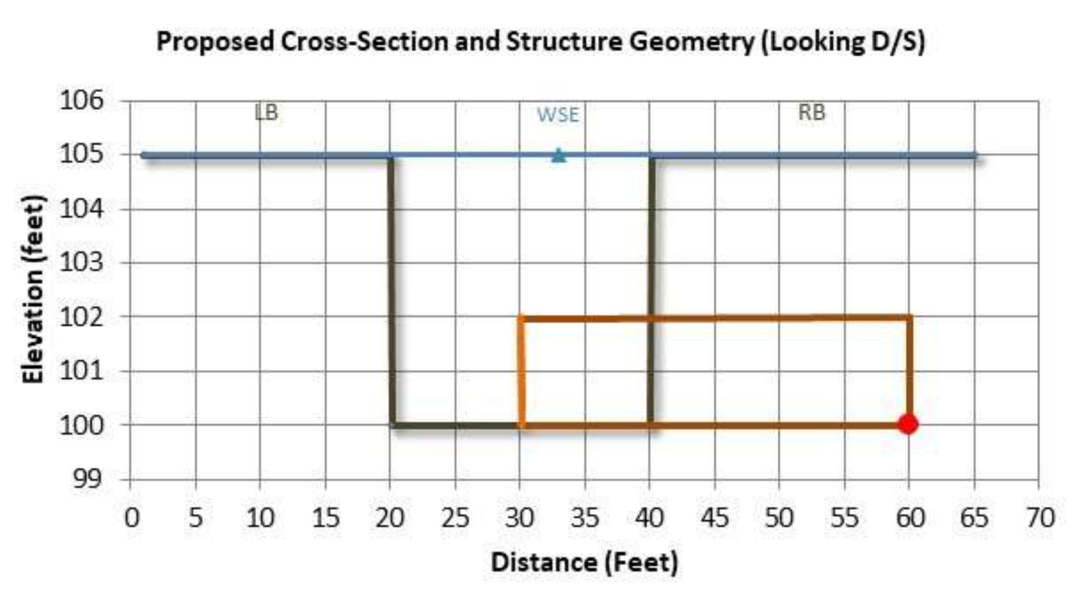


Buoyancy of a Buried Redwood Log: Summary of Forces

Driving Forces

- Buoyancy

$$B_{log} = 5,878\ lbs$$



Resisting Forces

- Weight of Log

$$W_{log} = 2,308\ lbs$$

- Weight of soil (submerged)

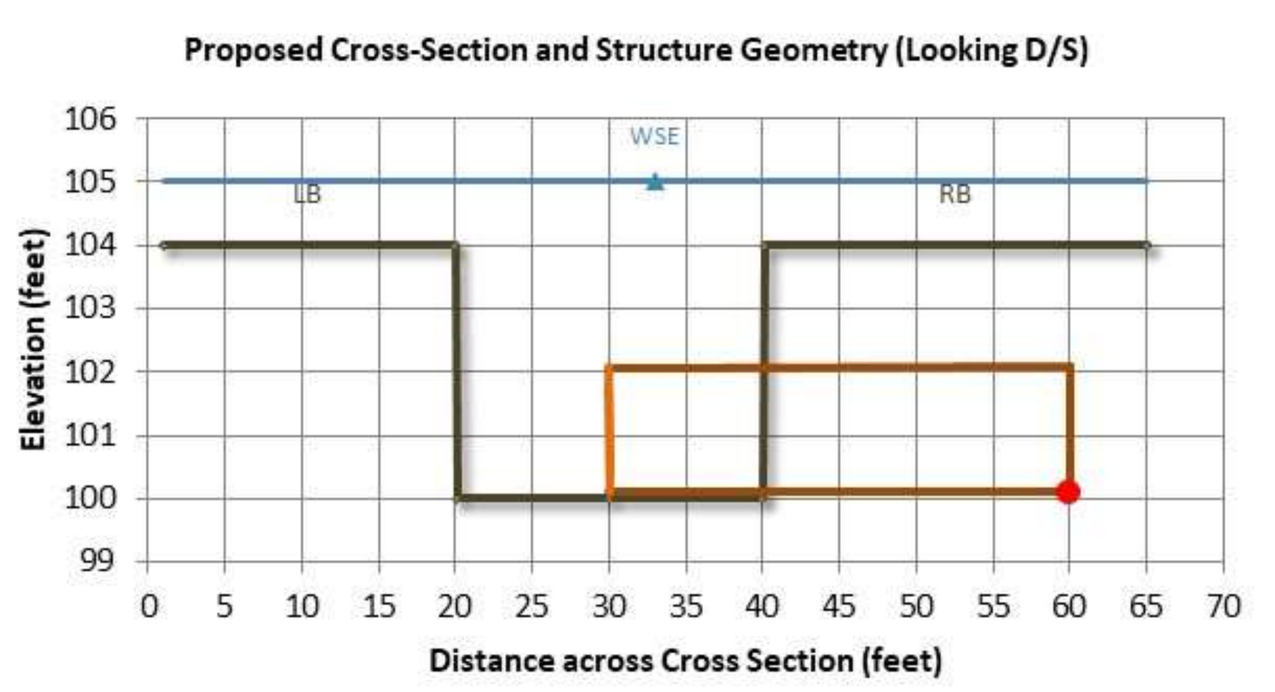
$$W_{soil=}6,720\ lbs$$

Buoyancy of a Buried Redwood Log: Factor of Safety (Force-Based)

$$FS = \frac{W_{log} + W_{soil}}{B_{log}}$$

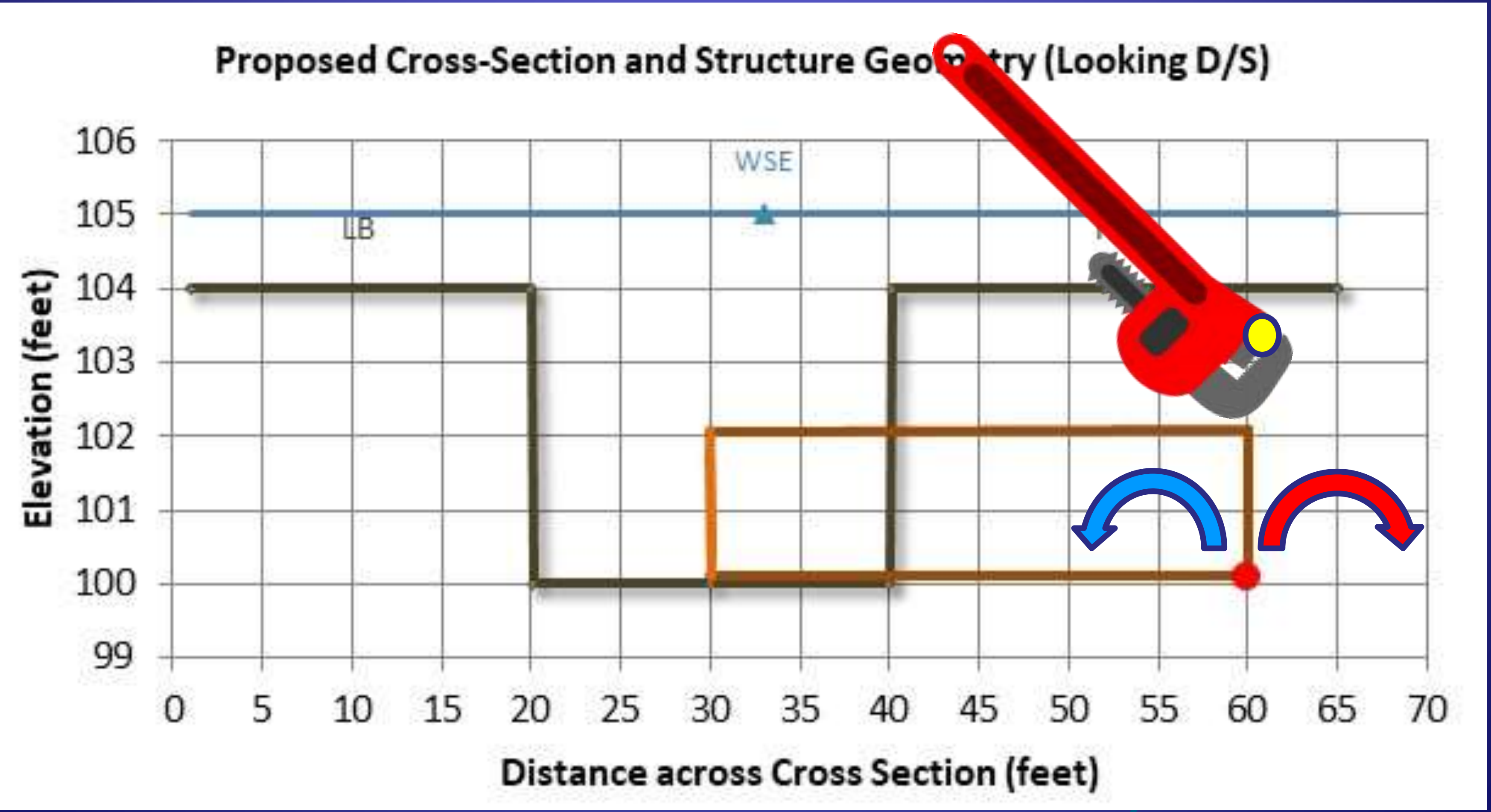
$$FS = \frac{2{,}308\ lbs + 6{,}720\ lbs}{5{,}878\ lbs}$$

$$\boldsymbol{FS = 1.53}$$



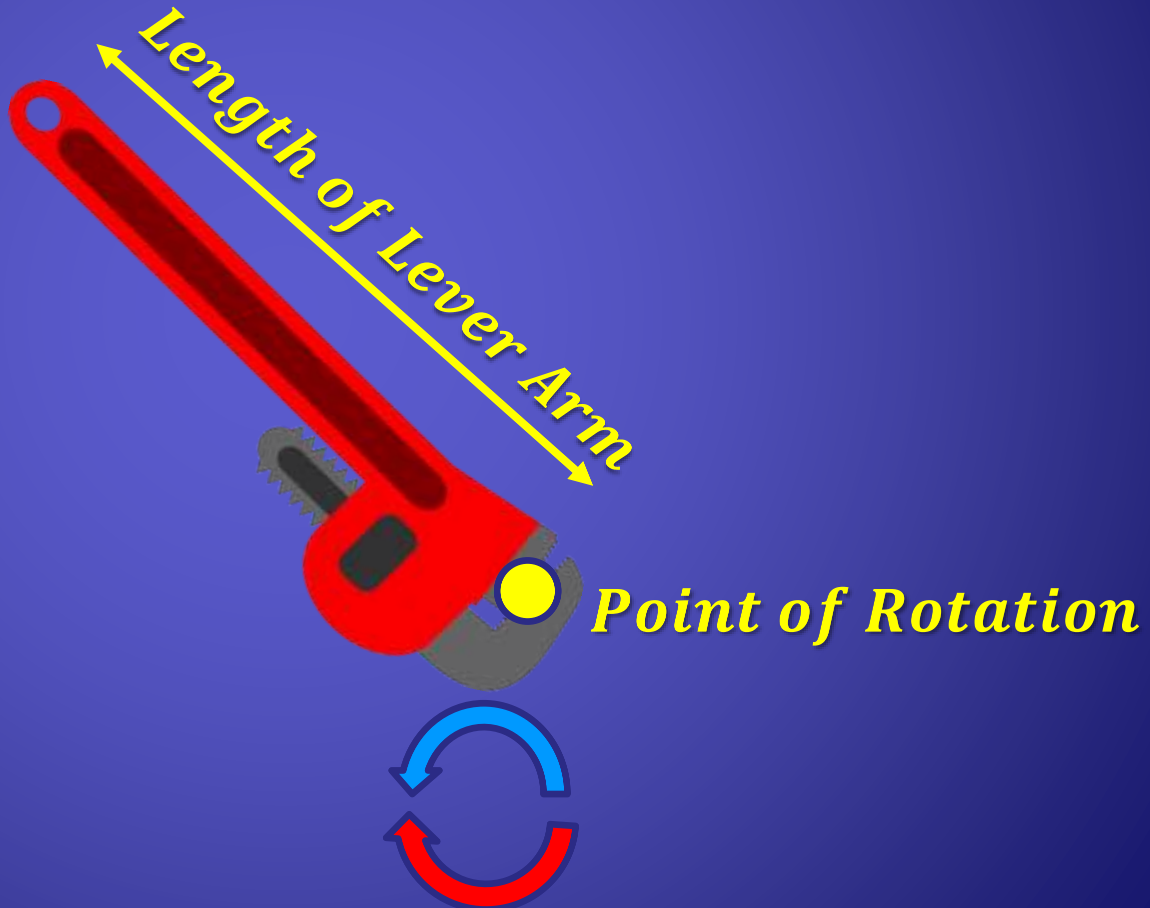
Buoyancy of a Buried Redwood Log: Factor of Safety (Moment-Based)

Driving Moments Vs Resisting Moments



Buoyancy of a Buried Redwood Log: Factor of Safety (Moment-Based)

Driving Moments Vs Resisting Moments

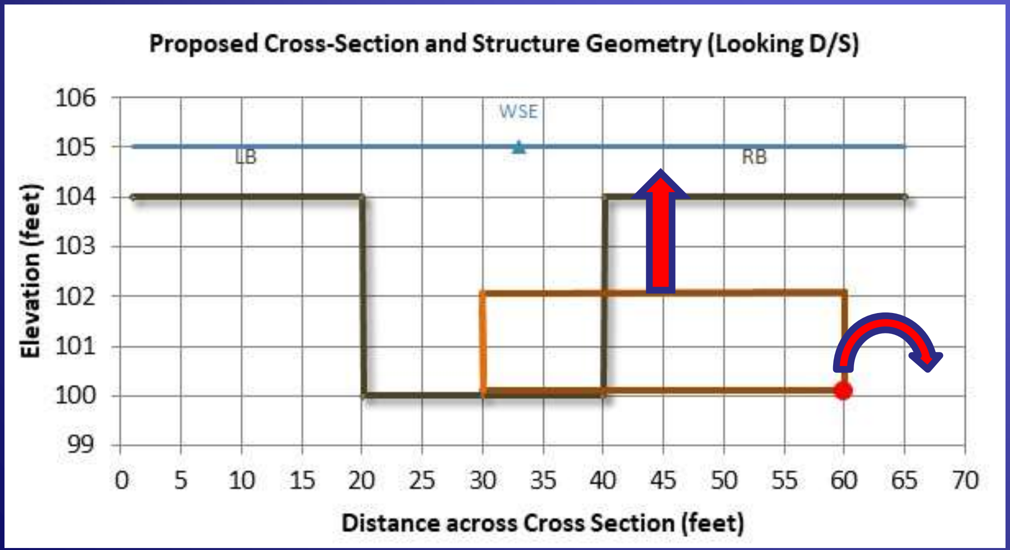


Buoyancy of a Buried Redwood Log: Factor of Safety (Moment Based)

Driving Moment-Buoyancy

$$M_{d-Buoy=} B_{log} C_{log}$$

C_{log} is length to <u>center of mass</u> of log = length to middle of log =15 feet

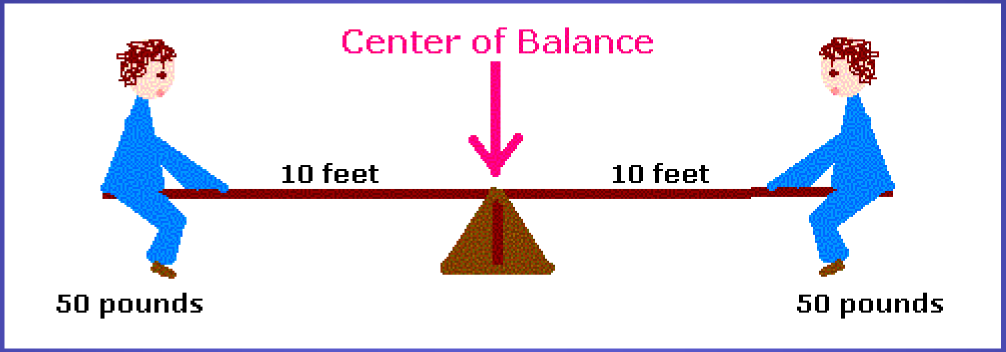


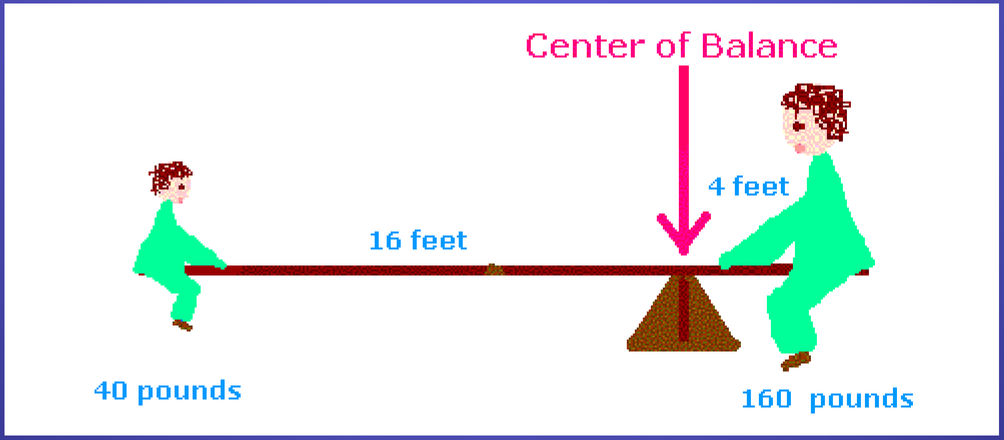
$$M_{d-Buoy=} 5{,}878\ lbs\ x\ 15\ feet$$

$$M_{d-Buoy=} 88{,}170\ foot\ lbs$$

Center of Mass?!?

=Center of Balance





Buoyancy of a Buried Redwood Log: Factor of Safety (Moment Based)

Resisting Moments-Moment of Log Weight

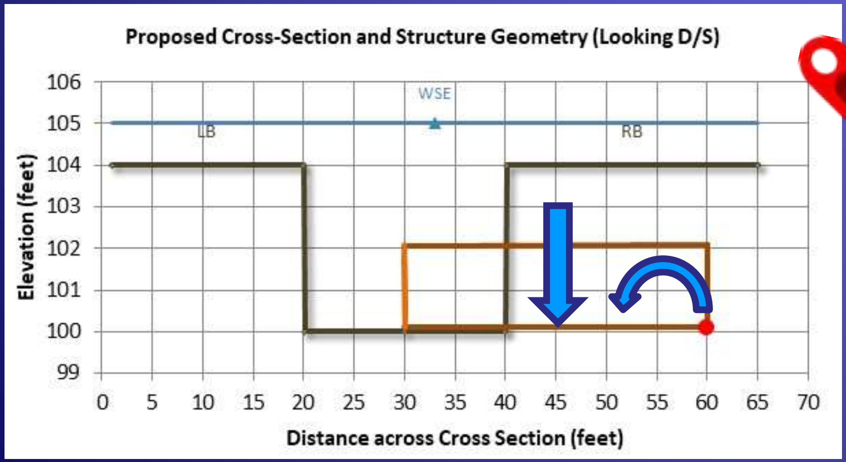
Moment of Log Weight:

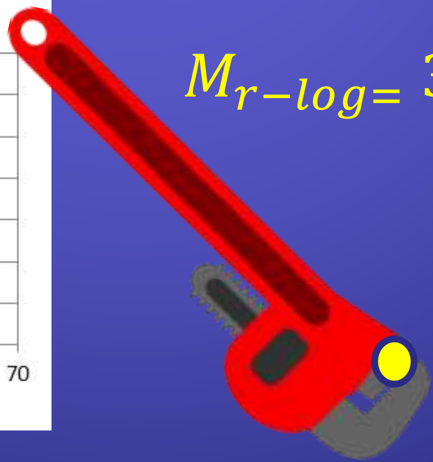
$$M_{r-log=}W_{log}C_{log}$$

C_{log} is length to the center of mass of log = length to middle of log = 15 feet

$$M_{r-log=}\ 2{,}308\ lbs\ x\ 15\ feet$$

$$M_{r-log=}\ 34{,}620\ foot\ lbs$$





Buoyancy of a Buried Redwood Log: Factor of Safety (Moment Based)

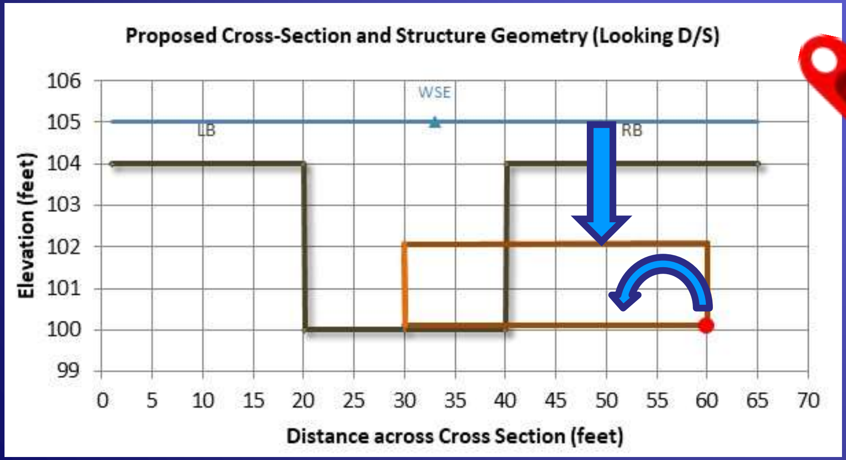
Resisting Moments-Moment of Soil Weight

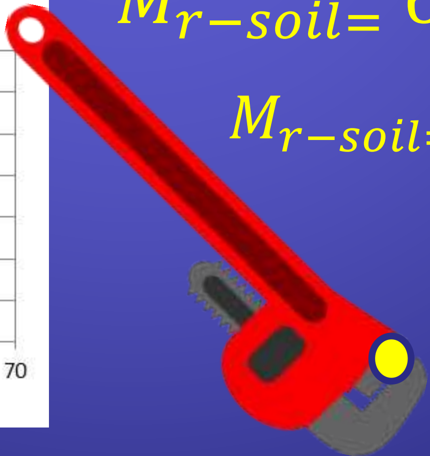
Moment of Soil Weight:

$$M_{r-soil=}W_{soil}C_{soil}$$

C_{log} is center of mass of soil over the log= 10 feet

<u>Without Root Wad</u>





$$M_{r-soil=}\ 6{,}720\ lbs\ x\ 10\ feet$$

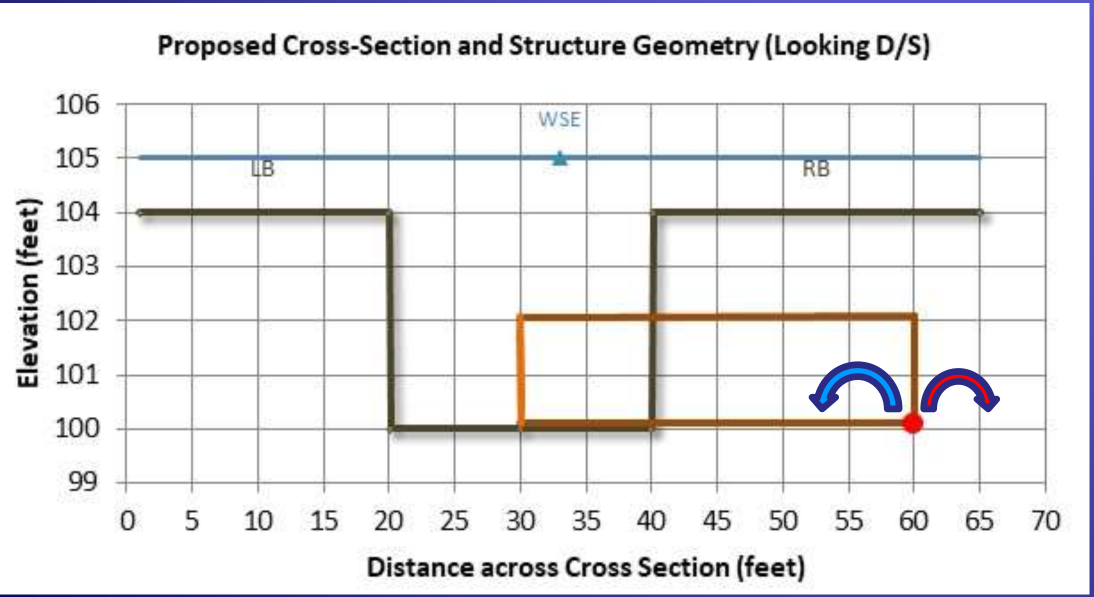
$$M_{r-soil=}\ 67{,}200\ foot\ lbs$$

Buoyancy of a Buried Redwood Log: Factor of Safety (Moment Based) Summary of Forces

Driving Moments

- Buoyancy

$$M_{d-Buoy=}\ 88,170\ foot - lbs$$



Resisting Moments

- Moment of Log Weight

$$M_{r-log=}\ 34,620\ foot - lbs$$

- Moment of Soil Weight

$$M_{r-soil=}\ 67,200 foot - lbs$$

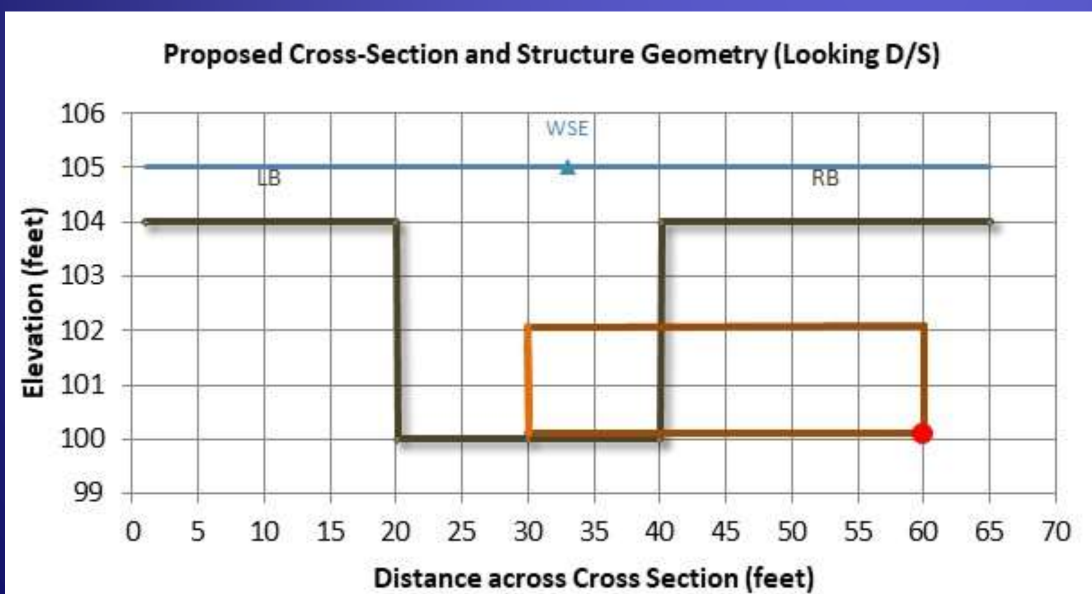
Buoyancy of a Buried Redwood Log: Factor of Safety (Moments)

$$FS = \frac{M_{r-log} + M_{r-soil}}{M_{d-Buoy}}$$

$$FS = \frac{34{,}620\ ftlbs + 67{,}200\ ftlbs}{88{,}170\ ftlbs}$$

Resisting Moments

Driving Moments



$$FS = 1.15$$

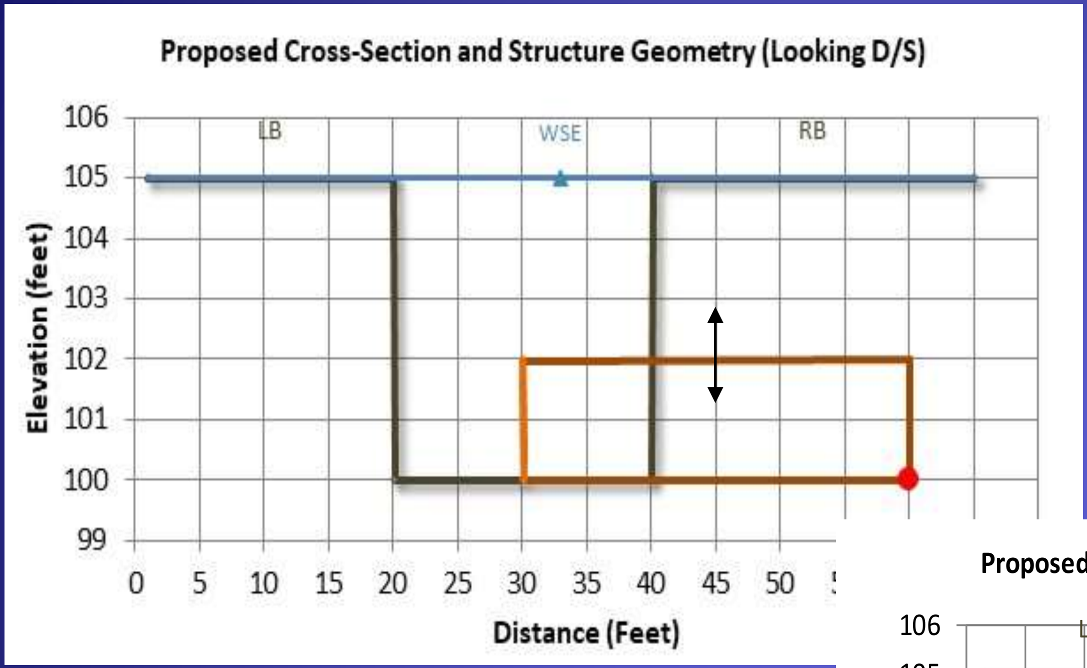
Your Turn

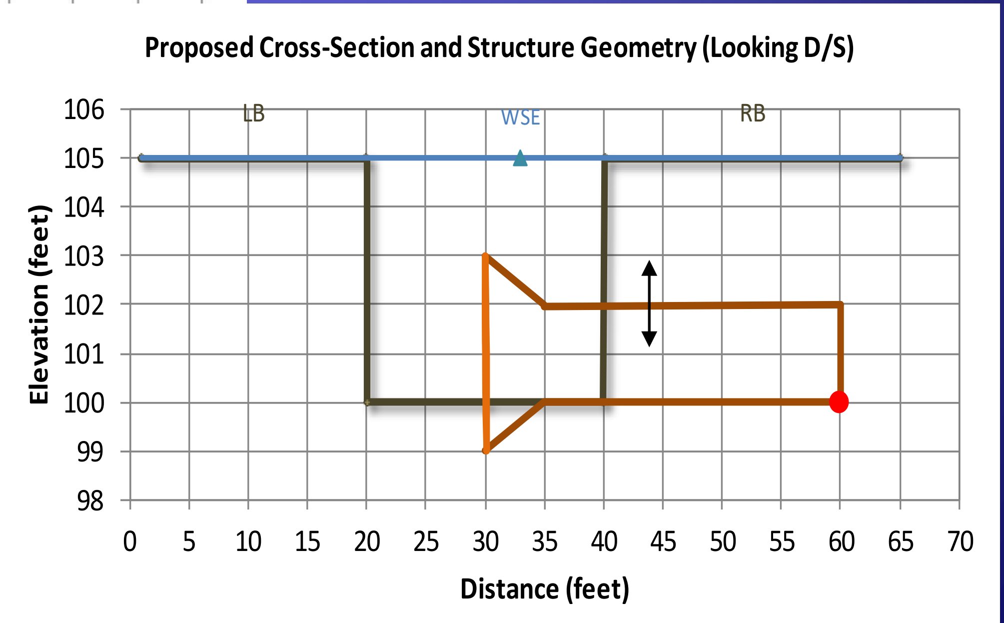
Scenarios	Group
Redwood Log in Silt	Example
Redwood Log in Gravel/Cobble	Group 1
Douglas Fir Log in Silt	Group 2
Douglas Fir Log in Gravel/Cobble	Group 3
Douglas Fir 4-foot dia. Root Wad in Gravel/Cobble	Group 4

Answers

Scenarios	Buoyancy Wood (lbs)	Weight Log (lbs)	Weight Soil (lbs)	FS (Force)	FS (Moment)
Redwood Log in Silt (Example)	5,878 lbs	2,308 lbs	6,720 lbs	1.53	1.15
Redwood Log in Gravel/Cobble (Group 1)	5,878 lbs	2,308 lbs	10,236 lbs	2.13	1.55
Douglas Fir Log in Silt (Group 2)	5,878 lbs	3,156 lbs	6,720 lbs	1.68	1.29
Douglas Fir Log in Gravel/Cobble (Group 3)	5,878 lbs	3,156 lbs	10,236 lbs	2.27	1.69
Douglas Fir 4' Root Wad in Gravel/Cobble (Group 4)	6,452 lbs	3,464 lbs	10,236 lbs	2.12	1.49

Differences in Centers of Mass





Good References and Tools

1. Knutson, M. and J. Fealko. 2014. Large Woody Materials-Risk Based Design Guidelines. U.S. Dept of the Interior, Bureau of Reclamation, Pacific NW Region, Boise, ID.

2. Rafferty, M. 2016. Computational Design Tool for Evaluating the Stability of Large Wood Structures. Technical Note TN-103.1. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center. 27 p.

https://www.fs.fed.us/biology/nsaec/assets/lw_design_tool_v1-1.xlsm

TEST TIME

30 YEARS IN THE MAKING: CALIFORNIA CONSERVATION CORPS INSTREAM LARGE WOOD RESTORATION TECHNIQUES

Mission Statement:

The young women and men of the Corps work hard protecting and restoring California's environment and responding to disasters, becoming stronger workers, citizens and individuals through their service.

Hard Work, Low Pay, Miserable Conditions and More

CCC UKIAH-FISHERIES

- **Project design and development, proposal submission, implementation and reporting**
- **Work as contractor/labor force for project partners**

SALMON RESTORATION PROGRAM

- **Partnered with CDFG in 1980 to conduct salmon habitat restoration (stream cleaning). The goal was to flush sediment and remove barriers to fish migration (log jams)**
- **CCC was a major contractor for stream clearance efforts**

WOOD IS GOOD

- **Around 1986, it became more widely accepted that it was good to have wood in the channel**
  - **Started leaving some wood in the channel and identifying places for structures**
  - **The CCC has installed over 6500 habitat structures**

SITE DESIGN

- 1990's - 2000's
- 1-3 pieces coming off one or both banks of channel. Channel spanning logs were rare.
- Most structures were hard anchored

SITE DESIGN

- **More channel spanning logs, logs coming off both banks and crossing or meeting in the channel**
- **Collect more small woody material/slow the water down**

HABITAT GOALS FOR LARGE WOOD STRUCTURES

- **Create pools**
- **Enlarge existing pools**
- **Collect and sort spawning gravels**
- **Add complex cover to existing pools and flatwater habitats**
- **Increase channel roughness and complexity**

IDENTIFYING SITE LOCATION

- Stream characteristics
- Habitat needs and potential for enhancement
- Availability of material
- Ways to stabilize sites
- Risk to infrastructure
- Access

COMMON OPPORTUNITIES FOR ENHANCEMENT

WHERE IS THE WOOD?

- Do we have any material around on the ground? Can we cut trees?

WOOD LOADING/FELLING TREES

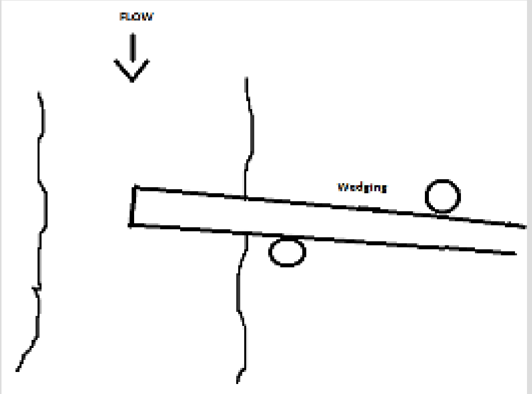
- **Ability to fell trees adjacent to project sites**
  - **Allows for higher wood loading densities**
  - **More reliability, and longevity**
  - **Reduces need for hard anchors**

STABILIZING THE STRUCTURE

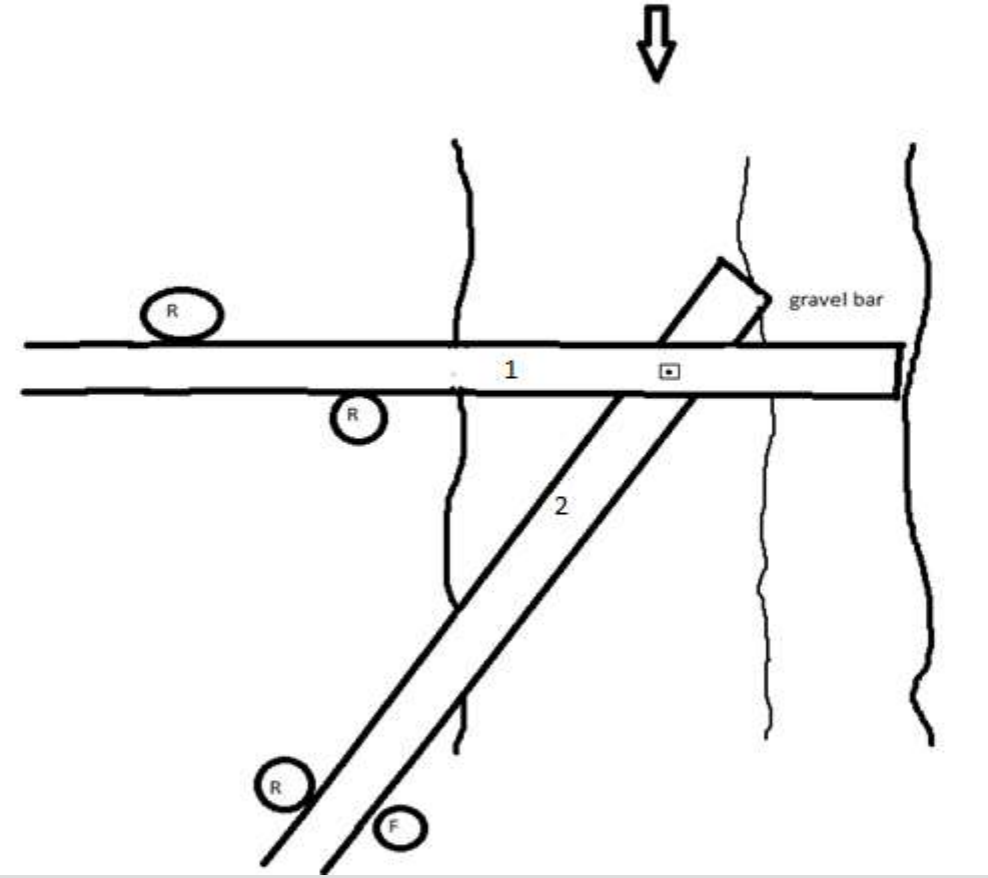
Trees, stumps, boulders or any hard points that can be used to brace structure

UNANCHORED/WEDGING

- **Utilize wedge-points or use full trees to avoid anchoring**
- **Reduces cost and amount of metal left in stream and riparian zone**
- **Allows structure to adjust over-time as pool develops**



MAKING PLANS



BUILDING SITES

- **LWD is moved into position utilizing grip-hoists and wire rope rigging techniques, and other hand tools**
- **To accomplish work, 12-15 person crews typically spike-camp near project reach for 8-day deployments**

ANCHORING/PINNING

- **Bolting LWD together and/or to live trees on the bank**
  - **Retains LWD in-place to protect downstream infrastructure**
  - **Allows for effective placement of shorter logs, making more cull logs on the forest floor viable for use in structures**

ANCHORING/PINNING

- **Varying levels of pinning and anchoring**

  -hard anchor logs to trees adjacent to channel with at least 2 pieces of rebar

  -hinge pin (soft anchor), can allow structure to adjust or settle as scouring occurs while preventing the log from floating out (used in conjunction with wedging)

  -pinning complex structures into a single unit, (no hard anchors, hinge pins)

WORKING TOGETHER
COLLABORATION/PARTNERSHIPS

- **Collaborate on development and implementation of large wood projects**
- **Serve as Labor-Force for anchoring and/or moving/positioning of LWD**
- **Work together in conjunction with heavy equipment to treat a watershed**

November 2012

September 2015

January 2016

August 2012

September 2015

November 2016

LWD Project Success

MARGIE CAISLEY
SENIOR HYDRAULIC ENGINEER
CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE

Background

- Role of instream wood – geomorphic → biologic
- Land use – forestry, agriculture, urbanization
- Previous wood clearing practices
- Accelerate natural recovery

What’s our setting?

- Many California streams have already experienced bed degradation
- Bed material is cobble or coarser, sometimes bedrock
- Disconnected from benches, side channels, and floodplains
- Lower groundwater levels and reduced summer base flow

Project Goals for Fish

- Rearing habitat – Pools with cover
- Spawning habitat – Gravel pool tailouts
- Velocity refugia
- Food sources – invertebrate production
- Healthy temperatures and dissolved oxygen concentrations

Restore Physical Processes

Raising the bed to reconnect to floodplains and side channels will

- Reduce stream power
- Deposit finer sediment such as gravel
- Allow pools to form at lower flows and scour deeper
- Retain spawning gravels
- Have side channels and floodplains become habitat again
- Recover groundwater levels and increase summer base flows

What’s that look like?

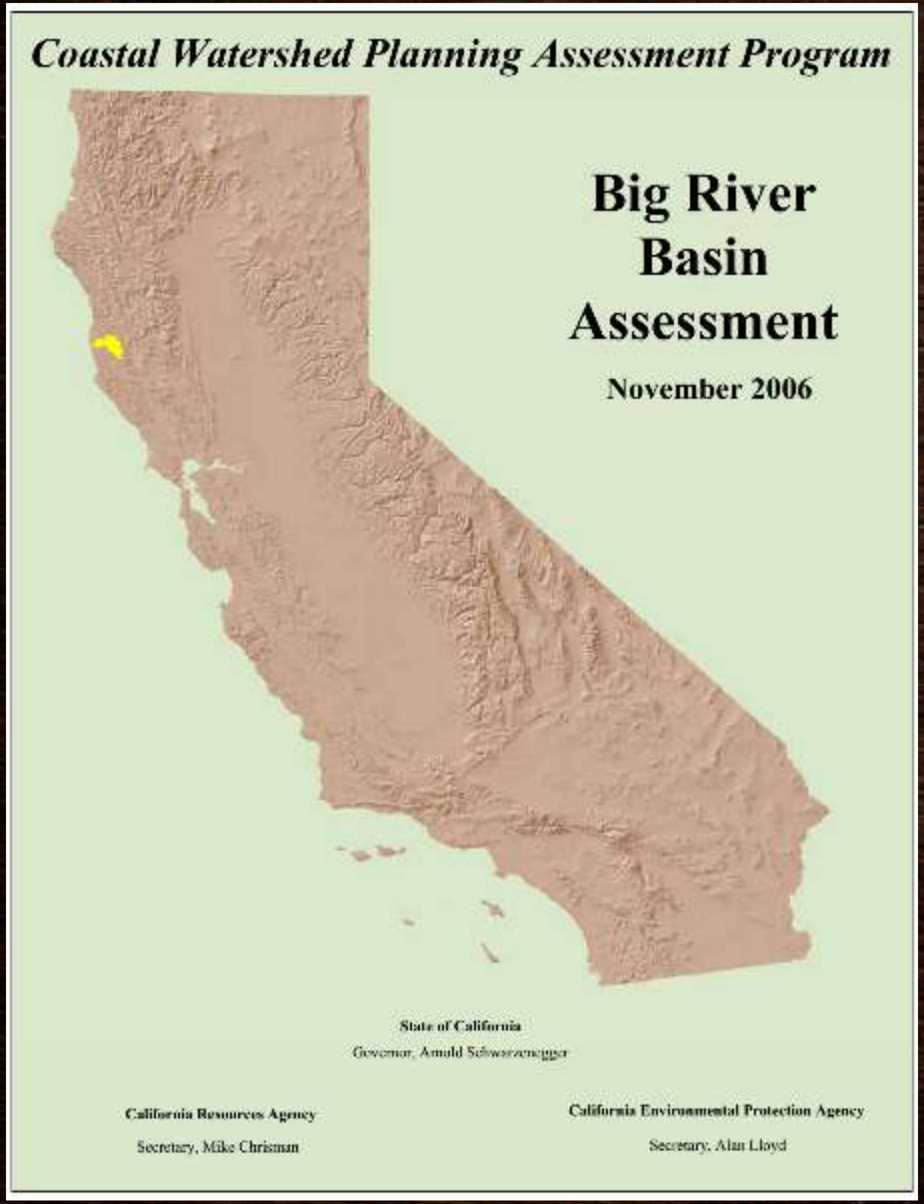
- Located in a bend
- Used a vertical post

- Captured large and small woody debris
- Resulted in gravel deposition and sorting both upstream and downstream
- Increasing Sinuosity

What are the steps for success?

- Watershed Planning – who, what, where, when, why?
- Identify opportunities
- Assess risks
- Site characterization
- Design
- Construction

Project Planning



Coastal Watershed Planning Assessment Program

Big River Basin Assessment

November 2006

State of California

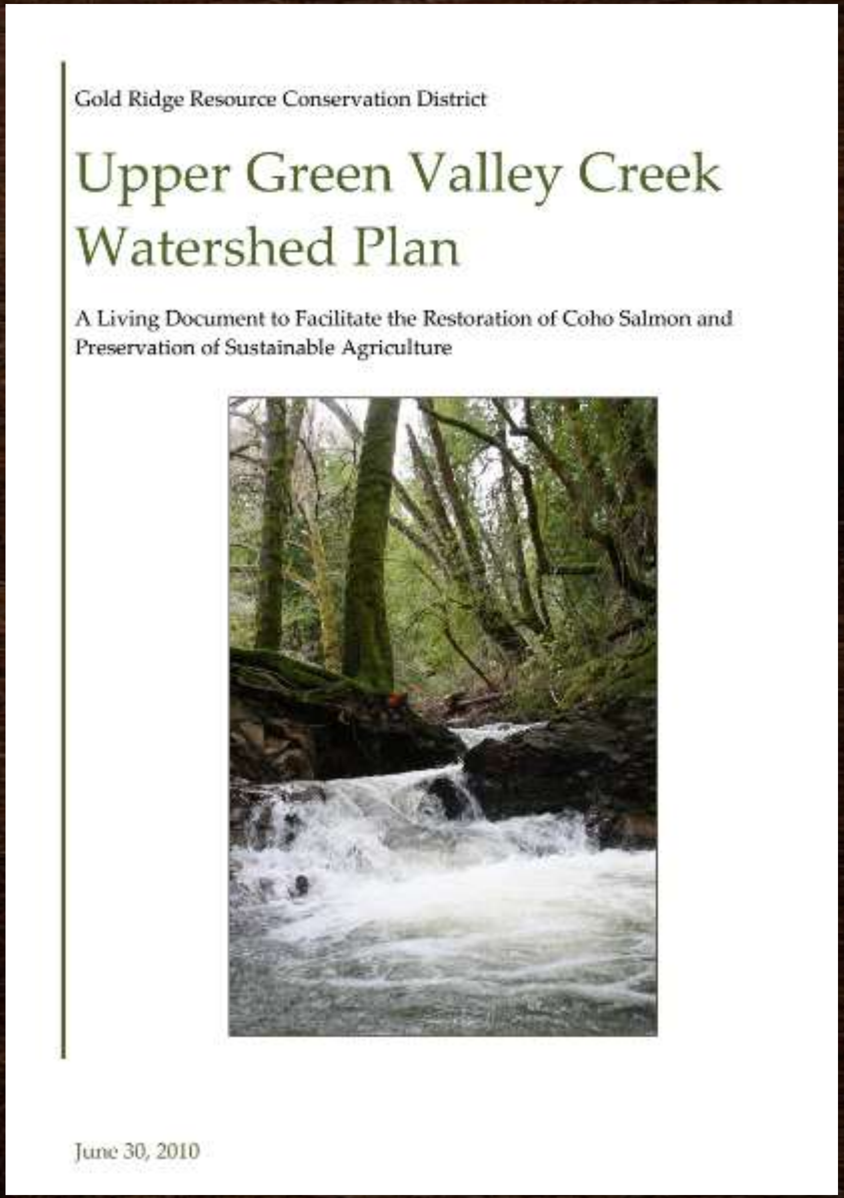
Governor, Arnold Schwarzenegger

California Resources Agency

Secretary, Mike Chrisman

California Environmental Protection Agency

Secretary, Alan Lloyd



Gold Ridge Resource Conservation District

Upper Green Valley Creek Watershed Plan

A Living Document to Facilitate the Restoration of Coho Salmon and Preservation of Sustainable Agriculture

June 30, 2010

Opportunities: Inset Benches and Floodplains

Albion River – Mendocino County

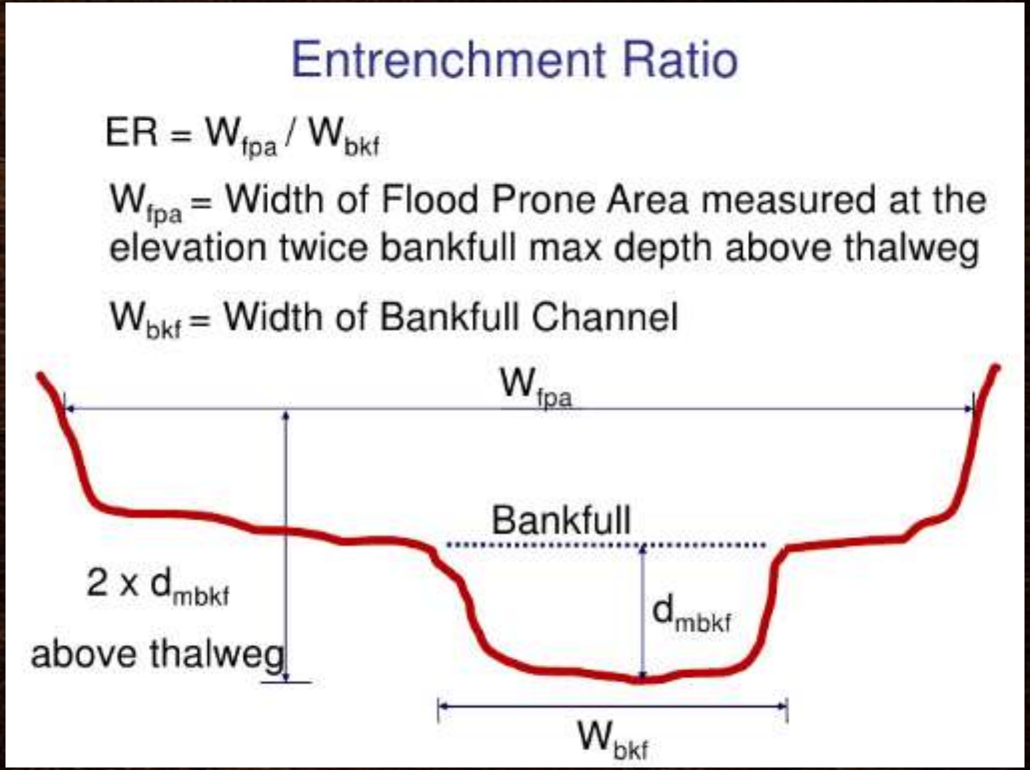
Fish Creek – Lawrence Creek Tributary

Risks

- Infrastructure
- Property
- Recreational Activities
- Erosion
- Environmental damage

Site Characterization – All projects

- Qualitative Geomorphic Assessment of planform, confinement, bed and bar forms, substrate
- Limited survey of longitudinal profile and cross-section to determine stream gradient, bankfull width and depth, and entrenchment ratio
- Sources of wood
- Areas for equipment access



Notes:
gradients of 1-3% recommended
ER<1.4 need more anchoring

Structure Categories

- Simple Low Risk – key piece size logs (1.5 x bankfull) or anchored to existing trees or bedrock
- Complex Low Risk – logs secured using piles, boulders or other material, or trenched into banks – require stability calcs
- High Risk – site has potential to harm public safety, private property, or infrastructure – stability calcs and PE required
- Use Watershed Plans, Opportunities, Risks, and Site Characterization to determine project goals and appropriate structure categories

Simple Structures = Small Goals?

Site 1820'
September 2015 - Facing Downstream

Site 1820'
January 2016 - Facing Downstream

Gravel Bar Connectivity

February 2016

March 2018

Fish Creek – trib to Lawrence

Improving Bed Material Composition

Fish Creek – trib to Lawrence

50’ d/s of LWD

5’ u/s of LWD

50’ u/s of LWD

100’ u/s of LWD

Why go complex when risk is low?

- Ideal geomorphic location for a structure may lack anchor points
  - No trees on the bank at a bend
  - Need a structure mid channel
- Stream is too wide to have opposing structures meet
- Entrenchment Ratio is less than 1.4 and stream power can rotate or break logs
- Control the water surface – make sure you meet your goal

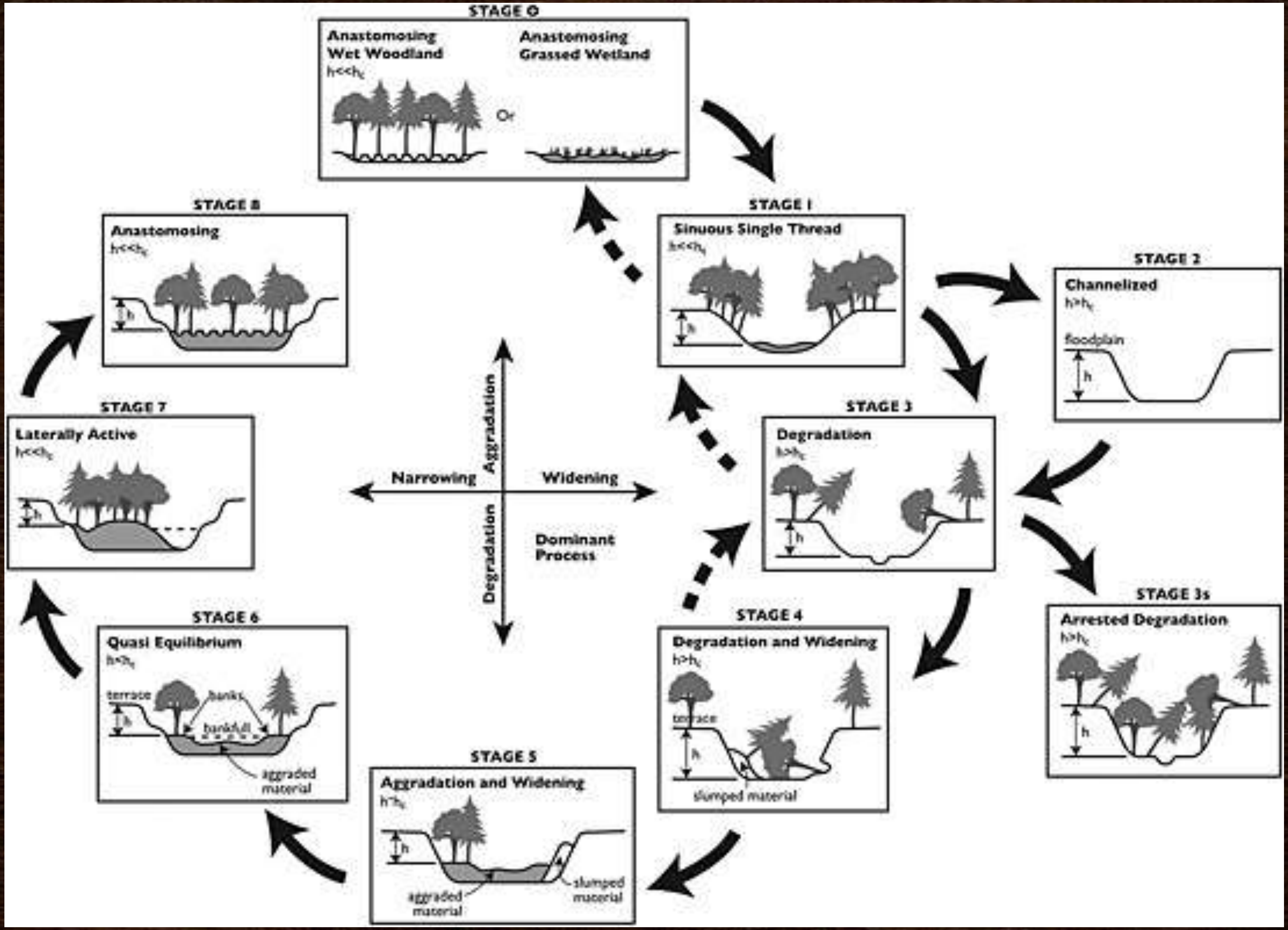
Mid-Channel Features - Bar Apex Jams

Site Characterization – Part II

For low risk complex and high risk projects:

- Quantitative assessment of bed and bank material
- Subsurface exploration
- Assessment of reach stability
- Other site constraints – access, permitting…
- Detailed topographic survey
- Hydrologic and hydraulic analyses

Reach Stability – Channel Evolution Model



Channel Evolution Model – who cares?

- Particularly in Stage 1 – if you don't address the drivers of incision your project won't last. It's not enough to just throw wood in the channel
- You may not want to arrest Stage 4 as it is what will supply material for aggradation – beware of stabilizing banks!
- Stage 3s may result from lack of sediment supply – no supply means no aggradation

What phase are you going through?

Green Valley Creek – Sonoma County - photo courtesy of SWRCB

Next Steps in Design - Iterative

- Project Layout – where to place structures to achieve goals
- Hydraulic Modeling
  - Determine size of structures
  - Check that goals are being met – go back to layout if necessary
  - Look for areas of concern – high velocities, etc.
  - Use model results for stability calculations
- Perform Stability Calculations
- Construction Details

Skipping some steps…

- Rachel is covering stability calculations
- Tom is covering working with contractors
- Chris, Ken, and the CCCs are covering construction
- Sadly, no one is covering hydraulic modeling
  - Manning's equation, 1D, 2D, 3D, Physical models – it's all been done
  - What do you want to know?

What is a successful LWD project?

- One that accomplishes the goals of the project
- Generic benefit to fish is not enough

Albion River – CCC Structure

When you take a river that looks like this
and make it look like this

Significant gravel deposition on bedrock
and cobble bed

Goal not achieved – Why???

- Structures failed - Logs relocated, shifted, rotated, shifted
  - Greater than design storm occurred?
  - Calculations incorrect, too low a safety factor for stability
  - Other design errors – ballast size
  - Not constructed according to plans

- Stream did not react as expected
  - Structure flanked
  - Inadequate design analyses
  - Hydrologic/watershed conditions
  - Site Selection

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Where'd my ballast go?

- What was your safety factor when doing stability calcs?
- What is your safety factor now?

Flanked Structure

Conclusions

- Geomorphic restoration leads to improved conditions for fish
- Need to be specific about goals
- Planning is important – lots of steps need to happen before design or construction
- Channel Evolution Model is important
- It's not always the contractor's fault