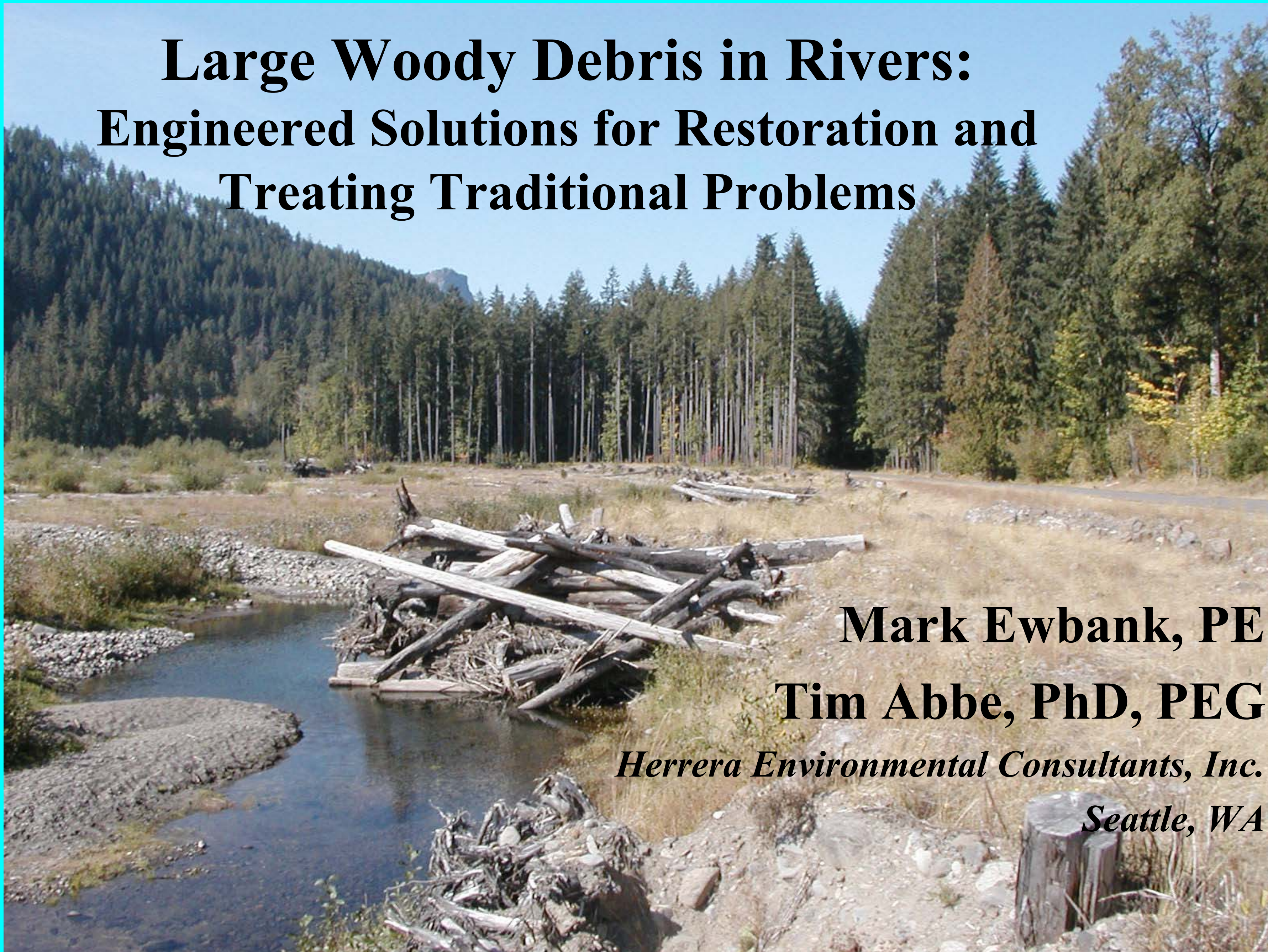


Large Woody Debris in Rivers:
Engineered Solutions for Restoration and Treating Traditional Problems

Mark Ewbank, PE

Tim Abbe, PhD, PEG

Herrera Environmental Consultants, Inc.

Seattle, WA

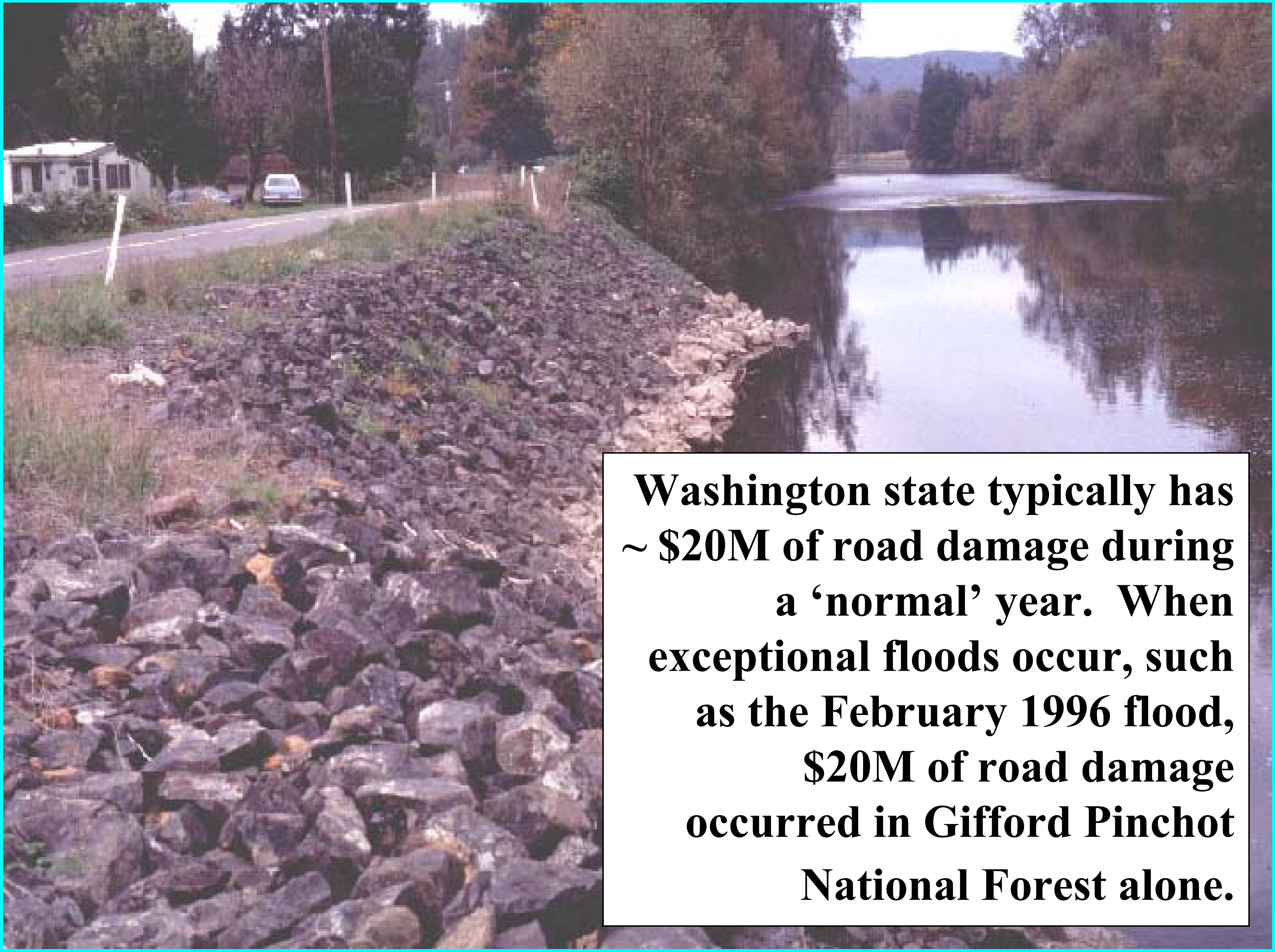
Talk outline:

Introduction and scientific background - Tim

Construction and engineering – Mark

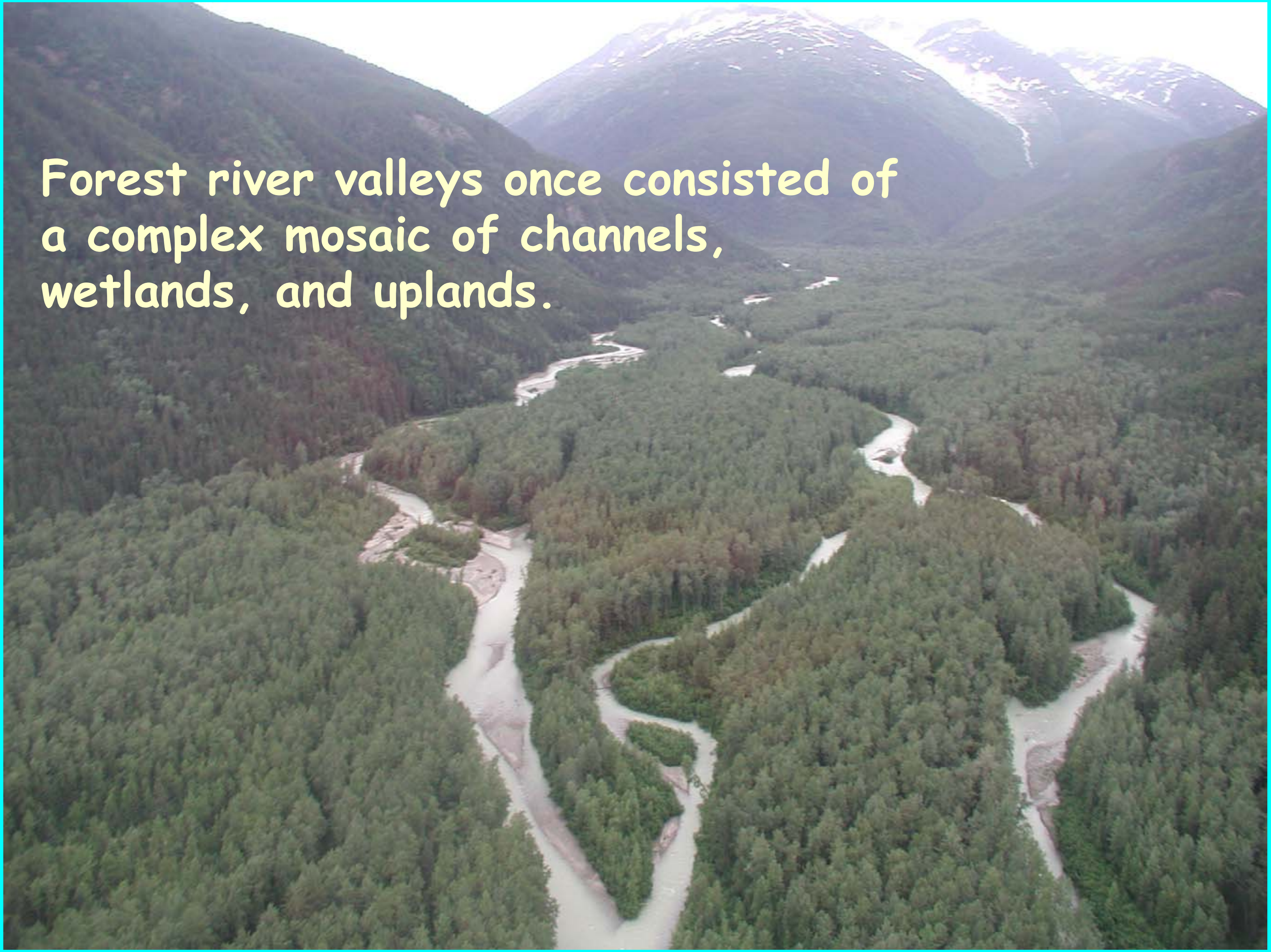
Bank erosion along rivers is a common problem that regularly threatens roads, property and infrastructure

Unfortunately, traditional bank protection techniques involve the use of non-native materials and structures that can severely impact aquatic habitat and riparian connections to the river.



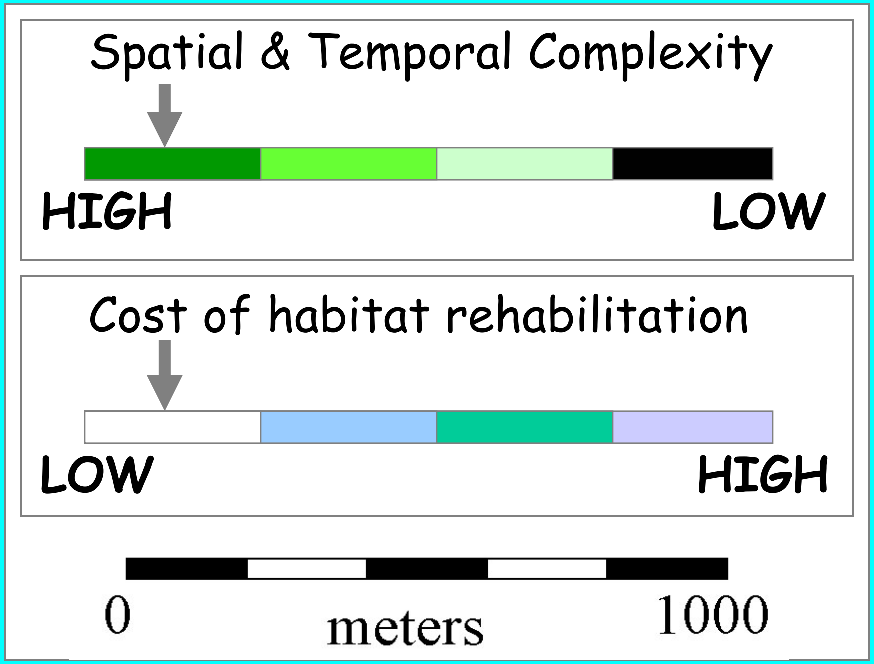
Washington state typically has ~ $20M of road damage during a ‘normal’ year. When exceptional floods occur, such as the February 1996 flood, $20M of road damage occurred in Gifford Pinchot National Forest alone.

The simplification of northwest rivers


Forest river valleys once consisted of
a complex mosaic of channels,
wetlands, and uplands.

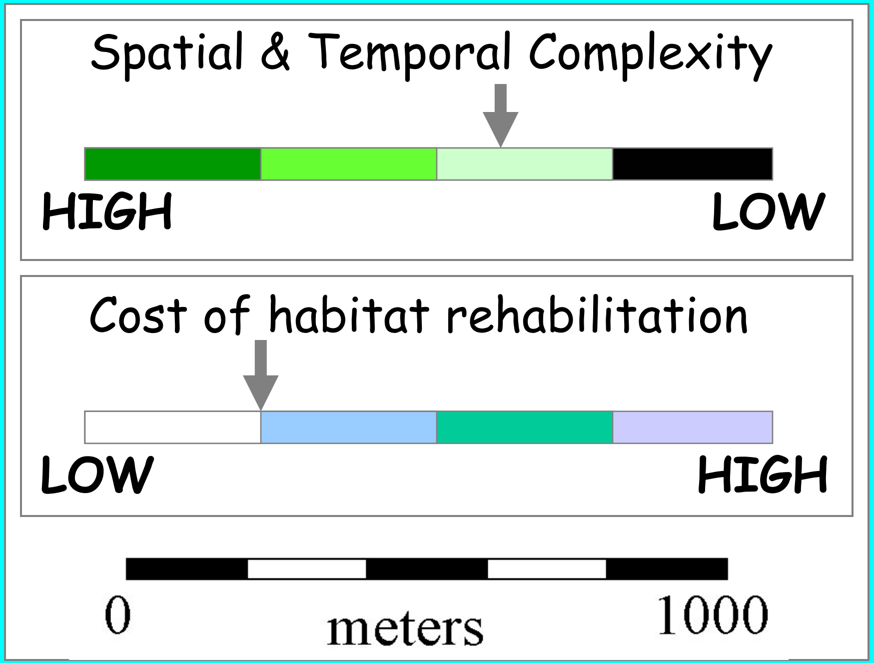
River Simplification

Sauk River



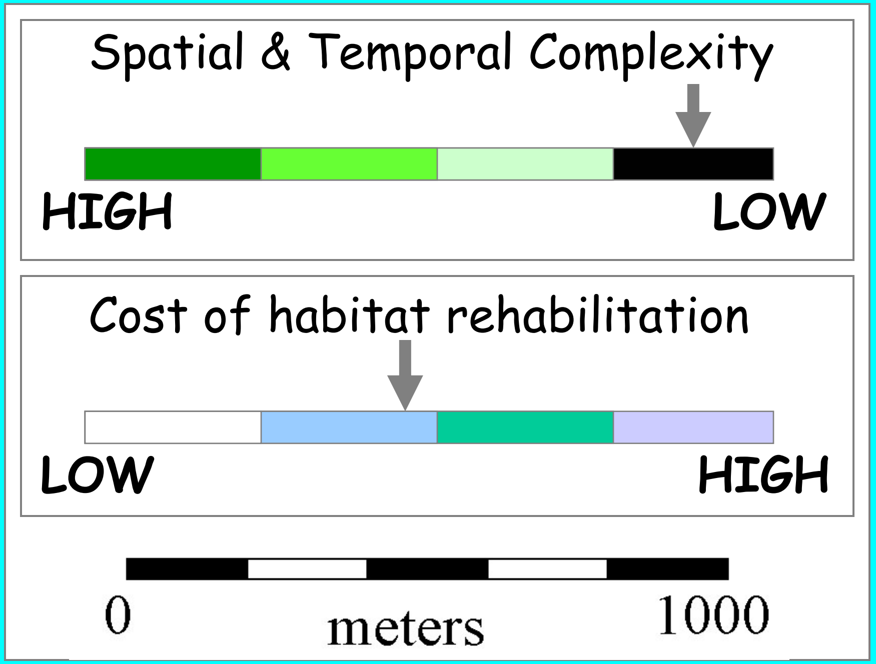
River Simplification

White River



River Simplification

Snoqualmie River



River Simplification

Duwamish River

Spatial & Temporal Complexity

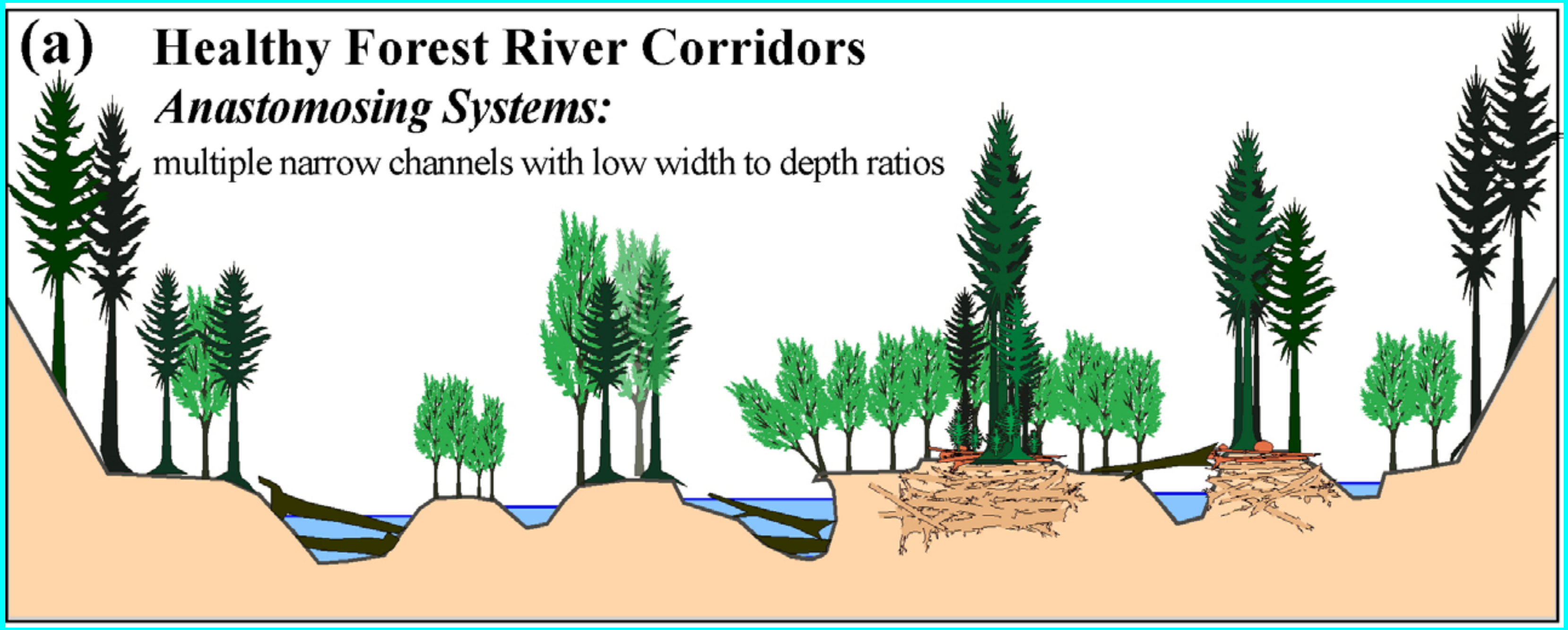
HIGH **LOW**

Cost of habitat rehabilitation

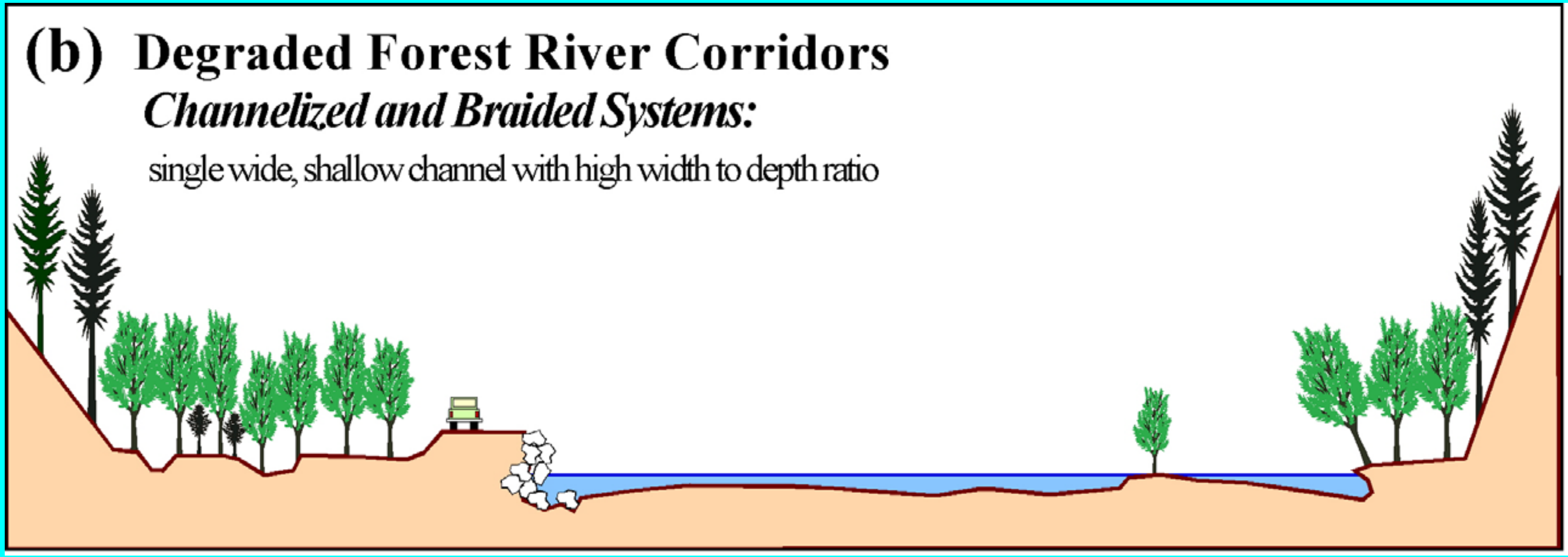
LOW **HIGH**

0 meters 1000

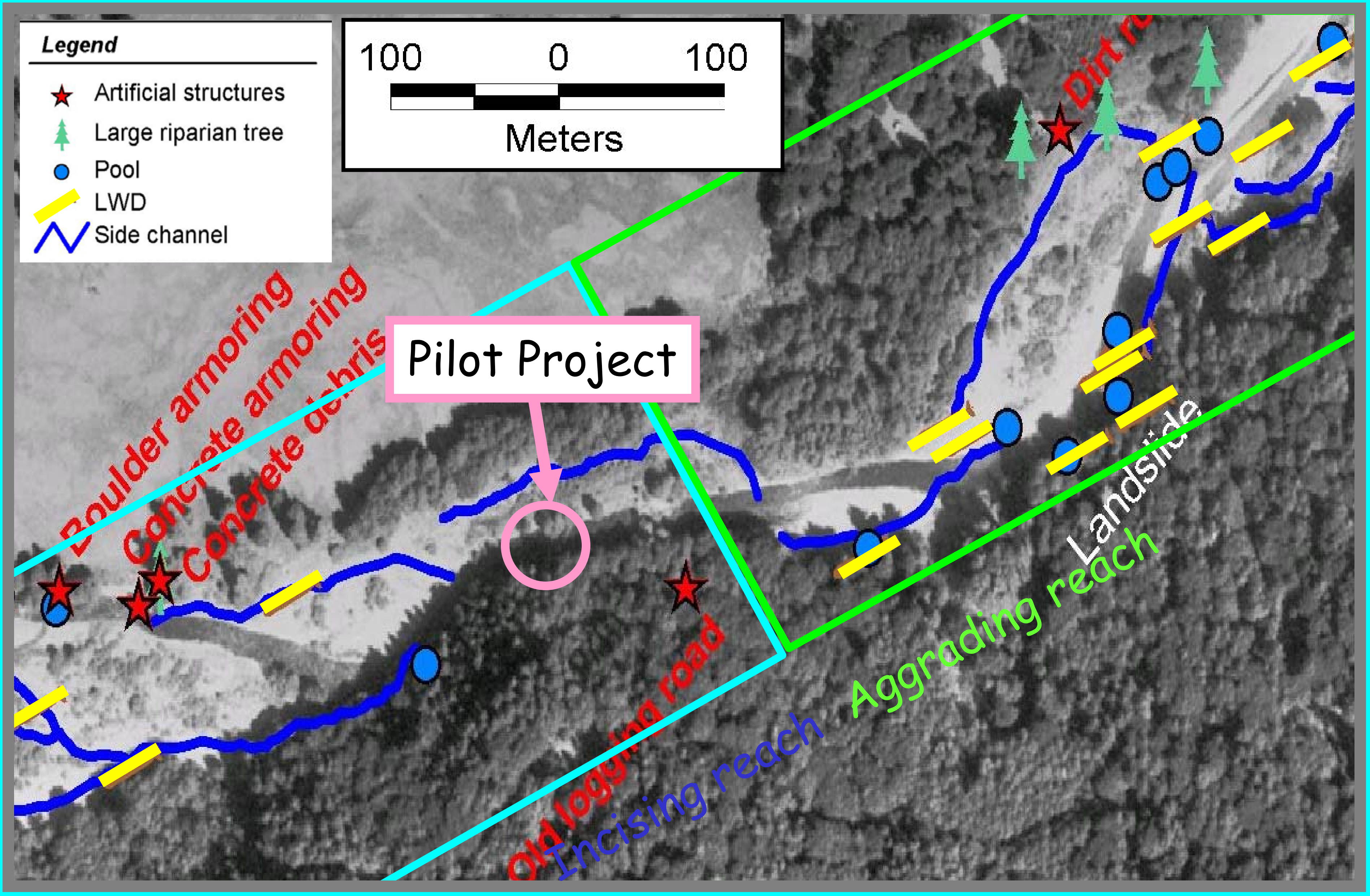
We have transformed complex systems …



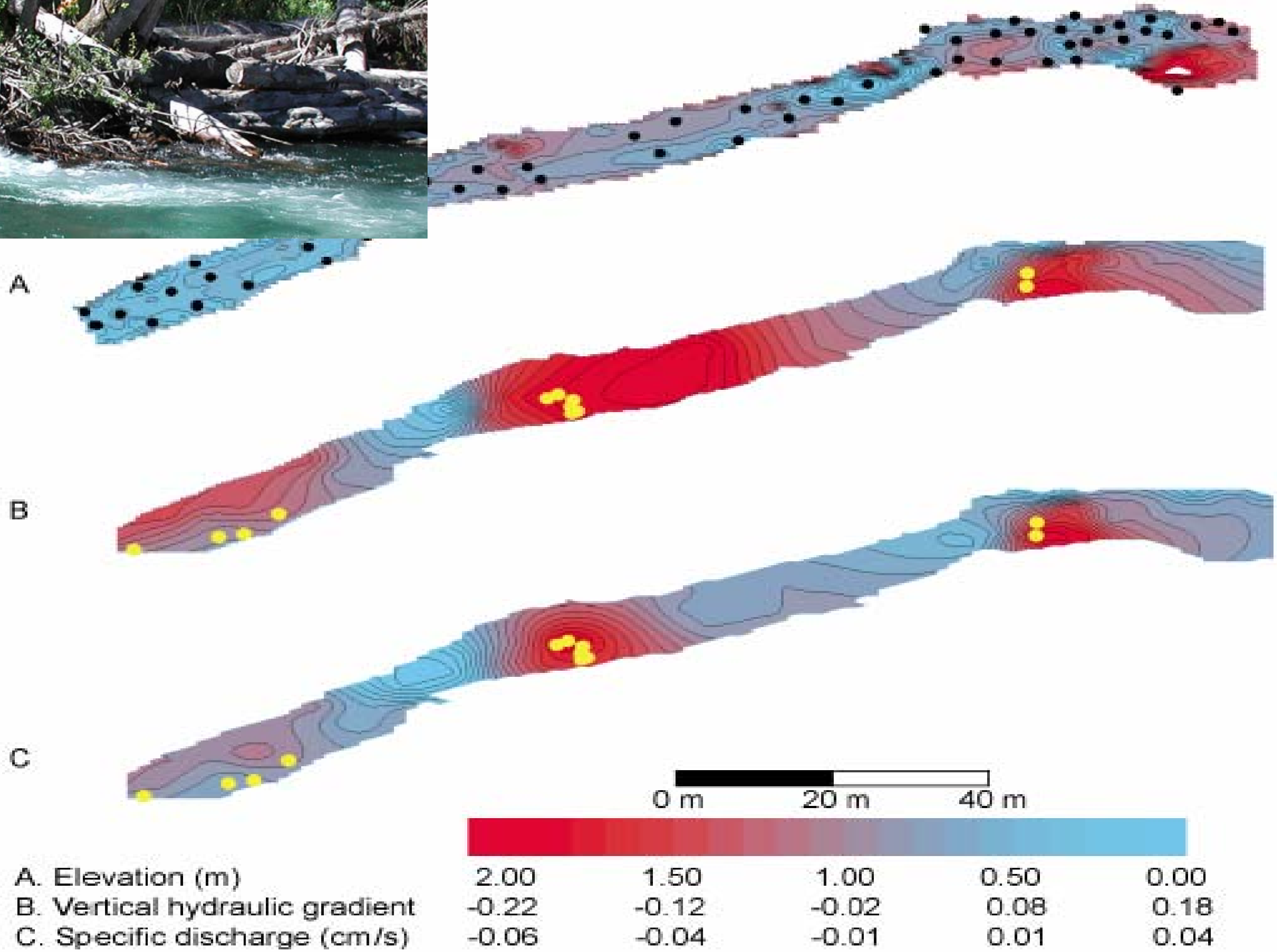
into simple ones …



What does physical complexity mean to salmon?

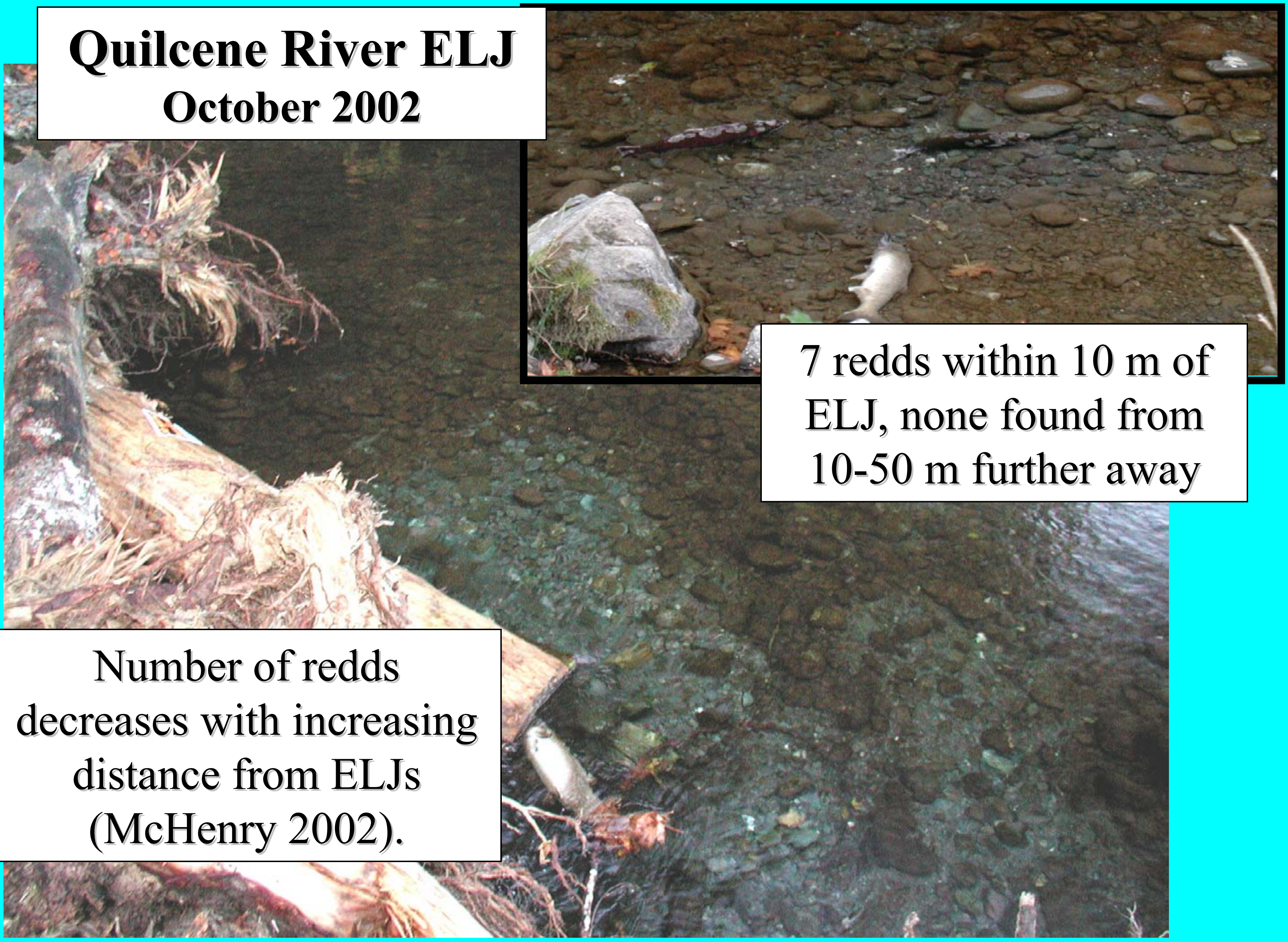

Legend
Artificial structures
Large riparian tree
Pool
LWD
Side channel
100
0
100
Meters
Pilot Project
Boulder armoring
Concrete armoring
Concrete debris
Old logging road
Dirt ro
Landslide
Incising reach
Aggrading reach

Salmon Redds are linked to hydraulic gradients driving hyporheic flow



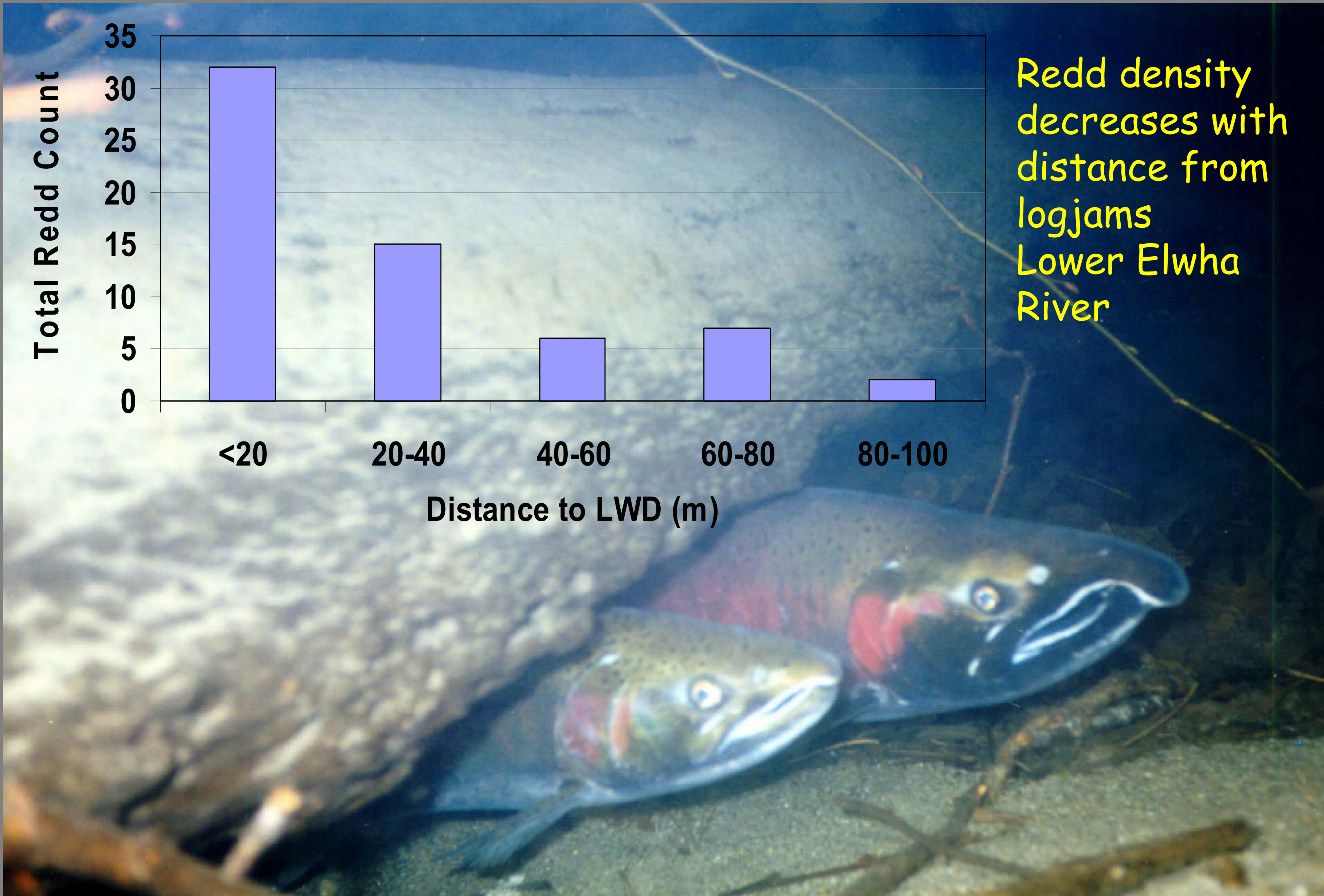
Baxter and Hauer 2000

Quilcene River ELJ
October 2002



7 redds within 10 m of ELJ, none found from 10-50 m further away

Number of redds decreases with increasing distance from ELJs (McHenry 2002).


35
30
25
20
15
10
5
0
Total Redd Count
<20
20-40
40-60
60-80
80-100
Distance to LWD (m)
Redd density decreases with distance from logjams Lower Elwha River

ELJs Can Provide Multiple Habitat Benefits

Hydraulic refugia
Habitat and refugia (pools, cover)
Forest refugia (long-term erosion protection)
Enhancement of hyporheic flow
Creation and maintenance of side channels
Sediment retention
Spawning riffles
Nutrient source (retain detritus & drift)

ELJs provide superior fish habitat

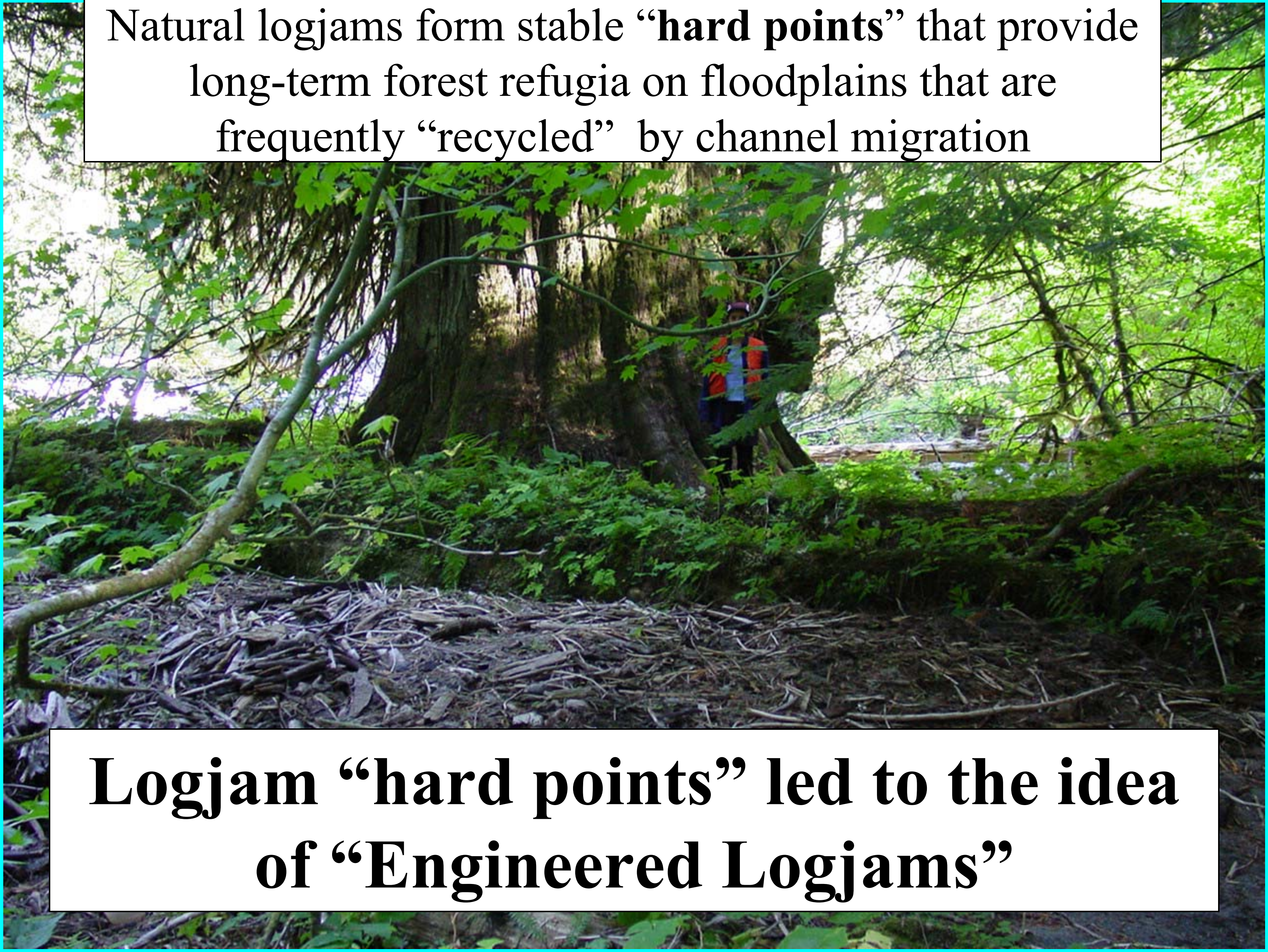
(e.g., Beamer & Henderson 1998; Peters et al. 1998, 2001; Piegay et al. 2001; USACE 2001, …)

<u>USFWS bank protection habitat comparison (Peters 2001)</u>

1. Only **LWD** stabilized sites (large quantities of LWD) consistently had **greater** fish densities than control areas
2. **Riprap** and riprap with LWD had **reduced** fish densities
3. Reduced fish densities at rock deflectors during the spring and summer, greater during the winter
4. Adding **LWD to riprap** had **little benefit** to fish
5. Adding LWD to rock deflectors provided some benefit to fish

Logjam
“hard points”

Natural logjams form stable “**hard points**” that provide long-term forest refugia on floodplains that are frequently “recycled” by channel migration

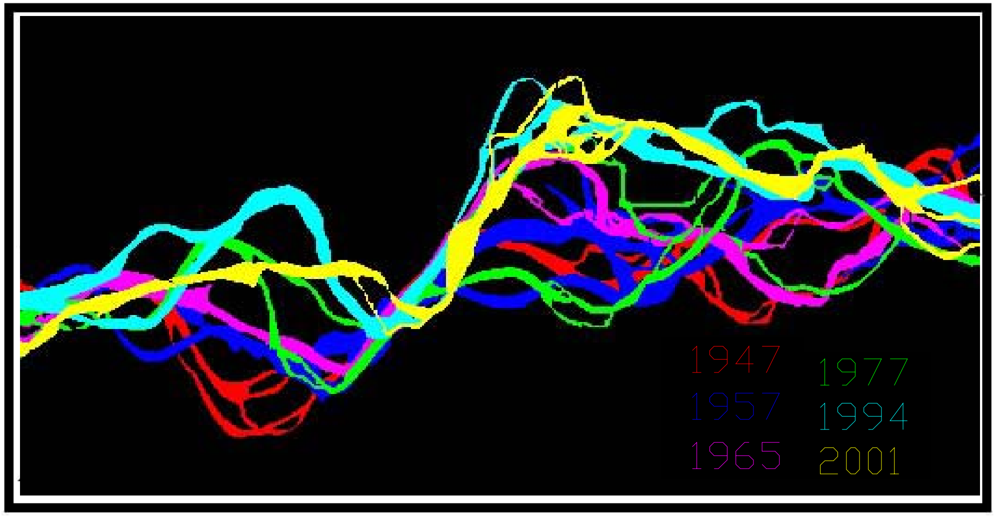


Logjam “hard points” led to the idea of “Engineered Logjams”

Elements of Engineered Logjam Technology

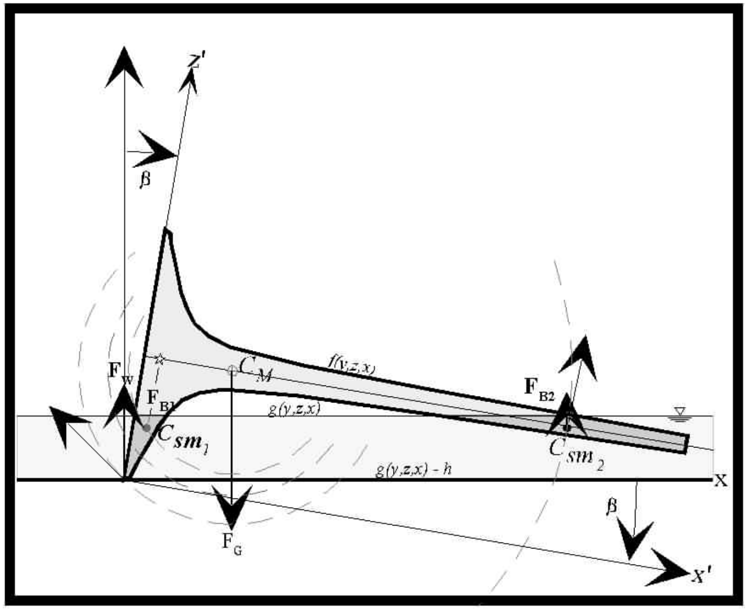
Herrera Environmental Consultants

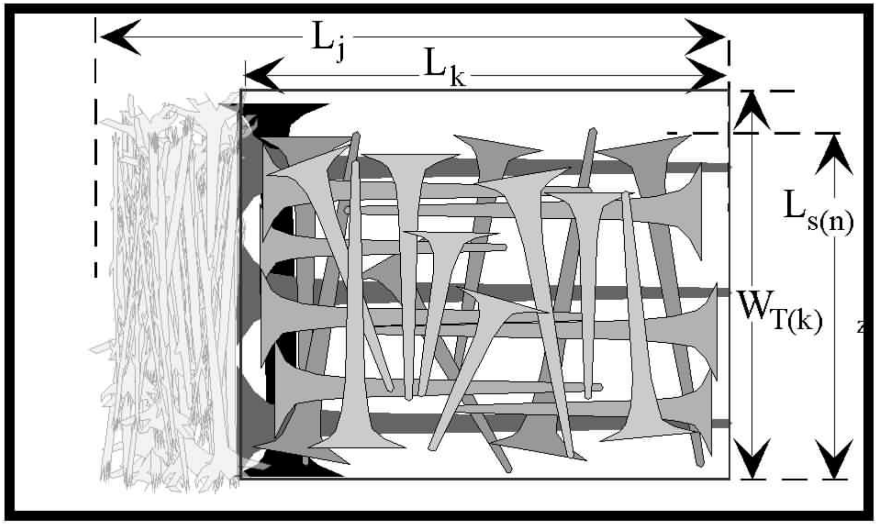
An ELJ design process …



1. Watershed and reach analysis encompassing project site to understand hydrology, sediment supply, channel dynamics and identify opportunities and constraints.

2. Identify potential natural models from reference basin and project site. Determine appropriate type, number, location, and size of ELJ structures.





3. Engineering analysis of key members and complete ELJ structure, including critical shear stress, bed scour, design drag, and cumulative force balance.

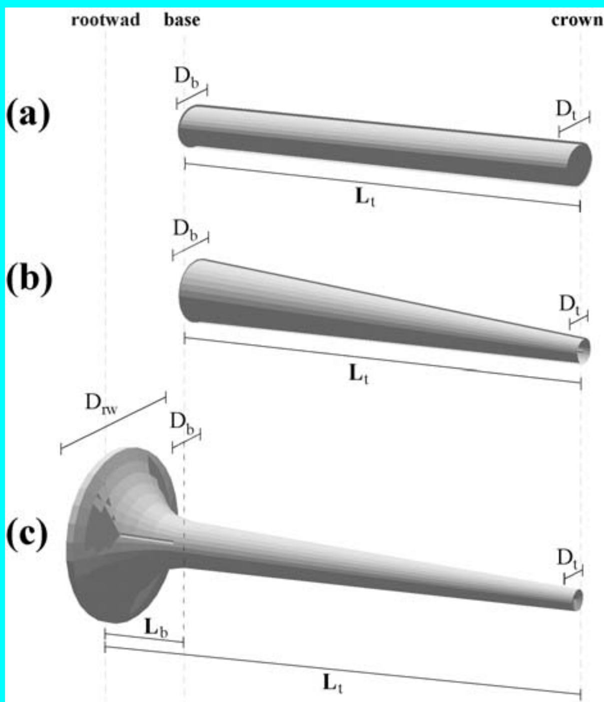
4. Develop final design plans and specifications, including necessary actions for construction to protect natural resources and water quality.

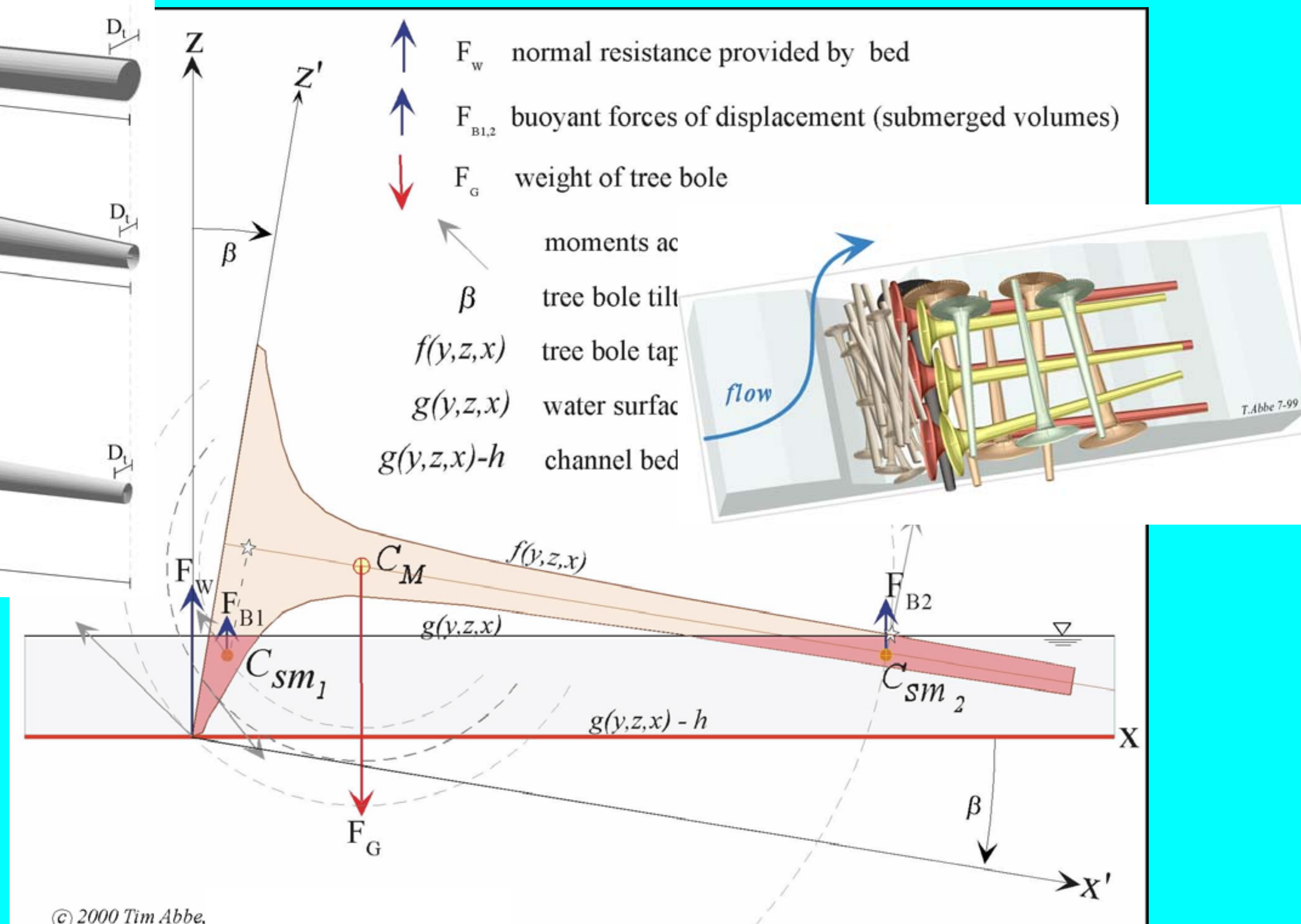
5

Construction of ELJ structures that restore natural conditions and processes to system.

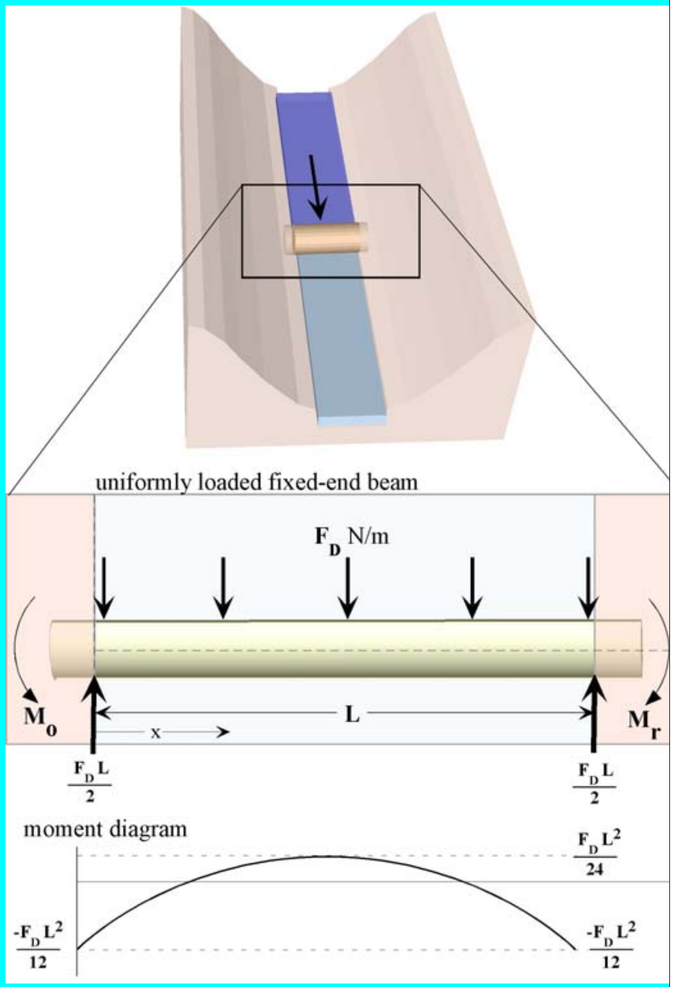

How can "wood" be stable in a river?
Examples of ELJ design analysis …

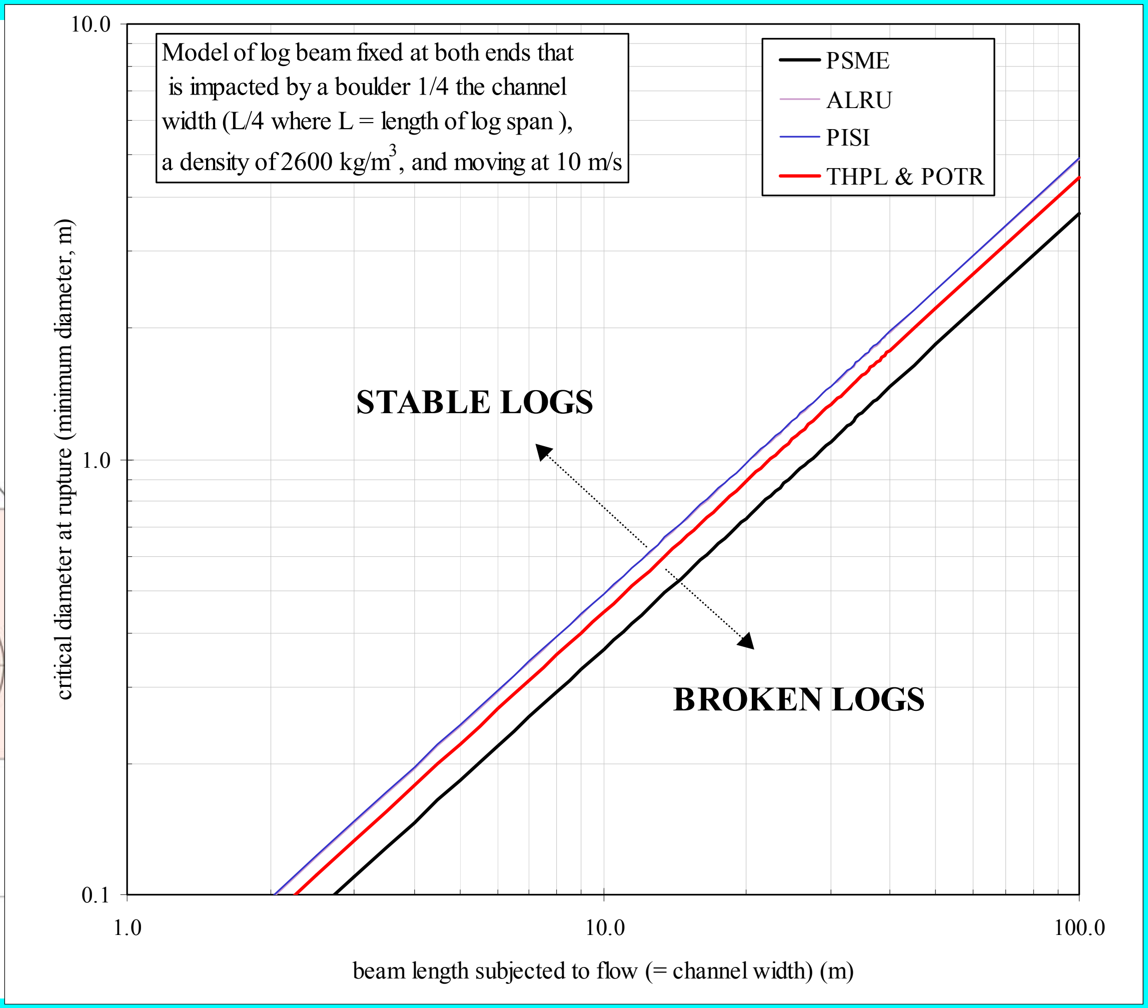
Examples of how we can quantify wood mechanics:



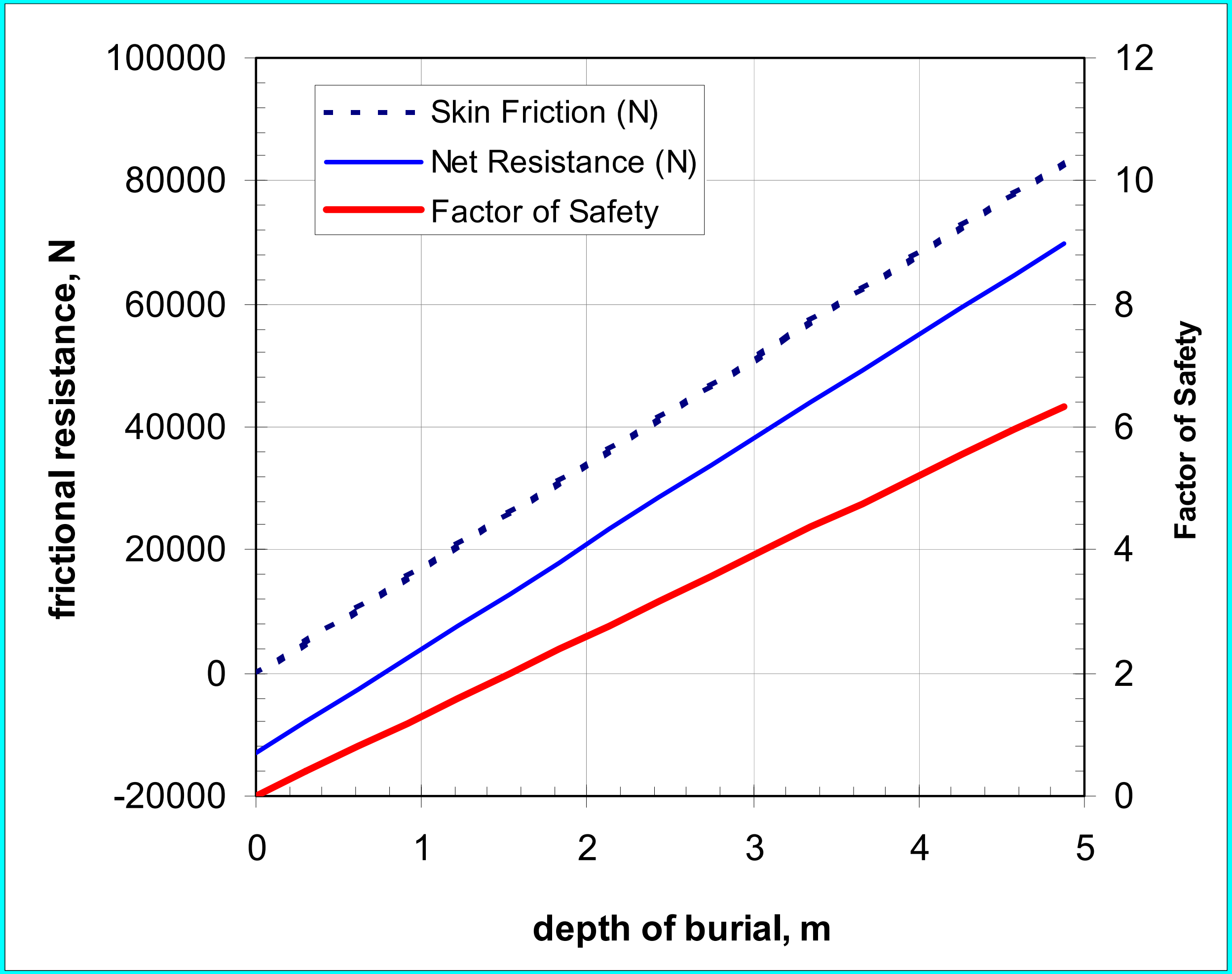


Strength limited models …





Examples of ELJ design analysis ...



wood stability:

Skin friction

Case of a completely submerged **timber pile** in hard sand:

L = 30 ft (9.1m)

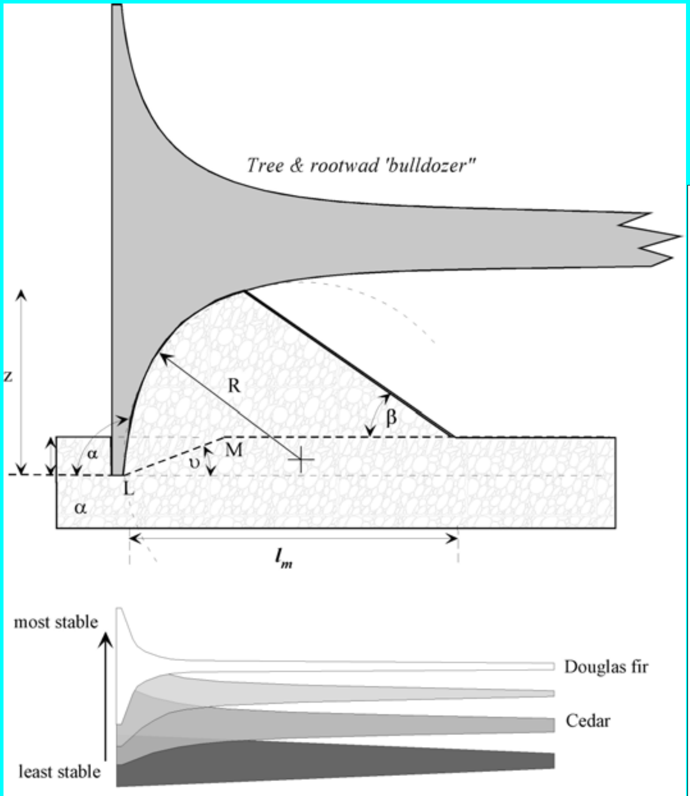
D = 2 ft (0.6m)

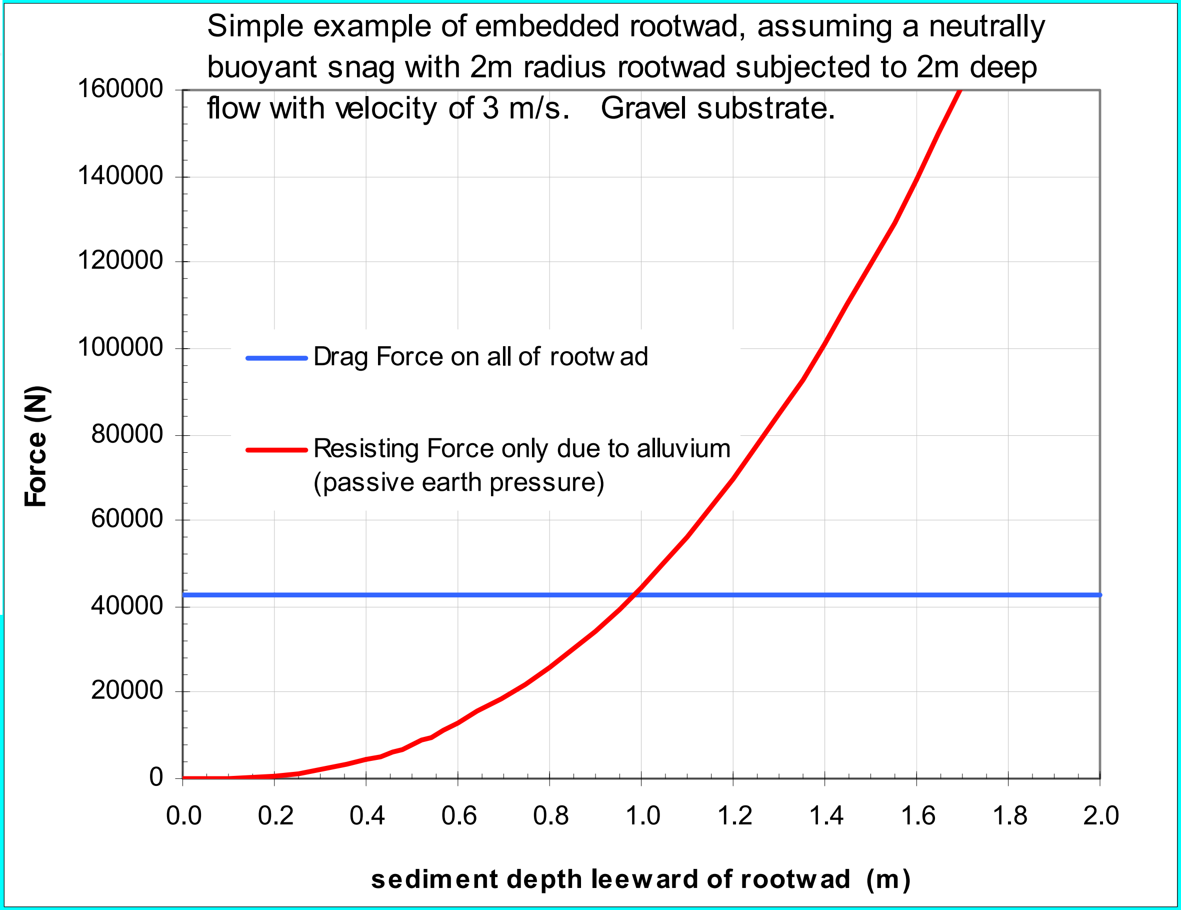
Sp. Gravity = 0.5

Examples of ELJ design analysis ...

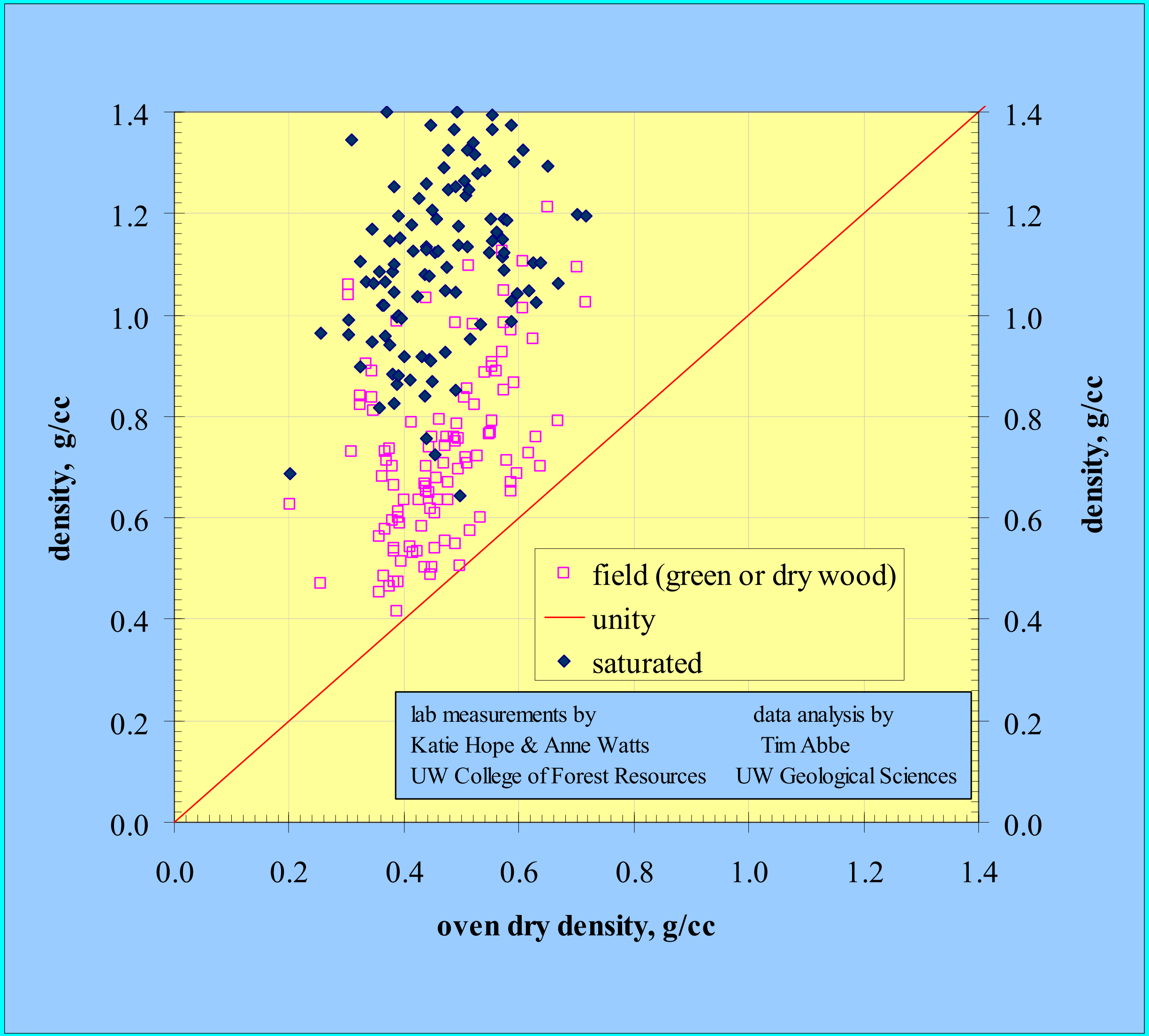
wood stability:

passive earth pressures

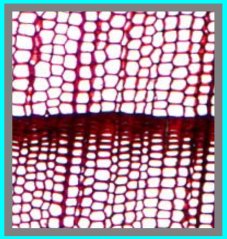




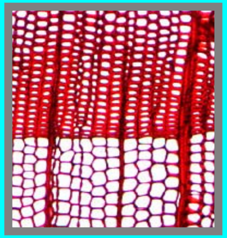
Examples of ELJ design analysis …



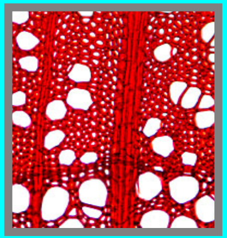
wood stability: **density**



γ~.385

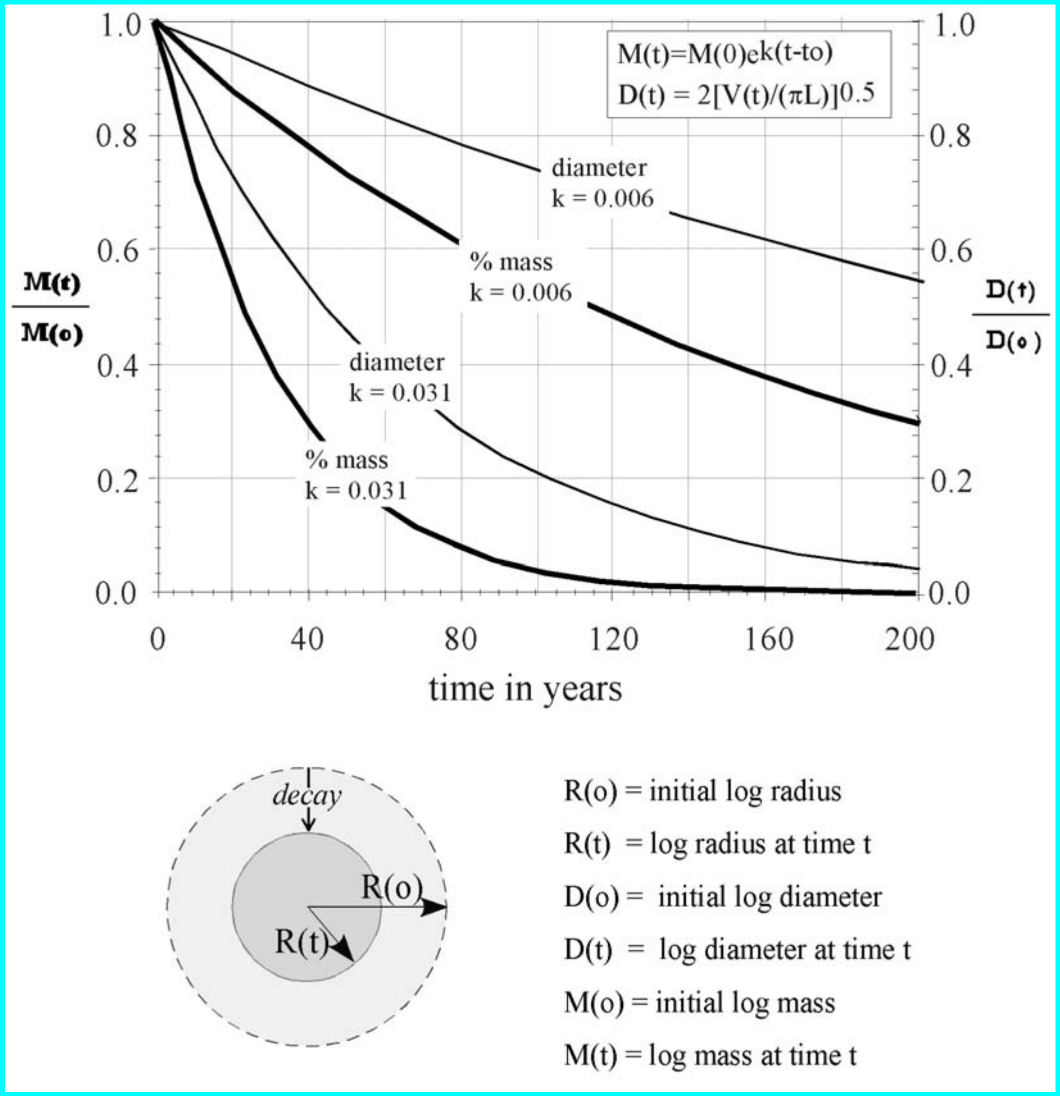


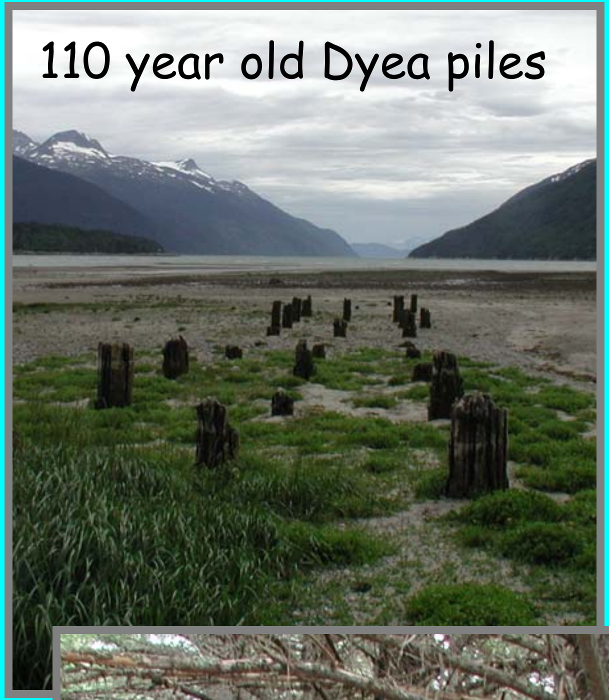
γ~.500



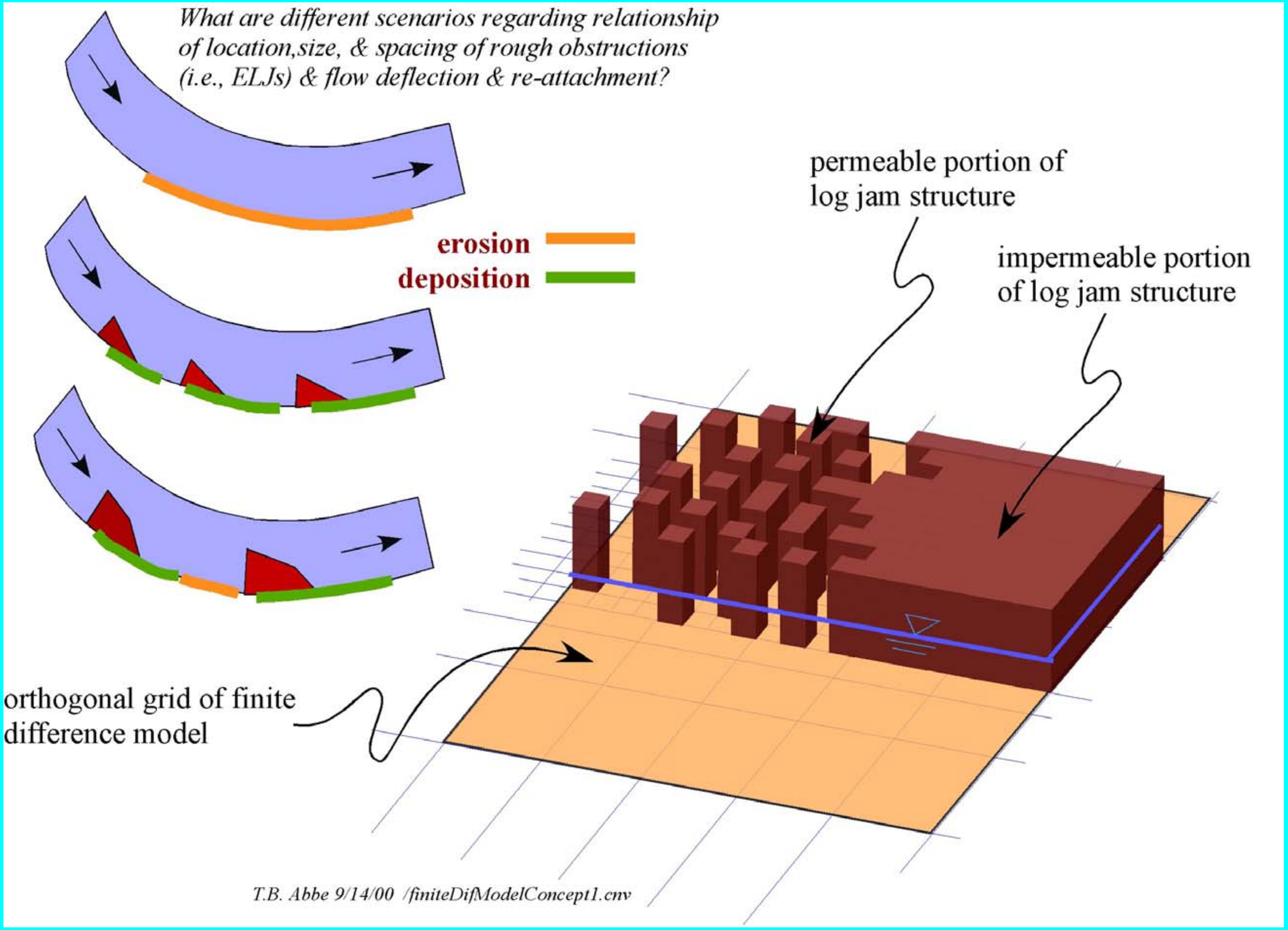
γ~.540

wood stability: **longevity**



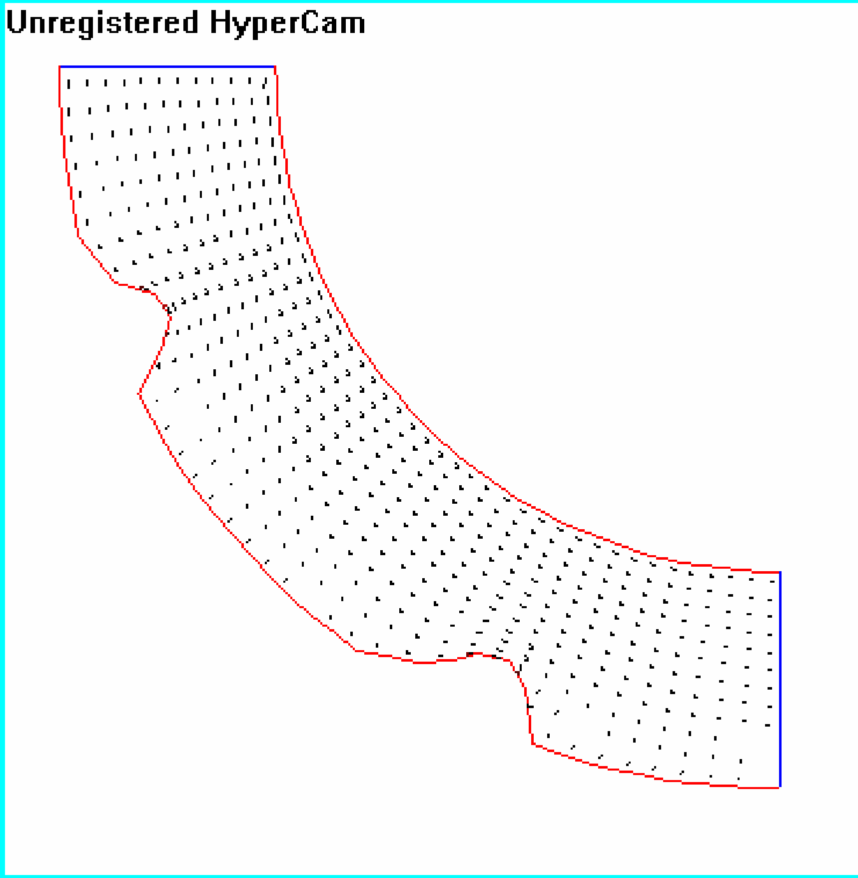


2-D modeling modeling with an orthogonal grid

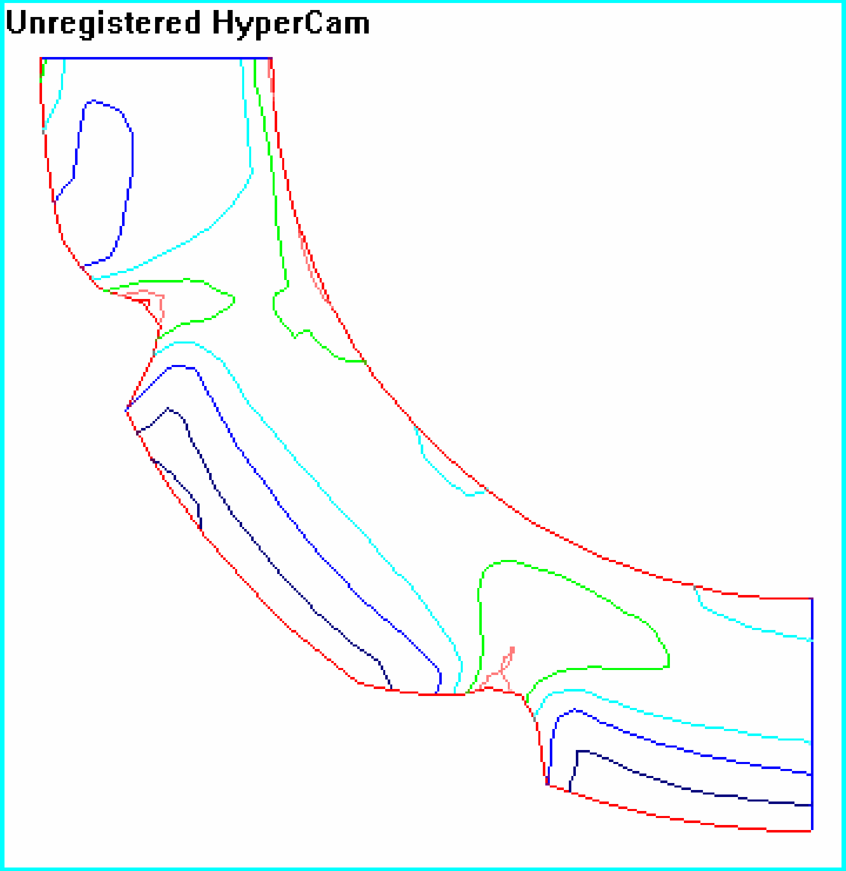


Example 2-D modeling output of flow around groins placed along a the outer bank of a meander

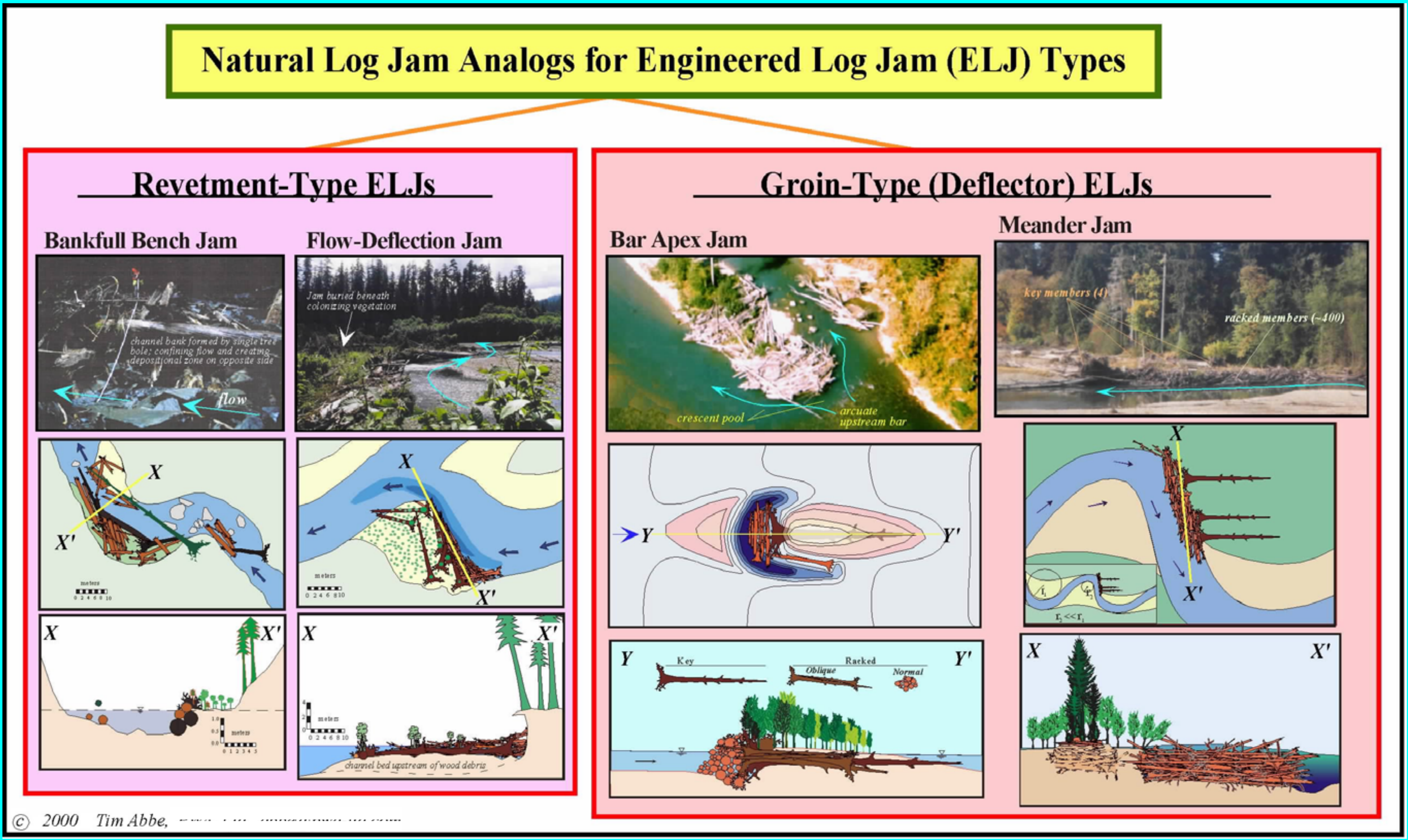
Flow Vectors



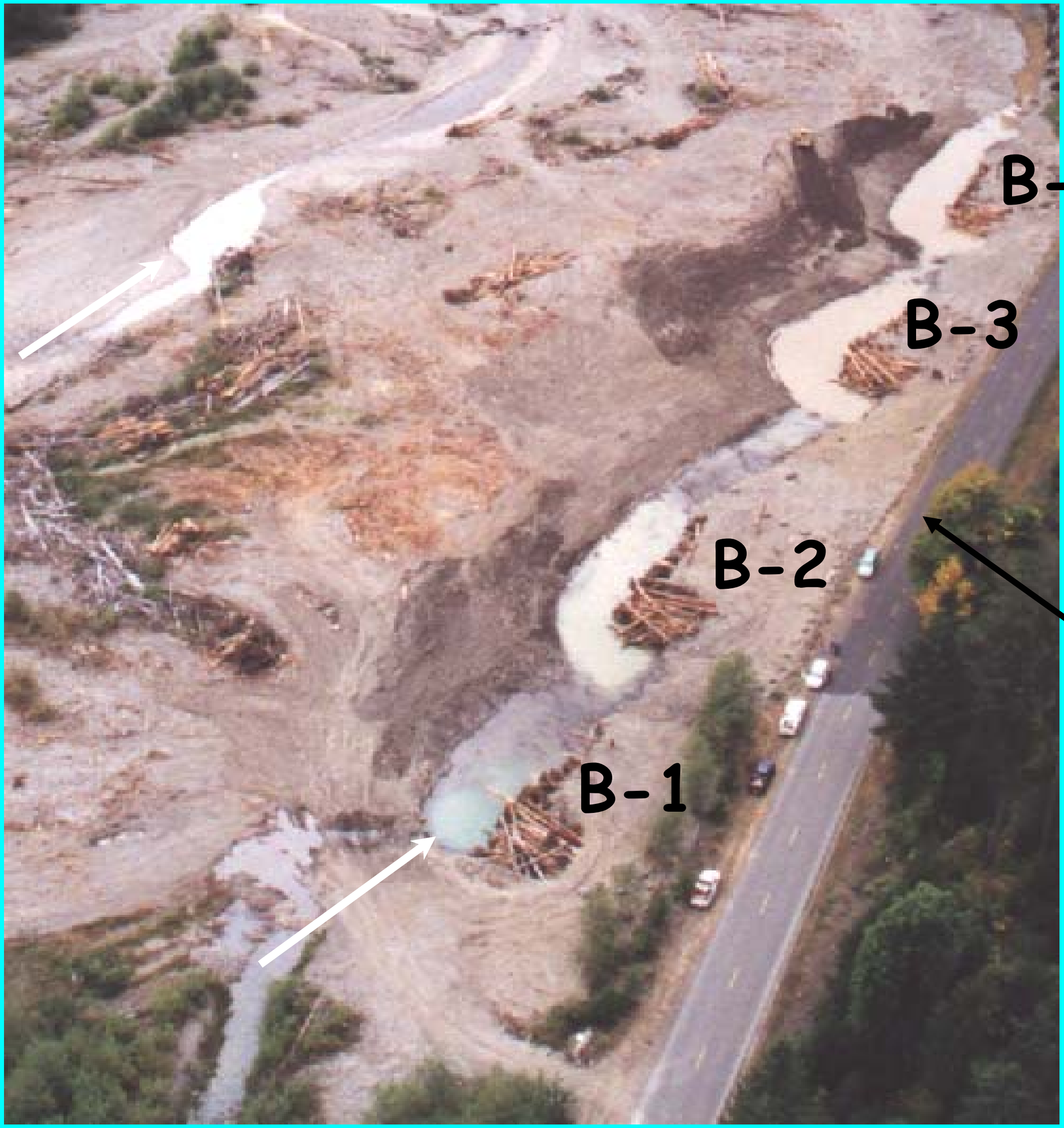
Bed Shear Stress



Select appropriate structures based on objectives, opportunities, and constraints



Examples of ELJ design analysis …

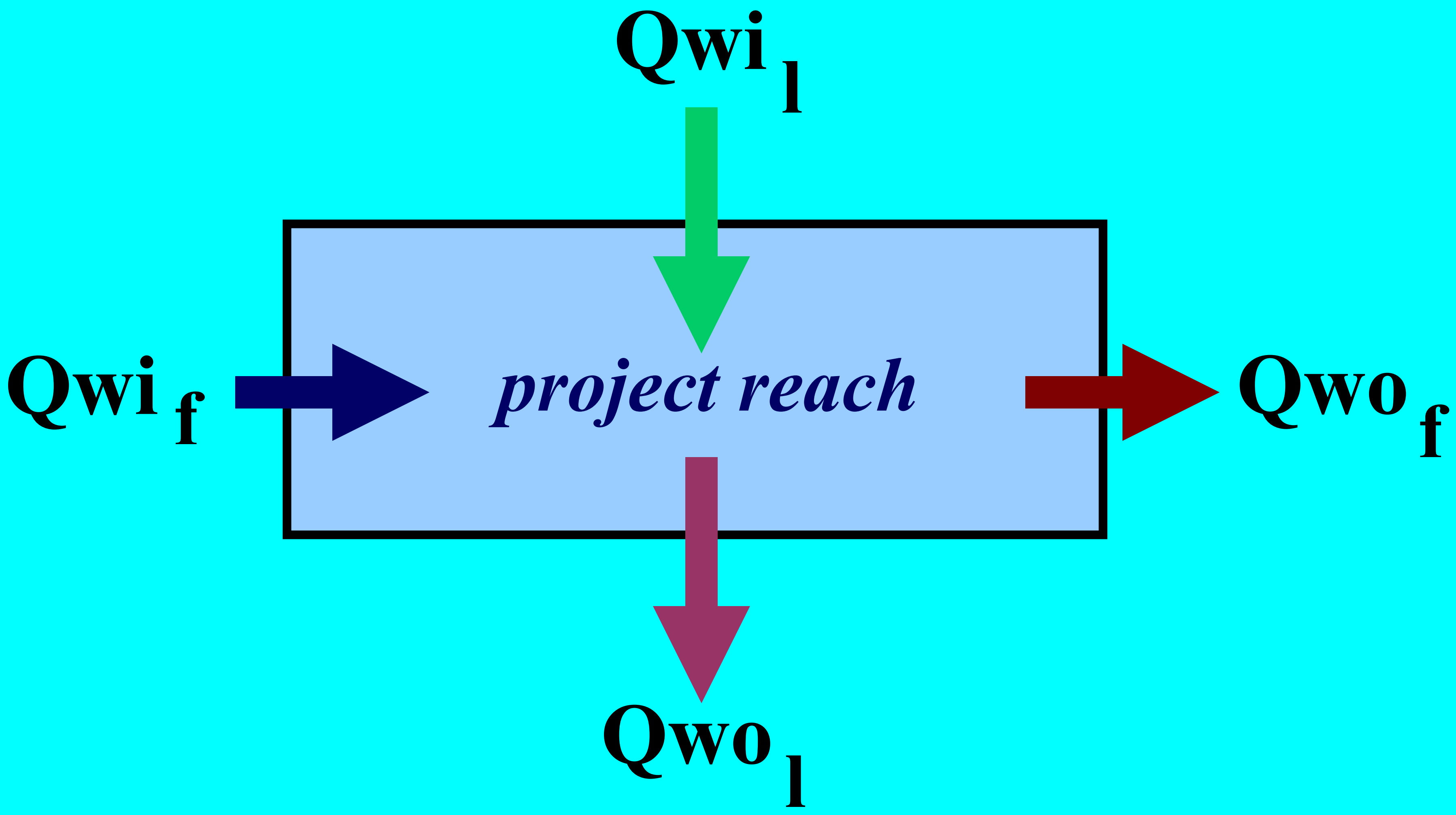


Structure siting

Black-top road is where Forest Road 23 washed out in 1996

Cispus River
Site B, RM 19,
October 1999

Wood Budgets



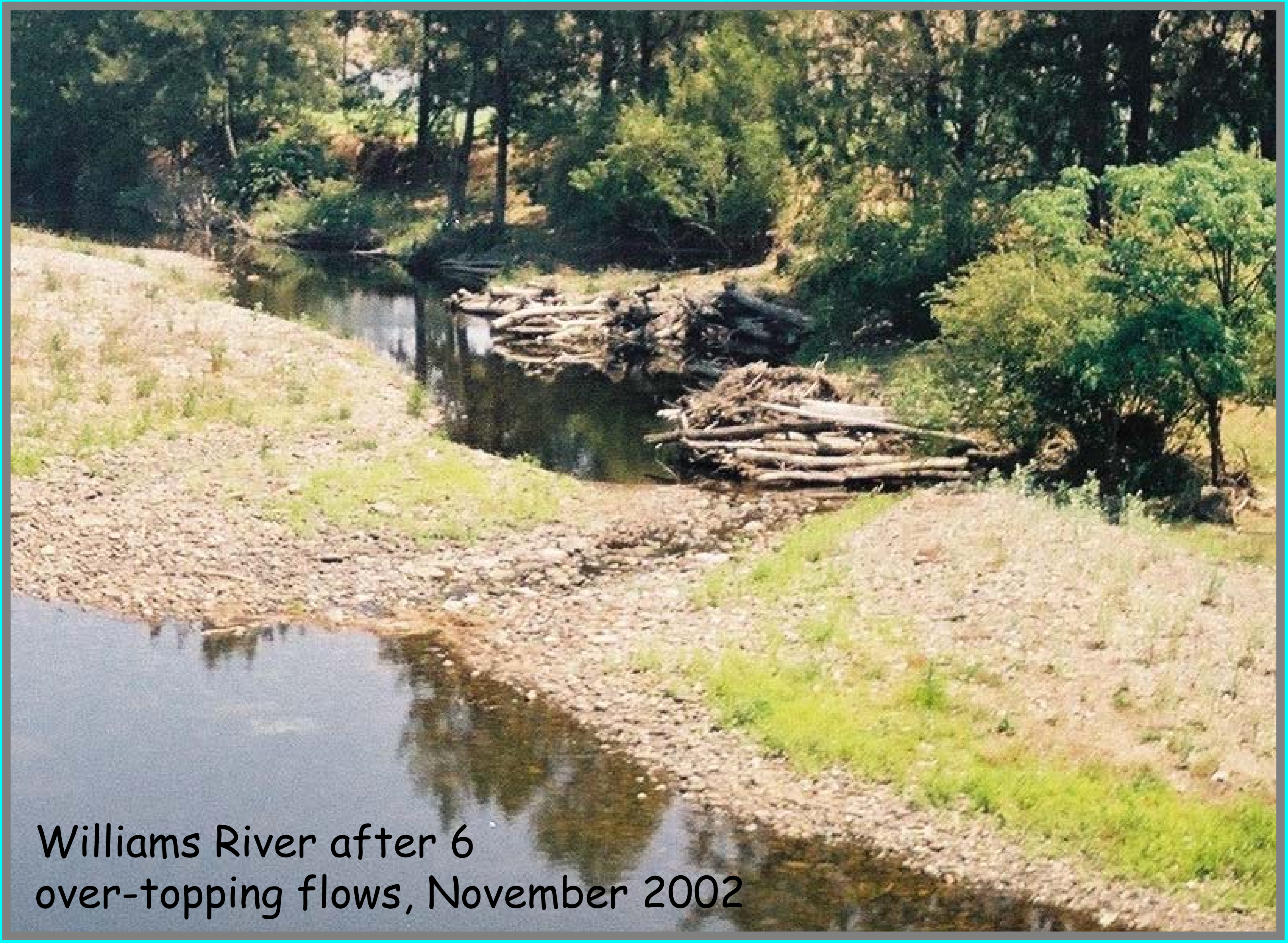

BEFORE:
Traditional Revetment

AFTER:
ELJ Flow Deflectors

Do Engineered Logjams Work?


2 m
Williams River ELJ
As-Built Conditions, 2000
SEP 24 2000

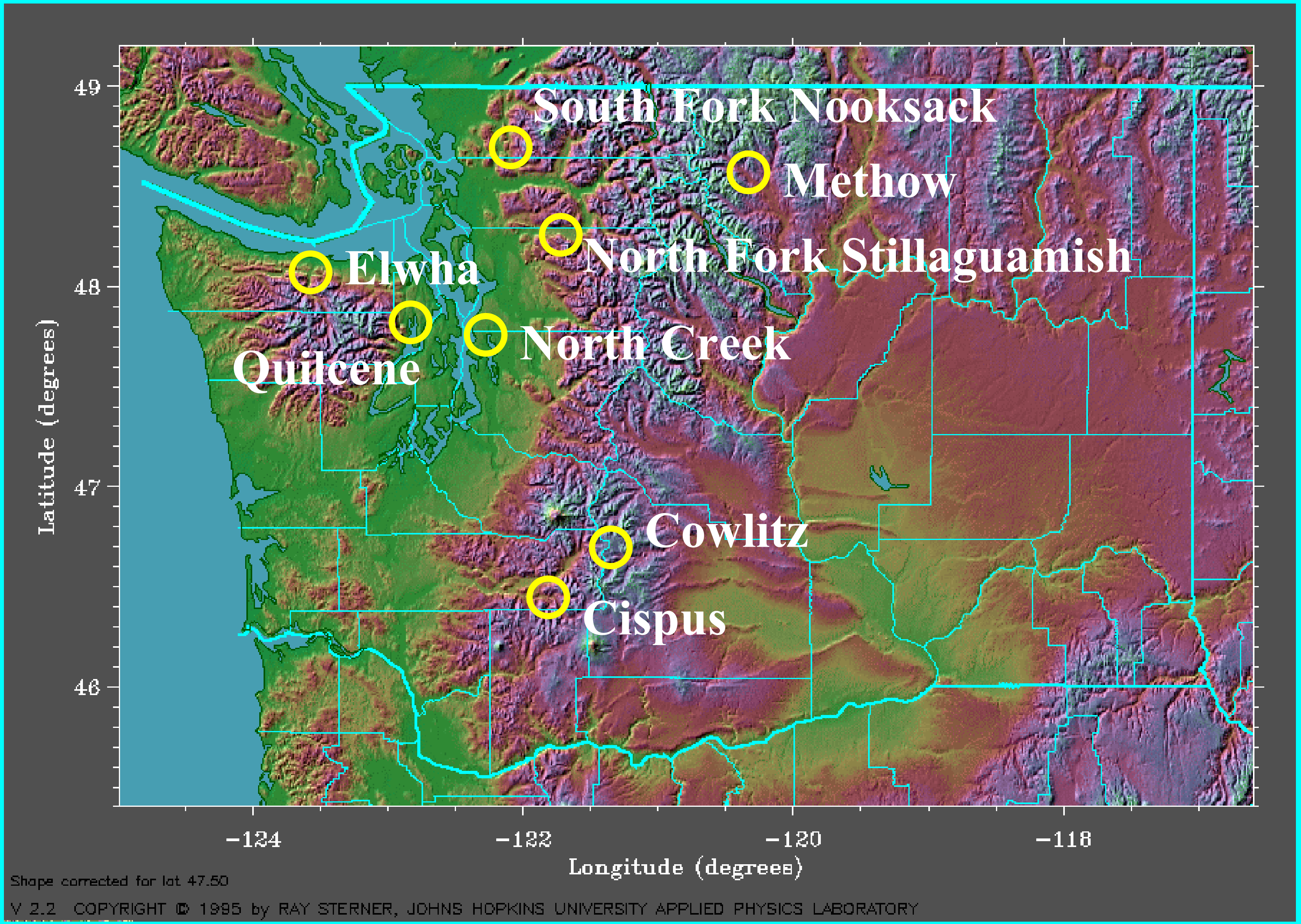
Williams River during flow
submerging structures by 2 m.


Williams River after 6
over-topping flows, November 2002

Basic ELJ Design Process

Establish a clear set of goals
Identify opportunities and constraints to achieve goals
Physical understanding of the river and site
geology, hydrology, hydraulics, geomorphology
Select appropriate types of ELJ structures
Select appropriate size and location for ELJs
Coordinate with permitting agencies
Complete engineering analyses
Complete engineering designs and specifications
Coordinate construction logistics
Implement adaptative management plan

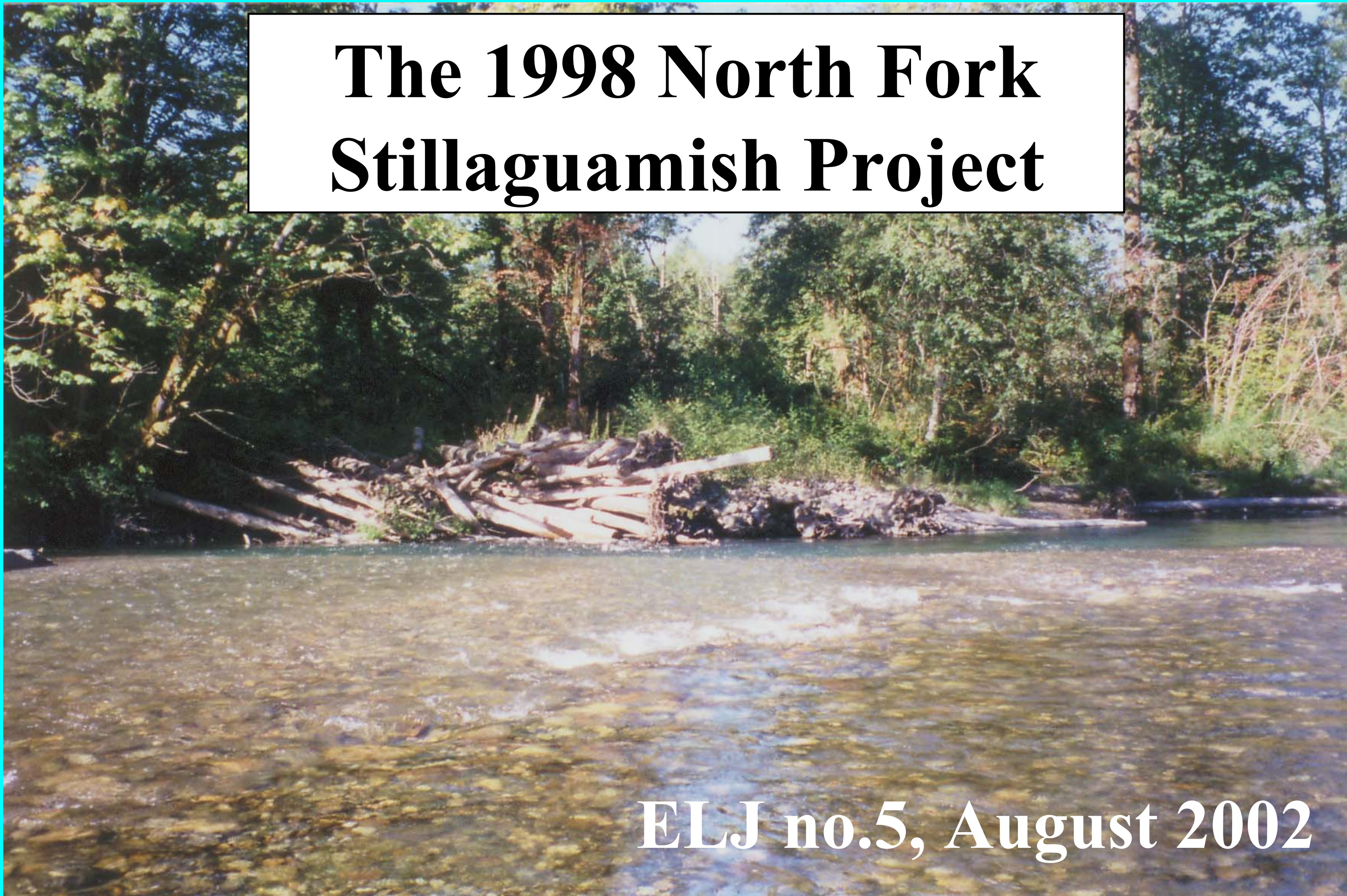
Washington ELJ Project Sites: 1995-2002

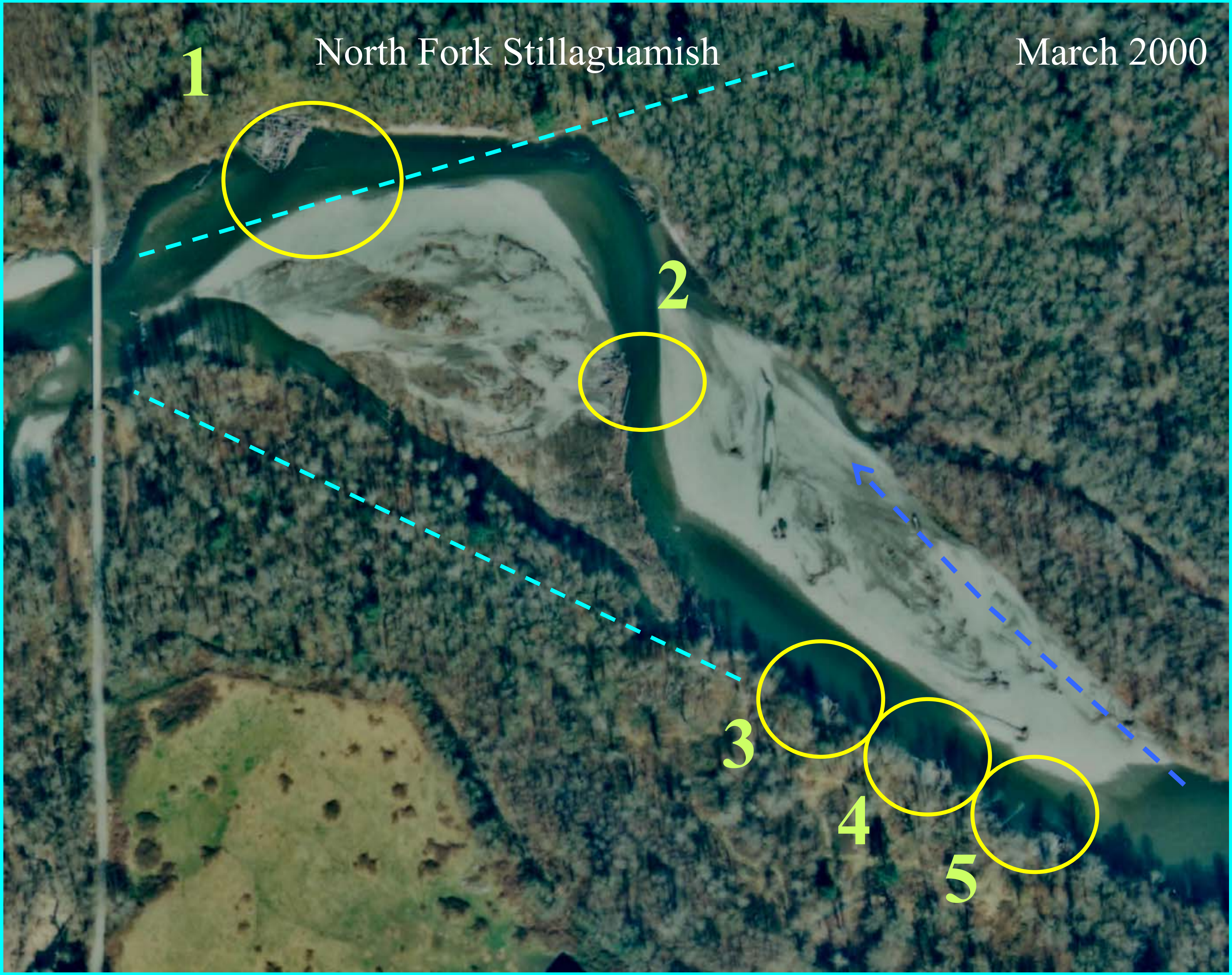


Example ELJ Projects which incorporated bank and/or bridge protection or grade-control as a principal objective.

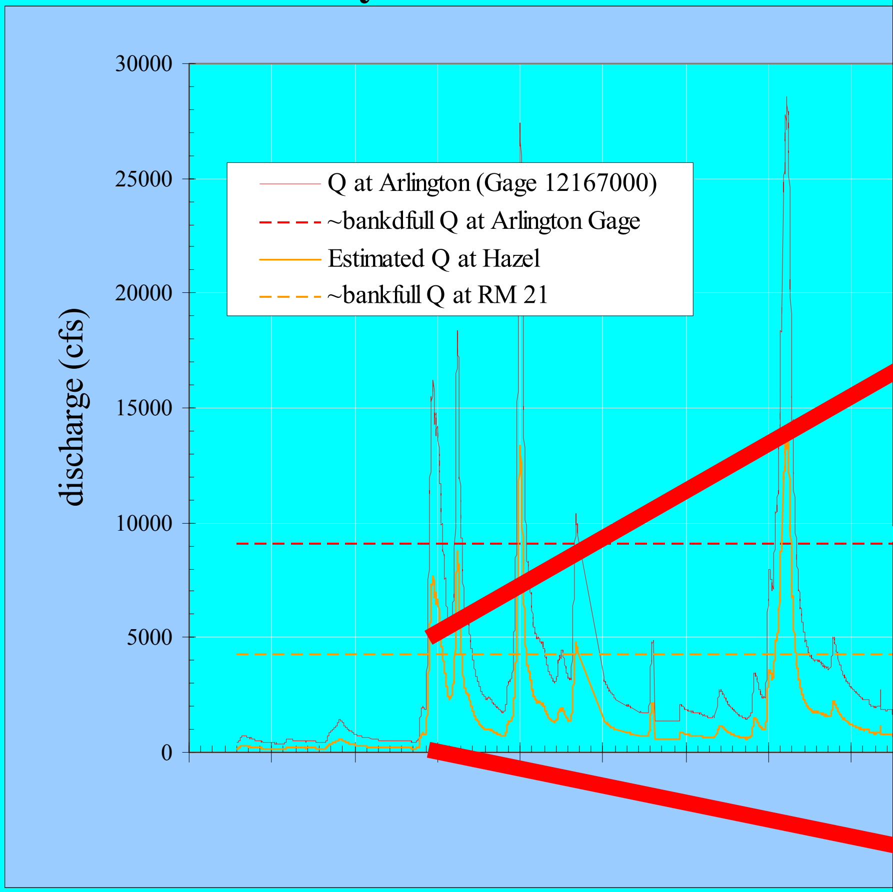
Year	River	Sponsor
1995	Cowlitz	Private landowner
1998	N.F. Stillaguamish	State, County, Federal
1998/2001	North Creek	State
1999-2002	Elwha	Tribe, State
1999	Cispus B & C	Federal
2000	S.F. Nooksack	Tribe, State
2001	Cispus A	Federal
2002	Methow	Private landowner
2002	Quilcene	Tribe, Private landowner

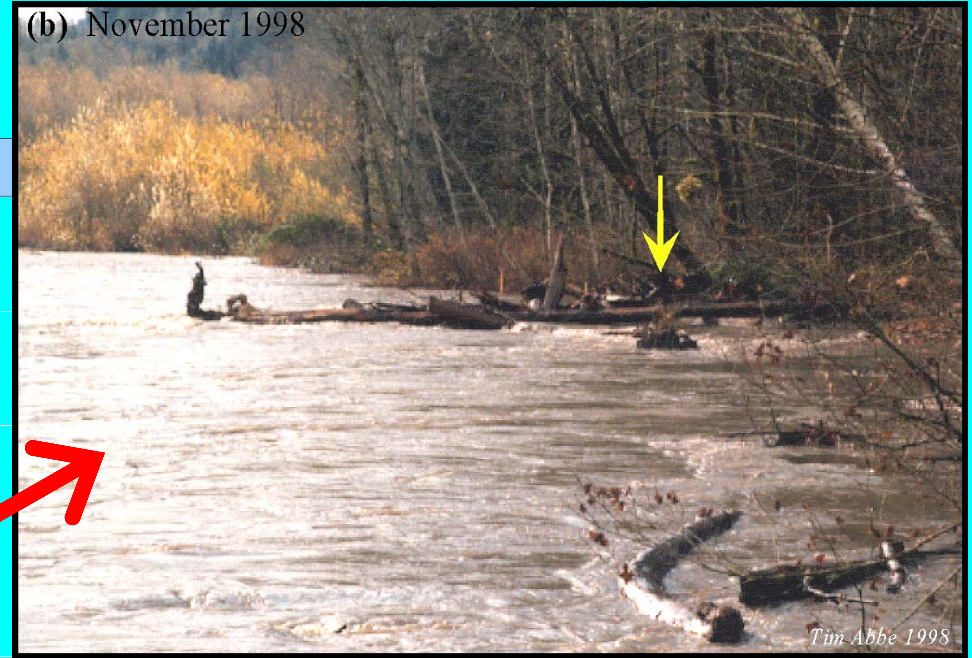
The 1998 North Fork Stillaguamish Project




North Fork Stillaguamish
March 2000
1
2
3
4
5

“Bank-full” discharge and stage relative to 1998 N.F. Stilly ELJ structures.





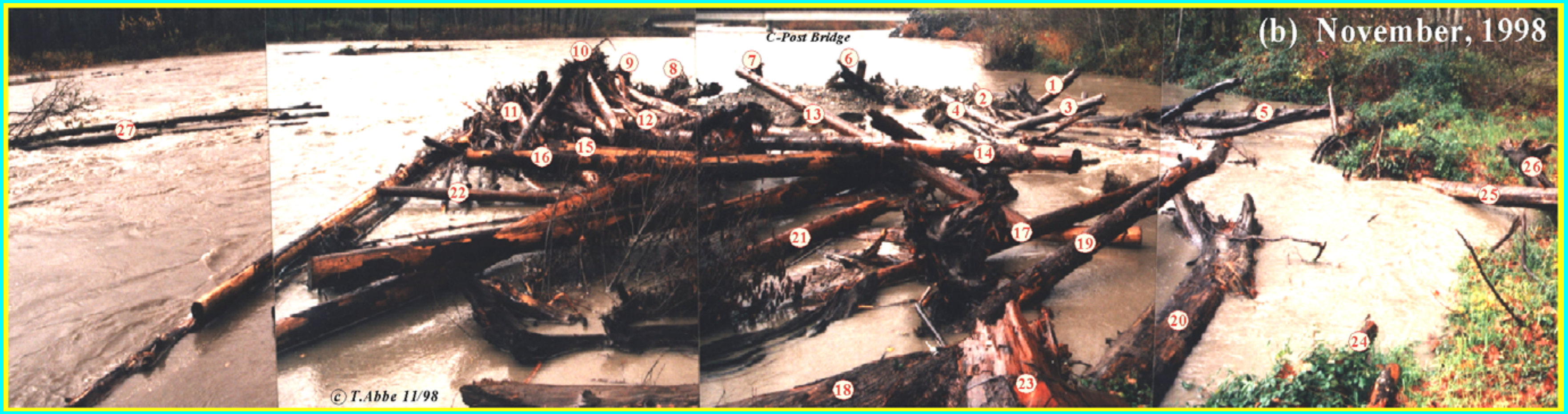
(b) November 1998

(a) September 1998

ELJs were submerged <u>8 times</u> in WY99 (4 more times between 10/1/99 and 12/31/99). As of May 2000 the 5 ELJs remain intact and have thus far been successful in meeting project objectives.

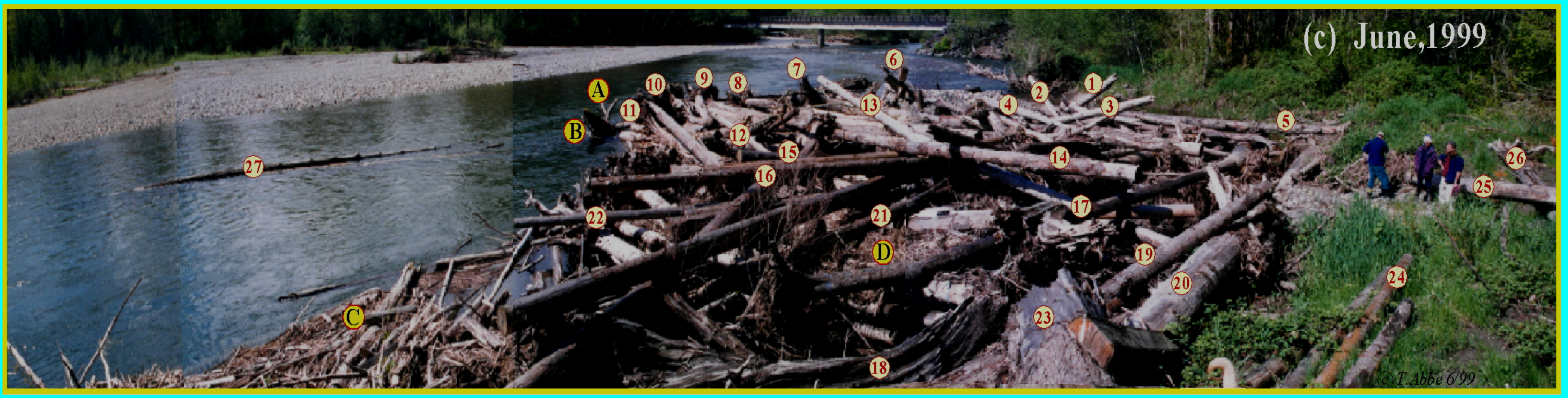
North Fork Stilly ELJ #1: 1998

As-built structure



North Fork Stilly ELJ #1: 1998

Bankfull stage

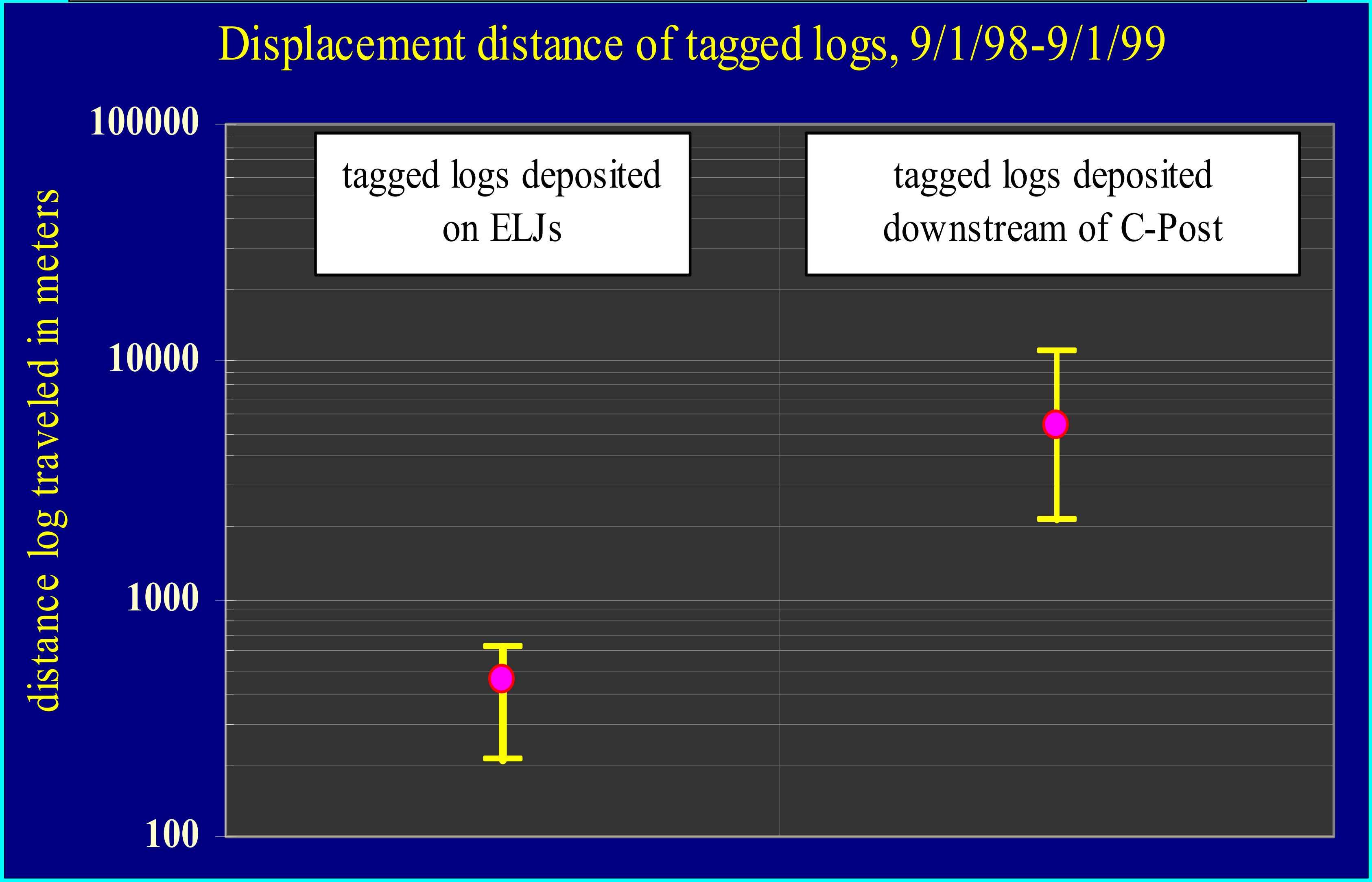


North Fork Stilly ELJ #1: 1999

After 8 peak flows equal or exceeding bankfull stage

Flotsam Trapping Efficiency of Engineered Log Jams

North Fork Stillaguamish River, 1998-1999



Bridges and Wood

1998: pre-existing conditions

1999: 8 peak flows >= bkf

2000: 16 peak flows >= bkf

2001: 17 peak flows >= bkf

Construction Engineering, Costs, and Implementation

Interdisciplinary Team Approach

- Geomorphology
- Hydraulics
- Hydrology
- Riparian condition
- Aquatic habitat
- Permitting implications
- Landscape architecture
- Cost estimating
- Construction engineering

Construction Considerations

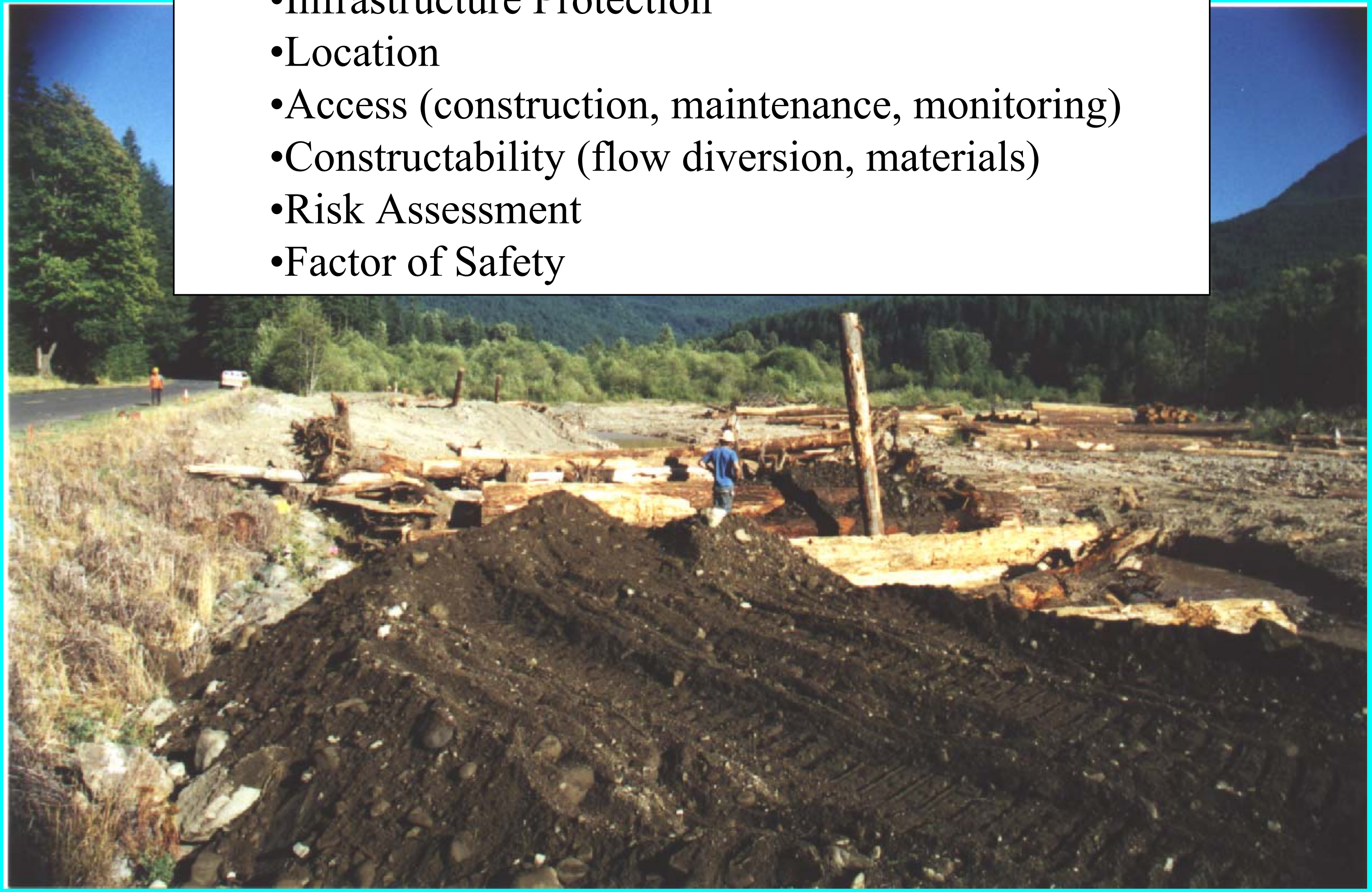
Standard Construction

Large Heavy Equipment Projects

Time of Year

Design Considerations

- •Safety
- •Infrastructure Protection
- •Location
- •Access (construction, maintenance, monitoring)
- •Constructability (flow diversion, materials)
- •Risk Assessment
- •Factor of Safety



More Construction Considerations

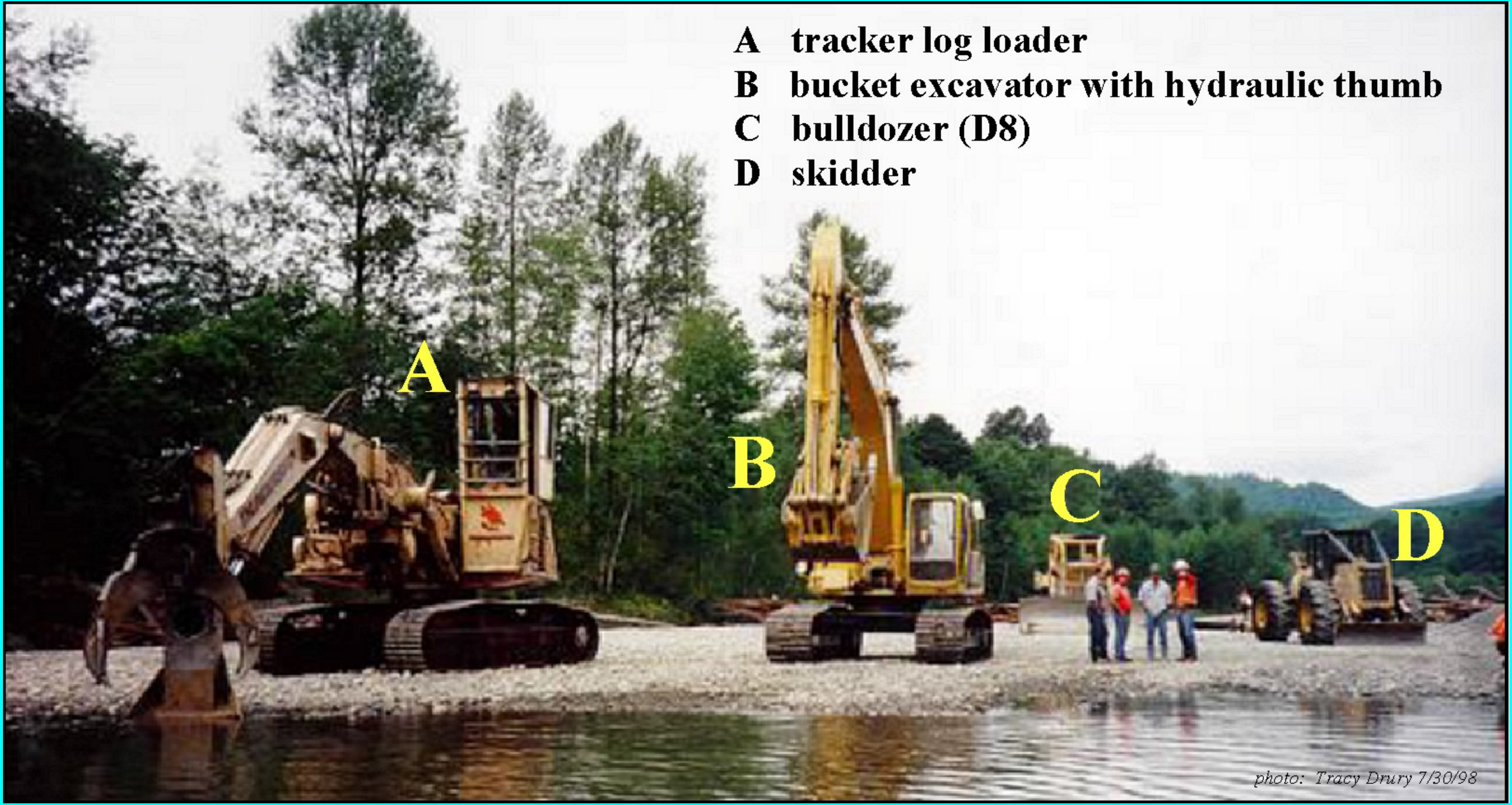
Similar to other conventional heavy equipment construction (grading, excavation, logging, rigging, structural)

Makes some otherwise unbuildable projects buildable

Access and Location

Temporary channel diversions

Access and Equipment



Material acquisition, transportation, and placement

Inspection and Contractor Training

Sustainable Solutions

- cost-effective, environmentally sustainable solutions to infrastructure protection
- incorporate environmental benefits while not sacrificing function ("self mitigating")

ELJ Applications in River Engineering

Bank and road protection

flow deflection and revetment structures

Bridge protection

retention of hazardous debris

channel alignment

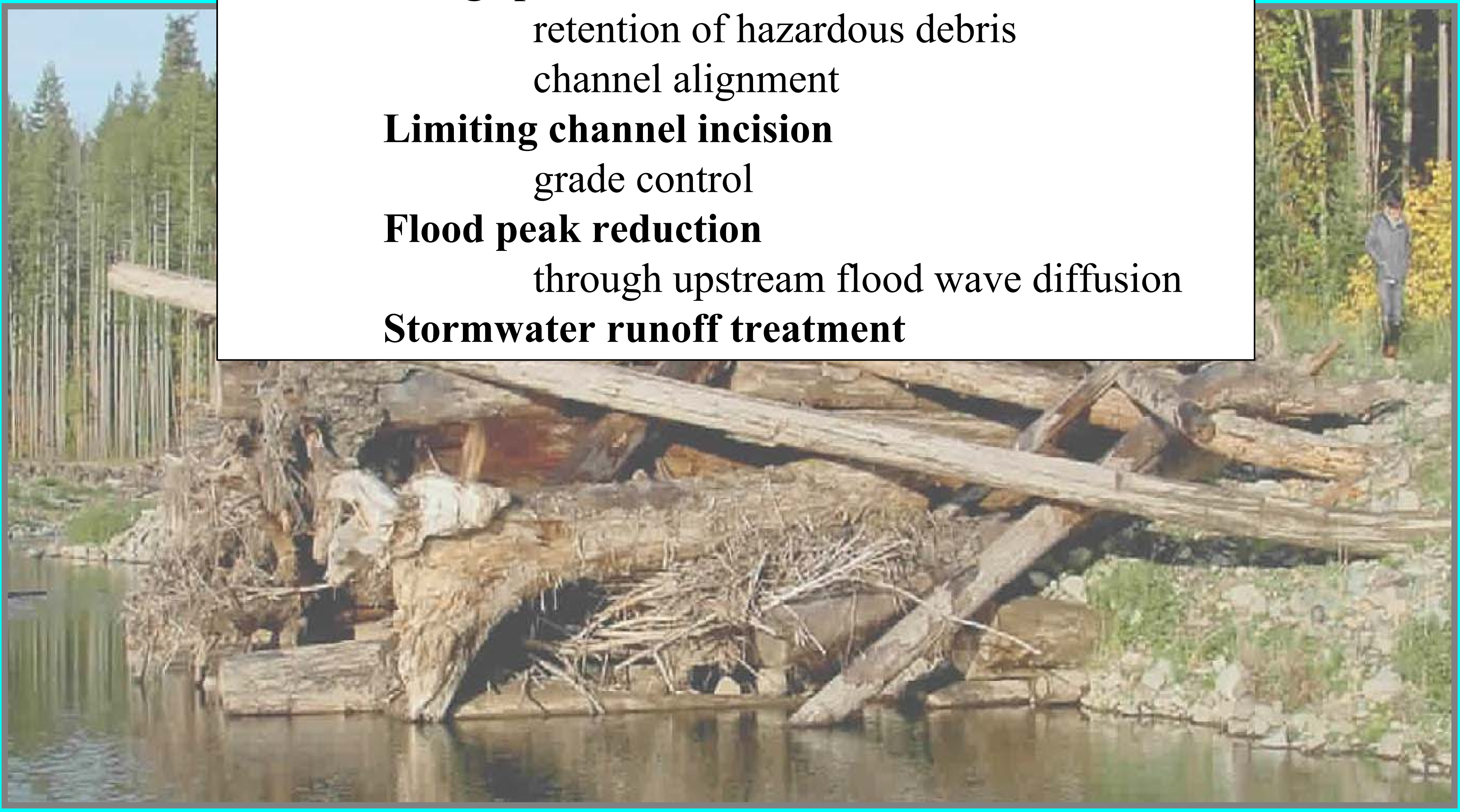
Limiting channel incision

grade control

Flood peak reduction

through upstream flood wave diffusion

Stormwater runoff treatment

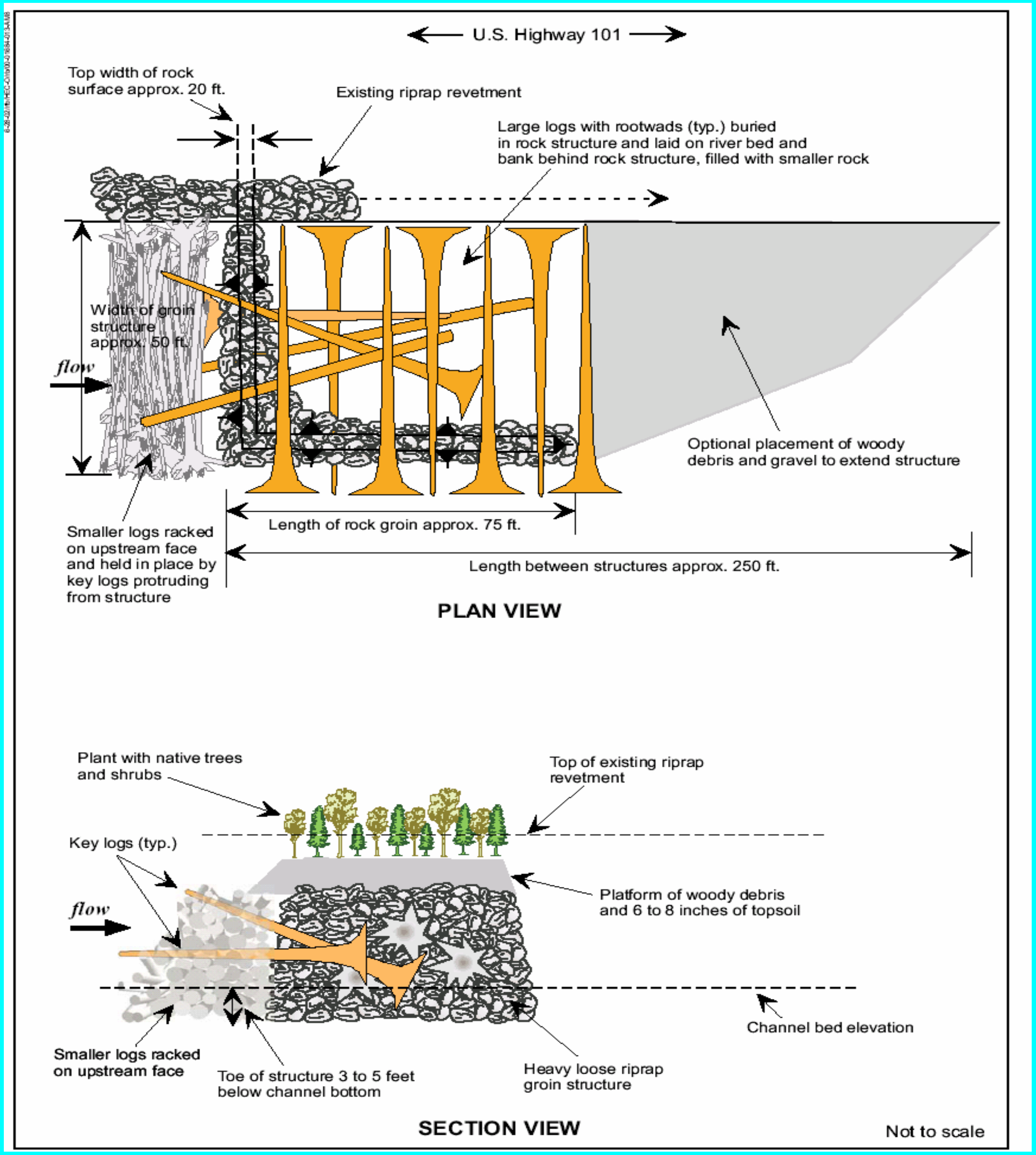


Self-mitigating projects work within the regulatory environment

1. County (SMA)
2. Fish and Wildlife (HPA)
3. Ecology (TMDLs, 401)
4. US Army Corps (404)
5. NMFS, USFW (ESA)
6. NMFS (Magnuson-Stevens Fisheries Conservation Act)

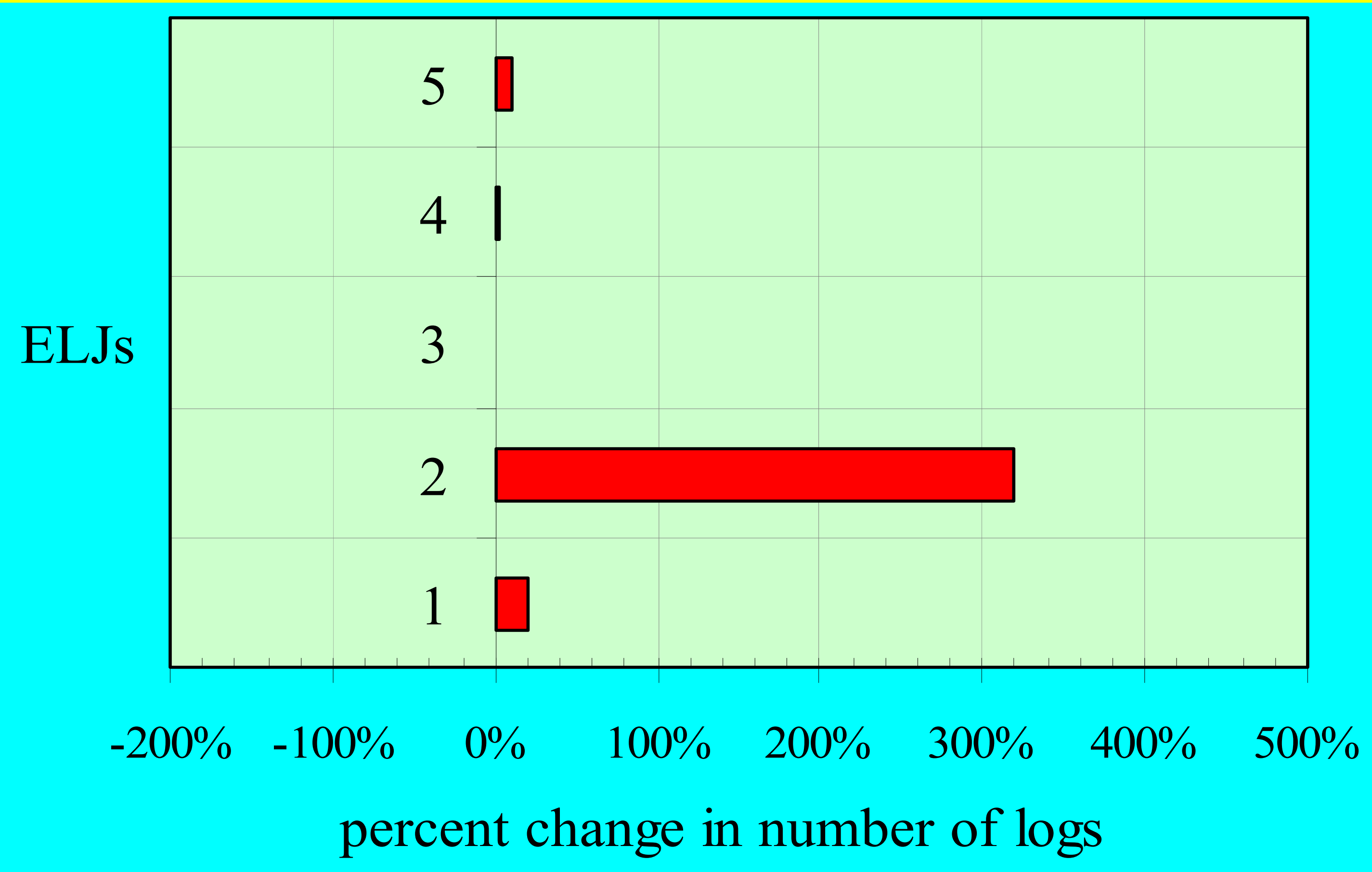

Self-mitigating solutions
are a win-win for us all

Selection of appropriate structures for site conditions, available materials and cost



North Fork Stillaguamish River ELJ Project: 1998 - 1999

- *98.4% of the tagged logs used in the ELJs remained after 8 peak flows equal or exceeding bankfull stage*
- *Four of the five ELJs (1, 2, 4, & 5) experienced a net gain in wood debris, with no detected change in ELJ #3*



Why we don't like cable?

Cable is:

1. Not natural
2. Not sustainable
3. Can threaten the integrity of a structure if improperly used
4. A potential liability w.r.t to human safety